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 a set of monthly turtle density rasters 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). Units in each cell in the turtle rasters are the percentage of all Mid-Atlantic turtles in each cell for each month. Monthly rasters are shown in **Figure 1**. See **Appendix A** for more details.

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 2**).

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. See **Appendix A** for more details.

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.

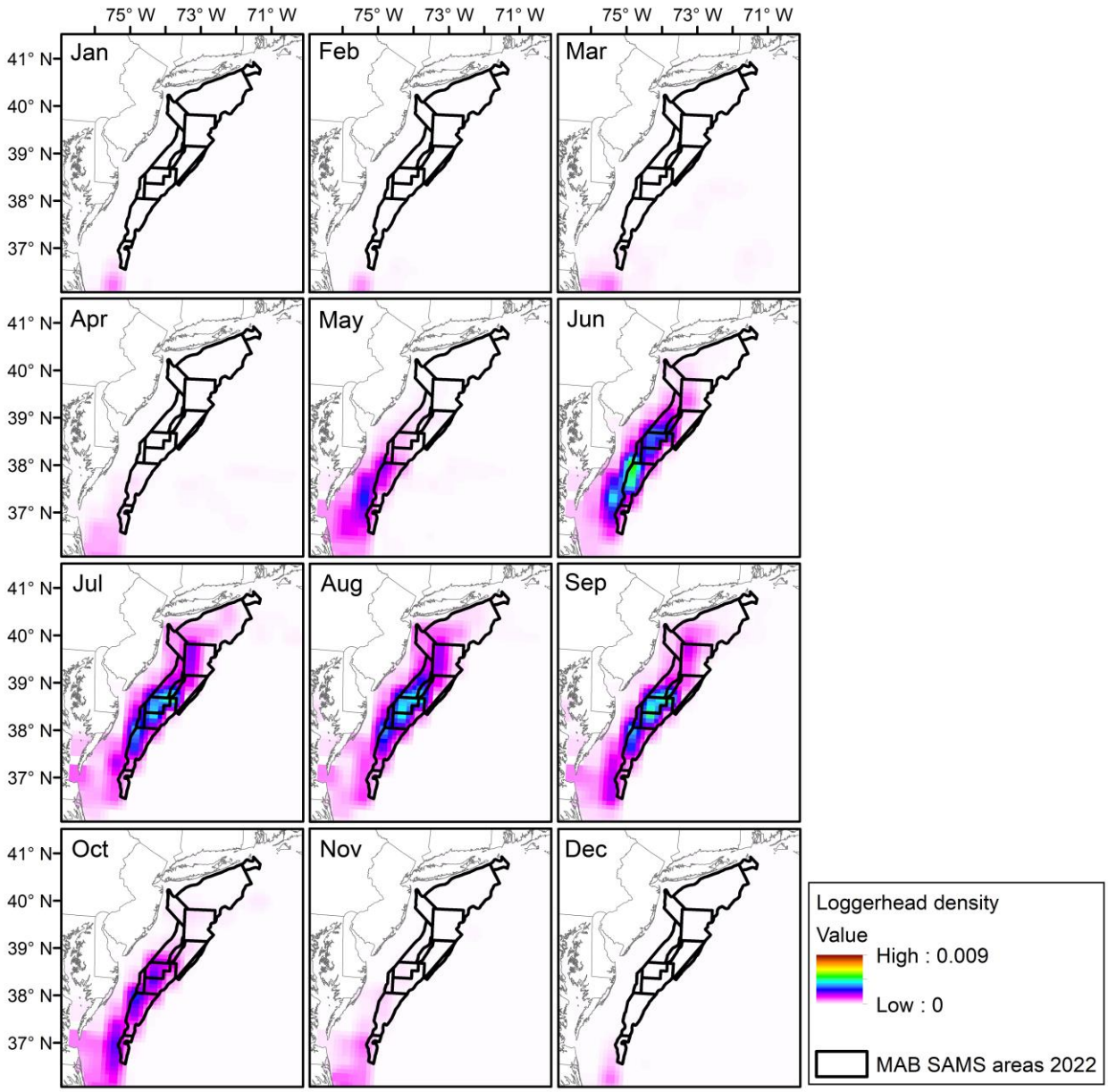


Figure 1. Monthly normalized turtle density maps based on the Winton et. al. 2018 model.

Relationships between scallop biomass/density and fishing effort

Estimated scallop biomass and yearly effort data by SAMS area for 2016 – 2020 was used to derive best-fitting linear relationships between scallop biomass or density and fishing effort for open and access areas. Yearly effort statistics by SAMS area were derived from VTR and VMS data (see **Appendix A** for more details). For open areas, effort had 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 2016 – 2020. See **Appendix A** for more details. Users can upload their own tables of proportional fishing effort by month when running multiple-alternative comparisons.

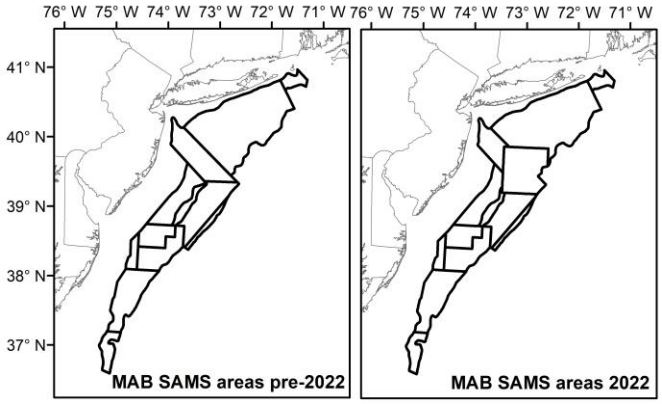


Figure 2. Mid-Atlantic Bight SAMS areas included in the tool.

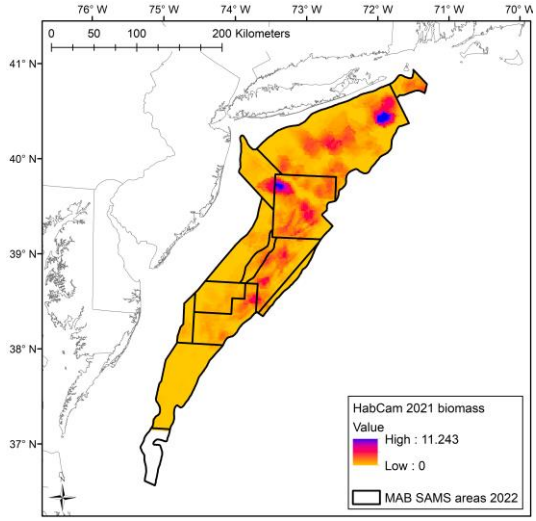


Figure 3. Default scallop biomass raster included in the tool.

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 4 and 5**):

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 4. 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 7.5 days, which is an estimate based on VTR reports for 15,000 to 18,000-lb trip lengths in MAAAs from FY2015 to FY2020.

Tool outputs: The tool outputs the following information (**Figure 4**):

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.

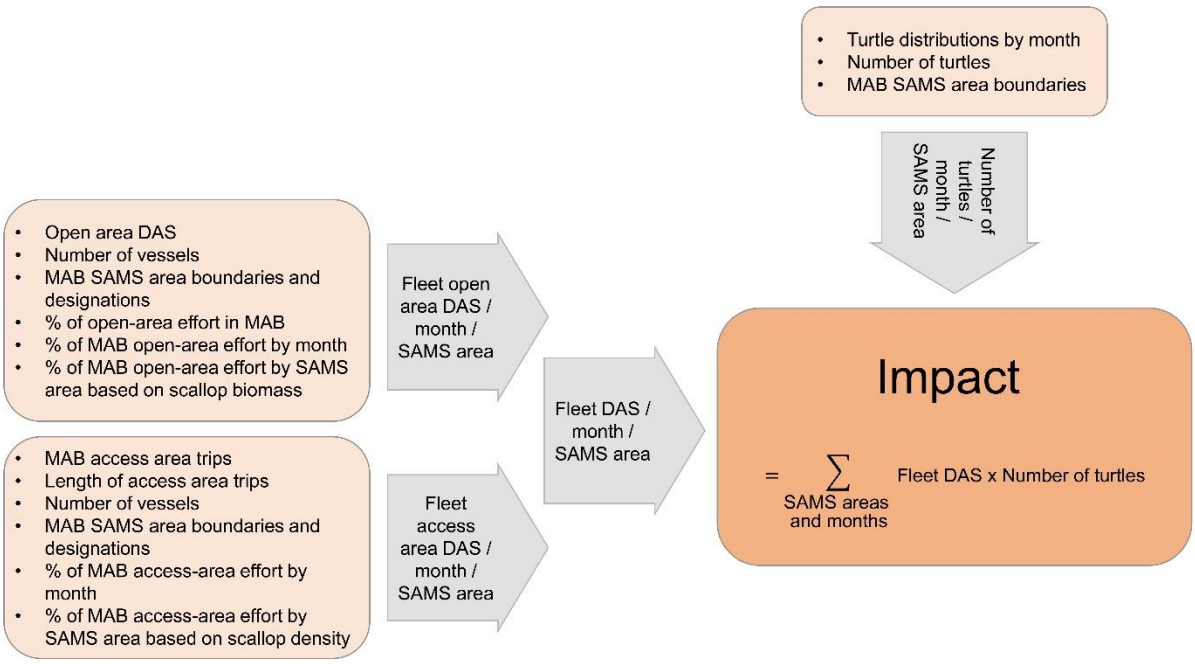


Figure 5. Flow chart showing tool components

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 6**):

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.

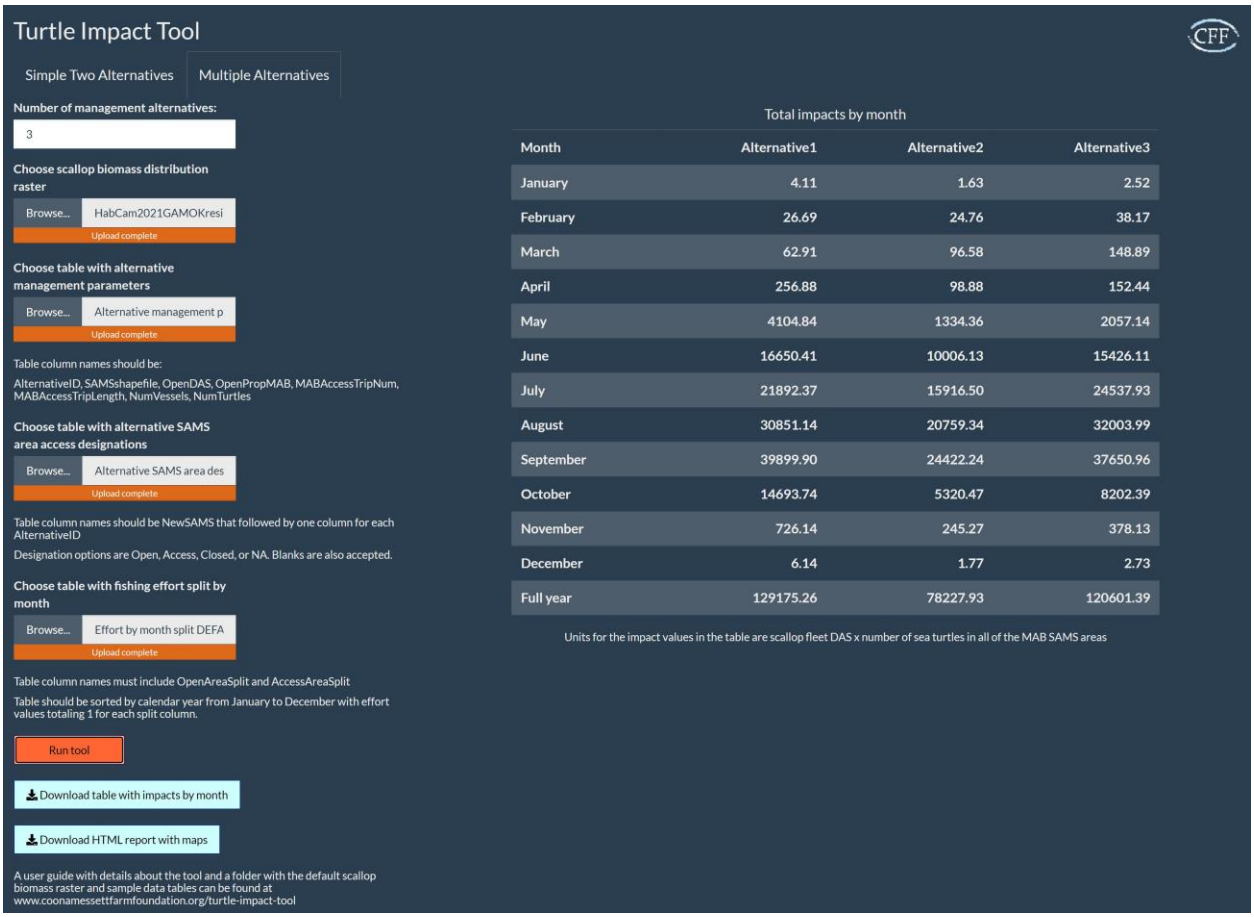
2) A table (csv file) with the alternative management parameters. The required column headings are shown in **Table 1**. The same table is also included as an example in the package folder (Alternative management parameters 3 EXAMPLE.csv).

3) A table (csv file) with the alternative MAB SAMS area designations. The required first column is shown in **Table 2**. The same table is also included as an example in the package folder (Alternative SAMS area designations 3 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 3**. 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 6**):

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



Month	Alternative1	Alternative2	Alternative3
January	4.11	1.63	2.52
February	26.69	24.76	38.17
March	62.91	96.58	148.89
April	256.88	98.88	152.44
May	4104.84	1334.36	2057.14
June	16650.41	10006.13	15426.11
July	21892.37	15916.50	24537.93
August	30851.14	20759.34	32003.99
September	39899.90	24422.24	37650.96
October	14693.74	5320.47	8202.39
November	726.14	245.27	378.13
December	6.14	1.77	2.73
Full year	129175.26	78227.93	120601.39

Figure 6. 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 as **Appendix B**.

Table 1: Example of table with alternative management parameters.

AlternativeID	SAMSshapefile	OpenDAS	OpenPropMAB	MABAccessTripNum	MABAccessTripLength	NumVessels	NumTurtles
A1	MABSAMSold	24	0.55	1	7.5	330	48700
A2	MABSAMS	24	0.55	0	0	330	48700
A3	MABSAMS	37	0.55	0	0	330	48700

Table 2: Example of table with alternative MAB SAMS area designations for the three alternatives shown in Table 1.

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

Table 3: 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	0.03	0.05
2	Feb	0.06	0.03
3	Mar	0.16	0.04
4	Apr	0.1	0.16
5	May	0.08	0.15
6	Jun	0.09	0.07
7	Jul	0.08	0.04
8	Aug	0.1	0.06
9	Sep	0.13	0.1
10	Oct	0.08	0.12
11	Nov	0.06	0.1
12	Dec	0.03	0.08

Appendix A

Loggerhead sea turtle monthly density rasters

The rasters included in the tool were derived from shapefiles of log(density) that are available through the Northeast Fisheries Science Center (NEFSC) (https://inport.nmfs.noaa.gov/inport/item/27337). Densities were modelled for 40x40km grid cells from Florida through southern Georges Bank (**Figure A-1**) and normalized so the sum of the densities in every cell equaled one. Therefore, use of these monthly density shapefiles assumes that the total number of loggerheads in the modelled area does not change month to month (i.e no significant immigration or emigration of turtles from the entire area). The shapefiles downloaded from the NEFSC site were processed as follows:

1. Log(density) values were converted to density values
2. 40x40km grid cells were split into 10x10km grid cells, with the densities values in each new cell equal to the density in the 40X40km cell divided by 16
3. Updated proportional density values in the 10x10km were smoothed using a low-pass filter in ArcGIS.

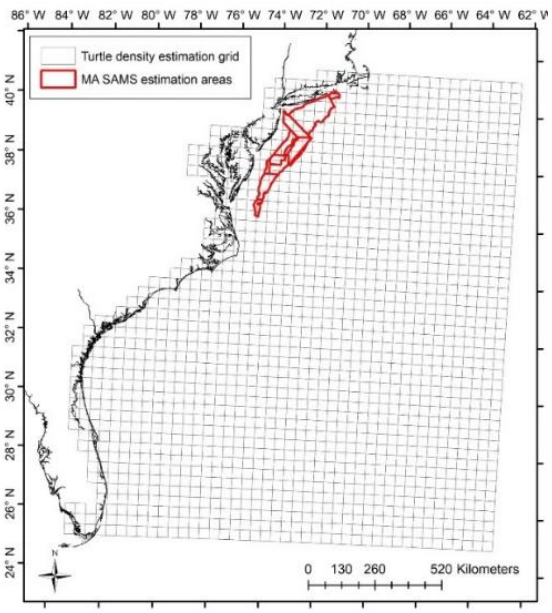


Figure A-1: Map showing the grid used for estimating turtle densities and the location of the Mid-Atlantic SAMS areas

Default scallop biomass raster

Scallop biomass (g/m^2) 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). We used a model with a Tweedie distribution because the count data was overdispersed 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 taken from marmap data downloaded with 1 minute resolution ("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 marmap grid. The gridded data was converted to a raster with 2x2km cells.

Using VTR and VMS data to generate model defaults

VTR data (FY2015 to FY2021) was cleaned to remove blank data cells and unrealistic data entries. Tow swept areas for each trip entry were estimated using distances based on tow start and end locations,

reported dredge widths, and reported dredge numbers. Additional data cleaning was completed in ArcGIS to remove tow locations that were on land or in Canadian waters.

VMS data (FY2016 to FY2021) was combined into data frames by fishing year. Locations and times reported in VMS data were used to calculate speeds at each location. A fishing speed filter (speeds were between 2.7 and 5.7 knots) was used to identify vessels were fishing, with this speed range based on conversations with commercial fishers operating large and small commercial scallop vessels. This data set was cleaned by removing locations on land and in depths over 200m.

SAMS-area labels, SAMS-area designations (open, access area, or closed), and fishing regions (MAB or Georges Bank 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 for the percentage of open area effort in MAB, the length of MAAA trips, and fishing effort per month.

Relationships between scallop biomass/density and fishing effort

Fishing effort based on swept area was estimated using VTR data from FY2015 to FY2020, while fishing effort based on hours fishing was estimated using VMS data from FY2016 to FY2020. Data from FY2021 was excluded because the fishing year was not complete. Scallop biomass was based on the combined estimates from multiple scallop surveys, 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 = 0.96 for swept area while fishing based on VTR data and R^2 = 0.94 for hours fishing based on VMS data, **Figures A-2A**). For access areas, effort had the strongest linear relationship with scallop density (R^2 = 0.78 for swept area while fishing based on VTR data and R^2 = 0.82 for hours fishing based on VMS data, **Figure A-2B**).

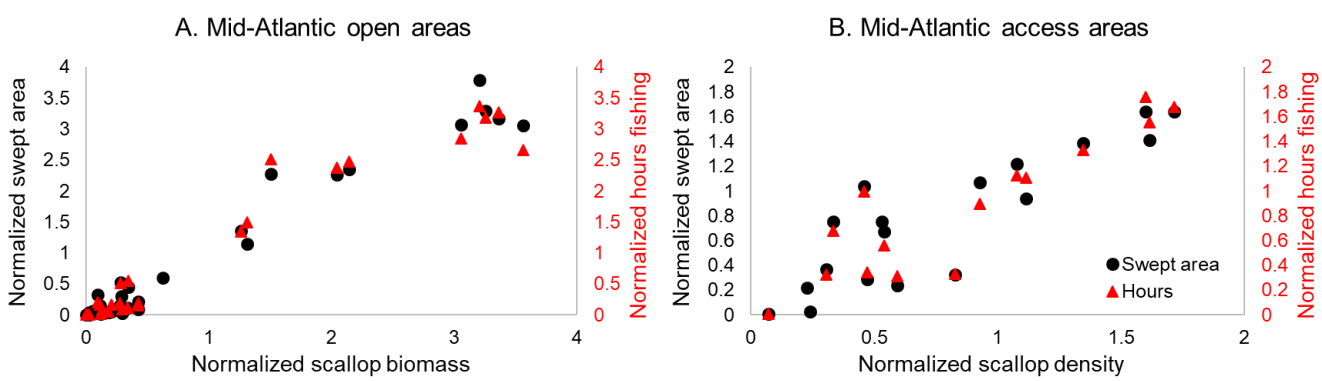


Figure A-2: (A) Open area scallop biomass vs fishing effort by SAMS area. (B) Access area scallop density vs fishing effort by SAMS area.

Estimated proportional fishing effort by month

Fishing effort by month was calculated for each fishing year for open and access areas from VTR and VMS data and averaged over the three fishing years. Estimates based on VMS and VTR were subsequently averaged to generate model default estimates for proportional fishing effort per month. Curves of proportional fishing effort per month over the course of a fishing year, generated using the VMS and VTR data, are shown in **Figure A-3**.

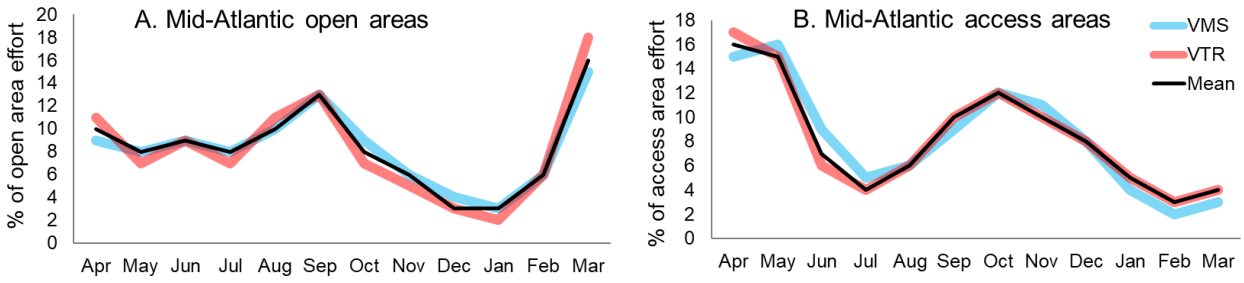


Figure A-3: (A) Estimated proportional fishing effort by month over one fishing year for open areas. (B) Estimated proportional fishing effort by month over one fishing year for Mid-Atlantic access areas. Values from the black mean curve are included as the default table for estimated proportional fishing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

Literature cited

New England Fishery Management Council (NEFMC). 2022. Framework Adjustment 34 to the Scallop Fishery Management Plan. https://s3.amazonaws.com/nefmc.org/220310-Framework-34-Final-Submission.pdf.

Pante E, Simon-Bouhet B. 2013. marmap: A package for importing, plotting and analyzing bathymetric and topographic data in R. PLoS ONE 8: e73051. doi:10.1371/journal.pone.0073051

Pebesma EJ. 2004. Multivariable geostatistics in S: the gstat package. Computers & Geosciences 30: 683-691.

Shono H. 2008. Application of the Tweedie distribution to zero-catch data in CPUE analysis. Fisheries Research 93: 154-162.

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.

Wood SN. 2011. Fast stable restricted maximum likelihood and marginal likelihood estimation of semiparametric generalized linear models. Journal of the Royal Statistical Society (B) 73: 3-36.

Appendix B

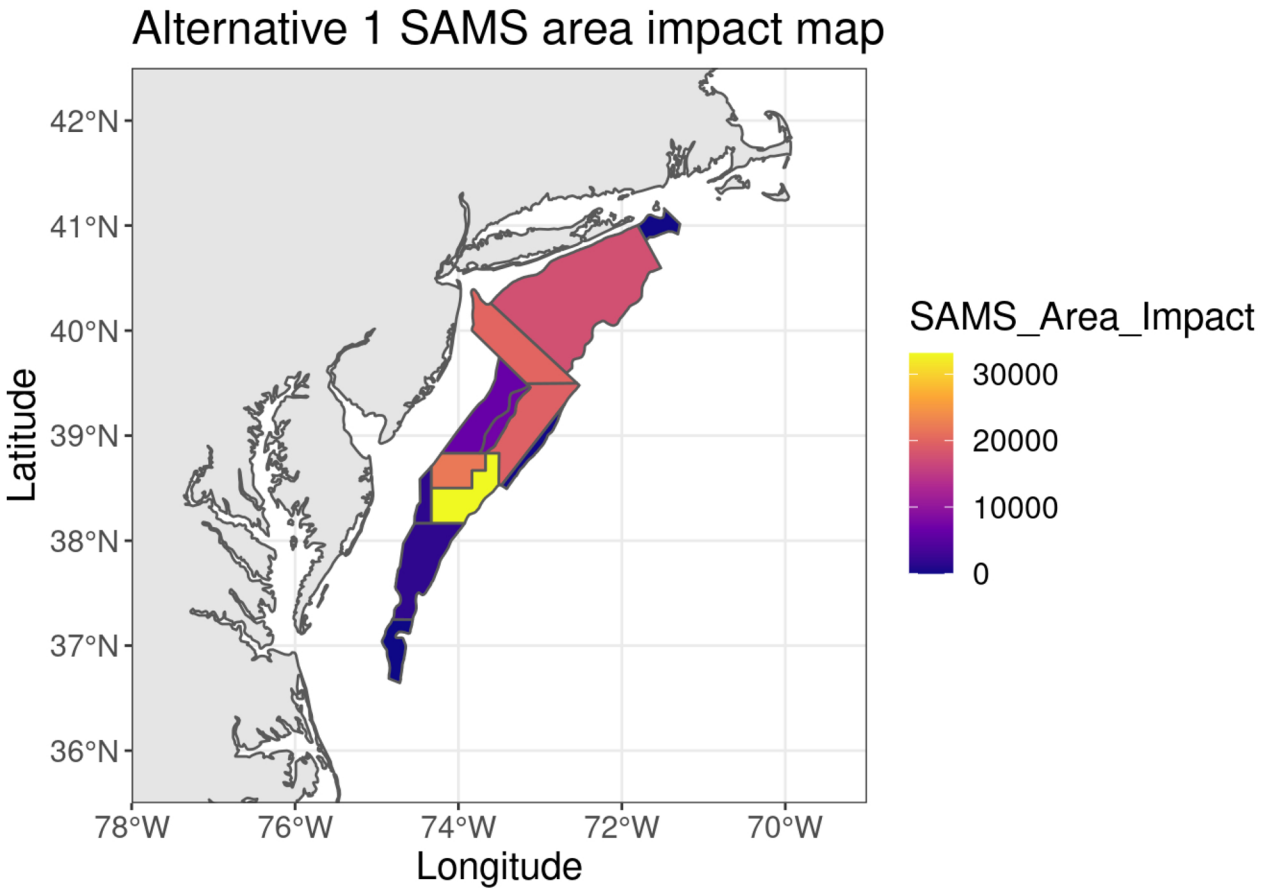
Turtle Impact Tool output

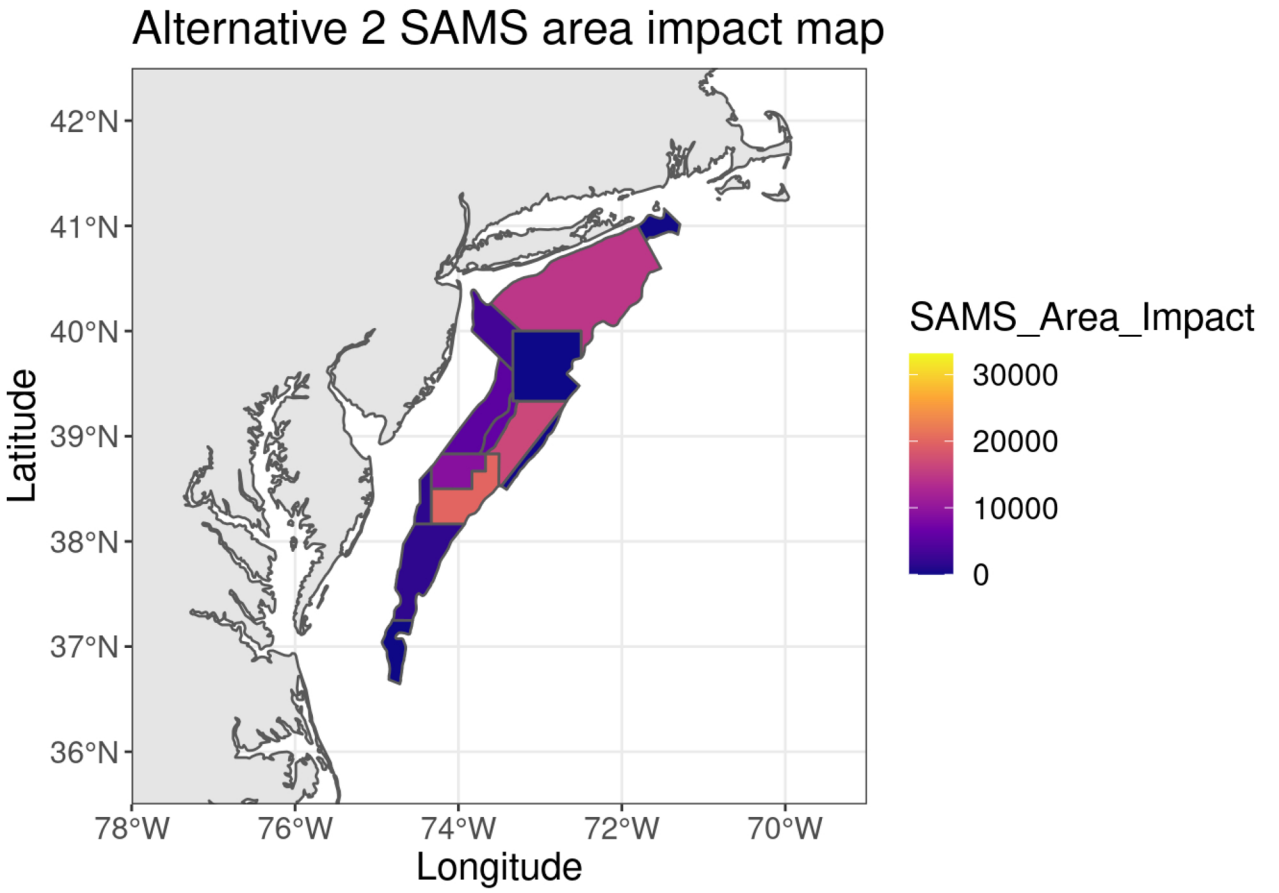
2022-05-05

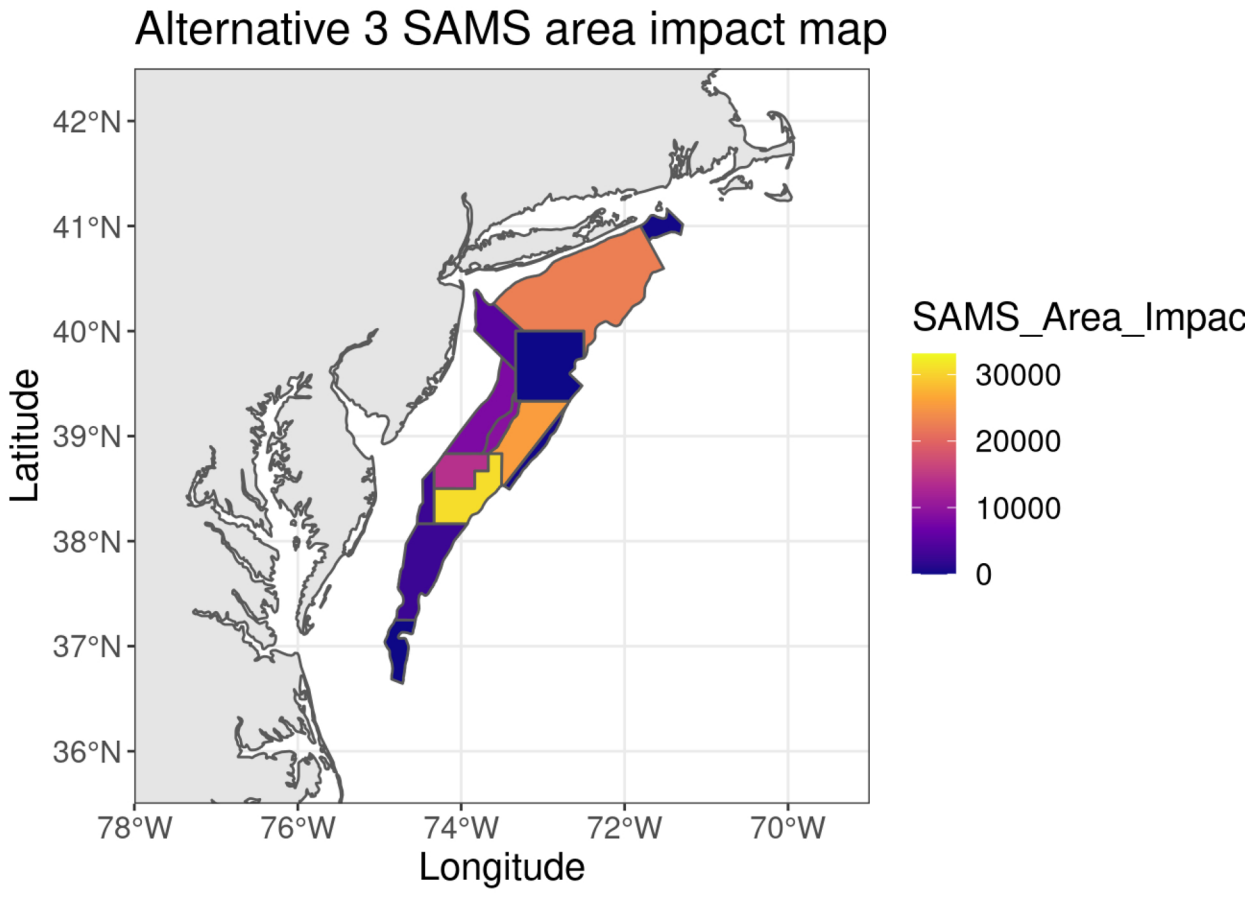
Output

Monthly and total impacts for alternatives

Month	Alternative1	Alternative2	Alternative3
January	4.109	1.631	2.515
February	26.694	24.760	38.172
March	62.913	96.575	148.886
April	256.876	98.880	152.440
May	4104.835	1334.360	2057.138
June	16650.412	10006.126	15426.110
July	21892.371	15916.496	24537.932
August	30851.137	20759.343	32003.987
September	39899.901	24422.244	37650.960
October	14693.741	5320.471	8202.393
November	726.138	245.272	378.127
December	6.138	1.771	2.730
Full year	129175.265	78227.929	120601.390


Alternative 1 SAMS area impact map
42°N
41°N
40°N
39°N
38°N
37°N
36°N
Latitude
78°W
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
78°W
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	SAMSshapefile	OpenDAS	OpenPropMAB	MABAccessTripNum	MABAccessTripLength	NumVessels	NumTurtles
A1	MABSAMSold	24	0.55	1	7.5	330	48700
A2	MABSAMS	24	0.55	0	0.0	330	48700
A3	MABSAMS	37	0.55	0	0.0	330	48700

Alternative SAMS area access designations

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

Monthly fishing effort splits

Month	MonthName	OpenAreaSplit	AccessAreaSplit
1	Jan	0.03	0.05
2	Feb	0.06	0.03
3	Mar	0.16	0.04
4	Apr	0.10	0.16
5	May	0.08	0.15
6	Jun	0.09	0.07
7	Jul	0.08	0.04
8	Aug	0.10	0.06
9	Sep	0.13	0.10
10	Oct	0.08	0.12
11	Nov	0.06	0.10
12	Dec	0.03	0.08