Fishing Effects Model
Percent Sediment Type
January 2, 2020

Prepared for:
Northeast Regional Ocean Council (NROC)
www.northeastoceandata.org

Prepared by:
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1 INTRODUCTION

The Northeast Fishing Effects Model combines seafloor data (sediment type, energy regime) with fishing effort data and parameters related to the interactions between fishing gear and seafloor habitats to generate percent habitat disturbance estimates in space and time. Fishing gear interacts with both living (biological) and non-living (geological) seafloor features. Diverse seabed types comprised of various combinations of biological and geological features occur in the Northwest Atlantic Ocean off the northeastern United States. These seabed structures constitute merely one element of complex fish habitats that also include the overlying water column and its features. Because sediment type data were available at a reasonable spatial resolution and representativeness across the model domain, sediments were used as a proxy for the diverse array of seabed types occurring in the region, with biological habitat elements inferred on the basis of sediment and energy classifications. This allows appropriate habitat/gear interaction parameters to be applied when the model is run.

Generally, the model domain extends north to south from the U.S./Canadian border to the N.C./S.C. border, and inshore to offshore from the coastline to the Exclusive Economic Zone boundary. The sediment grid covers this entire domain. Data inputs and outputs to Fishing Effects are gridded at a 5 km by 5 km resolution, with the exception of cells along the edge of the domain which are clipped to the coastline or Exclusive Economic Zone boundary and are therefore smaller.

This dataset constitutes a portion of the input data for the Fishing Effects Model. Five different sediment grain sizes plus a steep and deep habitat type are represented in the dataset, which indicates the proportion of each grain size occurring within each 5x5 grid. Each record in the dataset represents a unique grid cell with corresponding grid identification number. For each grid cell, the proportions across the five grain sizes and steep and deep habitat type sum to 1, such that the area of the grid cell is fully allocated to one or more of the six conditions.

Additional information about the model can be found in NEFMC (2019) and in the report for the precursor to Fishing Effects, the Swept Area Seabed Impact (SASI) Model (NEFMC 2011).

2 PURPOSE

The primary purpose of this dataset is to serve as a base layer for the Northeast Fishing Effects Model. A secondary purpose for this map of sediment grain sizes is to inform various spatial planning issues where seabed type is a consideration for decision making. It is important to understand caveats and limitations associated with both the underlying source data and this compilation when using the data for spatial planning. These limitations and caveats influence the Fishing Effects Model percent habitat disturbance results as well.

3 SOURCES AND AUTHORITIES

Various sources and types of sediment data were combined to generate this product. See section 11 for a map showing the footprint of each of these data sources.

Table 1. Sources of sediment data used in the Northeast Fishing Effects Model.

Source	Spatial geometry and size	Presence/absence mapping process
Bethoney, N. D. and K.D.E., Stokesbury. 2018. Methods for image-based surveys of benthic macroinvertebrates and their habitat exemplified by the drop camera survey of the Atlantic sea scallop. JoVES, 137: 1-10; DOI: doi:10.3791/57493.	Points, 187,720	Data was coded as presence/absence. We used 'silt' to denote mud habitat; 'sand' and 'sandRipple' to denote sand habitat; 'gravel' to denote gravel habitat; 'cobble' to denote cobble habitat; and 'rock' to denote boulder habitat.
U.S. Geological Survey. 2014. U.S. Geological Survey East Coast Sediment Texture Database. U.S. Geological Survey, Coastal and Marine Geology Program. Woods Hole Coastal and Marine Science Center, Woods Hole, MA.	Points, 27,784	'Clay', 'silt', 'sand', and 'gravel' are coded as proportions. We used 'clay' and 'silt' together to denote mud category. If proportions were greater than zero, the sediment was assumed present. These data points were excluded from the cobble and boulder interpolations.
Barnhardt, W. A., Kelley, J. T., Dickson, S. M., & Belknap, D. F. 1998. Mapping the Gulf of Maine with side-scan sonar: a new bottom-type classification for complex seafloors. Journal of Coastal Research, 646-659.	Polygon, 10,312 sq. km	Polygons were coded with a capital and lowercase letter for dominant and subordinate substrate, respectively. If a habitat category was coded by either the dominant or subordinate substrate, it was assumed present. 'M' was used to denote mud habitat; 'S' for sand habitat; 'G' for gravel habitat; and 'R' was used to denote boulder habitat. In this dataset 'R' corresponds to rock outcrops which are different from boulder habitats occurring elsewhere in the domain.
Regional Sediment Resource Management Workgroup (2014). Work Group Report: 2014 Massachusetts Ocean Management Plan Update. Massachusetts Office of Coastal Zone Management, 57pp.	Polygon, 9,572 sq. km	Polygons were coded with a capital and lowercase letter for dominant and subordinate substrate, respectively. If a habitat category was coded by either the dominant or subordinate substrate, it was assumed present. 'M' was used to denote mud habitat; 'S' for sand habitat; 'G' for gravel habitat; and 'R' was used to denote boulder habitat. The data set used here was

		updated by the Regional Sediment Resource Management Workgroup in 2014.
Narragansett Bay Estuary Program. 2017. Chapter 13: Benthic Habitat, in State of Narragansett Bay and Its Watershed: 2017 Technical Report (pp 246 – 259). Providence, RI.	Polygon, 2,191 sq. km	Polygons annotated by 'mud', 'sand', and 'gravel' denote the presence of each. 'Gravel mixes' denote gravel, and 'Muddy sand' denotes presence of both mud and sand.
ACUMEN. 2012. Atlantic Canyons Undersea Mapping Expedition Project Summary. https://oceanexplorer.noaa.gov/okeanos/explorations/acumen12/welcome.html.[1]	Polygon, 165 sq. km	Boundaries of all polygons indicate presence of deep/rocky category. ACUMEN is a 25 m^2 resolution digital elevation model. To develop this data product, a slope dataset was derived from the DEM, and then cells with values equal to or greater than 30 degrees were selected and dissolved into polygons. These areas with steep slopes tend to have rocky outcrops suitable for attached sessile fauna and were shown to contain corals almost all the time when observed with remotely operated vehicles or towed cameras.

4 COLLABORATORS

The Fishing Effects Model was developed collaboratively by the New England Fishery Management Council's Habitat Plan Development Team and the Fisheries, Aquatic Science, and Technology Laboratory at Alaska Pacific University. Team members included:

- Michelle Bachman, NEFMC staff
- Peter Auster, University of Connecticut/Mystic Aquarium
- Jessica Coakley, Mid-Atlantic Fishery Management Council
- Geret DePiper, NMFS/Northeast Fisheries Science Center
- Kathryn Ford, Massachusetts Division of Marine Fisheries
- Bradley Harris, Alaska Pacific University
- Julia Livermore, Rhode Island Division of Marine Fisheries
- Dave Packer, NMFS/ Northeast Fisheries Science Center
- Chris Quartararo, NEFMC staff
- Felipe Restrepo, Alaska Pacific University
- T. Scott Smeltz, Alaska Pacific University
- David Stevenson, NMFS Greater Atlantic Regional Fisheries Office
- Page Valentine, U.S. Geological Survey
- Alison Verkade, NMFS Greater Atlantic Regional Fisheries Office

5 DATABASE DESIGN AND CONTENT

- Feature Class Name: Fishing Effects Sediment
- Total Number of Unique Features: 13,157

[1] Polygons represent areas where the slope is greater than 30 degrees based on a 25 m resolution digital elevation model for the northeast U.S. canyon and slope region. Data come from a series of Atlantic Canyons Undersea Mapping Expeditions (ACUMEN) on NOAA's research vessels Hassler, Bigelow, and Okeanos Explorer. These mapping expeditions took place from February 2012 through August 2012.

- Dataset Status: Complete
- Native storage format: ArcGIS feature class
- Feature Type: Polygon

Table 2. Data dictionary

Line	Name	Definition	Type	Size[1]
1	OBJECTID	Uniquely identifies a feature	OBJECTID	*
2	Shape	Geometric representation of the feature	geometry	*
3	GridID	Unique GridID field used to link across model datasets	Long	9
4	Mud	Proportion of grid cell classified as mud grain size	Double	18, 15
5	Sand	Proportion of grid cell classified as sand grain size	Double	18, 15
6	GrPe	Proportion of grid cell classified as granule or pebble grain size	Double	18, 15
7	Cobble	Proportion of grid cell classified as cobble grain size	Double	18, 15
8	Boulder	Proportion of grid cell classified as boulder grain size	Double	18, 15
9	StDeep	Proportion of grid cell classified as steep and deep	Double	18, 15
10	Diversity	Number of distinct sediment classes (mud-boulder)	Long	10
11	Density	Number of sediment points (does not account for polygon data inputs)	Long	10

[1] Size for type double fields refers to precision and scale

6 SPATIAL REPRESENTATION

- Geometry Type: vector polygon
- Projection
    - Reference System: GCS_North_American_1983
    - Horizontal Datum: North American Datum 1983
    - Ellipsoid: Geodetic Reference System 1980
- Geographic extent: -82.87 to -63.95, 22.14 to 47.13
- IS0 19115 Topic Category: environment, oceans, geoscientificInformation
- Place Names: Cape Cod Bay, Georges Bank, Gulf of Maine, Maine Inner Continental Shelf, Massachusetts Bay, New Jersey Continental Shelf, New York Bight, North Atlantic Ocean, Southern New England Shelf
- Recommended Cartographic Properties:
  (Using ArcGIS ArcMap nomenclature)
  Classified, Standard Deviation, with unique class for values = 0
    Percent sediment type: Mud - 7 classes, color model R-G-B
      0 class: no color
      <-2.5 std dev: 252-253-191
      -2.5 - -1.5 std dev: 254-159-109

-1.5 - -0.5 std dev: 222-73-104
-0.5 - 0.5 std dev: 140-41-129
0.5 - 1.5 std dev: 59-15-112
1.5 - 2.5 std dev: 0-0-4

Commented [1]: This is how I will fill out this section once we get agreement from the PDT on the visualizations. Since this is tedious, I will wait until we have confirmation that they like this cartography!

- Scale range for optimal visualization:1,000,000 to 13,000,000

Commented [2]: I sort of eyeballed this based at the scales at which I would use the data.

7 METHODS AND DATA PROCESSING

A map of sediment-based habitat categories was developed in order to apply habitat vulnerabilities across the Northeast region. Six habitat types were classified: mud, sand, gravel, cobble, boulder, and steep/deep. Except for steep/deep these habitat types were classified based on grain size. The steep/deep category was based on slope derived from a 25 m^2 resolution digital elevation model along the edge of the shelf and was included to account for corals found at depth that are highly susceptible to impact and require long recovery times. Steep/deep habitats classified according to these data likely indicate the presence of rock outcroppings in canyons and along the continental slope where organisms requiring hard substrates for attachment are likely to find suitable habitat.

A sediment profile was constructed for 5 km grid cells across the Northeast region that represented the proportional contribution of each sediment type found in the grid cell. The sediment profiles were produced from a compilation of six data sources listed in section 3. The table in that section provides metadata for each data source. Two were provided as GIS databases with point spatial geometry; four were provided with polygonal spatial geometry. The most substantial sediment database included in this analysis was optical assessments from camera surveys provided by the Marine Fisheries Field Research Group at the University of Massachusetts Dartmouth School for Marine Science and Technology, which included over 187,000 sediment points distributed primarily throughout Georges Bank and the Mid-Atlantic. To improve the spatial coverage of sediment data, additional sediment points were downloaded from U.S. Geological Survey databases (https://cmgds.marine.usgs.gov/publications/of2005-1001/htmldocs/datacatalog.htm). Polygonal sediment data was limited to coastal regions along Maine and Massachusetts, Narragansett Bay, and deep/rocky regions beyond 200 m depth.

Each of the data sources used a different sediment classification system. To standardize these classifications, the original sediment classifications were converted to a presence/absence representation of each of the six sediment types used in this analysis. Details are given in the table in section 3. A summary of the categories interpreted from each data source is provided below.

Table 3. Crosswalk between data source classification and Fishing Effects classification.

Data source	**Mud**	**Sand**	**Granule/ Pebble**	**Cobble**	**Boulder**	**Steep/Deep**
Bethoney & Stokesbury 2018 (point)	**Mud**	**Sand**	**Granule/Pebble**	**Cobble**	**Boulder**	*Not mapped using these data*
USGS 2014 (point)	**Clay or silt**	**Sand**	**Gravel**	*Not mapped using these data*	*Not mapped using these data*	*Not mapped using these data*

Barnhardt et al 1998 (polygon)	**Mud**	**Sand**	**Gravel**	*Not mapped using these data*	**Rock**	*Not mapped using these data*
MA CZM 2014 (polygon)	**Mud**	**Sand**	**Gravel**	*Not mapped using these data*	**Rock**	*Not mapped using these data*
NBEP 2017 (polygon)	**Mud or muddy sand**	**Muddy sand or sand**	**Gravel**	*Not mapped using these data*	*Not mapped using these data*	*Not mapped using these data*
ACUMEN 2012 (polygon)	*Not mapped using these data*	*Not mapped using these data*	*Not mapped using these data*	*Not mapped using these data*	*Not mapped using these data*	**Entire dataset used to represent this category**

Despite a wide variability in the spatial distribution of sediment information support, sediment profiles were estimated on a consistent 5 km grid. The goal was to ensure the sediment data aligned with the resolution of the fishing data. To accommodate this varying spatial resolution of the sediment data, three different methods were used to convert presence/absence sediment data to sediment profiles depending on the geometry and/or density of points within a grid cell. In grid cells with polygonal sediment data, a modified area-weighted approach was used to calculate the proportion of each sediment within a grid cell:

$$\varphi_{i,s} = \frac{\sum_{j=1}^{n} \pi_{i,s,j}}{\sum_{s=1}^{6} \sum_{j=1}^{n} \pi_{i,s,j}}$$

where $\varphi_{i,s}$ is the proportion of sediment, s, in grid cell, i; and $\pi_{i,s,j}$ is the area of the jth polygon of n total polygons within a grid cell. Note that if no single polygon represented multiple sediments, the denominator would simply be equal to the area of the grid cell and be a straightforward area-weighted calculation.

In grid cells with eight or more sediment points, a similar method was used, except instead of using an area-weighted approach, a count of points with sediments present was used to calculate $\varphi_{i,s}$. The equation above was still the basis for the calculation, where j was an index of n total sediment points, and $\pi_{i,s,j}$ takes the value of 0 or 1 if sediment is absent or present, respectively.

In grid cells with less than eight points, an Ordinary Kriging spatial interpolation was first applied to the full domain to estimate the probability that each sediment was present at the center of a 2.5 km grid cells nested within the 5 km grid. This approach produced four estimations of sediment probabilities within each 5 km grid cell. Again, the equation above was used to calculate $\varphi_{i,s}$ in these grid cells, where $\pi_{i,s,j}$ was the estimated probability of presence for sediment s, and $n = 4$ was fixed, which corresponded to the four 2.5 km grid center points within each 5 km grid cell. The Kriging analysis was conducted in R (ver. 3.4.3) using the *gstat* package (Gräler *et al.*, 2016[2]).

[2] Gräler, B., Pebesma, E., & Heuvelink, G. 2016. Spatio-Temporal Interpolation using gstat. The R Journal 8(1), 204-218.

8 QUALITY PROCESS

- Attribute Accuracy: Attribute values are derived from authoritative metadata sources.
- Logical Consistency: These data are believed to be logically consistent.
- Completeness: The completeness of the data reflects the feature content of the data sources, and their associated metadata.
- Positional Accuracy: Positional accuracy may vary according to positioning methodology in the underlying data sources. Results are aggregated by Fishing Effects Model grid cell, with each cell having a resolution of 5 kilometers.
- Timeliness: Based on samples collected between 1934 and 2018.
- Use restrictions: Data are presented as is. Users are responsible for understanding the metadata prior to use. The New England Fishery Management Council shall be acknowledged as data contributors to any reports or other products derived from these data.
- Distribution Liability: All parties receiving these data must be informed of all caveats and limitations.

9 CAVEATS AND DISCUSSION

Commented [3]: I think we should discuss as a group, but a few general thoughts to start.

- Areas outside SMAST, MA CZM, and Barnhardt data will miss occurrence of rock/boulder, if it exists
- Rock and boulder are also not the same
- Areas outside SMAST will miss occurrence of cobble, if it exists
- The ledges in the GOM seems to be showing larger areas of cobble and boulder habitat than may exist in reality. Perhaps because nearby areas have low number of points?
- The methods used to generate the sediment data compiled by USGS often do not have the ability to sample the largest grain sizes, cobble and boulder. Therefore, even in areas of high point data density, these larger grain sizes may be under-represented. This could be occurring in Long Island Sound, Buzzards Bay, and Massachusetts Bay. While in general sediments are finer in the Mid-Atlantic Bight as compared to New England, there are localized areas of high data density (>7 points) associated with data from the USGS database along the coast of NJ, DE, MD, and NC as well. Other than these areas, locations with greater than 7 points per grid were surveyed with drop camera, capable of detecting the larger grain sizes.

10 REFERENCES

NEFMC (2011). Omnibus Essential Fish Habitat Amendment 2 Final Environmental Impact Statement. Appendix D: The Swept Area Seabed Impact (SASI) approach: a tool for analyzing the effects of fishing on Essential Fish Habitat. Newburyport, MA, New England Fishery Management Council**:** 257p.

NEFMC (2019). Fishing Effects Model Northeast Region. Newburyport, MA, New England Fishery Management Council**:** 109p.

Smeltz, T. S., B. P. Harris, J. V. Olson and S. A. Sethi (2019). "A seascape-scale habitat model to support management of fishing impacts on benthic ecosystems." Canadian Journal of Fisheries and Aquatic Sciences: 1-9.

11 FIGURES

Figure 1. Massachusetts Coastal Zone Management sediment map domain.

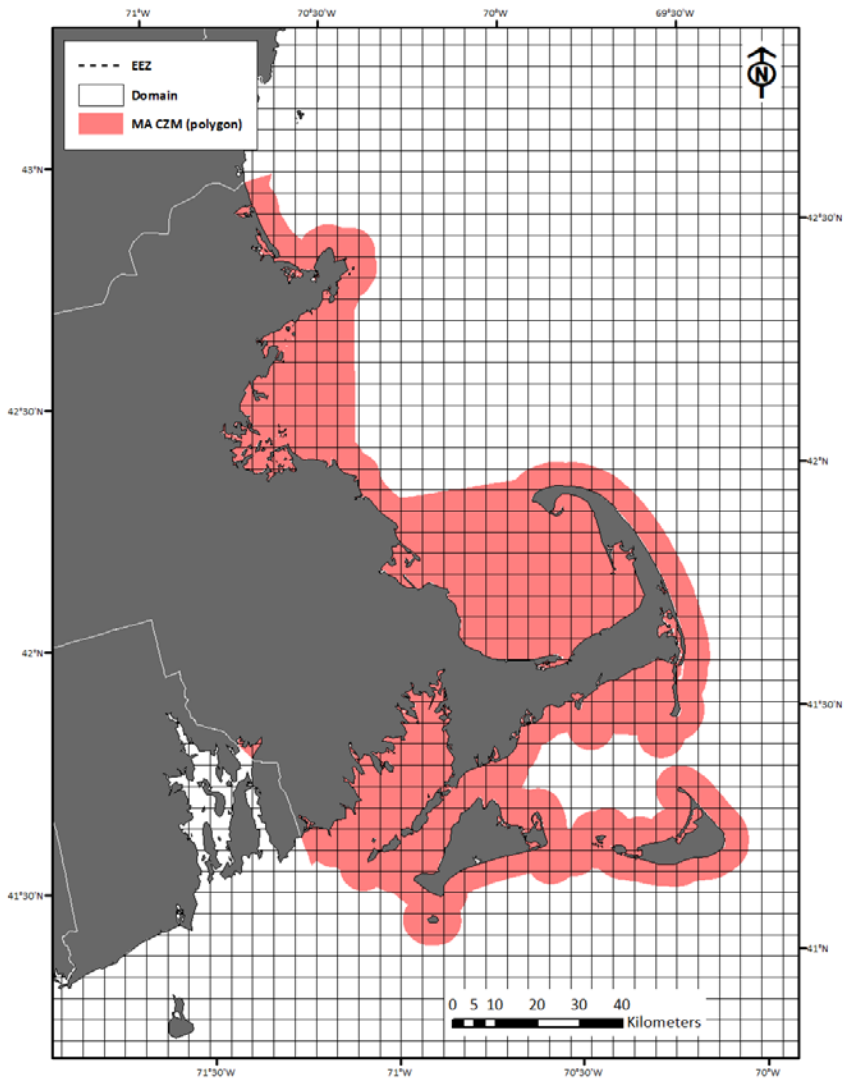


Figure 2. Maine Bottom Type Data sediment map domain.

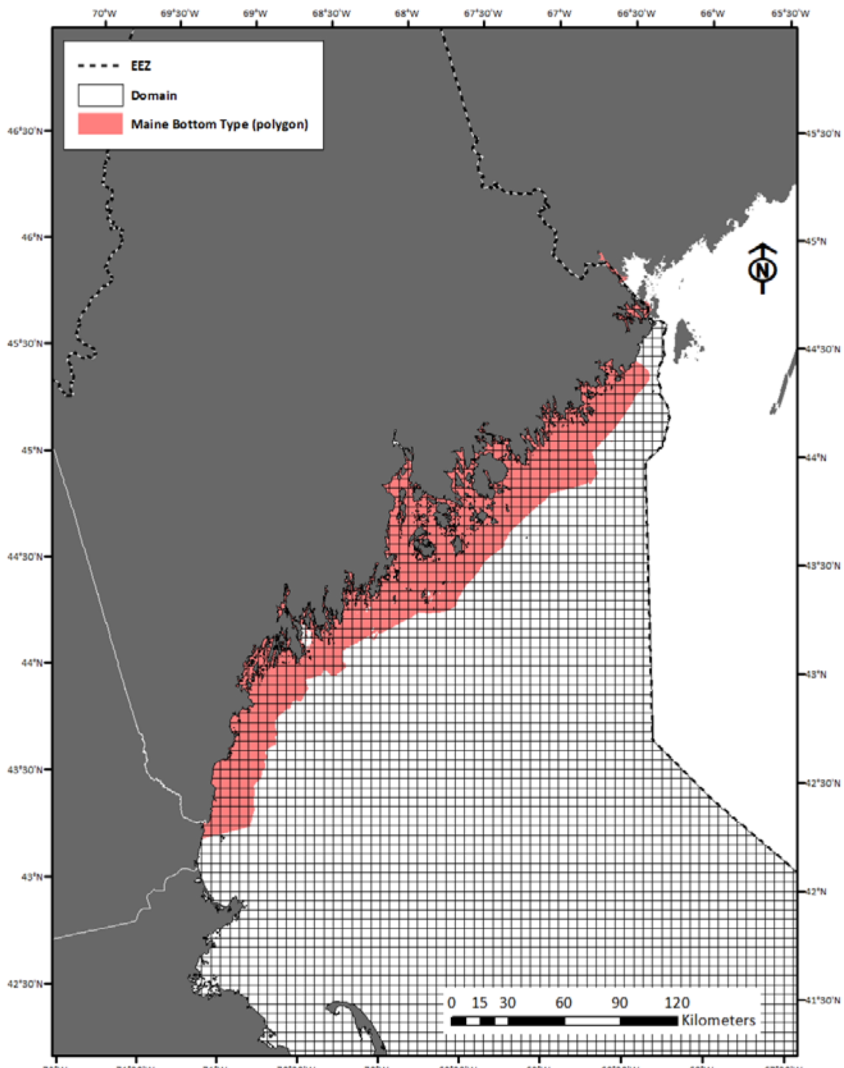


Figure 3. Narragansett Bay Estuary Program sediment map domain.

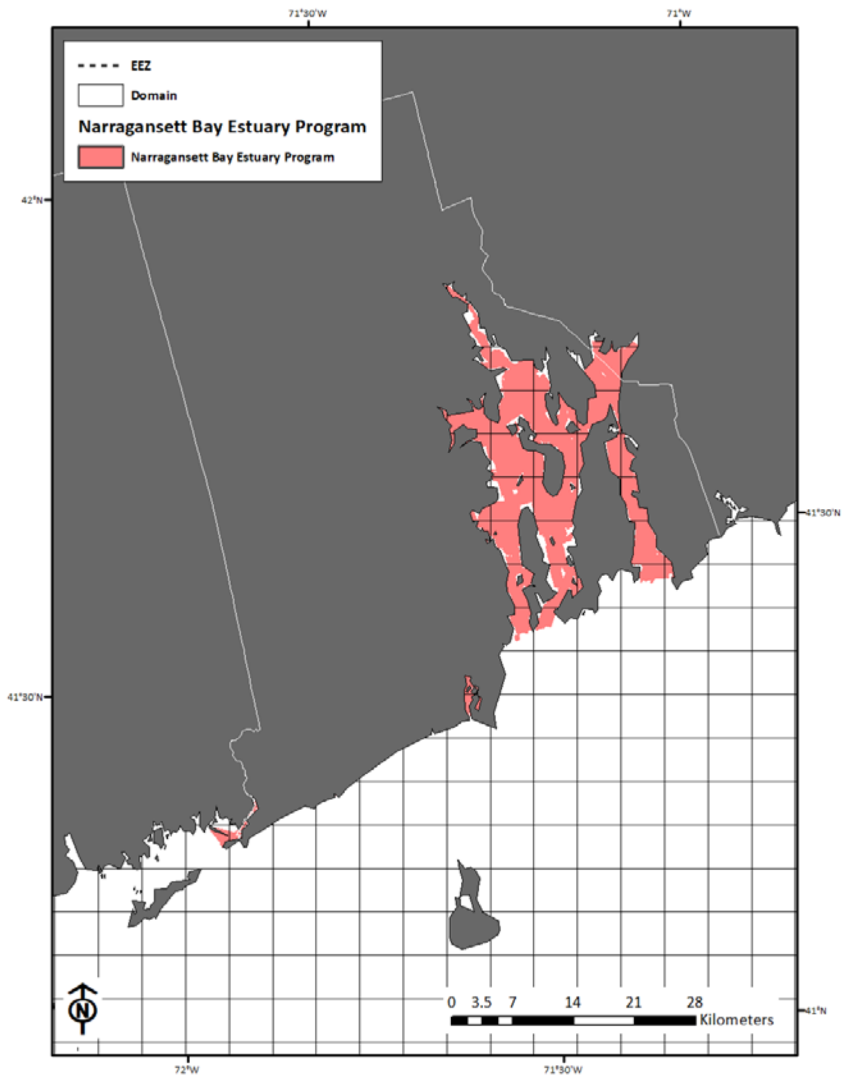


Figure 4. ACUMEN data. Includes a 1 point border around the data to render them visible at this scale.

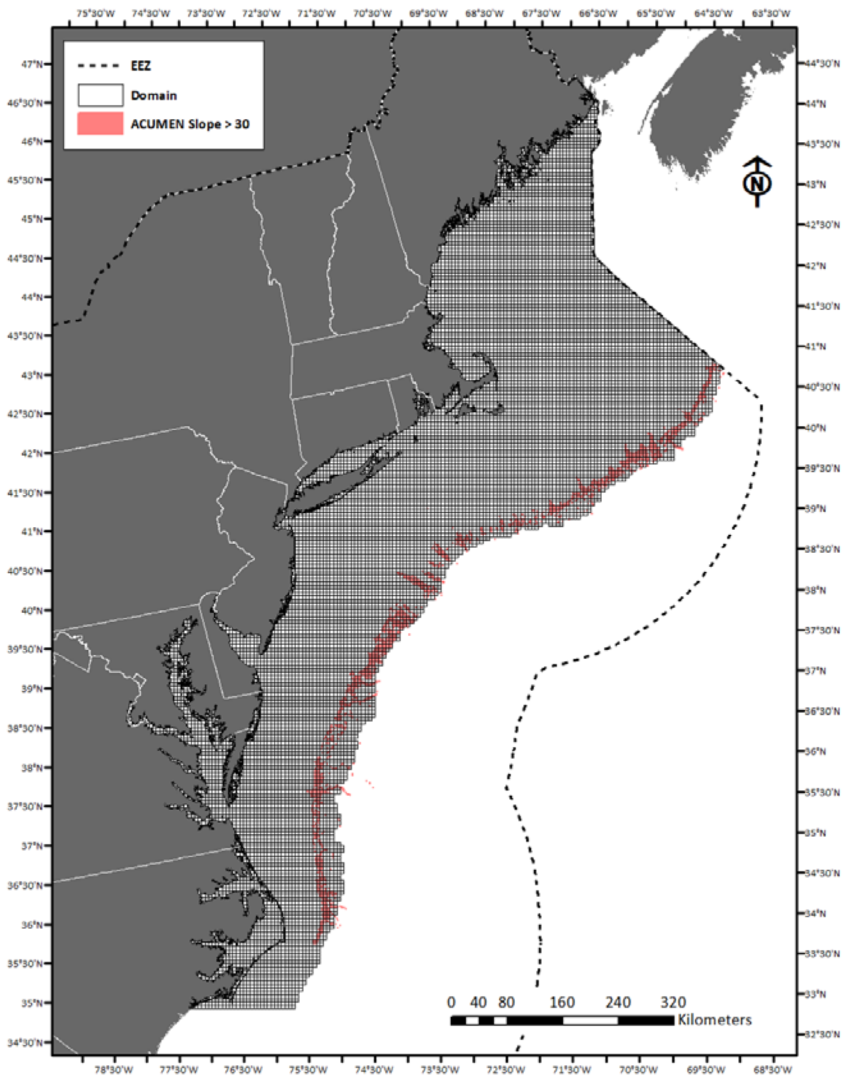


Figure 5. Data points from Bethoney and Stokesbury 2018.

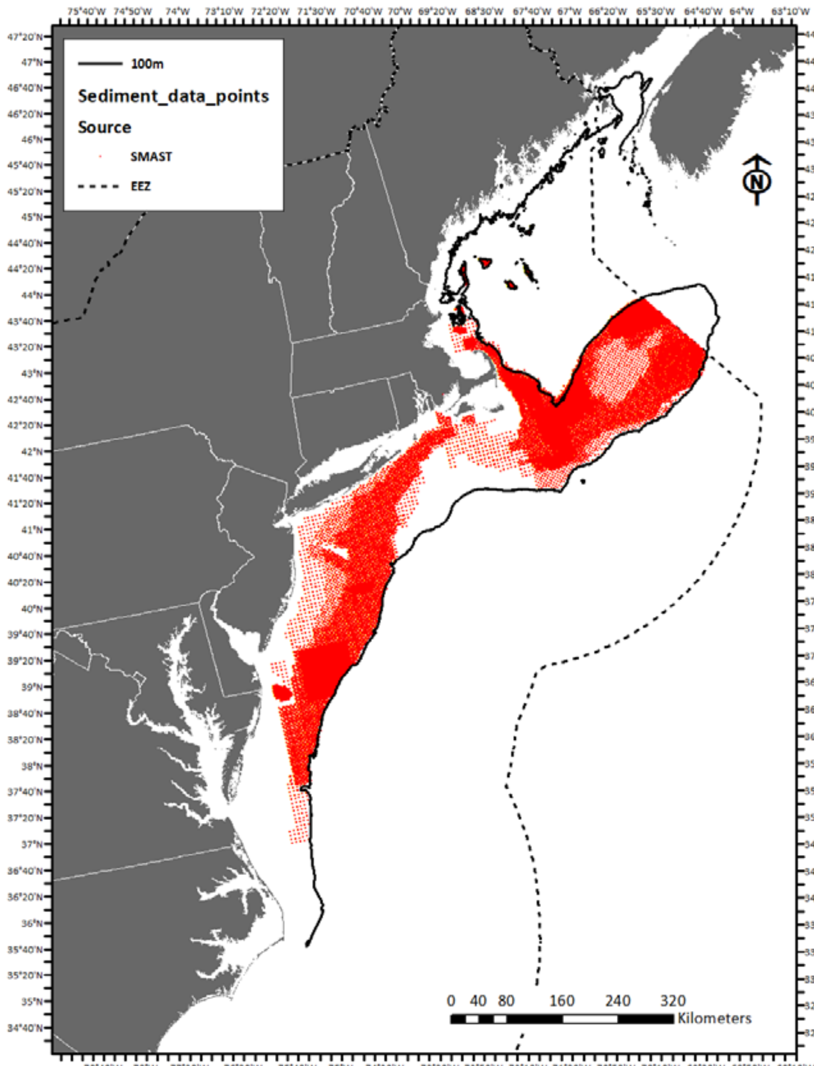


Figure 6. Data points from USGS 2014.

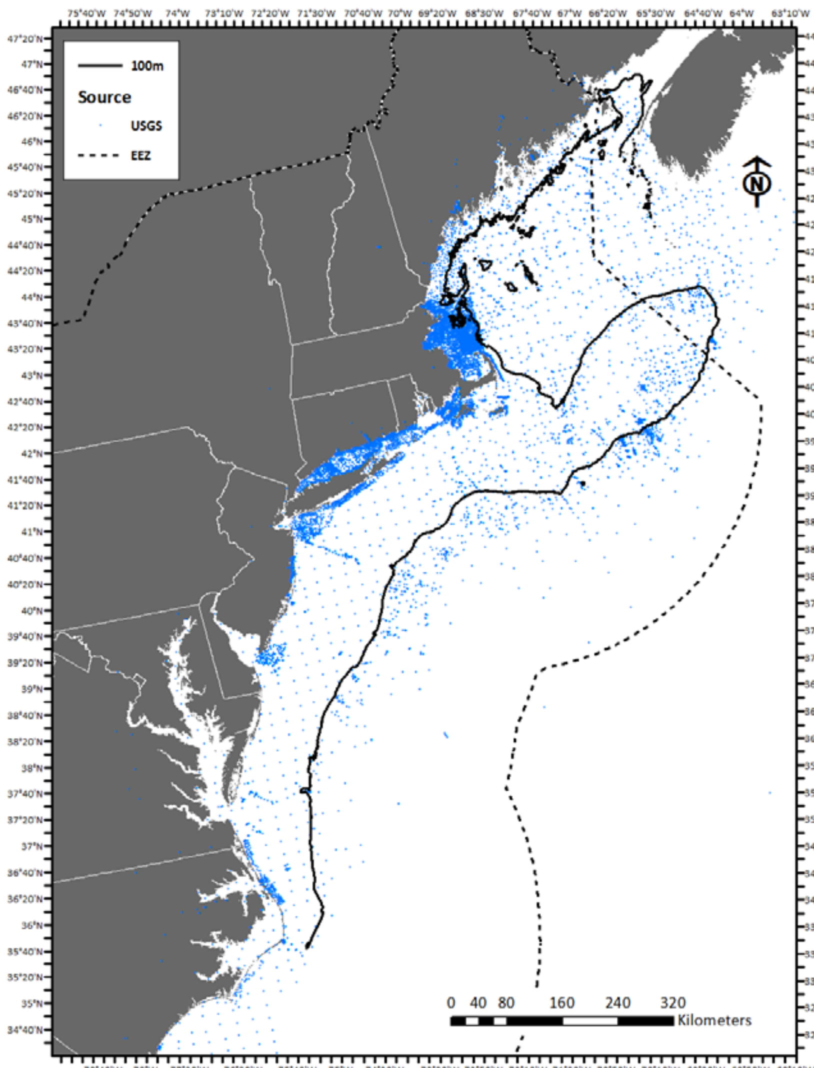


Figure 7. Percent mud by grid cell. Zero values are not mapped.

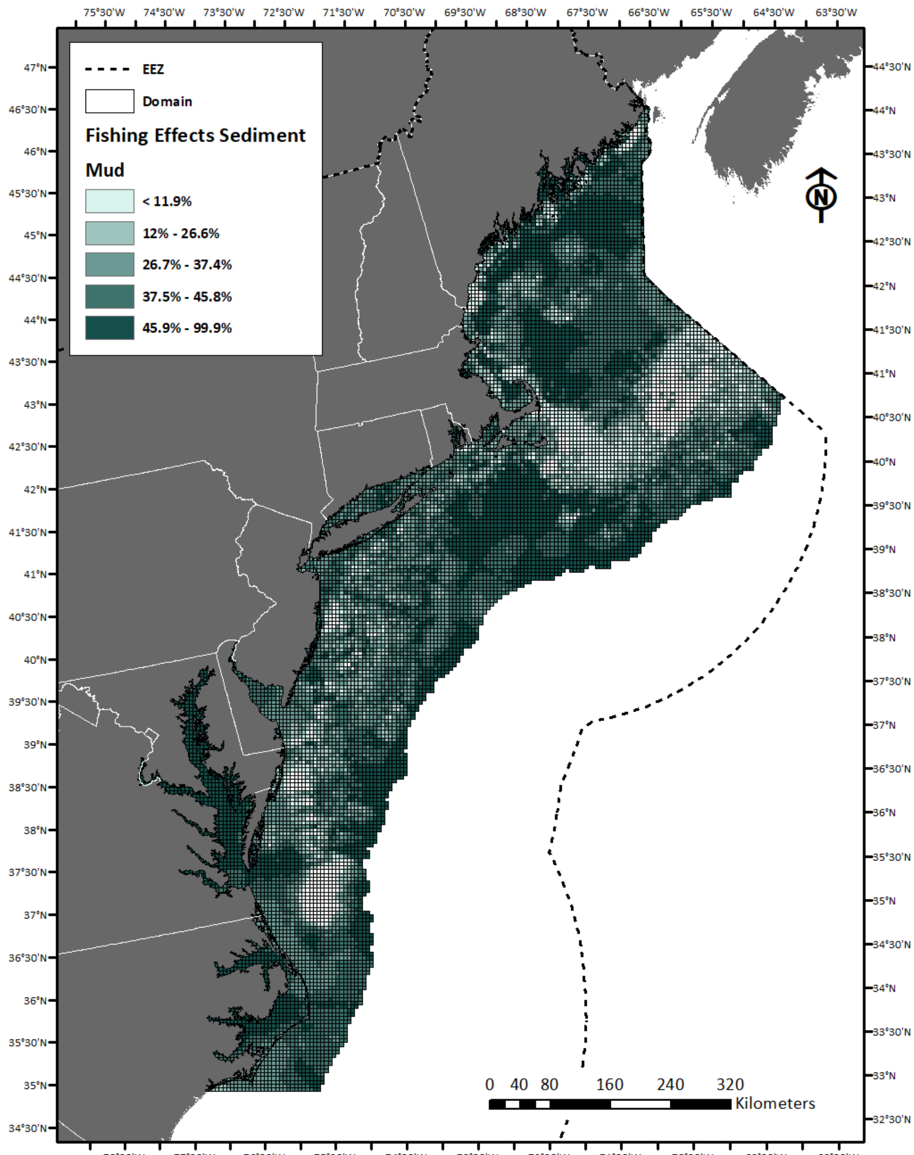


Figure 8. Percent sand by grid cell. Zero values are not mapped.

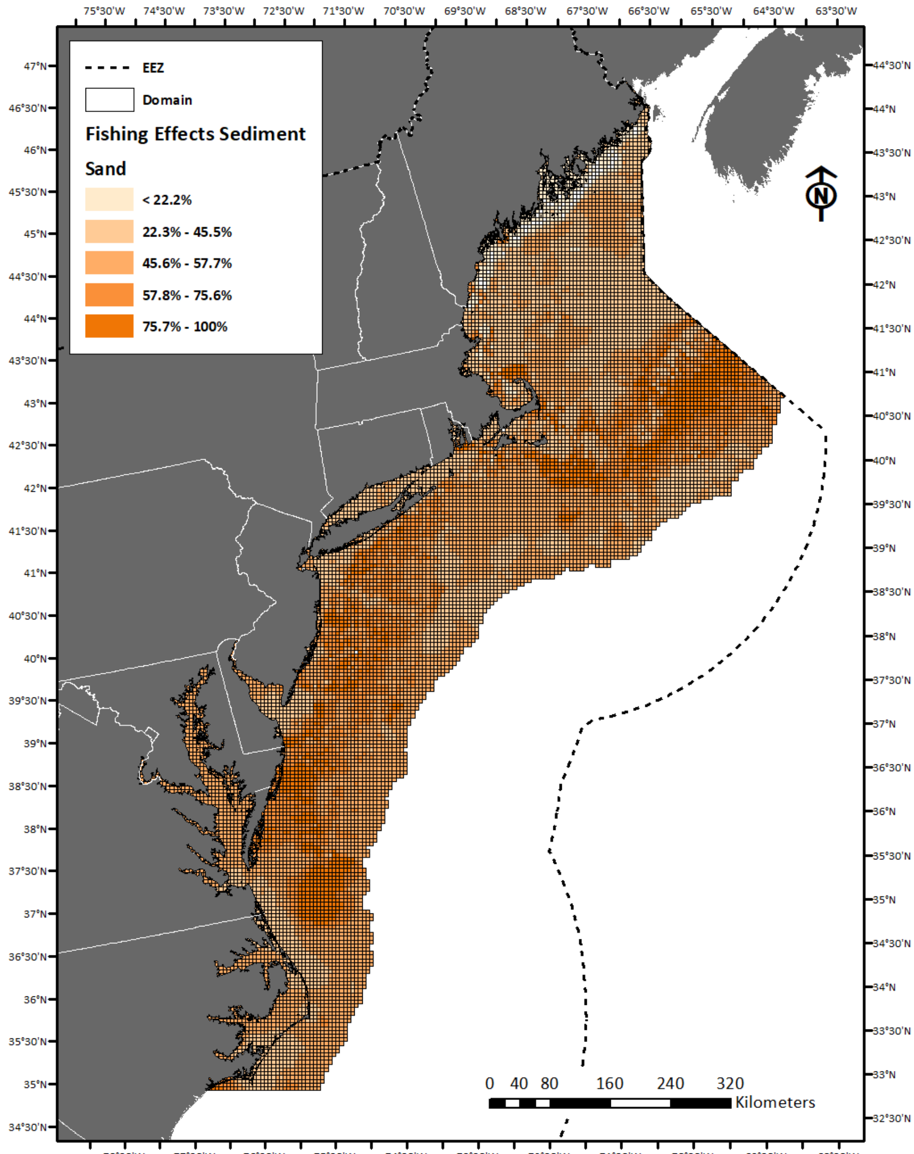


Figure 9. Percent granule/pebble by grid cell. Zero values are not mapped.

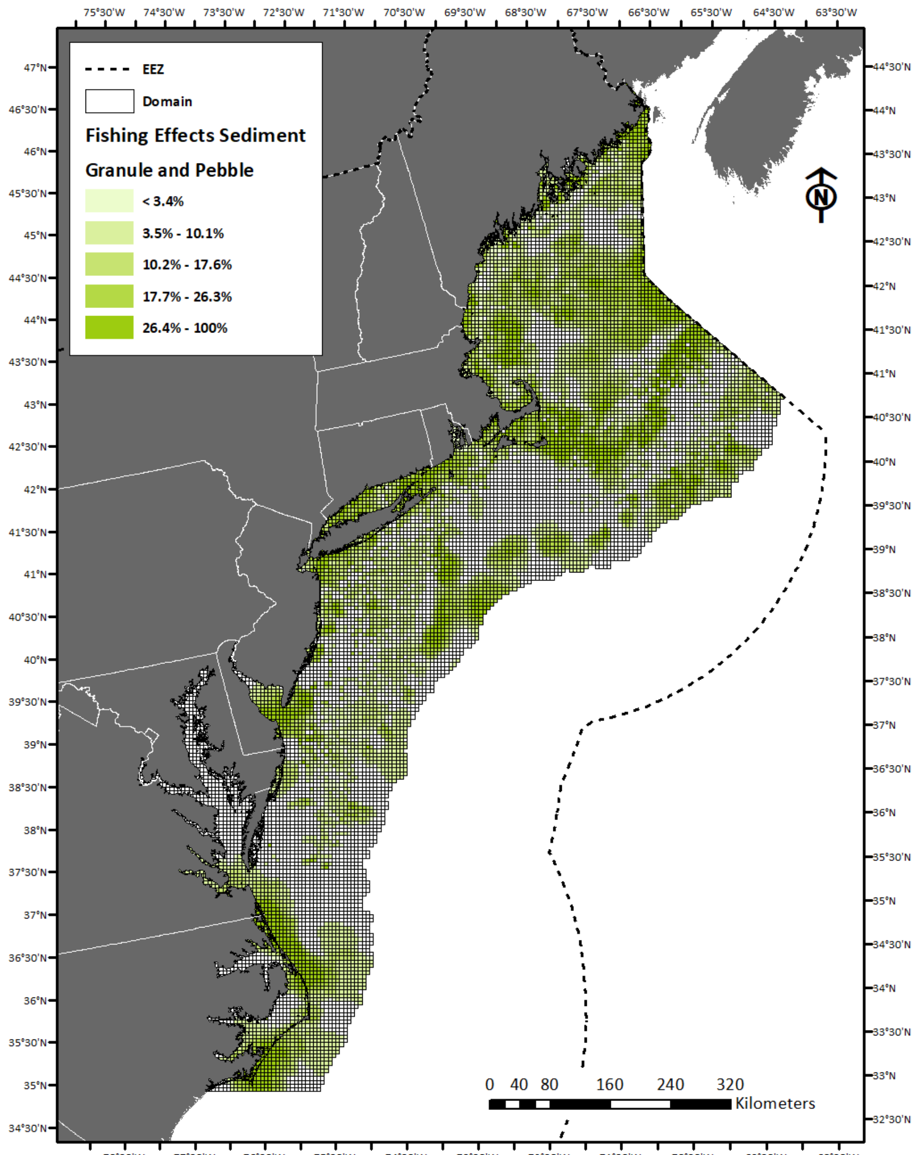


Figure 10. Percent cobble by grid cell. Zero values are not mapped.

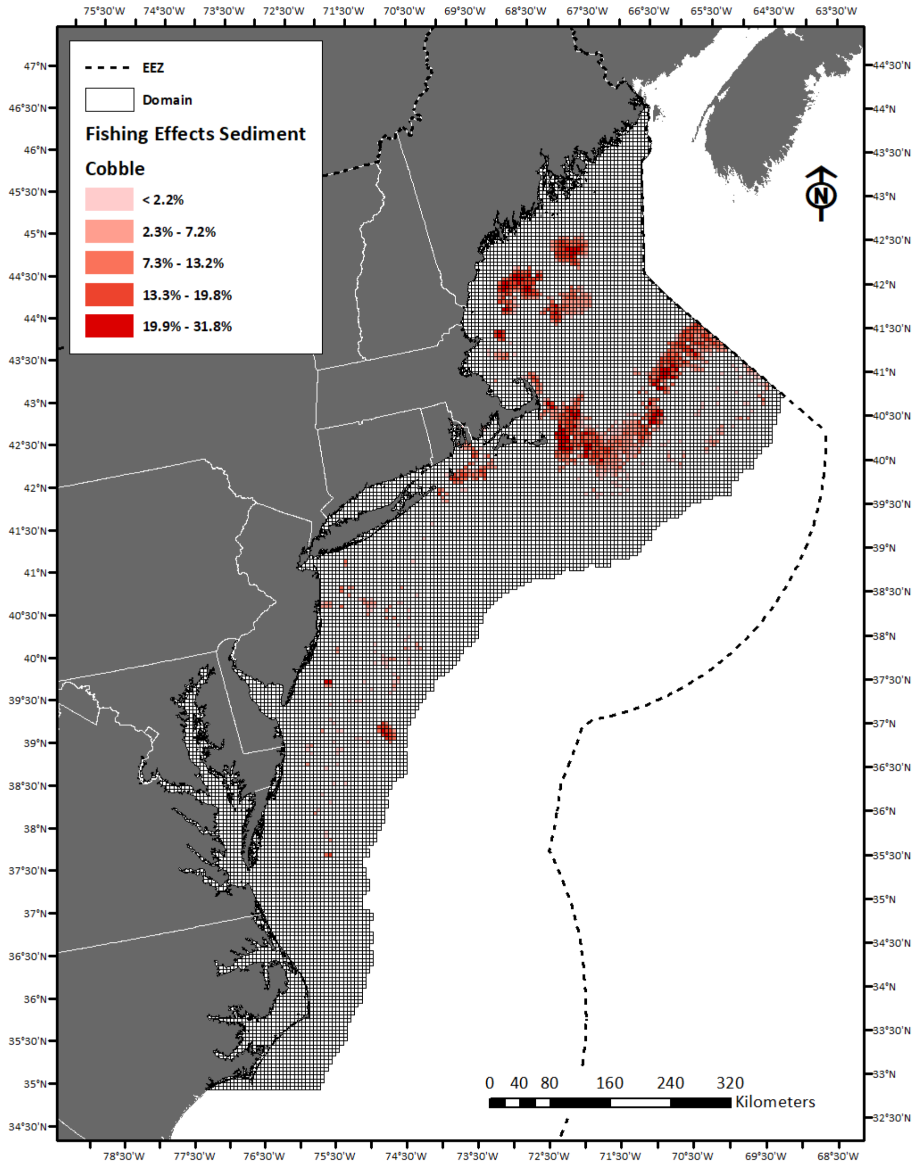


Figure 11. Percent boulder by grid cell. Zero values are not mapped.

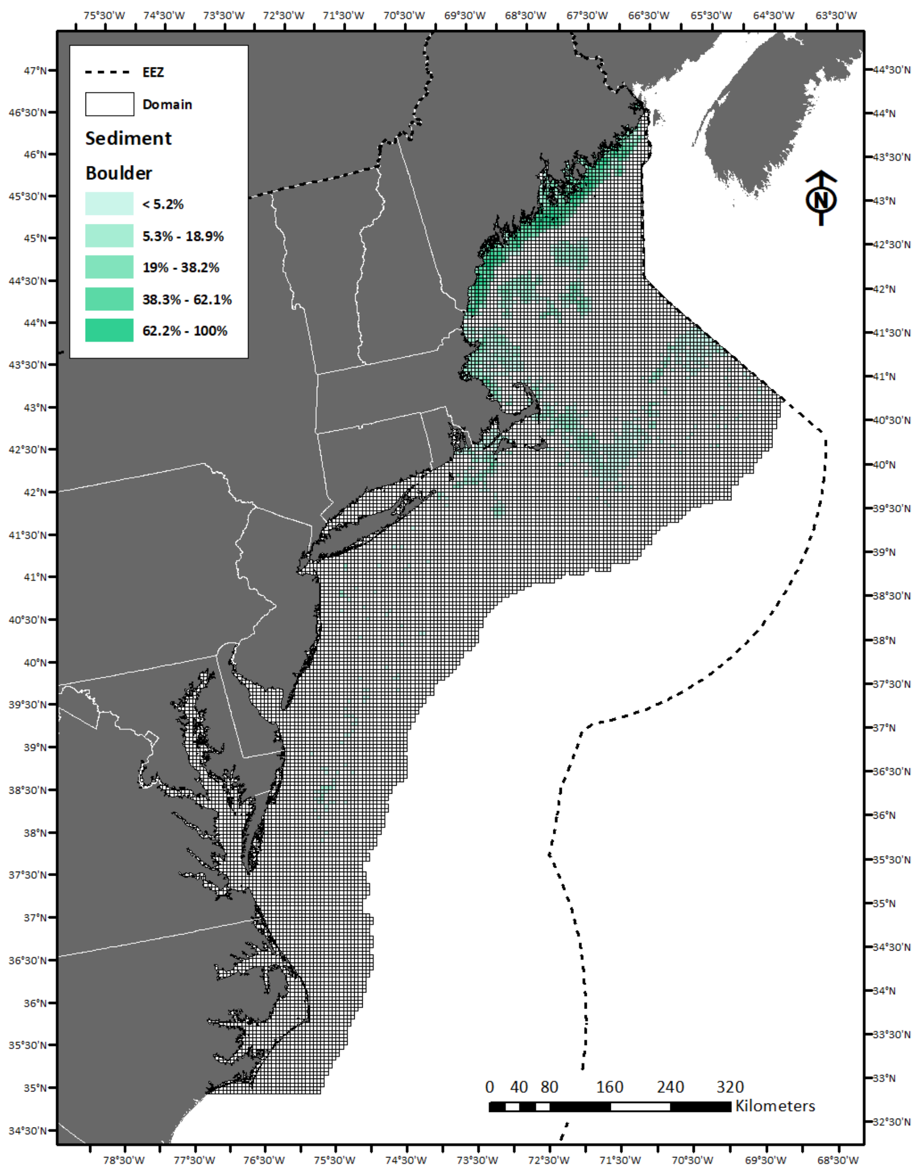
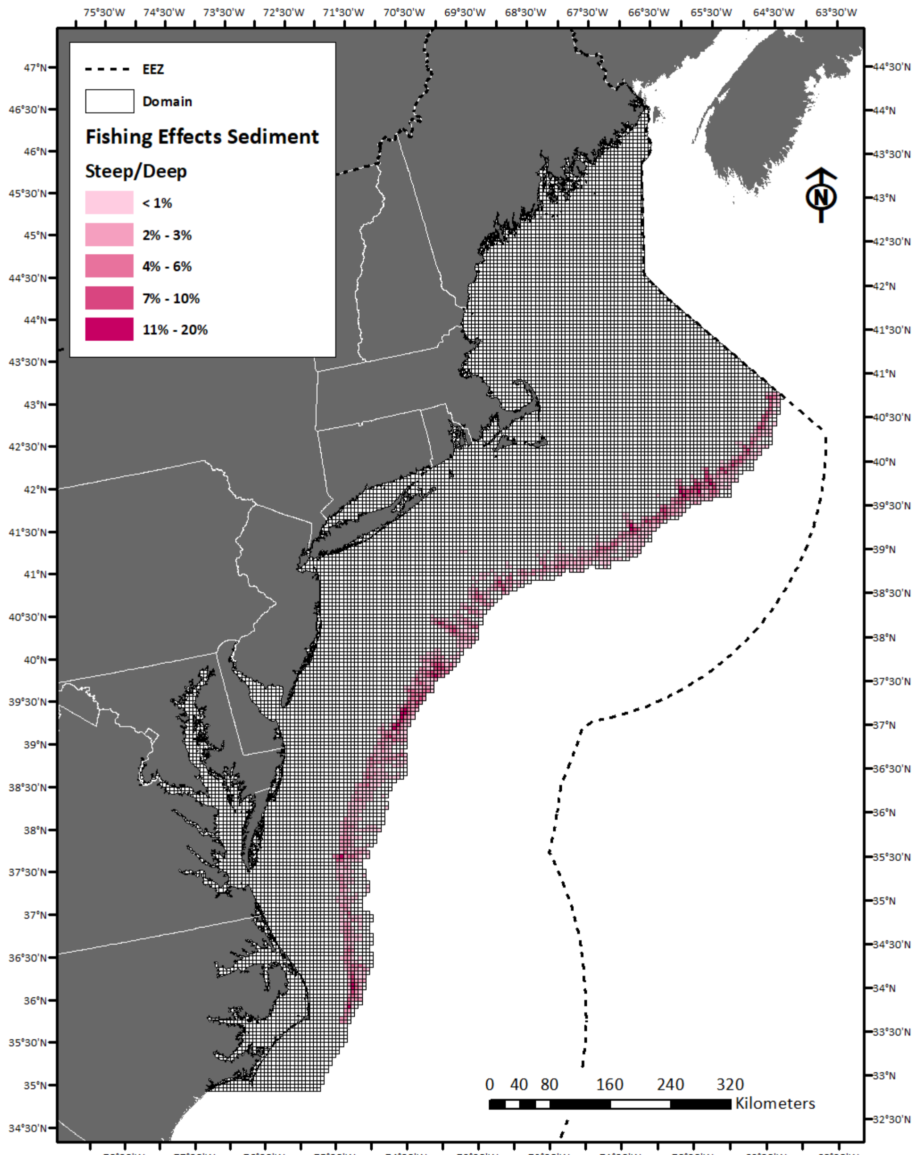


Figure 12. Percent steep and deep by grid cell. Zero values are not mapped such that domain (hatched) shows through.



Fishing Effects Model
Sediment Data Density
January 2, 2020

Prepared for:
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Prepared by:
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1 INTRODUCTION

The Northeast Fishing Effects Model combines seafloor data (sediment type, energy regime) with fishing effort data and parameters related to the interactions between fishing gear and seafloor habitats to generate percent habitat disturbance estimates in space and time. Fishing gear interacts with both living (biological) and non-living (geological) seafloor features. Diverse seabed types comprised of various combinations of biological and geological features occur in the Northwest Atlantic Ocean off the northeastern United States. These seabed structures constitute merely one element of complex fish habitats that also include the overlying water column and its features. Because sediment type data were available at a reasonable spatial resolution and representativeness across the model domain, sediments were used as a proxy for the diverse array of seabed types occurring in the region, with biological habitat elements inferred on the basis of sediment and energy classifications. This allows appropriate habitat/gear interaction parameters to be applied when the model is run.

Generally, the model domain extends north to south from the U.S./Canadian border to the N.C./S.C. border, and inshore to offshore from the coastline to the Exclusive Economic Zone boundary. The sediment grid covers this entire domain. Data inputs and outputs to Fishing Effects are gridded at a 5 km by 5 km resolution, except for cells along the edge of the domain which are clipped to the coastline or Exclusive Economic Zone boundary and are therefore smaller.

This dataset indicates the number of data points occurring within each 5x5 grid cell (data density). Each record in the dataset represents a unique grid cell with corresponding grid identification number. In areas where there were existing polygon interpretations of sediments, these are used instead of the point-based interpolations to determine the percent sediment values in the final sediment dataset. The polygon data are not included in this sediment data density product, only points. The methods for generating the percent sediment grid, including the use of polygon vs. point data in specific locations, are explained in the metadata document for that dataset.

Additional information about the model can be found in NEFMC (2019) and in the report for the precursor to Fishing Effects, the Swept Area Seabed Impact (SASI) Model (NEFMC 2011).

2 PURPOSE

The primary purpose of this dataset is to indicate data density associated with the percent sediment base layer for the Northeast Fishing Effects Model. Percent sediment values in cells with fewer observations may be less reliable than values calculated for grids with multiple grain size observations. The associated map of sediment grain sizes (percent sediment map) can be used to inform various spatial planning issues where seabed type is a consideration for decision making. It is important to understand caveats and limitations associated with both the underlying source data and this compilation when using the data for spatial planning. These limitations and caveats influence the Fishing Effects Model percent habitat disturbance results as well.

3 SOURCES AND AUTHORITIES

Various sources and types of sediment data were combined to generate this product. See percent sediment metadata for details.

4 COLLABORATORS

The Fishing Effects Model was developed collaboratively by the New England Fishery Management Council's Habitat Plan Development Team and the Fisheries, Aquatic Science, and Technology Laboratory at Alaska Pacific University. Team members included:

- Michelle Bachman, NEFMC staff
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- David Stevenson, NMFS Greater Atlantic Regional Fisheries Office
- Page Valentine, U.S. Geological Survey
- Alison Verkade, NMFS Greater Atlantic Regional Fisheries Office

5 DATABASE DESIGN AND CONTENT

- Feature Class Name: Fishing Effects Sediment
- Total Number of Unique Features: 13,157 (corresponds with the percent disturbance results)
- Dataset Status: Complete
- Native storage format: ArcGIS feature class
- Feature Type: Polygon

Table 1. Data dictionary.

Line	Name	Definition	Type	Size[1]
1	OBJECTID	Uniquely identifies a feature	OBJECTID	*
2	Shape	Geometric representation of the feature	geometry	*
3	GridID	Unique GridID field used to link across model datasets	Long	9
4	Mud	Proportion of grid cell classified as mud grain size	Double	18, 15
5	Sand	Proportion of grid cell classified as sand grain size	Double	18, 15
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8	Boulder	Proportion of grid cell classified as boulder grain size	Double	18, 15
9	StDeep	Proportion of grid cell classified as steep and deep	Double	18, 15
10	Diversity	Number of distinct sediment classes (mud-boulder)	Long	10
11	Density	Number of sediment points (does not account for polygon data inputs)	Long	10

6 SPATIAL REPRESENTATION

- Geometry Type: vector polygon
- Projection
  - Reference System: GCS_North_American_1983
  - Horizontal Datum: North American Datum 1983
  - Ellipsoid: Geodetic Reference System 1980
- XY Resolution: XY Scale is .000000001
- Tolerance: 0.000000008983153
- Geographic extent: -82.87 to -63.95, 22.14 to 47.13
- ISO 19115 Topic Category: environment, oceans, geoscientificInformation
- Place Names: Cape Cod Bay, Georges Bank, Gulf of Maine, Maine Inner Continental Shelf, Massachusetts Bay, New Jersey Continental Shelf, New York Bight, North Atlantic Ocean, Southern New England Shelf
- Recommended Cartographic Properties:
  (Using ArcGIS ArcMap nomenclature)
  For Sediment data density (number of points per grid cell):
  Classified, Manual classification, 9 classes, color model R-G-B
    0: no color
    1: 217-217-217
    2: 204-204-204

Commented [1]: Emily - Not sure how I figure out what these are? Maybe not applicable to polygon data?

Commented [2]: Agree - N/A

3: 191-191-191
4: 179-179-179
5: 166-166-166
6: 153-153-153
7: 140-140-140
8-1916: 52-52-52

- Scale range for optimal visualization:1,000,000 to 13,000,000

Commented [3]: I sort of eyeballed this based at the scales at which I would use the data.

7 METHODS AND DATA PROCESSING

The number of points in each grid cell was determined by…

Commented [4]: Felipe: I'm not exactly sure how this was done. I would have done a spatial join in ArcMap but maybe you did something else.

8 QUALITY PROCESS

- Attribute Accuracy: Attribute values are derived from authoritative metadata sources.
- Logical Consistency: These data are believed to be logically consistent.
- Completeness: The completeness of the data reflects the feature content of the data sources, and their associated metadata.
- Positional Accuracy: Positional accuracy may vary according to positioning methodology in the underlying data sources. Results are aggregated by Fishing Effects Model grid cell, with each cell having a resolution of 5 kilometers.
- Timeliness: Based on samples collected between 1934 and 2018.
- Use restrictions: Data are presented as is. Users are responsible for understanding the metadata prior to use. The New England Fishery Management Council shall be acknowledged as data contributors to any reports or other products derived from these data.
- Distribution Liability: All parties receiving these data must be informed of all caveats and limitations.

9 CAVEATS AND DISCUSSION

As described in the metadata document for the Percent Sediment Type layer, percent sediment for each grid was calculated using one of three methods: (1) a modified area-weighted approach for cells with polygonal sediment data, (2) a similar approach but based on counts instead of areas for cells without polygon data but with 8 or more point data values, or (3) an Ordinary Kriging spatial interpolation for cells with less than 8 point data values.

Data density alone is not necessarily and indicator of data quality. A major qualifier is that the methods used to generate the sediment data compiled by USGS often do not have the ability to sample the largest grain sizes, cobble and boulder. Therefore, even in areas of high point data density, these larger grain sizes may be under-represented. This could be occurring in Long Island Sound, Buzzards Bay, and Massachusetts Bay. While in general sediments are finer in the Mid-Atlantic Bight as compared to New England, there are localized areas of high data density (>7 points) associated with data from the USGS database along the coast of NJ, DE, MD, and NC as well. Other than these areas, locations with greater than 7 points per grid were surveyed with drop camera, capable of detecting the larger grain sizes.

Commented [5]: I feel like this paragraph should also be in the metadata caveats/discussion section for "Percent Sediment Type". I copied it there.

Also, if USGS grab samples tend to underestimate grain size (because they are not sampling cobble/boulder habitat), are the SMAST drop camera surveys overestimating grain sizes? Can the camera detect the difference between mud and sand with the same level of precision/detail as the USGS particle analysis?

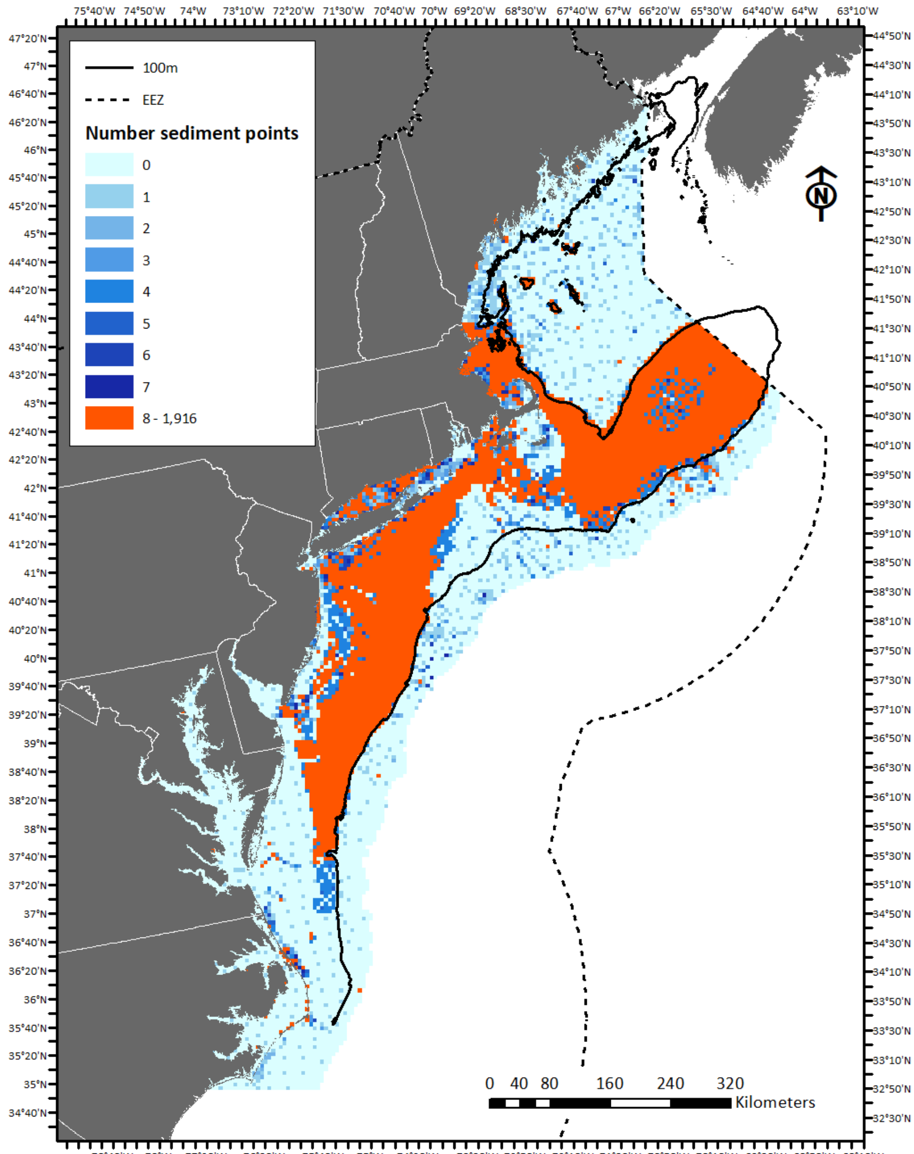
Commented [6]: I would agree with copying this there. And no, the drop camera can't discern between fine grain sizes the same way that a grab sample is able to.

10 REFERENCES

NEFMC (2011). Omnibus Essential Fish Habitat Amendment 2 Final Environmental Impact Statement. Appendix D: The Swept Area Seabed Impact (SASI) approach: a tool for analyzing the effects of fishing on Essential Fish Habitat. Newburyport, MA, New England Fishery Management Council**:** 257p.

NEFMC (2019). Fishing Effects Model Northeast Region. Newburyport, MA, New England Fishery Management Council**:** 109p.

11 FIGURES



100m
EEZ
Number sediment points
0
1
2
3
4
5
6
7
8 - 1,916
N
0 40 80 160 240 320
Kilometers

Fishing Effects Model
Sediment Diversity
January 2, 2020

Prepared for:
Northeast Regional Ocean Council (NROC)
www.northeastoceandata.org

Prepared by:
Michelle Bachman
New England Fishery Management Council
50 Water St. Mill 2
Newburyport, MA 01950

1 INTRODUCTION

The Northeast Fishing Effects Model combines seafloor data (sediment type, energy regime) with fishing effort data and parameters related to the interactions between fishing gear and seafloor habitats to generate percent habitat disturbance estimates in space and time. Fishing gear interacts with both living (biological) and non-living (geological) seafloor features. Diverse seabed types comprised of various combinations of biological and geological features occur in the Northwest Atlantic Ocean off the northeastern United States. These seabed structures constitute merely one element of complex fish habitats that also include the overlying water column and its features. Because sediment type data were available at a reasonable spatial resolution and representativeness across the model domain, sediments were used as a proxy for the diverse array of seabed types occurring in the region, with biological habitat elements inferred on the basis of sediment and energy classifications. This allows appropriate habitat/gear interaction parameters to be applied when the model is run.

Generally, the model domain extends north to south from the U.S./Canadian border to the N.C./S.C. border, and inshore to offshore from the coastline to the Exclusive Economic Zone boundary. The sediment grid covers this entire domain. Data inputs and outputs to Fishing Effects are gridded at a 5 km by 5 km resolution, with the exception of cells along the edge of the domain which are clipped to the coastline or Exclusive Economic Zone boundary and are therefore smaller.

This dataset indicates the number of different sediment types associated with each cell in the percent sediment grid used as an input to Fishing Effects. Five different sediment grain sizes are represented in this dataset, mud, sand, granule/pebble, cobble, and boulder. Each record in the dataset represents a unique grid cell with corresponding grid identification number.

Additional information about the model can be found in NEFMC (2019) and in the report for the precursor to Fishing Effects, the Swept Area Seabed Impact (SASI) Model (NEFMC 2011).

2 PURPOSE

The primary purpose of this dataset is to indicate the number of sediment categories associated with each grid cell in the percent sediment base layer for the Northeast Fishing Effects Model. This provides a rough indication of the diversity of sediment types occurring across different portions of the domain. The associated map of sediment grain sizes can be used to inform various spatial planning issues where seabed type is a consideration for decision making. It is important to understand caveats and limitations associated with both the underlying source data and this compilation when using the data for spatial planning. These limitations and caveats influence the Fishing Effects Model percent habitat disturbance results as well.

3 SOURCES AND AUTHORITIES

Various sources and types of sediment data were combined to generate this product. See percent sediment metadata for details.

4 COLLABORATORS

The Fishing Effects Model was developed collaboratively by the New England Fishery Management Council's Habitat Plan Development Team and the Fisheries, Aquatic Science, and Technology Laboratory at Alaska Pacific University. Team members included:

- Michelle Bachman, NEFMC staff
- Peter Auster, University of Connecticut/Mystic Aquarium
- Jessica Coakley, Mid-Atlantic Fishery Management Council
- Geret DePiper, NMFS/Northeast Fisheries Science Center
- Kathryn Ford, Massachusetts Division of Marine Fisheries
- Bradley Harris, Alaska Pacific University
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- Chris Quartararo, NEFMC staff
- Felipe Restrepo, Alaska Pacific University
- T. Scott Smeltz, Alaska Pacific University
- David Stevenson, NMFS Greater Atlantic Regional Fisheries Office
- Page Valentine, U.S. Geological Survey
- Alison Verkade, NMFS Greater Atlantic Regional Fisheries Office

5 DATABASE DESIGN AND CONTENT

- Feature Class Name: Fishing Effects Sediment
- Total Number of Unique Features: 13,157
- Dataset Status: Complete
- Native storage format: ArcGIS feature class
- Feature Type: Polygon

Table 1. Data dictionary.

Line	Name	Definition	Type	Size[1]
1	OBJECTID	Uniquely identifies a feature	OBJECTID	*
2	Shape	Geometric representation of the feature	geometry	*
3	GridID	Unique GridID field used to link across model datasets	Long	9
4	Mud	Proportion of grid cell classified as mud grain size	Double	18, 15
5	Sand	Proportion of grid cell classified as sand grain size	Double	18, 15
6	GrPe	Proportion of grid cell classified as granule or pebble grain size	Double	18, 15
7	Cobble	Proportion of grid cell classified as cobble grain size	Double	18, 15
8	Boulder	Proportion of grid cell classified as boulder grain size	Double	18, 15
9	StDeep	Proportion of grid cell classified as steep and deep	Double	18, 15
10	Diversity	Number of distinct sediment classes (mud-boulder)	Long	10
11	Density	Number of sediment points (does not account for polygon data inputs)	Long	10

[1] Size for type double fields refers to precision and scale

6 SPATIAL REPRESENTATION

- Geometry Type: vector polygon
- Projection
  - Reference System: GCS_North_American_1983
  - Horizontal Datum: North American Datum 1983
  - Ellipsoid: Geodetic Reference System 1980
- Geographic extent: -82.87 to -63.95, 22.14 to 47.13
- IS0 19115 Topic Category: environment, oceans, geoscientificInformation
- Place Names: Cape Cod Bay, Georges Bank, Gulf of Maine, Maine Inner Continental Shelf, Massachusetts Bay, New Jersey Continental Shelf, New York Bight, North Atlantic Ocean, Southern New England Shelf
- Recommended Cartographic Properties:
  (Using ArcGIS ArcMap nomenclature)
  For Sediment diversity (number of distinct sediment classes):
  Classified, Manual classification, 5 classes, color model R-G-B
  5: 0-0-4
  4: 86-16-110
  3: 187-55-82
  2: 249-140-10

1: 252-255-164

- Scale range for optimal visualization:1,000,000 to 13,000,000

Commented [1]: I sort of eyeballed this based at the scales at which I would use the data.

7 METHODS AND DATA PROCESSING

The number of sediment types in each cell was calculated by....

Commented [2]: Felipe: Before I got the updated data set from you, I did this with a CountIf function in Excel, but guessing that's not what you did!

8 QUALITY PROCESS

- Attribute Accuracy: Attribute values are derived from authoritative metadata sources.
- Logical Consistency: These data are believed to be logically consistent.
- Completeness: The completeness of the data reflects the feature content of the data sources, and their associated metadata.
- Positional Accuracy: Positional accuracy may vary according to positioning methodology in the underlying data sources. Results are aggregated by Fishing Effects Model grid cell, with each cell having a resolution of 5 kilometers.
- Timeliness: Based on samples collected between 1934 and 2018.
- Use restrictions: Data are presented as is. Users are responsible for understanding the metadata prior to use. The New England Fishery Management Council shall be acknowledged as data contributors to any reports or other products derived from these data.
- Distribution Liability: All parties receiving these data must be informed of all caveats and limitations.

9 CAVEATS AND DISCUSSION

All five sediment classes occur in three primary locations: (1) grids directly offshore RI; (2) on the back side of Cape Cod, continuing along the Great South Channel, and east along the northern flank of Georges Bank; and (3) in various shallow banks and ledges in the Gulf of Maine, including Jeffreys Bank, Stellwagen Bank, Fippennies Ledge, Cashes Ledge, and Platts Bank. Occasional grids in the Mid-Atlantic Bight include all five sediments but boulder and cobble are rare in that region.

The spatial distribution of grids with four sediment classes is generally similar, but also includes much of the inshore Gulf of Maine. One reason for this is that the Maine Bottom Type (Barnhardt et al 1998) and Massachusetts Office of Coastal Zone Management data sets only have four classes, mud, sand, gravel (coded as granule-pebble) and rock outcrop (coded as boulder). The Fishing Effects cobble and boulder categories fall within Barnhardt's/MA CZM's gravel categories, such that there is not an ideal correspondence between the Fishing Effects classification and these sources. Rock outcrops are not identified in other data sets contributing to the sediment grid.

Other locations in the domain that are classified as having two or three of the five sediment grain sizes may be classified this way because only three sediment types are present, but the source data documents all five, or because the source data only document three classes. This is the case with the USGS database, where sampling gears contributing information to this data set are generally not capable of sampling cobble and boulder sizes, so these two types cannot be mapped using the USGS data. Also, the Narragansett Bay Estuary Program data classifies sediments as mud, sand, or gravel, and gravel was mapped to the granule pebble sediment type in Fishing Effects. That being said, large areas of Georges Bank and the Mid-Atlantic Bight mapped with drop camera (which is expected to provide a complete picture of the grain sizes occurring in these areas) only have mud, sand, and/or granule-pebble classes.

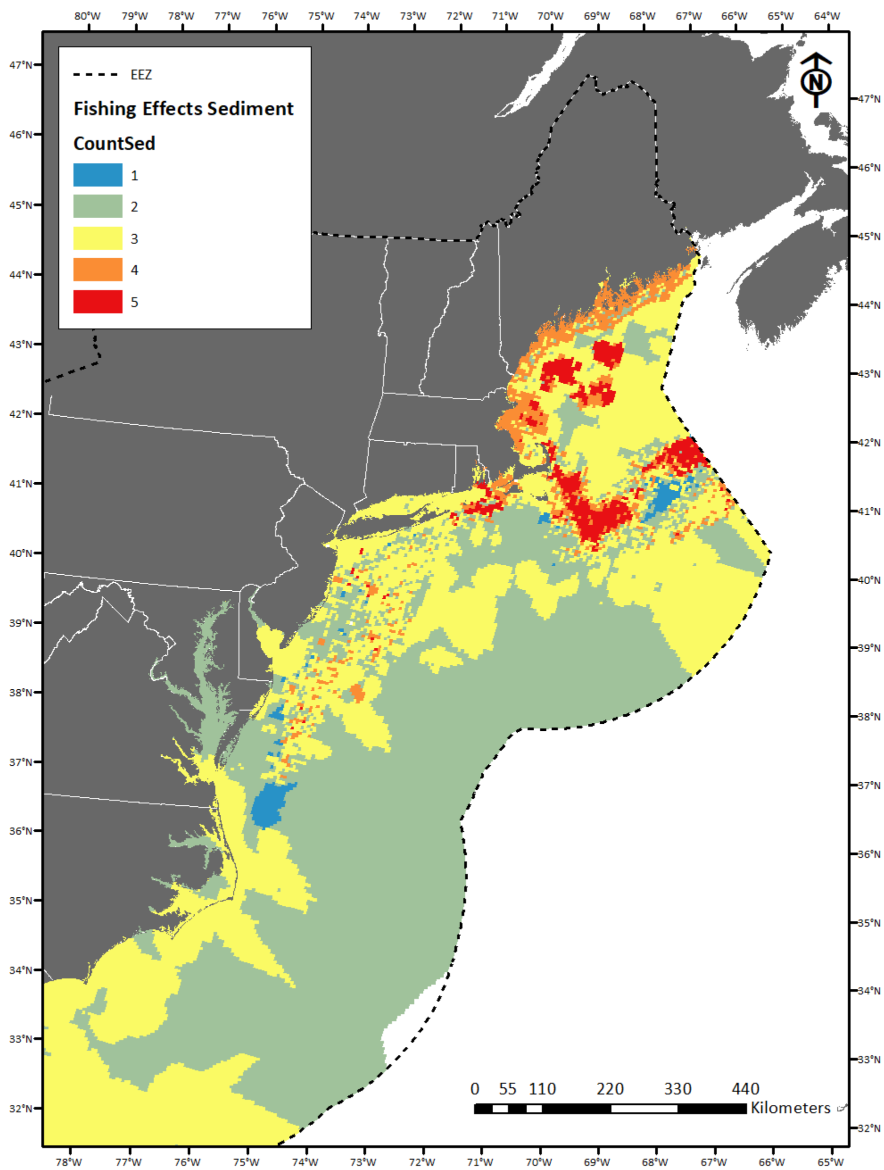
Locations with a single sediment type are rare, but there is a large area in the center of Georges Bank that is mapped as 100% sand.

10 REFERENCES

NEFMC (2011). Omnibus Essential Fish Habitat Amendment 2 Final Environmental Impact Statement. Appendix D: The Swept Area Seabed Impact (SASI) approach: a tool for analyzing the effects of fishing on Essential Fish Habitat. Newburyport, MA, New England Fishery Management Council**:** 257p.

NEFMC (2019). Fishing Effects Model Northeast Region. Newburyport, MA, New England Fishery Management Council**:** 109p.

11 FIGURES


EEZ
Fishing Effects Sediment
CountSed
1
2
3
4
5
0 55 110 220 330 440
Kilometers

Fishing Effects Model
Percent Habitat Disturbance
November 8, 2019

Prepared for:
Northeast Regional Ocean Council (NROC)
www.northeastoceandata.org

Prepared by:
Michelle Bachman
New England Fishery Management Council
50 Water St. Mill 2
Newburyport, MA 01950

1 INTRODUCTION

These datasets constitute the primary outputs of the Northeast Fishing Effects Model (Fishing Effects). The model combines seafloor data (sediment type, energy regime) with fishing effort data and parameters related to the interactions between fishing gear and seafloor habitats to generate percent habitat disturbance estimates in space and time. The model differentiates six types of bottom-tending fishing gears: trawl, scallop dredge, clam dredge, longline, gillnet, and trap. Data inputs and outputs to Fishing Effects are gridded at a 5 km by 5 km resolution, except for cells along the edge of the domain which are clipped to the coastline or Exclusive Economic Zone boundary and are therefore smaller. The model outputs are monthly estimates of percent seabed habitat disturbance for each of these six gear types, by grid cell, from 1996-2017. There is also a combined output where all fishing effort across the six gear types is run through the model at once, and the outputs are monthly percent disturbance by grid cell across all bottom-tending gears. Note that while there are types of trawls, longlines, and gillnets that are fished off bottom, those are excluded from modeling efforts.

Generally, the model domain extends north to south from the U.S./Canadian border to the N.C./S.C. border. While the base grid extends inshore to offshore from the coastline to the Exclusive Economic Zone boundary, the percent disturbance outputs extend only to the shelf break because this is the limit of fishing activity with bottom-tending gears in the northeast region. This is important because disturbance metrics summarized at the scale of the region rely on the total model footprint as the denominator, and these estimates are not meaningful percentages if total disturbance is reported over large areas that are not fished.

Additional information about the model can be found in NEFMC (2019) and in the report for the precursor to Fishing Effects, the Swept Area Seabed Impact (SASI) Model (NEFMC 2011). Smeltz et al (2019) describes a version of Fishing Effects implemented in the North Pacific region.

2 PURPOSE

The Magnuson Stevens Fishery Conservation and Management Act requires regional fishery management councils to designate essential fish habitats (EFH) for all species managed. EFH means those waters and substrate necessary for spawning, breeding, feeding, and growth to maturity. The primary purpose of the fishing disturbance products is to document spatial and temporal trends in habitat disturbance due to fishing, in order to inform spatial and gear-specific fishery management strategies related to minimization of adverse fishery impacts to essential fish habitats.

3 SOURCES AND AUTHORITIES

The data inputs of the Fishing Effects model include a benthic sediment/energy map and fishing effort as swept area. Metadata for the sediment map are described in a separate document. Energy classification is based on depth or benthic boundary shear stress data (see NEFMC 2011 for methods). Fishing effort data were obtained from the Northeast Fishery Science Center, either from Vessel Trip Reports or Clam Logbooks (see summary below). Model parameters defining how fishing effort data are modified initially upon entering the model at a given time step, and how fishing effort decays over time, are described in NEFMC 2011, NEFMC 2019, and Smeltz et al 2019.

4 COLLABORATORS

The Fishing Effects Model was developed collaboratively by the New England Fishery Management Council's Habitat Plan Development Team and the Fisheries, Aquatic Science, and Technology Laboratory at Alaska Pacific University. Team members included:

- Michelle Bachman, NEFMC staff
- Peter Auster, University of Connecticut/Mystic Aquarium
- Jessica Coakley, Mid-Atlantic Fishery Management Council
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- Felipe Restrepo, Alaska Pacific University
- T. Scott Smeltz, Alaska Pacific University
- David Stevenson, NMFS Greater Atlantic Regional Fisheries Office
- Page Valentine, U.S. Geological Survey
- Alison Verkade, NMFS Greater Atlantic Regional Fisheries Office

5 DATABASE DESIGN AND CONTENT

- Feature Class Names: disturbProps_allGear, disturbProps_BottomTrawlGear, disturbProps_scaGear, disturbProps_hyGear, disturbProps_gillnetGear, disturbProps_longliGear, disturbProps_trapGear
- Total Number of Unique Features: 13,157
- Dataset Status: Complete
- Native storage format: ArcGIS feature class
- Feature Type: Polygon

Table 1. Data dictionary

Line	Name	Definition	Type	Size[1]
1	FID	Uniquely identifies a feature	OBJECTID	*
2	Shape	Geometric representation of the feature	geometry	*
3	SP_ID	Sequential unique identifier	String	5
4	GridID	Unique GridID field used to link across model datasets	Long	9
5	Jan1996	Proportion of cell disturbed by all gears or an individual gear type at the end of January 1996	Double	23, 15
6	Feb1996	Proportion of cell disturbed by all gears or an individual gear type at the end of February 1996	Double	23, 15
Analogous format for months between Feb 1996-Dec 2017				
256	Dec2017	Proportion of cell disturbed by all gears or an individual gear type at the end of December 2017	Double	23, 15

[1] Size for type double fields refers to precision and scale

6 SPATIAL REPRESENTATION

- Geometry Type: vector polygon
- Projection
  - Reference System: GCS_North_American_1983
  - Horizontal Datum: North American Datum 1983
  - Ellipsoid: Geodetic Reference System 1980
- Geographic extent: -82.87 to -63.95, 22.14 to 47.13
- ISO 19115 Topic Category: environment, oceans, geoscientificInformation
- Place Names: Cape Cod Bay, Georges Bank, Gulf of Maine, Maine Inner Continental Shelf, Massachusetts Bay, New Jersey Continental Shelf, New York Bight, North Atlantic Ocean, Southern New England Shelf
- Recommended Cartographic Properties:
  - (Using ArcGIS ArcMap nomenclature)
  - We will need to figure out what the best symbology is and summarize it here.
- Scale range for optimal visualization:1,000,000 to 13,000,000

Commented [1]: Emily - For later

Commented [2]: I sort of eyeballed this based at the scales at which I would use the data.

7 METHODS AND DATA PROCESSING

The Fishing Effects model disaggregates fishing effort by gear type and classifies habitat into six types based on five substrate types (mud, sand, granule-pebble, cobble, boulder), plus steep and deep habitats that are expected to contain deep-sea corals and other associated species. Geological and biological features are inferred to each of these habitat types (see NEFMC 2011, 2019 for details). With respect to a feature-gear-substrate-energy combination, 'vulnerability' represents the extent to which the effects of fishing gear on a feature are adverse. 'Vulnerability' is defined as the combination of how susceptible the feature is to a gear effect and how quickly it can recover following the fishing impact.

Specifically, susceptibility is defined as the percentage of total habitat features encountered by fishing gear during a hypothetical single pass fishing event that have their functional value reduced, and recovery is defined as the time in years that would be required for the functional value of that unit of habitat to be restored. However, because functional value is difficult to assess directly, and will vary for each managed species using the feature for shelter, feature removal or damage was used as a proxy for reduction in functional value. In order to make the susceptibility and recovery information work as a set of model parameters, the susceptibility and recovery of each feature-gear-substrate-energy combination were scored on a 0-4 scale as summarized in Table 6. Quantitative susceptibility percentages in the table indicate the proportion of features in the path of the gear likely to be modified to the point that they no longer provide the same functional value. Recovery does not necessarily mean a restoration of the exact same features, but that after recovery the habitat would have the same functional value.

Table 2. Susceptibility and recovery values. The score of 4 is only used in specific steep and deep/deep-sea coral areas.

Code	Quantitative definition of susceptibility	Quantitative definition of recovery
0	0–10%	< 1 year
1	>10%-25%	1-2 years
2	25-50%	2 – 5 years
3	>50%	> 5 years
4	n/a	10-50 years

Susceptibility and recovery were scored based on information found in the scientific literature, to the extent possible, combined with professional judgment where research results are lacking or inconsistent. The approach is detailed in NEFMC 2011, including "rules" for matrix evaluation. Each matrix listed in Table 2 includes the features present in that particular substrate and energy environment, gear effects related to that gear type and feature combination, susceptibility and recovery for each feature, and the literature deemed relevant to assigning susceptibility "S" and recovery "R" for a particular feature and gear combination. A complete set of S-R matrices by gear type (otter trawl, scallop dredge, hydraulic dredge, longline, gillnet, and trap) can be found in NEFMC 2019. These were updated slightly from the versions used in the original SASI model (NEFMC 2011).

Table 3. Matrices evaluated. Each substrate-type matrix included both energy environments and all associated features.

Gear type	Mud	Sand	Granule-pebble	Cobble	Boulder	Deep-sea coral
All trawl gears	X	X	x	X	X	X (New)
Scallop dredge	X	X	X	X	X	
Hydraulic dredge	-	X	X	X (New)	X (New)	
Longline	X	X	X	X	X	X (New)
Gillnet	X	X	X	X	X	X (New)
Trap	X	X	X	X	X	X (New)

In order to quantify fishing effort in like terms and compare the relative effects of different fishing gears, fishing effort inputs to the Fishing Effects model (e.g. number of trips, tows, sets) are converted to area swept in km^2, regardless of gear type. Simple quantitative models convert fishing effort data to area swept. These models provide an estimate of contact-adjusted area swept, measured in km^2 and are unchanged from the original SASI model. They are documented in NEFMC 2011 and NEFMC 2019 Appendix A. Regardless of gear type, the area swept models have three requirements:

- Total distance towed, or, in the case of fixed gears, total length of the gear;
- Width of the individual gear components; and
- Contact indices for the various gear components.

Fishing activity in the northeast region is documented using various methods, including vessel trip reports (often referred to as logbooks), satellite-based vessel monitoring systems, and at-sea observations by scientific personnel. The trip footprints used for Fishing Effects rely on positions (roughly one per trip) in vessel trip reports, or for clam trips, clam logbooks, with the estimated spread of fishing activity from that point estimated using other spatial data on fishing activity, including at-sea observer and vessel monitoring system. These trip-level footprints were developed using modeling approach that is routinely used for various fisheries management applications in the northeast region (DePiper 2014, Benjamin et al. 2018). Once tables of area swept values from individual trips were generated, they were joined with spatial data products that estimate the footprint of each trip, and area swept was distributed over this footprint.

Spatial datasets in raster format were prepared by overlaying the swept area footprints for a specific gear type and month, based on the date sailed of each trip. Finally, these monthly gear-specific rasters were joined to the 5x5 grid in order to serve as inputs to the Fishing Effects model.

8 QUALITY PROCESS

- Attribute Accuracy: Attribute values are derived from authoritative metadata sources.
- Logical Consistency: These data are believed to be logically consistent.
- Completeness: The completeness of the data reflects the feature content of the data sources, and their associated metadata.
- Positional Accuracy: Positional accuracy may vary according to positioning methodology in the underlying data sources. Note that Vessel Trip Reports often represent each fishing trip by a single latitude/longitude. Results are aggregated by Fishing Effects Model grid cell, with each cell having a resolution of 5 kilometers.
- Timeliness: Based on sediment samples collected between 1934 and 2018 and fishing activity occurring between 1996 and 2017.
- Use restrictions: Data is presented as is. Users are responsible for understanding the metadata prior to use. The New England Fishery Management Council shall be acknowledged as data contributors to any reports or other products derived from these data.
- Distribution Liability: All parties receiving these data must be informed of all caveats and limitations.

9 CAVEATS AND DISCUSSION

To be developed.

Commented [3]: From PJA: want to suggest the metadata include language about variability and sensitivity of estimated habitat disturbance and how timing of impacts will influence patterns in habitat state (all from the sensitivity analysis). Not sure what maps/data you are posting at the data portal but want to make sure users understand(?) the estimates have some significant variability (i.e., sec 7 of the report).

10 REFERENCES

NEFMC (2011). Omnibus Essential Fish Habitat Amendment 2 Final Environmental Impact Statement. Appendix D: The Swept Area Seabed Impact (SASI) approach: a tool for analyzing the effects of fishing on Essential Fish Habitat. Newburyport, MA, New England Fishery Management Council: 257p.

NEFMC (2019). Fishing Effects Model Northeast Region. Newburyport, MA, New England Fishery Management Council: 109p.

Smeltz, T. S., B. P. Harris, J. V. Olson and S. A. Sethi (2019). "A seascape-scale habitat model to support management of fishing impacts on benthic ecosystems." Canadian Journal of Fisheries and Aquatic Sciences: 1-9.

11 FIGURES

Given that these are best presented as animations I might skip the figures here.

Fishing Effects Model
Intrinsic Habitat Vulnerability to Fishing
November 26, 2019

Prepared for*:*
Northeast Regional Ocean Council (NROC)
www.northeastoceandata.org

Prepared by:
Michelle Bachman
New England Fishery Management Council
50 Water St. Mill 2
Newburyport, MA 01950

1 INTRODUCTION

These datasets constitute a secondary set of outputs from the Northeast Fishing Effects Model (Fishing Effects). The model combines seafloor data (sediment type, energy regime) with fishing effort data and parameters related to the interactions between fishing gear and seafloor habitats to generate percent habitat disturbance estimates in space and time. The model differentiates six types of bottom-tending fishing gears: trawl, scallop dredge, clam dredge, longline, gillnet, and trap. Data inputs and outputs to Fishing Effects are gridded at a 5 km by 5 km resolution, except for cells along the edge of the domain which are clipped to the coastline or Exclusive Economic Zone boundary and are therefore smaller. The model outputs are monthly estimates of percent seabed habitat disturbance for each of these six gear types, by grid cell, from 1996-2017.

Generally, the model domain extends north to south from the U.S./Canadian border to the N.C./S.C. border. While the base grid extends inshore to offshore from the coastline to the Exclusive Economic Zone boundary, the percent disturbance outputs extend only to the shelf break because this is the limit of fishing activity with bottom-tending gears in the northeast region. This is important because disturbance metrics summarized at the scale of the region rely on the total model footprint as the denominator, and these estimates are not meaningful percentages if total disturbance is reported over large areas that are not fished.

Additional information about the model can be found in NEFMC (2019) and in the report for the precursor to Fishing Effects, the Swept Area Seabed Impact (SASI) Model (NEFMC 2011).

2 PURPOSE

The Magnuson Stevens Fishery Conservation and Management Act requires regional fishery management councils to designate essential fish habitats (EFH) for all species managed. EFH means those waters and substrate necessary for spawning, breeding, feeding, and growth to maturity. The primary purpose of the fishing disturbance products is to inform spatial and gear-specific fishery management strategies related to minimization of adverse fishery impacts to essential fish habitats. While the primary percent disturbance outputs from Fishing Effects rely on realized distributions of fishing effort between 1996 and 2017, the intrinsic habitat vulnerability products apply a constant level of fishing disturbance across all grid cells of the model, at each monthly timestep. This type of product is of value to managers because fishing effort is influenced by numerous factors which are subject to change, including spatial closures that prohibit certain types of gear in specific locations. The intrinsic vulnerability products allow the Council to predict which areas would be vulnerable to impact, even in the absence of existing fishing pressure.

3 SOURCES AND AUTHORITIES

The data inputs of the Fishing Effects model include a benthic sediment/energy map and fishing effort as swept area. Metadata for the sediment map are described in a separate document. Energy classification is based on depth or benthic boundary shear stress data (see NEFMC 2011 for methods). Fishing effort data were obtained from the Northeast Fishery Science Center, either from Vessel Trip Reports or Clam Logbooks (see summary below). Model parameters defining how fishing effort data are modified initially upon entering the model at a given time step, and how fishing effort decays over time, are described in NEFMC 2011, NEFMC 2019, and Smeltz et al 2019.

4 COLLABORATORS

The Fishing Effects Model was developed collaboratively by the New England Fishery Management Council's Habitat Plan Development Team and the Fisheries, Aquatic Science, and Technology Laboratory at Alaska Pacific University. Team members included:

- Michelle Bachman, NEFMC staff
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- Felipe Restrepo, Alaska Pacific University
- T. Scott Smeltz, Alaska Pacific University
- David Stevenson, NMFS Greater Atlantic Regional Fisheries Office
- Page Valentine, U.S. Geological Survey
- Alison Verkade, NMFS Greater Atlantic Regional Fisheries Office

5 DATABASE DESIGN AND CONTENT

- Feature Class Name: HabVuln_BottomTrawl_95, HabVuln_Gillnet_95, HabVuln_Hydrualic_95, HabVuln_Longline_95, HabVuln_Scallop_95, HabVuln_Trap_95, HabVuln_BottomTrawl_Median, HabVuln_Gillnet_Median, HabVuln_Hydrualic_Median, HabVuln_Longline_Median, HabVuln_Scallop_Median, HabVuln_Trap_Median,
- Total Number of Unique Features: 10,871
- Dataset Status: Complete
- Native storage format: ArcGIS feature class
- Feature Type: Polygon

Table 1. Data dictionary

Line	Name	Definition	Type	Size[1]
1	FID	Uniquely identifies a feature	OBJECTID	*
2	Shape	Geometric representation of the feature	geometry	*
3	SP_ID	Sequential unique identifier	String	5
4	GridID	Unique GridID field used to link across model datasets	Long	9
5	Jan1996	Proportion of cell disturbed by all gears or an individual gear type at the end of January 1996	Double	23, 15
6	Feb1996	Proportion of cell disturbed by all gears or an individual gear type at the end of February 1996	Double	23, 15
Analogous format for months between Feb 1996-Dec 2017				
256	Dec2017	Proportion of cell disturbed by all gears or an individual gear type at the end of December 2017	Double	23, 15

[1] Size for type double fields refers to precision and scale

6 SPATIAL REPRESENTATION

- Geometry Type: vector polygon
- Projection
  - Reference System: GCS_North_American_1983
  - Horizontal Datum: North American Datum 1983
  - Ellipsoid: Geodetic Reference System 1980
- Geographic extent: -82.87 to -63.95, 22.14 to 47.13
- ISO 19115 Topic Category: environment, oceans, geoscientificInformation
- Place Names: Cape Cod Bay, Georges Bank, Gulf of Maine, Maine Inner Continental Shelf, Massachusetts Bay, New Jersey Continental Shelf, New York Bight, North Atlantic Ocean, Southern New England Shelf
- Recommended Cartographic Properties:
  - (Using ArcGIS ArcMap nomenclature)
  - We will need to figure out what the best symbology is and summarize it here.
- Scale range for optimal visualization:1,000,000 to 13,000,000

7 METHODS AND DATA PROCESSING

The Fishing Effects model disaggregates fishing effort by gear type and classifies habitat into six types based on five substrate types (mud, sand, granule-pebble, cobble, boulder), plus steep and deep habitats that are expected to contain deep-sea corals and other associated species. Geological and biological features are inferred to each of these habitat types (see NEFMC 2011, 2019 for details). With respect to a feature-gear-substrate-energy combination, 'vulnerability' represents the extent to which

Commented [1]: Emily - For later

Commented [2]: The two analyses (median vs. 95th percentile) have such different distributions of percent disturbance results that we will need two sets of bins for the data per gear type.

Commented [3]: I sort of eyeballed this based at the scales at which I would use the data.

the effects of fishing gear on a feature are adverse. 'Vulnerability' is defined as the combination of how susceptible the feature is to a gear effect and how quickly it can recover following the fishing impact.

Specifically, susceptibility is defined as the percentage of total habitat features encountered by fishing gear during a hypothetical single pass fishing event that have their functional value reduced, and recovery is defined as the time in years that would be required for the functional value of that unit of habitat to be restored. However, because functional value is difficult to assess directly, and will vary for each managed species using the feature for shelter, feature removal or damage was used as a proxy for reduction in functional value. In order to make the susceptibility and recovery information work as a set of model parameters, the susceptibility and recovery of each feature-gear-substrate-energy combination were scored on a 0-4 scale as summarized in Table 6. Quantitative susceptibility percentages in the table indicate the proportion of features in the path of the gear likely to be modified to the point that they no longer provide the same functional value. Recovery does not necessarily mean a restoration of the exact same features, but that after recovery the habitat would have the same functional value.

Table 2. Susceptibility and recovery values. The score of 4 is only used in specific steep and deep/deep-sea coral areas.

Code	Quantitative definition of susceptibility	Quantitative definition of recovery
0	0–10%	< 1 year
1	>10%-25%	1-2 years
2	25-50%	2 – 5 years
3	>50%	> 5 years
4	n/a	10-50 years

Susceptibility and recovery were scored based on information found in the scientific literature, to the extent possible, combined with professional judgment where research results are lacking or inconsistent. The approach is detailed in NEFMC 2011, including "rules" for matrix evaluation. Each matrix listed in Table 3 includes the features present in that particular substrate and energy environment, gear effects related to that gear type and feature combination, susceptibility and recovery for each feature, and the literature deemed relevant to assigning susceptibility "S" and recovery "R" for a particular feature and gear combination. A complete set of S-R matrices by gear type (otter trawl, scallop dredge, hydraulic dredge, longline, gillnet, and trap) can be found in NEFMC 2019. These were updated slightly from the versions used in the original SASI model (NEFMC 2011).

Table 3. Matrices evaluated. Each substrate-type matrix included both energy environments and all associated features.

Gear type	Mud	Sand	Granule-pebble	Cobble	Boulder	Deep-sea coral
All trawl gears	X	X	x	X	X	X (New)
Scallop dredge	X	X	X	X	X	
Hydraulic dredge	-	X	X	X (New)	X (New)	
Longline	X	X	X	X	X	X (New)
Gillnet	X	X	X	X	X	X (New)
Trap	X	X	X	X	X	X (New)

In order to quantify fishing effort in like terms and compare the relative effects of different fishing gears, fishing effort inputs to the Fishing Effects model (e.g. number of trips, tows, sets) are converted to area swept in km^2, regardless of gear type. Simple quantitative models convert fishing effort data to area swept. These models provide an estimate of contact-adjusted area swept, measured in km^2 and are unchanged from the original SASI model. They are documented in NEFMC 2011 and NEFMC 2019 Appendix A. Regardless of gear type, the area swept models have three requirements:

- Total distance towed, or, in the case of fixed gears, total length of the gear;
- Width of the individual gear components; and
- Contact indices for the various gear components.

Fishing activity in the northeast region is documented using various methods, including vessel trip reports (often referred to as logbooks), satellite-based vessel monitoring systems, and at-sea observations by scientific personnel. The trip footprints used for Fishing Effects rely on positions (roughly one per trip) in vessel trip reports, or for clam trips, clam logbooks, with the estimated spread of fishing activity from that point estimated using other spatial data on fishing activity, including at-sea observer and vessel monitoring system. These trip-level footprints were developed using modeling approach that is routinely used for various fisheries management applications in the northeast region (DePiper 2014, Benjamin et al. 2018). Once tables of area swept values from individual trips were generated, they were joined with spatial data products that estimate the footprint of each trip, and area swept was distributed over this footprint.

Spatial datasets in raster format were prepared by overlaying the swept area footprints for a specific gear type and month, based on the date sailed of each trip. Finally, these monthly gear-specific rasters were joined to the 5x5 grid in order to serve as inputs to the Fishing Effects model.

In order to select the level of disturbance to apply as the default, real fishing effort data were examined to understand typical swept area values associated with each gear type. Two model runs were completed for each gear type, one based on the median value of swept area ratio and one based on the 95% quantile. The swept area ratios for each gear, as well as the resulting mean and standard deviation habitat disturbance values, are shown below. Values are only estimated for full grid cells (25 km^2). Putting the same amount of swept area into smaller partial/edge grids inflates the disturbance estimates for these grids.

Table 4. Intrinsic habitat vulnerability analysis effort inputs and summary statistics

Gear type	Effort calculation	Swept Area Ratio (year^{-1} grid^{-1})	Mean habitat disturbance	Standard deviation habitat disturbance
Bottom Trawls	Median	0.17	26%	13%
	95% quantile	4.7	88%	2.4%
Scallop dredge	Median	0.015	4.5%	9.9%
	95% quantile	1.06	68%	7.6%
Hydraulic dredge	Median	0.0022	1.2%	6.1%
	95% quantile	0.090	18%	13%
Traps	Median	3.0e-4	0.2%	2.8%
	95% quantile	0.047	6.5%	11%
Longlines	Median	2.8e-4	0.2%	2.7%
	95% quantile	0.021	3.5%	8.9%
Gillnets	Median	7.7e-5	0.1%	2.8%
	95% quantile	0.0051	1.3%	6.4%

8 QUALITY PROCESS

- Attribute Accuracy: Attribute values are derived from authoritative metadata sources.
- Logical Consistency: These data are believed to be logically consistent.
- Completeness: The completeness of the data reflects the feature content of the data sources, and their associated metadata.
- Positional Accuracy: Positional accuracy may vary according to positioning methodology in the underlying data sources. Note that Vessel Trip Reports often represent each fishing trip by a single latitude/longitude. Results are aggregated by Fishing Effects Model grid cell, with each cell having a resolution of 5 kilometers.
- Timeliness: Based on sediment samples collected between 1934 and 2018 and fishing activity occurring between 1996 and 2017.
- Use restrictions: Data are presented as is. Users are responsible for understanding the metadata prior to use. The New England Fishery Management Council shall be acknowledged as data contributors to any reports or other products derived from these data.
- Distribution Liability: All parties receiving these data must be informed of all caveats and limitations.

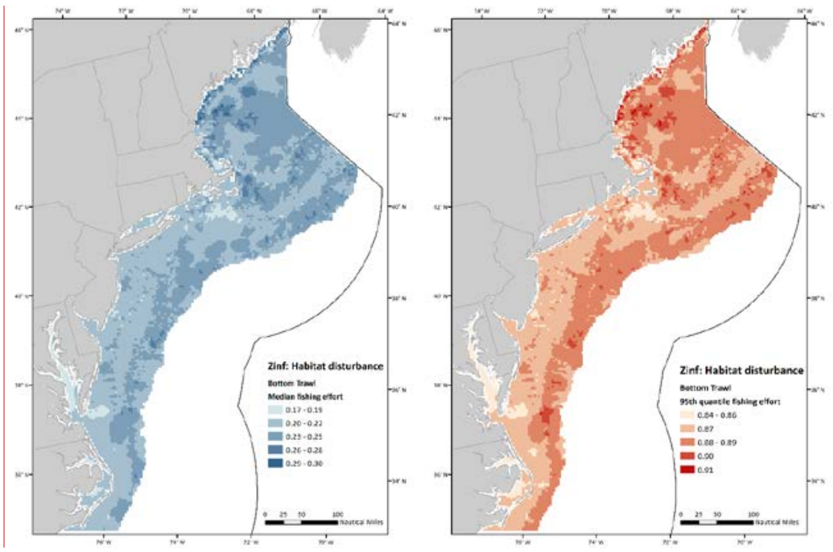
9 CAVEATS AND DISCUSSION

Need to develop.

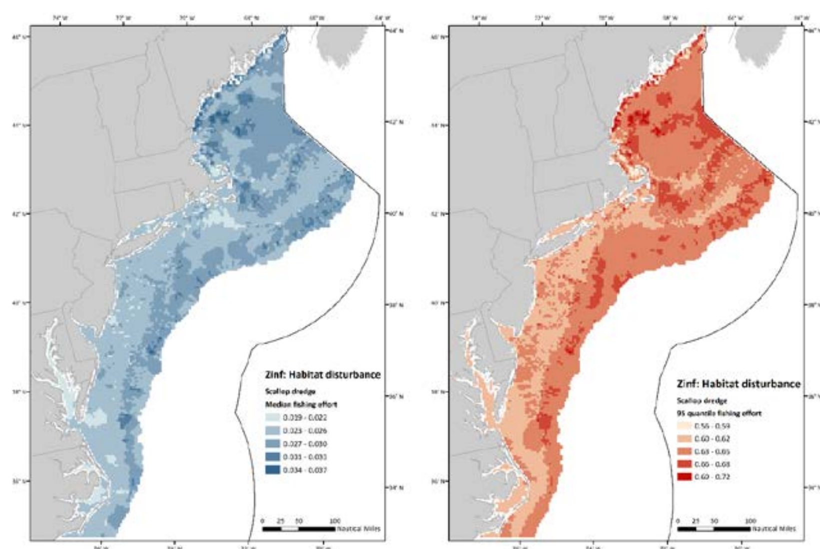
10 FIGURES

I think it makes sense to include a figure at “equilibrium” for each gear and the 95% and median values.

Map 16. Z_{∞} habitat disturbance for bottom trawls.



Map 17. Z_{∞} habitat disturbance for Scallop dredges.



Commented [4]: I don't have in my notes whether or not we decided to include animations for these. If not, which month/year (or mean?) should we be representing?

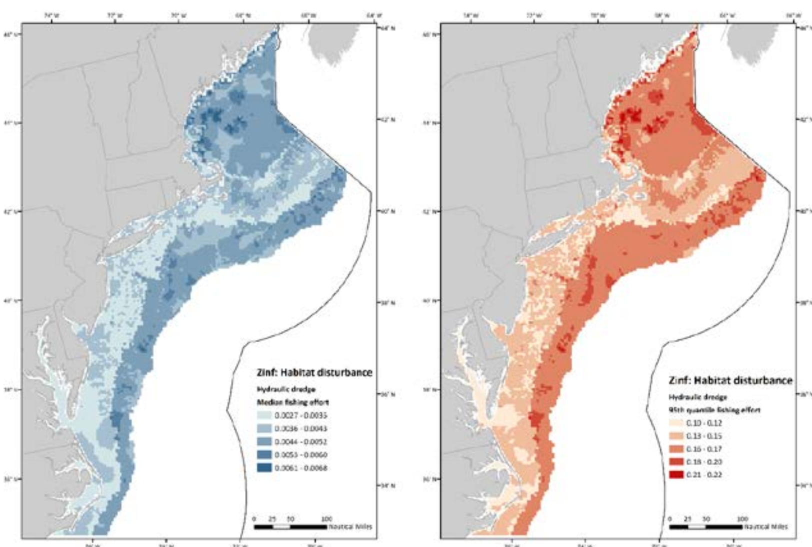
Commented [5]: _Marked as resolved_

Commented [6]: _Re-opened_

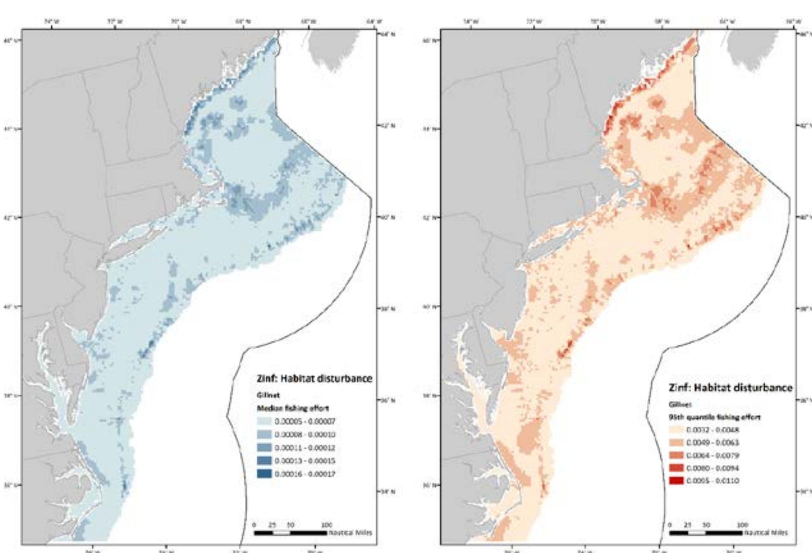
Commented [7]: I think we want to use the terminal year of the time series to display, since after a time the model comes to equilibrium.

Commented [8]: (last month of the terminal year)

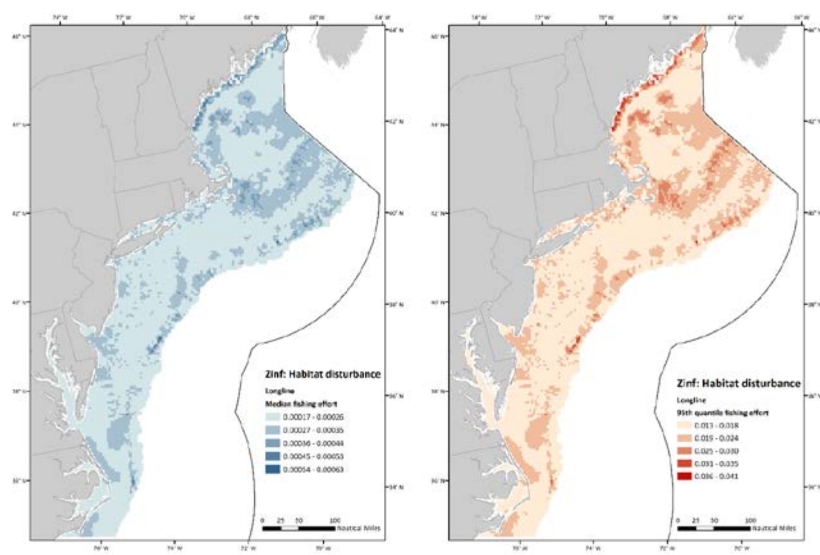
Map 18. Z_{∞} habitat disturbance for hydraulic dredges.



Map 19. Z_{∞} habitat disturbance for gillnets.



Map 20. Z_{∞} habitat disturbance for longlines.



Map 21. Z ∞ habitat disturbance for traps.