Developing a tool to quantify the impact of the scallop fishery on loggerhead sea turtles

Final Report

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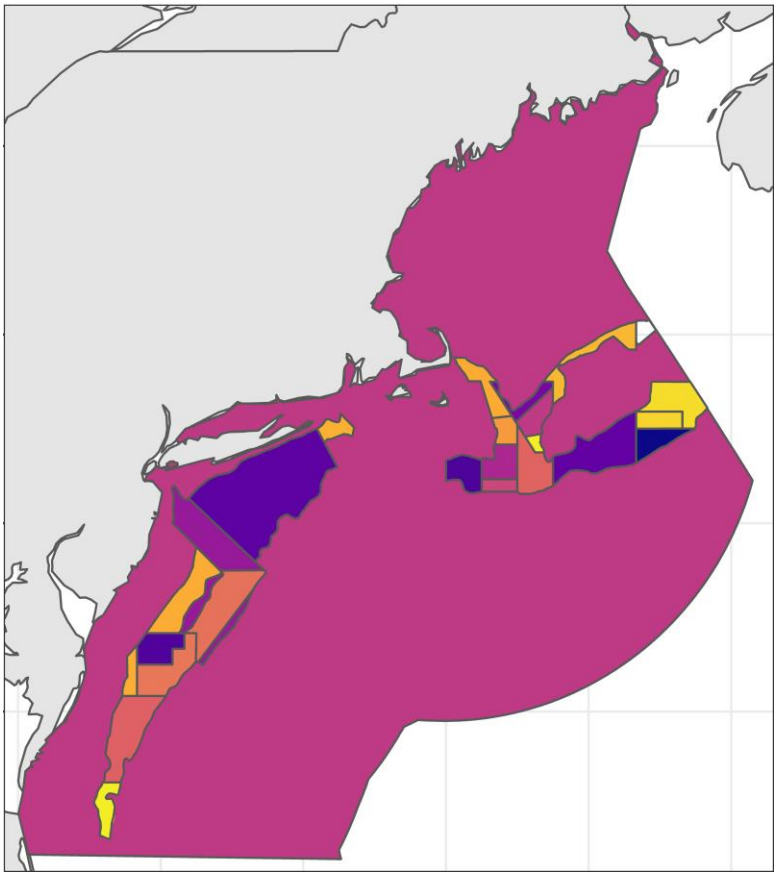

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Project Title: Developing a tool to quantify the impact of the scallop fishery on loggerhead sea turtles

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Organization: Coonamessett Farm Foundation, Inc. (CFF)

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Executive Summary

Bycatch of sea turtles has been a known issue for the scallop industry since the early 2000s, with fishery observers documenting takes of loggerhead sea turtles (*Caretta caretta*) more than those of any other species. Until recently, sea turtle takes by the scallop fishery were estimated using a monitoring proxy based on dredge hours in the Mid-Atlantic Bight (MAB) from May through November. This indirect approach was required because turtle takes by scallop dredges are rarely observed, and takes cannot be calculated from on-deck observations. As an unfunded output of the turtle tagging program funded by the Sea Scallop Research Set-Aside, Coonamessett Farm Foundation began developing the Turtle Impact Tool to provide conservative estimates of the relative impact of different scallop fishery management alternatives on loggerhead sea turtles. The tool incorporates spatially and temporally specific data for monthly turtle densities, derived from loggerhead tagging programs, and for scallop fishing effort, derived from scallop survey programs, Vessel Trip Reporting (VTR) data, and Vessel Monitoring System (VMS) data. No assumptions are made about the likelihood of scallop dredges interacting with co-occurring turtles. Impact estimates are based on estimates for the number of days that scallop vessels are fishing in each MAB Scallop Area Management Simulator (SAMS) area and the number of turtles that are in the same MAB SAMS area each month.

This goal of this project was to improve the tool and advance through the preliminary design phase to implementation on a publicly accessible website. The specific objectives of the project included:

(1) Incorporating more extensive data sets from turtle tagging efforts, VMS, and VTR.

(2) Upgrading the tool with new capabilities and functions.

(3) Determining if output from the tool could provide an alternate surrogate for turtle takes that incorporates seasonal and spatial distributions of loggerheads and scallop fishing effort.

(4) Sharing the tool with managers and other interested parties during informational sessions.

All project objectives were successfully completed with some modifications. Turtle data in the tool now runs through 2019. VTR and VMS fishery inputs used for tool development include data through Fishing Year (FY) 2022, and data that was received allowed more in depth analysis of key model parameters and trends in scallop fishing activity from FY2015 through FY2022. The improved tool now offers two options for users to compare impacts from scallop fishery management alternatives. Two management alternatives can be assessed by entering model parameters directly into the graphical user interface (GUI). Tool results, including impact maps and a table showing the relative impacts of the two alternatives, are displayed on the GUI if this option is used. Users can also opt to enter data for multiple management alternatives by putting together data tables (csv files) for these alternatives. Users can download impact data tables and reports that include impact tables and maps when this option is used. The Turtle Impact Tool is currently hosted on shinyapps.io through March 2024.

Project timeline

Funding period: April 1, 2021 – March 31, 2023

Applied for access to confidential fisheries data: April 15, 2021

Final agreement signed for access to fisheries data: August 10, 2021

Received VTR data: August 13, 2021 (batch 1) and April 11, 2023 (batch 2)

Received VMS data: November 15, 2021 (batch 1) and May 1, 2023 (batch 2)

Turtle Impact Tool uploaded to R Shiny website: April 7, 2022

Presentation of Turtle Impact Tool at RSA Share Day: May 5, 2022

Updated Turtle Impact Tool uploaded to R Shiny website: July 21, 2023

Project management and participation

Project management, algorithm and app development, and reporting: Liese Siemann

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Background

Bycatch of sea turtles has been a known issue for the scallop industry since the early 2000s, with fishery observers documenting takes of loggerhead sea turtles (*Caretta caretta*) more than those of any other species (Murray 2011, NMFS 2012). Estimated sea turtle takes peaked prior to September 2006 when the use of turtle chain mats became required in the Mid-Atlantic Bight (MAB) from May through November (Murray 2011). In order for the National Marine Fisheries Service (NMFS) to allow continued operation of the fishery, it must continue to determine that it will not "jeopardize the continued existence" of loggerheads or any other species listed under the Endangered Species Act (ESA) (NMFS 2012). Tracking the number of takes by the scallop fishery is complicated. Fisheries observers are not present on all fishing trips, and lethal interactions between turtles and scallop dredges could occur even if turtles are not caught in the dredge bag.

Until recently, sea turtle takes by the scallop fishery were estimated using a monitoring proxy based on dredge hours in the MAB from May through November. This indirect approach was required because turtle takes by scallop dredges are rarely observed and takes cannot be calculated from on-deck observations. The proxy established in the 2012 Biological Opinion (BiOp) was based on the average number of fishery dredge hours during the 2007 and 2008 fishing years after turtle chain mats were required, assuming that if the fishery continues to take the same number or fewer turtles per year, turtle populations impacted by the scallop fishery will not be jeopardized (Murray 2011, NMFS 2012). Reasonable and Prudent Measures, including requirements for continued research on sea turtle and fishery interactions, were included in the BiOp to further minimize any impacts of incidental takes. In 2020, the sea scallop fishery triggered an ESA Section 7 Consultation because fishery dredge hours exceeded the proxy value in 2016. This required review of the industry to determine why this occurred and writing of a new BiOp and associated measures to allow the fishery to continue operation without adversely impacting sea turtles.

Issues surrounding the new BiOp were compounded by court decisions ruling that the use of the dredge-hour surrogate as a monitoring proxy was inadequate (Oceana v Wilber Ross and Fisheries Survival Fund 2020). The court ordered NMFS to better justify use of the surrogate by demonstrating a predictive relationship between dredge hours and turtle takes or "select a more appropriate surrogate or other mechanism for monitoring loggerhead takes resulting from dredge fishing." As a result, a new method was developed using stratified-ratio estimators to generate loggerhead observed and unobservable interactions with the scallop dredge fishery using data from the Northeast Fisheries Observer Program and commercial fishing data (Murray 2021). These new estimates of sea turtle bycatch were incorporated into the 2021 BiOp for the scallop fishery (NMFS 2021).

Preliminary design of the Turtle Impact Tool

As an unfunded output of the turtle tagging program funded by the Sea Scallop Research Set-Aside (RSA), Coonamessett Farm Foundation (CFF) began developing the Turtle Impact Tool to provide conservative estimates of the relative impact of different scallop fishery management alternatives on loggerhead sea turtles. The tool incorporates spatially and temporally specific data for monthly turtle densities, derived from loggerhead tagging programs, and for scallop fishing effort, derived from scallop survey programs, Vessel Trip Reporting (VTR) data, and Vessel Monitoring System (VMS) data. No assumptions are made about the likelihood of scallop dredges interacting with co-occurring turtles. Impact estimates are based on estimates for the number of days that scallop vessels are fishing in each MAB Scallop Area Management Simulator (SAMS) area and the number of turtles that are in the same MAB SAMS area each month.

The original version was developed with input from sea turtle and scallop biologists and statisticians at the Northeast Fisheries Science Center (NEFSC) and the Greater Atlantic Regional Fisheries Office (GARFO). It was designed to run as an R Shiny app, but the app was not made public or hosted on any websites. Users could input details about two different scallop management alternatives, including open area days-at-sea (DAS) and the number of trips allocated to MAB rotational access areas. Options for SAMS area shapefiles were limited to areas defined before 2020, and scallop data could only be entered into the tool as biomass estimates by SAMS area from the yearly scallop assessment surveys. Output was a table with turtle impact ratios and a total turtle impact map for each alternative. The impact ratios could be used to determine which scallop fishery management alternative would result in a higher impact on loggerheads.

Project objectives and upgrades

This goal of this project was to improve the tool and advance through the preliminary design phase to implementation on a publicly accessible website (shinyapps.io). The specific objectives of the project included:

(1) Incorporating more extensive data sets from turtle tagging efforts, VMS, and VTR.

(2) Upgrading the tool with new capabilities and functions (**Table 1**).

(3) Determining if output from the tool could provide an alternate surrogate for turtle takes that incorporates seasonal and spatial distributions of loggerheads and scallop fishing effort.

(4) Sharing the tool with managers and other interested parties during informational sessions.

Table 1. *Main upgrades to the Turtle Impact Tool.*

	Original version	**Upgrades in Turtle Impact Tool 2.0**
Input	Limited to two management alternatives	Up to 10 management alternatives
	Turtle data limited to modeled 2004-2016 and observed 2016-2018 tagging data	Turtle data will be updated with newer tagging data
	Access area designations limited to combinations from recent years	Access area designations will be flexible with independent assignments per SAMS area
	Monthly fishing effort equal for May-November and December-April and based on FY2018 data only	Monthly fishing effort designations will be flexible with defaults based on more years of data
Output	View total impact maps	View and download total impact and monthly impact maps
	View impact ratio table	View and download tables with impact ratios and total and monthly impact values
	Impact as scallop fleet DAS x number of sea turtles in all of the MAB SAMS areas	Impact also calculated as dredge hours x number of sea turtles in all of the MAB SAMS areas

The improved tool now offers two options for users to compare impacts from scallop fishery management alternatives. Two management alternatives can be assessed by entering model parameters directly into the graphical user interface (GUI). Tool results, including impact maps and a table showing the relative impacts of the two alternatives, are displayed on the GUI if this option is used. Users can also opt to enter data for multiple management alternatives by putting together data tables (csv files) for these alternatives. Users can download impact data tables and reports that include impact tables and maps when this option is used.

The user guide is included at the end of the report as **Appendix A**. Additional information about methods used to meet the project objectives are included in this report. All details about the GUI and using the tool are included in the user guide.

Methods and Results

Loggerhead sea turtle monthly density

The tool includes two sets of monthly turtle density rasters. The first is based on monthly densities derived from a geostatistical model that was developed using 2004-2016 tagging data from 271 tags deployed by six tagging programs in the western North Atlantic (Winton et. al. 2018). The rasters included in the tool were derived from shapefiles of log(density) from this model that are available through the NMFS (https://inport.nmfs.noaa.gov/inport/item/27337). The rasters in the tool were derived by subdividing the 40×40km grid squares from Winton et al. (2018) into 16 smaller 10×10km cells, recalculating the proportional densities for each smaller grid cell, and using a low-pass filter on the new dataset to generate the rasters in **Figure A1**.

Table 2. *Number of tagged turtles per year. Tagged turtles with tags that remained active over more than one calendar year were counted each year, so the total number is not equal to the sum from each year.*

Year	Number of turtles
2009	2
2010	16
2011	37
2012	52
2013	40
2014	33
2015	24
2016	28
2017	39
2018	48
2019	6
Total	192

The tool also includes a set of monthly turtle density rasters derived by binning 2009-2019 tagging data collected by CFF in collaboration with the NEFSC Protected Species Branch using funding from the scallop RSA program and funding to the NEFSC (**Figure A2**, Patel et al. 2021). Over the decade of tagging efforts, 192 loggerheads were tagged, and total numbers of tagged turtles per year are shown in **Table 2**. Daily tagged turtle locations, derived by interpolating raw tag data using the methods in Patel et al. (2021), were binned into 10×10km grid squares by year and month.

Map figures are included in the tool user guide in **Appendix A**.

Fishing effort analysis

Tool defaults for fishing effort and the relationships between scallop biomass or density and fishing effort were derived using VTR and VMS data as independent measures of fishing effort. Additional summary statistics for trends in the scallop fishery from 2015 through 2022 were also estimated.

VTR data (FY2015 to FY2022) for scallop trips was cleaned to remove blank data cells and unrealistic data entries. All codes for the scallop fishery, including standard and turtle-deflector dredges with and without turtle chain mats and scallop trawls were included in the analysis (ie. DRS, DSC, DTS, DTC, and OTC) because it was not focused only on impacts from scallop dredges (**Table 3**). Effort, as hours fishing in a 10×10km grid square, was estimated based on the tow number, gear number, and length of the tow. Additional data cleaning was completed in ArcGIS to remove tow locations that were on land, in Canadian waters, or in depths over 200m.

VMS data (FY2016 to FY2022) was combined into data frames by fishing year. Locations and times reported in the supplied VMS data were used to calculate speeds at each location. A fishing speed filter (2.7 to 5.7 knots) was applied to identify vessels were fishing, with this speed range based on conversations with commercial fishermen operating large and small commercial scallop

vessels. Effort, as hours fishing, was estimated based on the time spent fishing in each 10×10km grid square. gear number, and length of the tow.

Table 3. *Breakdown of scallop fishing trips by gear code and region from FY2015 through FY 2022. MAB=Mid-Atlantic Bight, GB=Georges Bank, TDD=turtle-deflector dredge.*

Gear code and type	Number of MAB trips	Number of GB trips
DRS - standard dredge	24,955	37,294
DRC - standard dredge with chain mat	3,748	190
DTS - TDD	2,116	1,201
DTC - TDD with chain mat	6,461	2,147
OTC - scallop trawl	1,246	4
Totals	38,526	40,836

The fishing effort shapefiles generated using VTR and VMS data were used to estimate fishing effort in a range of categories. SAMS-area labels, SAMS-area designations (open, access area, or closed), and fishing regions - MAB or Georges Bank (GB) through the Gulf of Maine - were added to each row of data in the cleaned VTR and VMS data tables. These data tables were used to derive the default model estimates included with the tool. All available years of VMS and VTR data were used to estimate the proportion of open area fishing effort in MAB (**Figure 1**), and all available years of VTR data were used to estimate the length of MAAA trips (**Figure 2**). Data from FY2018 through FY2021 were used to estimate fishing effort per month (**Figure 3** and **Table A3**). Years prior to 2018 were excluded from the monthly effort analysis because the start of the fishing year changed in 2018 from March to April. FY2022 was also excluded from this analysis because there were no access areas in the MAB.

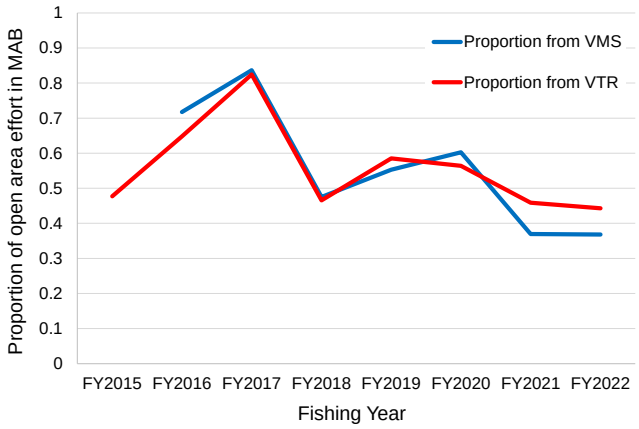

Figure 1. *Proportion of open area fishing effort in the Mid-Atlantic Bight (MAB) from FY2015 through FY2022. The mean proportion for all fishing years using VMS = 0.560 and the mean proportion for all fishing years using VTR = 0.558. Tool default is 0.55.*

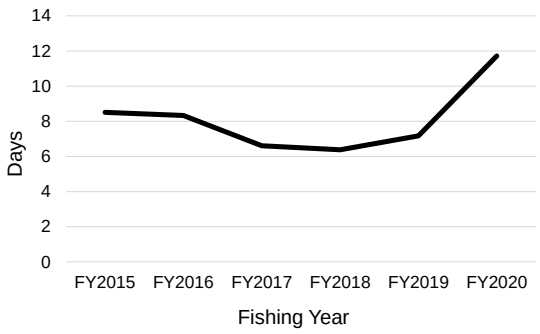

Figure 2. *Mean lengths of Mid-Atlantic Access Area (MAAA) trips based on VTR data. The mean length for all years = 7.9 days. Tool default is 8 days.*

Fishing effort estimates from 2015 through 2021 were also used to verify the linear relationships between fishing effort and scallop biomass and density that formed the basis for the tool estimates. Scallop biomass was based on the combined estimates from multiple scallop surveys that are used for scallop assessments, with scallop density calculated using the area of each SAMS area in square km. To allow inclusion of data from multiple years, biomass and effort data were normalized by year across all access or open areas (mean = 1 for each category). For open areas, effort had the strongest linear relationship with scallop biomass (R^2 = 0.98 based on VTR data and R^2 = 0.97 based on VMS data, **Figure 4A**). For access areas, effort had the strongest linear

relationship with scallop density (R^2 = 0.94 based on VTR data and R^2 = 0.96 based on VMS data, **Figure 4B**).

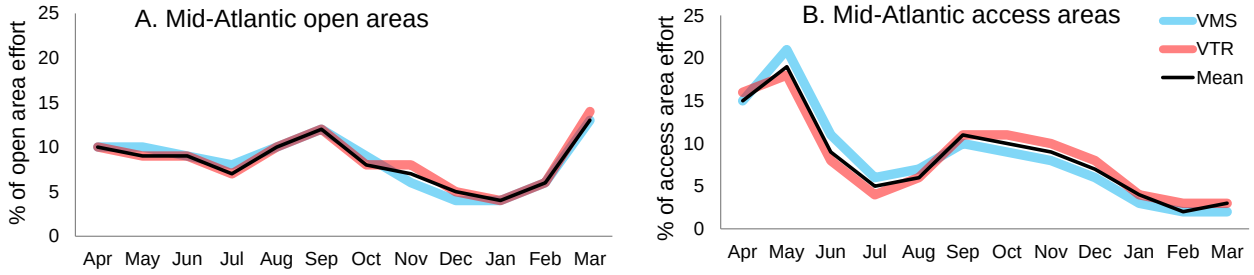

Figure 3. *(A) Estimated proportional fishing effort by month over one fishing year for open areas in the Mid-Atlantic. (B) Estimated proportional fishing effort by month over one fishing year for Mid-Atlantic access areas. Values from the black mean curve are included as the default table for estimated proportional fishing effort by month in the model.*

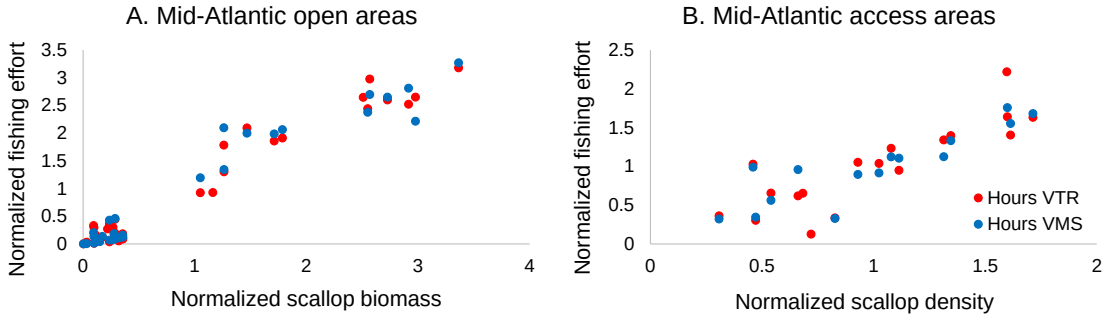

Figure 4. *(A) Mid-Atlantic open area scallop biomass vs fishing effort by Scallop Area Management Simulator (SAMS) area. (B) Mid-Atlantic access area scallop density vs fishing effort by SAMS area.*

Default scallop biomass raster

Scallop biomass (g/m2) was modeled using a Tweedie distribution as a function of location (easting and northing in UTM zone 18) and depth using data from the HabCam v3 surveys in 2021 ("gam" function in the R package "mgcv", Wood 2011). A model with a Tweedie distribution was used because the count data was over dispersed with a high proportion of zero values (Shono 2008). Scallop biomass across the MAB SAMS areas was predicted using location and depths across the Mid-Atlantic region, downloaded with one-minute resolution from National Oceanic and Atmospheric Administration databases ("getNOAAbathy" function in R package "marmap", Pante & Simon-Bouhet 2013). Ordinary kriging was used to model the distribution of model residuals ("variogram" function in the R package "gstat", Pebesma 2004), and model outputs from the Tweedie model and ordinary kriging of residuals were summed to generate final scallop biomass estimates for each point in the bathymetry grid. The gridded data was converted to a raster with 2×2km cells (**Figure A4**).

Comparison of Turtle Impact Tool output and surrogates to turtle takes used in management

To compare estimates of turtle impacts generated by the tool to published estimates used in the most recent 2021 BiOp (Murray 2021), monthly impacts to loggerheads were calculated using custom R code, based on the original version of the tool, that incorporates the scallop biomass numbers used for scallop assessments. The Winton et al. (2018) rasters were used as the turtle distribution inputs and the SAMS areas and status for each (open/closed/access area) matched those for each

framework. Default values for the number of turtles (48,700) and the number of vessels fishing (330) were used for the analysis. The open area DAS and number of access area trips were based on the frameworks for the fishery during each year included in the comparison (e.g., 2015, 2016, 2018, and 2019), summarized in Framework 32 (NEFMC 2020), and the proportion of open area fishing and length of access area trips were based on the analyses summarized in **Figures 1 and 2**. All of the parameters are shown in **Table 4**. FY2017 was excluded from the analysis because access area fishing was allocated on an uneven basis under Framework 28, with one trip allocated to the combined Hudson Canyon, Elephant Trunk Open, and Delmarva access areas and one trip allocated to these three areas plus the Elephant Trunk Flex access area (NEFMC 2017).

Murray (2021) estimated total interactions between loggerheads and scallop dredges as the sum of estimates for observable interactions and inferred interactions. Interactions were estimated after stratifying fishing effort based on month and gear type, with seasonal occurrence of loggerheads in the MAB defined as May through December. To generate impact estimates from the Turtle Impact Tool for comparison to the total interaction estimates in Murray (2021), monthly estimates for May-December were summed to provide an estimate for the same seasonal period.

Table 4. *Management parameters used to generate impact estimates from the Turtle Impact Tool for comparisons to the total interaction estimates in Murray (2021).*

Fishing Year	Open area DAS	Allocated MAAA trips	Proportion of open area fishing in the MAB	Length of access area trips	Number of vessels	Number of turtles
2019	24	3	0.58	6.38	330	48,700
2018	24	2	0.45	6.6	330	48,700
2016	34.55	3	0.62	8.51	330	48,700
2015	30.86	3	0.46	6.59	330	48,700

Due to the small number of paired estimates (n=4), no statistical analysis was undertaken. Examination of a scatter plot comparing the data (**Figure 5**) indicates that the relationship between the two estimates was close to linear for 2015, 2016, and 2018. However, the tool estimated a much larger impact on loggerheads for 2019 relative to the total interaction method in Murray (2021).

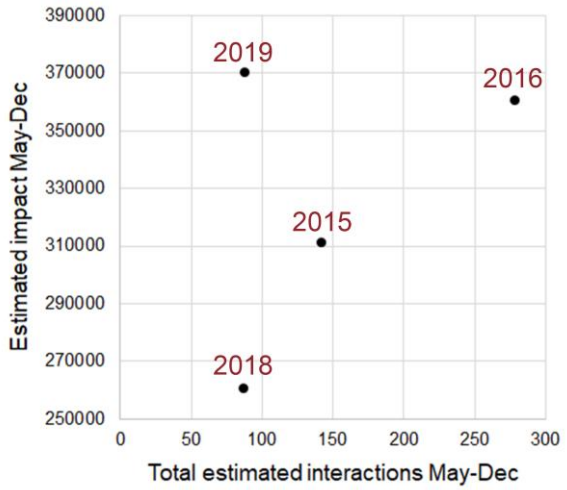

Figure 5. *Scatter plot of total estimated interactions from Murray (2021) against estimated impacts based on the Turtle Impact Tool. Years are shown above each data point.*

Evaluation

Accomplishments by objective are described below.

(1) ***Incorporating more extensive data sets from turtle tagging efforts, VMS, and VTR.***

The years included in data sets used for generating components of the tool were all increased. Turtle data in the tool now runs through 2019, a two-year increase over the data through 2017 that was included in the original version of the tool. VTR and VMS fishery inputs used for tool development include data through FY 2022, and raw data was received from NMFS to allow more in-depth analysis of key model parameters. The original tool estimates were based on processed data products from GARFO.

(2) ***Upgrading the tool with new capabilities and functions.***

Most of the planned upgrades listed in **Table 1** were completed as explained below:

- Users can now enter more than ten management alternatives into the tool at once for comparisons of a range of management alternative in one run.
- Turtle data included in the tool was updated with newer tagging data through 2019.
- Access area designations are fully flexible, and users can independently assign management status by SAMS area. This is done through the use of radio buttons for the two alternative comparisons or through a csv file for the multiple alternative comparisons.
- Monthly fishing effort designations have been improved based on an analysis of VTR and VMS data.
- Users can view and download total impact maps as part of an R markdown report (R package "rmarkdown", Allaire et al. 2020) based on the results of the multiple-alternative analysis. Monthly maps were not included in these reports because the processing time was excessive and some computers testing the code had issues with trying to generate large numbers of maps (13 per alternative tested if monthly maps were included).
- Users can view and download tables in csv format with impact ratios and total and monthly impact values.
- Impact estimates were not converted to dredge hours × number of sea turtles, although this option was tested. Impact is still calculated based on DAS. When the conversion to dredge hours was tested, the impact values increased by orders of magnitude, and feedback from those that tested the code consistently indicated that the numbers were harder to grasp intuitively.

(3) ***Determining if output from the tool could provide an alternate surrogate for turtle takes that incorporates seasonal and spatial distributions of loggerheads and scallop fishing effort.***

Estimated impact from May through December from the tool was compared to total interaction estimates in Murray (2021). This comparison covered only four years, but the relationship was close to linear for three of those years. The one year that was an outlier was 2019. The Turtle Impact Tool estimated that impact from the scallop fishery in 2019 would be high, on order with the impact in 2016 (**Figure 5**). Murray (2021) estimated that total interactions between the scallop dredge fishery would be relatively low.

The reason for the difference in these estimates is unclear. The Turtle Impact Tool bases its estimates on the predicted overlap between fishing activity and turtles. The estimates for the spatiotemporal distributions of fishing effort derived using VTR and VMS data were very similar, suggesting that the data going into the model was reasonable and backed by two different sources of independent data. Furthermore, there is a strong linear relationships between fishing effort and scallop biomass and density (**Figure 4**), indicating that this critical aspect of the tool estimates is also reasonable. However, no assumptions are made about the likelihood of scallop dredges interacting with co-occurring turtles, and this could be critical for generating impact estimates. Turtle behavior and vertical distributions in the water column could significantly impact their interaction rates with scallop dredges.

A recent study that also evaluated the use of spatiotemporal overlap between commercial fishing activity and loggerhead turtle distributions concluded that overlap might not be a good proxy for

encounter or bycatch risk (Hatch et al. 2023). However, this analysis also compared overlap indices to published loggerhead interaction estimates, including those in Murray (2021) and earlier estimates based on dredge hours that have been challenged in court and are no longer used (Murray 2011). It should be noted that it seems unlikely that interactions between loggerheads and the scallop fishery would be similar in 2018 and 2019, as predicted by Murray (2021), when the number of allocated trips to the MAAA increased from two to three trips (**Table 4**) and the proportion of open area fishing effort in the MAB also increased (**Figure 1**).

(4) ***Sharing the tool with managers and other interested parties during informational sessions.***

The tool was shared with managers and fishermen at the RSA Share Day hosted by the Scallop Plan Development Team in May 2022. This included a demonstration of tool use and sharing the site where the tool is hosted at https://lsiemann.shinyapps.io/tit2/. The tool will be hosted on this website through March 2024 with the funding from the grant.

Discussion

The biggest advantage of the Turtle Impact Tool for estimating impacts of the scallop fishery on protected loggerhead sea turtles is its ease of use. Users can quickly estimate the relative impacts of new management alternatives on sea turtles with a scallop biomass raster, generated yearly by the NEFSC. The example included with the tool and highlighted in the user guide (end of **Appendix A**) demonstrates how the tool could be used to determine the impact of opening the New York Bight Closure (NYB-Closure) to fishing if the entire MAB remains open to fishing and DAS allocations are 24 or 30 days total. Notably, both options would likely result in less impact to loggerheads than the allocations in 2021 when the Hudson Canyon and Elephant Truck access areas were in place (Alternatives 3 and 4 vs Alternative 1 in the first table in the example report and **Figure A7**). Furthermore, if the NYB-Closure is opened and the open-area allocation is held at 24 DAS, impact would likely remain similar or go down (Alternatives 3 vs Alternative 2 in the first table in the example report and **Figure A7**).

The original tool used the scallop biomass estimates by SAMS area that are estimated based on the scallop assessment surveys and published in the scallop frameworks. However, after the NYB-Closure was established, changing the boundaries of the SAMS areas, the tool was changed to allow users to select alternative SAMS-area boundaries. This change altered the way scallop biomass data is entered into the tool (i.e., as a biomass raster instead of biomass estimates by SAMS area). The original method, using biomass estimates by SAMS area, was used to generate the impact values for comparison to the total interaction estimates in Murray (2021). This code is available upon request.

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Appendix A – Turtle Impact Tool 2.0 User Guide with example R markdown report

The user guide and example tables are available at https://www.coonamessettfarmfoundation.org/turtle-impact-tool.

Turtle Impact Tool 2.0

The Turtle Impact Tool was created to provide conservative estimates for the impact of different scallop fishery management alternatives on loggerhead sea turtles. This tool incorporates spatially and temporally specific data for monthly turtle densities, derived from loggerhead tagging programs, and for scallop fishing effort, derived from scallop survey programs, Vessel Trip Reporting (VTR) data, and Vessel Monitoring System (VMS) data. No assumptions are made about the likelihood of scallop dredges interacting with co-occurring turtles. Impact estimates are based on estimates for the number of days that scallop vessels are fishing in each Mid-Atlantic Bight (MAB) Scallop Area Management Simulator (SAMS) area and the number of turtles that are in the same MAB SAMS area each month.

Users can change key components of scallop fishery management plans for the limited access (LA) fleet, including the open area days-at-sea (DAS) allocations, the number of trips in Mid-Atlantic Access Areas (MAAAs), and the shapefile used to defined the MAB SAMS areas and therefore the boundaries for open, closed, and rotational access areas. Values entered into the tool can be adjusted to incorporate additional fishing effort from part-time and occasional vessels by increasing the number of vessels above just those with full-time permits.

The tool offers two options for users to compare impacts from scallop fishery management alternatives. Two management alternatives can be assessed by entering model parameters directly into the graphical user interface (GUI). Tool results, including impact maps and a table showing the relative impacts of the two alternatives, are displayed on the GUI if this option is used. Users can also opt to enter data for multiple management alternatives by putting together data tables (csv files) for these alternatives. Users can download impact data tables and reports that include impact tables and maps when this option is used.

Tool components

Loggerhead sea turtle monthly density

The tool includes two sets of monthly turtle density rasters. The first is based on monthly densities derived from a geostatistical model that was developed using 2004-2016 tagging data from 271 tags deployed by six tagging programs in the western North Atlantic (**Figure 1**, Winton et. al. 2018). It also includes a set of monthly turtle density rasters derived by binning 2009-2019 tagging data collected by CFF in collaboration with the NEFSC Protected Species Branch using funding from the scallop RSA program (**Figure 2**, Patel et al. 2021).

Mid-Atlantic Bight (MAB) Scallop Area Management Simulator (SAMS) areas

The tool includes two shapefiles for the most recent MAB SAMS areas including the area (km^2) of each region: the MAB SAMS areas prior to fishing year (FY) 2022 and the new 2022 MAB SAMS areas that include a closure in the New York Bight (**Figure 3**).

Scallop biomass across the MAB

The tool includes a default scallop biomass raster based on data collected during the 2021 Coonamessett Farm Foundation (CFF) HabCam v3 survey (**Figure 3**). Users can also use their own scallop biomass rasters when running multiple-alternative comparisons.

Management designations for each SAMS area

Users can change the management designations for each SAMS area (open, closed, access area) using radio buttons on the two-alternative tab. Users upload a table with the management status for each SAMS area for each alternative when using the multiple-alternative tab (example in **Table 1**).

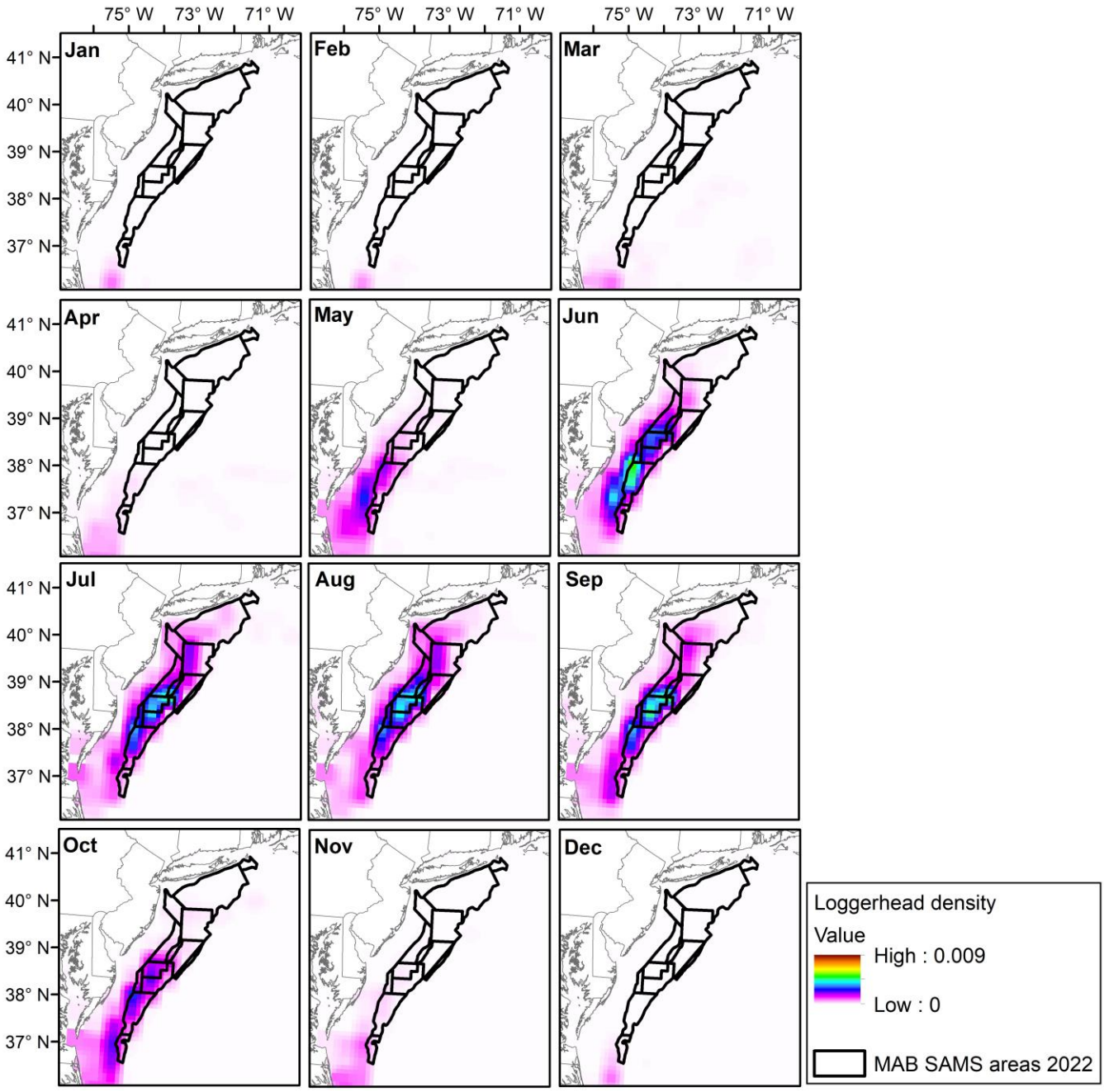

Figure 1. Monthly normalized turtle density maps based on the Winton et. al. 2018 model.

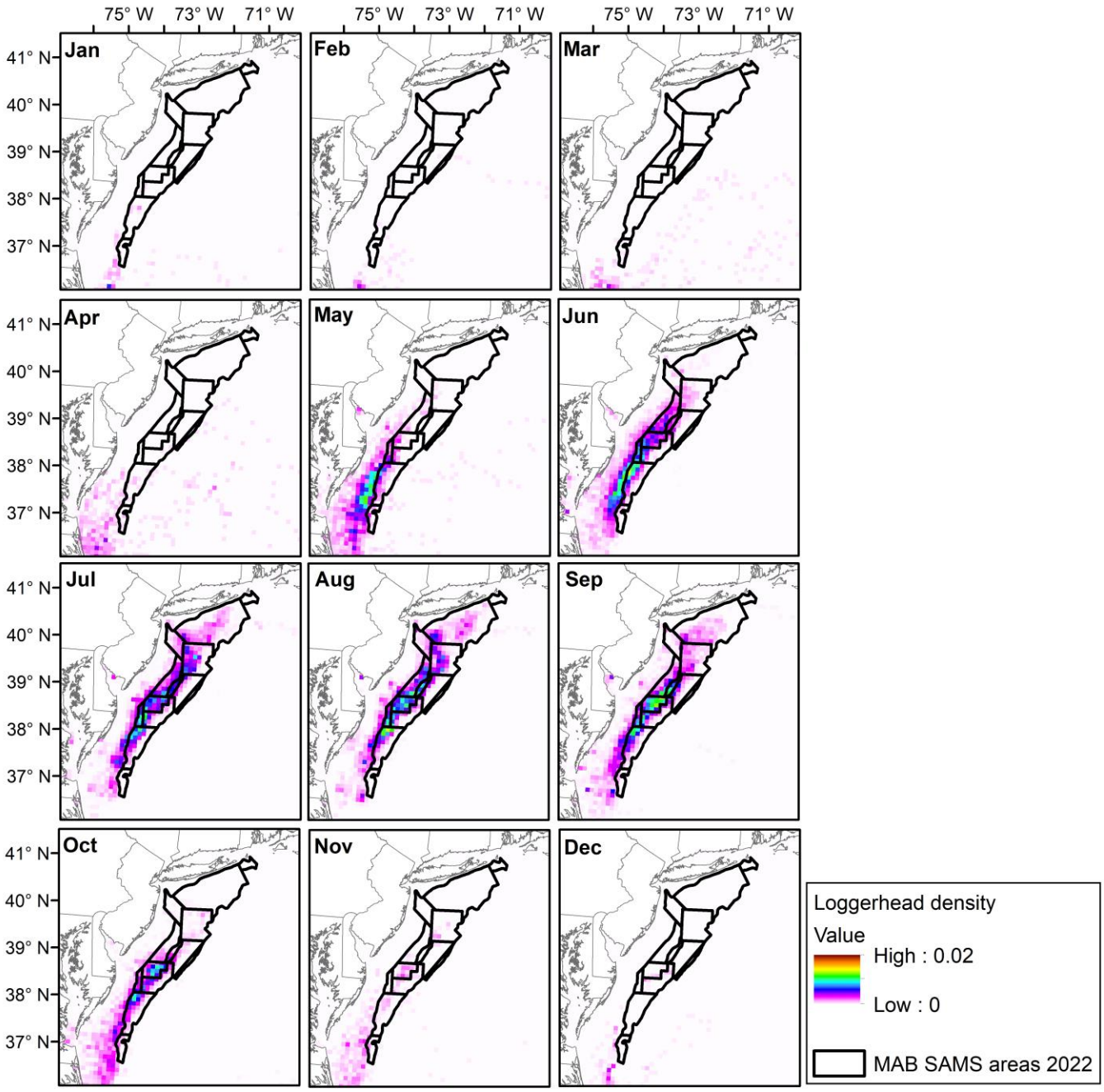

Figure 2. Monthly normalized turtle density maps based on tagging data from 2009-2019.

Relationships between scallop biomass/density and fishing effort

Estimated scallop biomass and yearly effort data by SAMS area for 2015 – 2022 were used to derive best-fitting linear relationships between scallop biomass or density and fishing effort for open and access areas. Effort has a linear relationship with scallop biomass in open areas and with scallop density in access areas.

Estimated proportional fishing effort by month

The tool includes a default table of proportional fishing effort by month for MAB open and access areas based on VTR and VMS data from FY 2018 through FY2021 (**Table 2**). Users can upload their own tables of proportional fishing effort by month when running multiple-alternative comparisons.

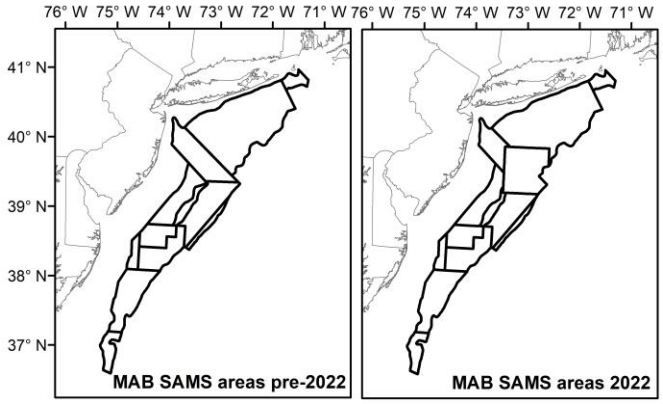

Figure 3. Mid-Atlantic Bight SAMS areas included in the tool.

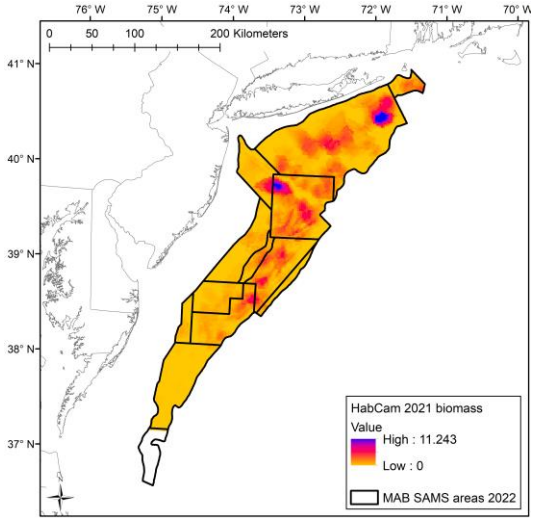

Figure 4. Default scallop biomass raster included in the tool.

The R Shiny app

The Turtle Impact Tool runs as an R Shiny app. The app includes two options for running the tool (separate tabs). The option labeled "Simple Two Alternatives" uses the default scallop biomass raster and all of the inputs are entered on the GUI. Tool outputs, including maps and a table of impact ratios, are displayed on the GUI only. The option labeled "Multiple Alternatives" allows users to supply their own scallop biomass raster, or use the default scallop biomass raster, and enter information for multiple alternatives by uploading csv files. Impact estimates for all of the Alternatives are displayed on the GUI, and users can download this table and/or a report that includes the displayed table, impact maps for each alternative, and details about the inputs used for that analysis. can download this table and/or a report that includes the displayed table, impact maps for each alternative, and details about the inputs used for that analysis.

Simple Two Alternatives

User inputs: To run the tool using this option, users input the following parameters for two management alternatives (**Figures 5 and 6**):

1) The MAB SAMS areas to be used. The default selection is the SAMS areas before 2022.

2) The management designations for each SAMS area. The default selections are the designations that were in place during FY2020 and FY2021.

3) The number of full-time equivalent scallop vessels. The default value of 330 is based on the number of full-time limited access vessels plus half of the part-time limited access vessels over the last 10 years (Table 35 in NEFMC 2022).

4) The loggerhead sea turtle population size. The default value of 48,700 turtles is based on the most recent estimates for the Mid-Atlantic loggerhead population (Table 9 in NEFSC 2011), rounded to the nearest 100.

5) The number of open area DAS.

Figure 5. The Turtle Impact Tool User Interface. This shows the appearance of the "Simple Two Alternatives" tab of the GUI after the tool runs.

6) The percentage of open area effort in MAB. The tool provides a default value of 55%, which is an estimate based on VTR and VMS data, rounded to the nearest 5%. (see Appendix A for more details)

7) The number of trips in MAAAs.

8) The length of MAAA trips in DAS – the tool provides a default of 8 days, which is an estimate based on VTR reports for 15,000 to 18,000-lb trip lengths in MAAAs from FY2016 through FY2021.

Tool outputs: The tool outputs the following information (**Figure 6**):

1) A table with impact ratios for each month and the full year.

2) Total turtle impact maps for each alternative with matching scales for easy comparisons.

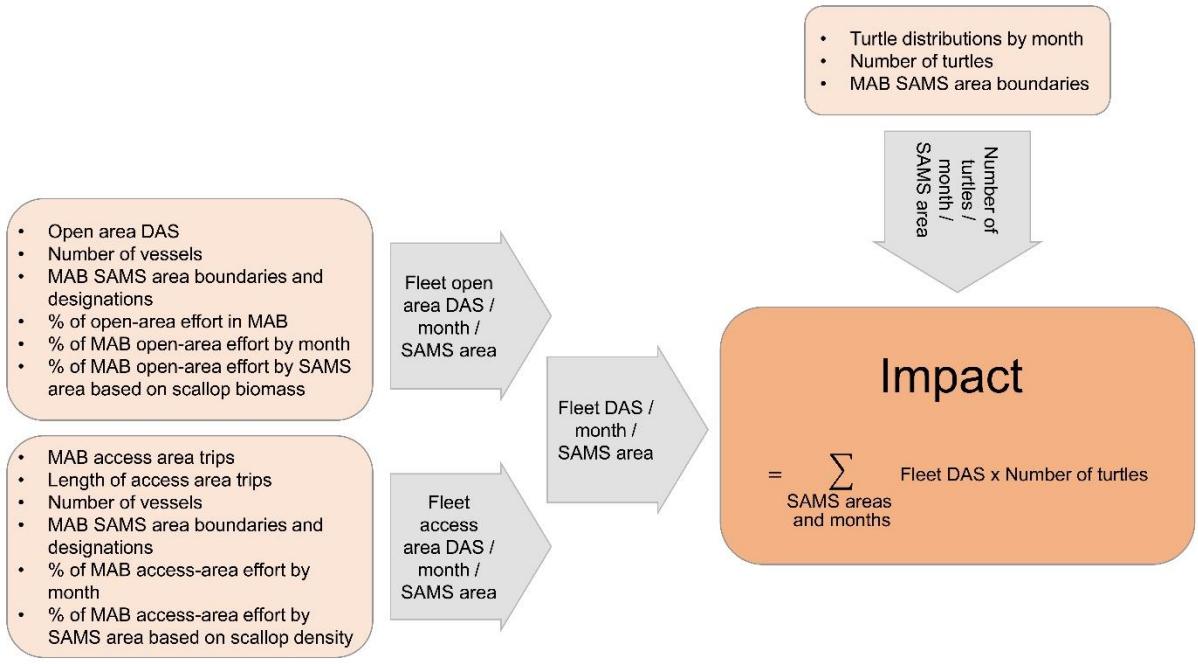

Figure 6. Flow chart showing tool components

Multiple Alternatives

User inputs: To run the tool using this option, users upload the following files with input parameters for multiple alternatives The recommended maximum number = 10 to avoid long run times if more are included. The files that need to be uploaded include the following (**Figure 7**):

1) A raster that defines the spatial distribution and abundance of scallop biomass in the MAB. This can be the included default raster HabCam2021GAMOKresiduals.tif or a raster supplied by the user.

2) A table (csv file) with the alternative management parameters. The required column headings are shown in **Table 1**. The same table is also included as an example in the package folder (Alternative management parameters 4 EXAMPLE.csv).

3) A table (csv file) with the alternative MAB SAMS area designations. The required first column is shown in **Table 3**. The same table is also included as an example in the package folder (Alternative SAMS area designations 4 EXAMPLE.csv).

4) A table (csv file) with proportional fishing effort by month for MAB open and access areas. The required first column and column headings are shown in **Table 2**. Note that only one table can be included per run. The same table is also included as as the default table in the package folder (Effort by month split DEFAULT.csv).

Tool outputs: The tool outputs the following information (**Figure 7**):

1) A table with impacts for each month and the full year for each alternative.

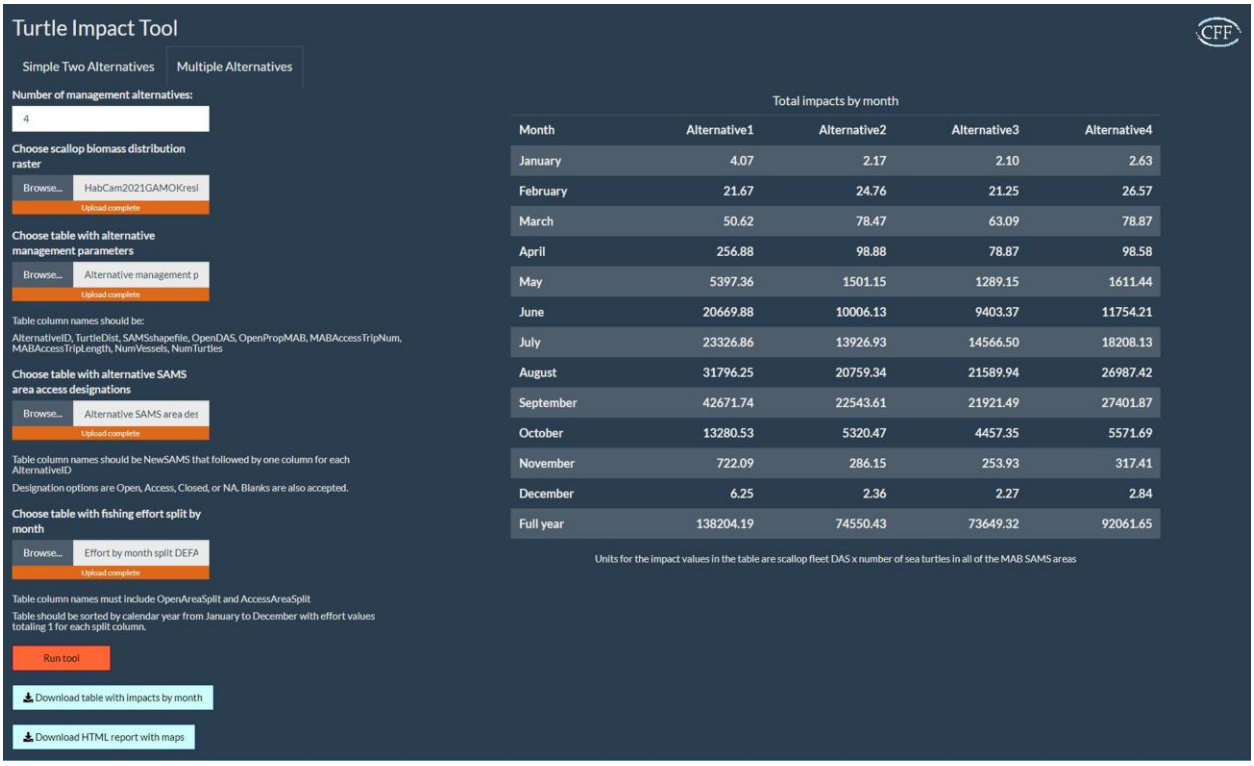

Figure 7. The Turtle Impact Tool User Interface. This shows the appearance of the "Multiple Alternatives" tab of the GUI after the tool runs using the included example and default files.

Tool downloads: The tool lets users download the following products:

1) The table with impacts for each month and the full year for each alternative that is displayed when analysis is completed (as a csv file).

2) A report (html format) that includes the above table, total impact maps for all alternatives, and all user inputs (name of the scallop biomass raster and copies of the three uploaded tables). An example of the report is included at the end of the guide.

Literature cited

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Winton MV, Fay G, Haas HL, Arendt M, Barco S, James MC, Sasso C, Smolowitz R. 2018. Estimating the distribution and relative density of satellite-tagged loggerhead sea turtles using geostatistical mixed effects models. Marine Ecology Progress Series 586: 217-32.

Table 1: Example of table with alternative management parameters.

AlternativeID	TurtleDist	SAMSshapefile	OpenDAS	OpenPropMAB	MABAccessTripNum	MABAccessTripLength	NumVessels	NumTurtles
A1	Model	MABSAMSold	24	0.55	1	8	330	48700
A2	Model	MABSAMS	24	0.55	0	0	330	48700
A3	Model	MABSAMSold	24	0.55	0	0	330	48700
A4	Model	MABSAMSold	30	0.55	0	0	330	48700

Table 2: Default table for proportional fishing effort by month for MAB open and access areas. Note that the sum of values in the columns "OpenAreaSplit" and "AccessAreaSplit) are each equal to one.

Month	MonthName	OpenAreaSplit	AccessAreaSplit
1	Jan	0.04	0.04
2	Feb	0.06	0.02
3	Mar	0.13	0.03
4	Apr	0.1	0.15
5	May	0.09	0.19
6	Jun	0.09	0.09
7	Jul	0.07	0.05
8	Aug	0.1	0.06
9	Sep	0.12	0.11
10	Oct	0.08	0.1
11	Nov	0.07	0.09
12	Dec	0.04	0.07

Table 3: Example of table with alternative MAB SAMS area designations for the three alternatives shown in Table 1.

NewSAMS	A1	A2	A3	A4
BI	Open	Open	Open	Open
LI	Open	Open	Open	Open
Nearshore-N	Open	Open	Open	Open
Nearshore-S	Open	Open	Open	Open
NYB	Open	Open	Open	Open
NYB-West	Open	Open	Open	Open
NYB-East	Open	Open	Open	Open
NYB-Closure	NA	Closed	NA	NA
HCS	Access	Open	Open	Open
ET-Open	Access	Open	Open	Open
ET-Flex	Access	Open	Open	Open
DMV	Open	Open	Open	Open
VIR	Open	Open	Open	Open

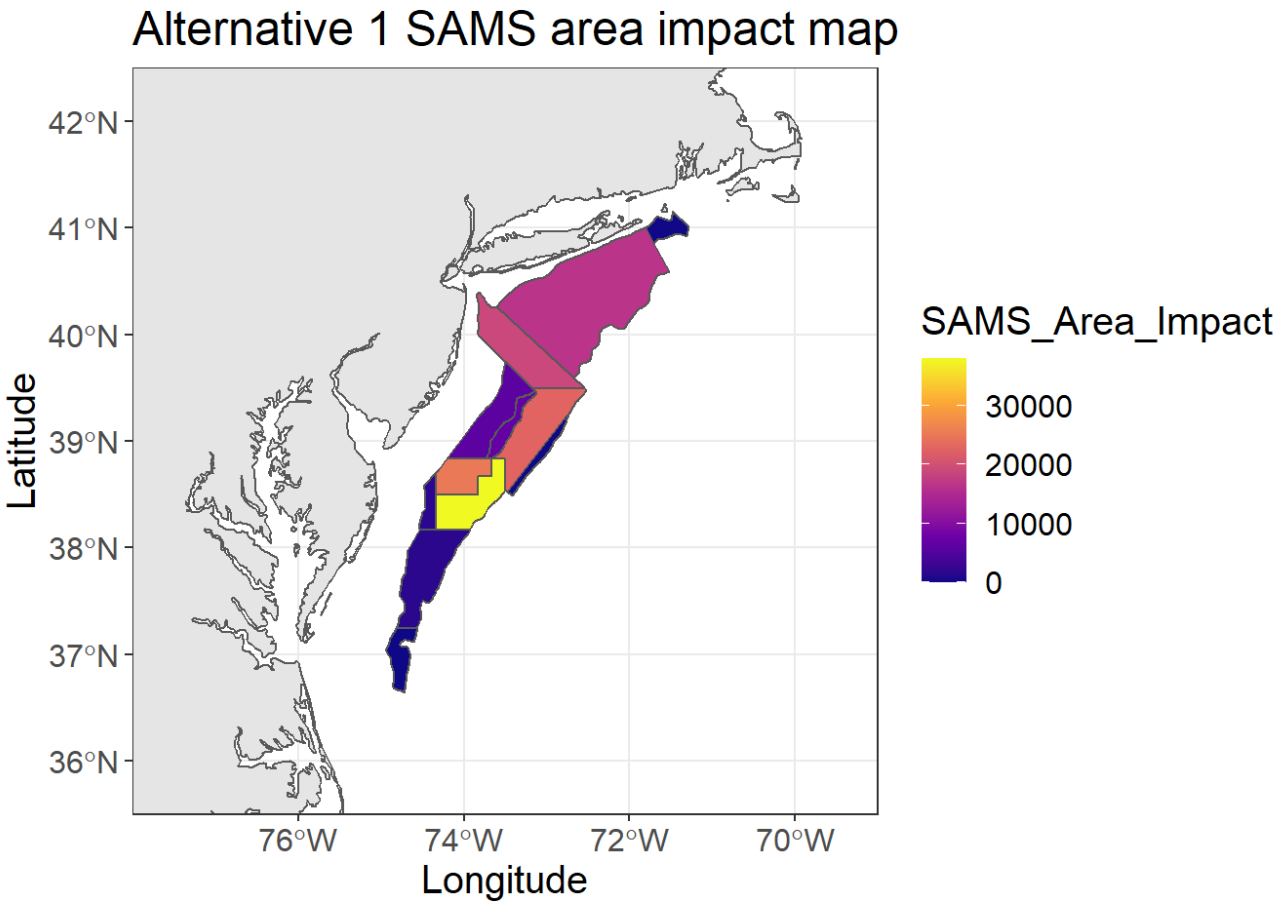
Turtle Impact Tool output

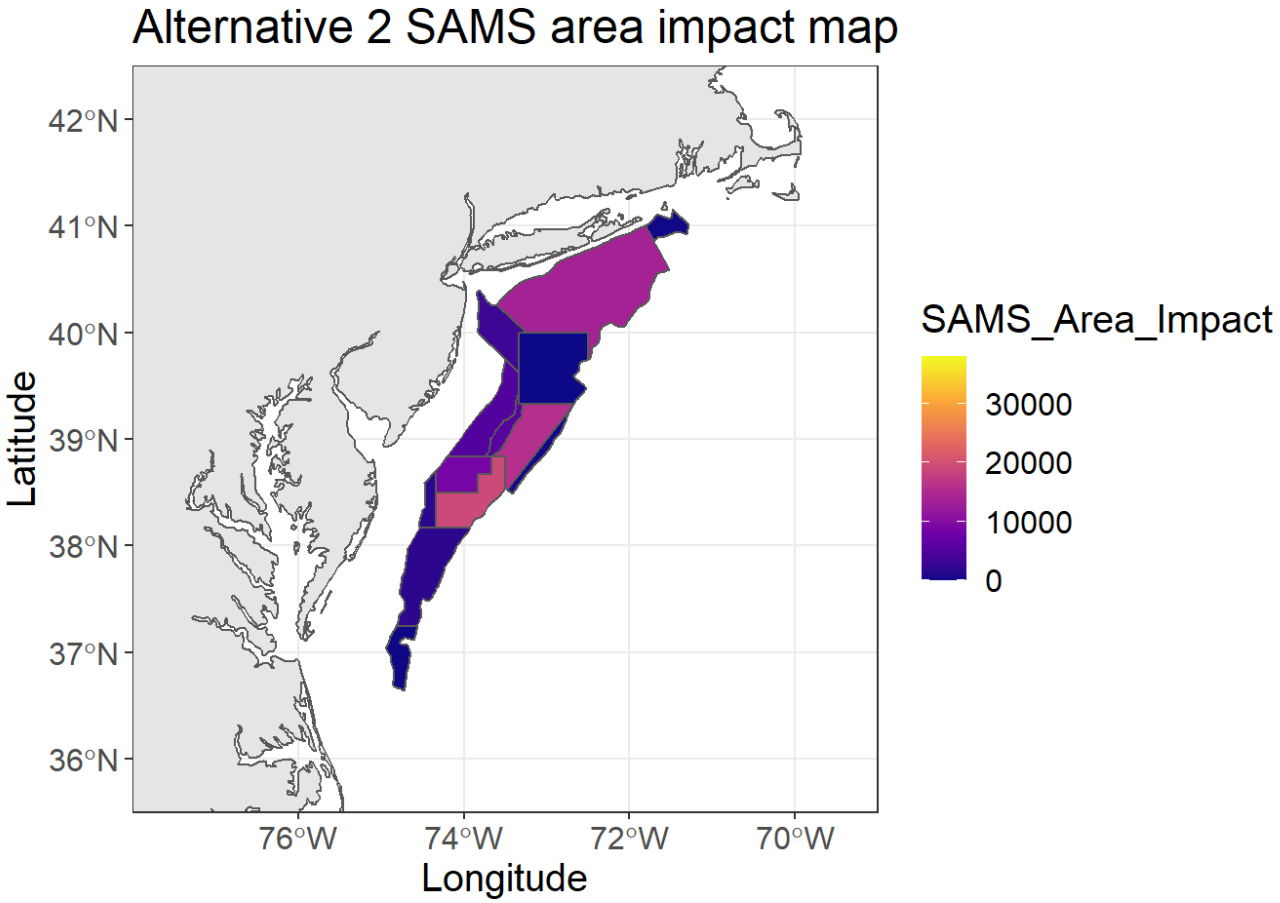
2023-07-19

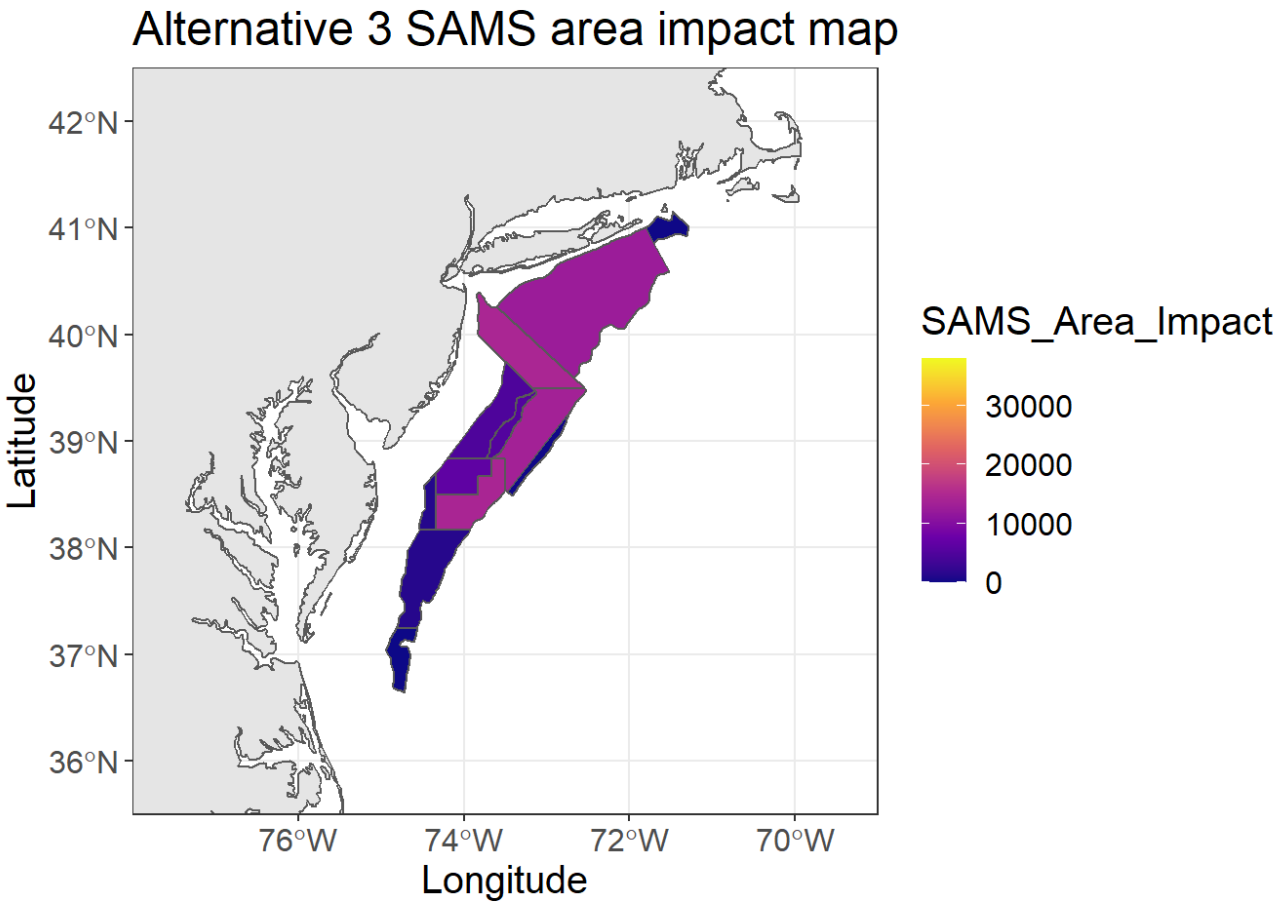
Output

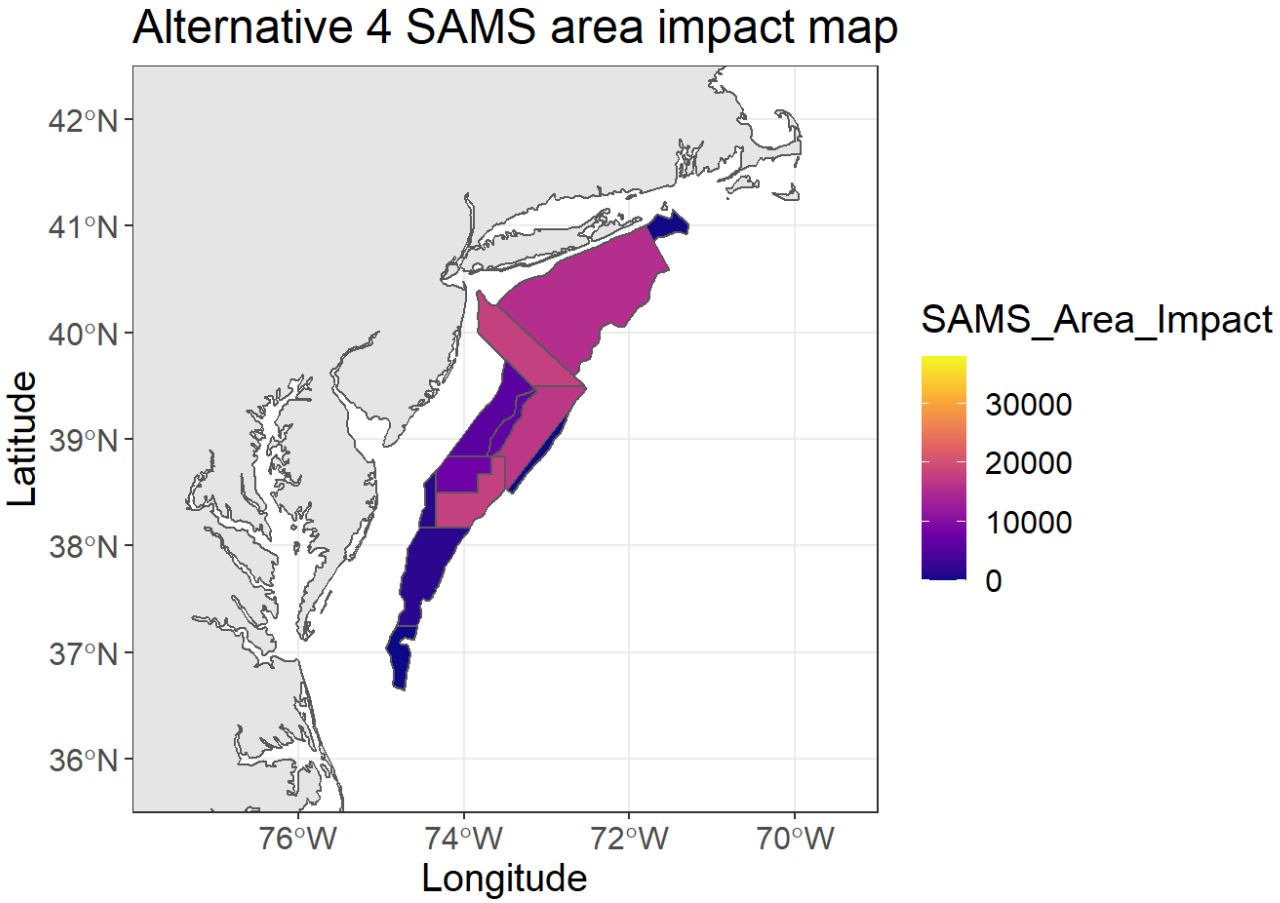
Monthly and total impacts for alternatives

Month	Alternative1	Alternative2	Alternative3	Alternative4
January	4.069	2.175	2.102	2.627
February	21.667	24.760	21.255	26.568
March	50.618	78.467	63.095	78.869
April	256.876	98.880	78.866	98.582
May	5397.358	1501.155	1289.155	1611.443
June	20669.881	10006.126	9403.371	11754.214
July	23326.859	13926.934	14566.502	18208.128
August	31796.249	20759.343	21589.935	26987.419
September	42671.743	22543.610	21921.494	27401.867
October	13280.531	5320.471	4457.350	5571.687
November	722.091	286.150	253.926	317.408
December	6.247	2.361	2.271	2.839
Full year	138204.189	74550.432	73649.322	92061.651


Alternative 1 SAMS area impact map
42°N
41°N
40°N
39°N
38°N
37°N
36°N
Latitude
76°W
74°W
72°W
70°W
Longitude
SAMS_Area_Impact
30000
20000
10000
0


Alternative 2 SAMS area impact map
42°N
41°N
40°N
39°N
38°N
37°N
36°N
Latitude
76°W
74°W
72°W
70°W
Longitude
SAMS_Area_Impact
30000
20000
10000
0


Alternative 3 SAMS area impact map
42°N
41°N
40°N
39°N
38°N
37°N
36°N
Latitude
76°W
74°W
72°W
70°W
Longitude
SAMS_Area_Impact
30000
20000
10000
0


Alternative 4 SAMS area impact map
42°N
41°N
40°N
39°N
38°N
37°N
36°N
Latitude
76°W
74°W
72°W
70°W
Longitude
SAMS_Area_Impact
30000
20000
10000
0

Input data

Scallop biomass raster = HabCam2021GAMOKresiduals.tif

Alternative management parameters

AlternativeID	TurtleDist	SAMSshapefile	OpenDAS	OpenPropMAB	MABAccessTripNum	MABAccessTripLength	NumVessels	NumTurtles
A1	Model	MABSAMSold	24	0.55	1	8	330	48700
A2	Model	MABSAMS	24	0.55	0	0	330	48700
A3	Model	MABSAMSold	24	0.55	0	0	330	48700
A4	Model	MABSAMSold	30	0.55	0	0	330	48700

Alternative SAMS area access designations

NewSAMS	A1	A2	A3	A4
BI	Open	Open	Open	Open
LI	Open	Open	Open	Open
Nearshore-N	Open	Open	Open	Open
Nearshore-S	Open	Open	Open	Open
NYB	Open	Open	Open	Open
NYB-West	Open	Open	Open	Open
NYB-East	Open	Open	Open	Open
NYB-Closure	NA	Closed	NA	NA
HCS	Access	Open	Open	Open
ET-Open	Access	Open	Open	Open
ET-Flex	Access	Open	Open	Open
DMV	Open	Open	Open	Open
VIR	Open	Open	Open	Open

Monthly fishing effort splits

Month	MonthName	OpenAreaSplit	AccessAreaSplit
1	Jan	0.04	0.04
2	Feb	0.06	0.02
3	Mar	0.13	0.03
4	Apr	0.10	0.15
5	May	0.09	0.19
6	Jun	0.09	0.09
7	Jul	0.07	0.05
8	Aug	0.10	0.06
9	Sep	0.12	0.11
10	Oct	0.08	0.10
11	Nov	0.07	0.09
12	Dec	0.04	0.07