A brief summary of the Swept Area Seabed Impact (SASI) Model: a tool to estimate the impacts of fishing on Essential Fish Habitat

The Swept Area Seabed Impact (SASI) model combines fishing effort data and estimates of habitat vulnerability in a spatial context. In particular, the model has two components, a method to convert all fishing effort data into contact-adjusted swept area, and an assessment of the vulnerability of habitats to gears, that are combined on a substrate- and energy-based spatial grid.

Upon completion, the model will be used to develop and analyze management alternatives intended to minimize the effects of fishing on essential fish habitat to the extent practicable. The model can be updated and improved as new sources of fishing effort or habitat data become available, or as underlying assumptions are refined based on emerging research. Looking beyond the Omnibus EFH Amendment, the SASI model is intended for long-term use in evaluating the impacts of future management actions on fish habitats.

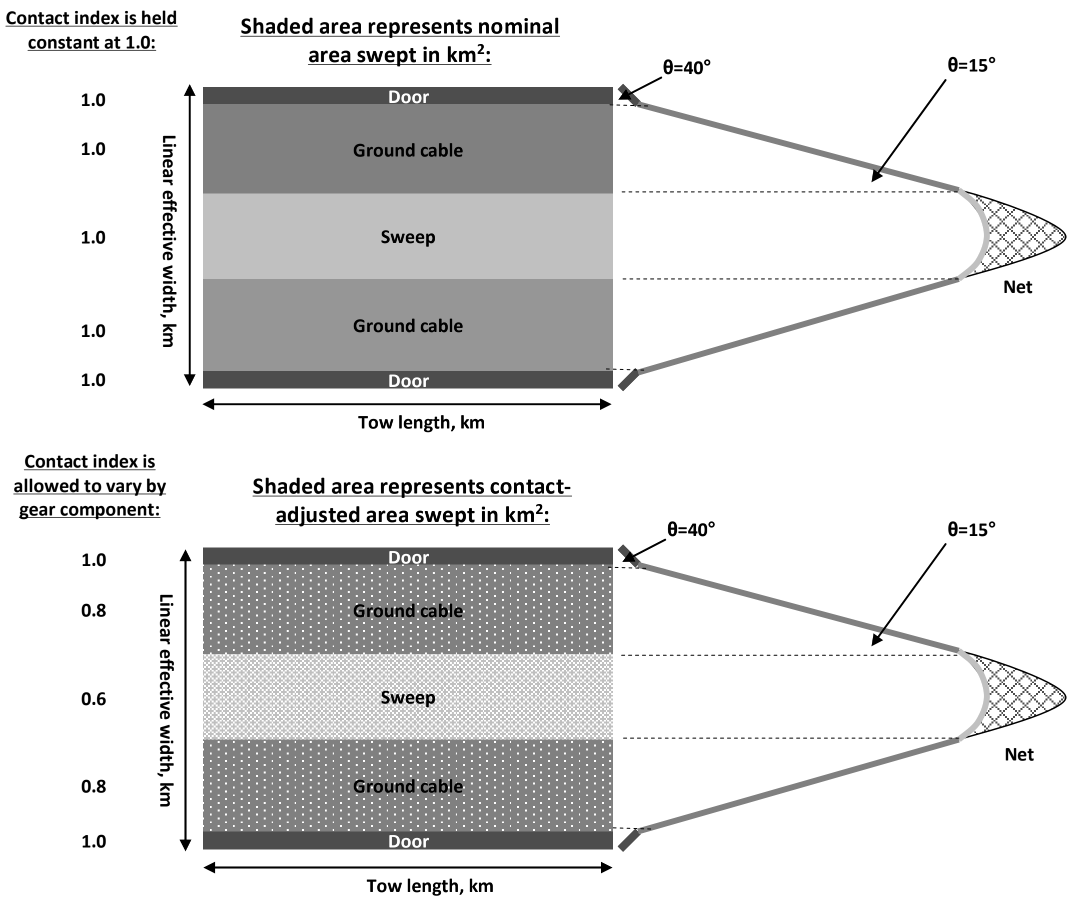
Fishing effort estimation

In order to compare habitat impacts resulting from various types of fishing gears, all fishing effort in the SASI model is represented using a common area swept currency. The first step was to classify effort into nine major bottom-tending gear types: generic/groundfish trawls, shrimp trawls, squid trawls, raised footrope trawls, New Bedford-style scallop dredges, surf clam and ocean quahog hydraulic dredges, lobster and deep-sea red crab traps, bottom gill nets, and bottom longlines. These gear types are commonly used in areas designated as EFH for NEFMC-managed species to target species managed by the NEFMC and/or MAFMC.

Effort data used for the area swept calculations comes from fishery-dependent sources including observer, vessel trip report, and vessel monitoring system. Data elements include the width of the gear components, the length of each tow, and the number of tows per trip, and the number of trips. Data are temporally and spatially specific at various levels of resolution depending on the source.

By gear type, assumptions were made regarding the angle of attack of each gear component in order to calculate a linear effective width for each gear component individually and then for the gear as a whole. This linear effective width is then multiplied by the length of the tow to generate nominal area swept. A priori assumptions about the contact of each gear component with the seabed are used to convert nominal area swept to contact-adjusted area swept. These contact indices are expressed as proportions, ranging from zero to one, such that contact adjusted area swept is always less than or equal to nominal area swept. A schematic of this calculation for trawl gears is shown in Figure 1. Although the area swept for each tow is calculated separately, resulting contact adjusted area swept values in km^2 may be summed by trip, year, gear type, etc.

Figure 1 – Area swept schematic (top down view). The upper portion shows nominal area swept, and the lower portion shows contact adjusted area swept.



Vulnerability Assessment

The purpose of the vulnerability assessment is to estimate the magnitude of the impacts that result from the physical interaction of fish habitats and fishing gears. It is important to recognize that the vulnerability assessment only considers (a) adverse (vs. positive) effects and (b) habitat associated with the seabed (vs. the seabed and the water column).

For ease in evaluating impacts, fish habitat was divided into components, which were further subdivided into features. In particular, the vulnerability assessment identifies two structural components, geological and biological, and a prey component. Structural features identified include bedforms, biogenic burrows, sponges, macroalgae, etc. These may either provide shelter for managed species directly, or provide shelter for their prey. Prey features are broad taxonomic groupings such as decapod shrimp, polychaetes, etc., that are routinely consumed by managed species.

The vulnerability assessment uses a series of matrices to organize and present qualitative estimates of susceptibility and recovery for each feature by fishing gear type. While all components (geological, biological, and prey) are assumed to occur in every habitat type, the presence or absence of particular features is assumed to vary based on substrate type and natural disturbance (energy) regime. Thus, habitat types in the vulnerability assessment are distinguished by dominant substrate, level of natural disturbance, and the presence or absence of various structural and prey features. As an example, the otter trawl/mud matrix with its component features is shown in Figure 2.

Figure 2 – Sample matrix for generic trawl gears in mud substrates.

Gear type (Generic trawl)								
Substrate (Mud)								
Feature type	*Feature*	*Gear effects*	*Studies documenting gear-substrate-feature interaction (high energy)*	*Studies documenting gear-substrate-feature interaction (low energy)*	*S*	*R- high*	*R-low*	*Notes*
Geological	Featureless	resuspension, compression, geochem			*(0-3)*	*(0-3)*	*(0-3)*	
Geological	Biogenic depressions	filling			*(0-3)*	*(0-3)*	*(0-3)*	
Geological	Biogenic burrows	filling, crushing			*(0-3)*	*(0-3)*	*(0-3)*	
Geological	Bedforms	smoothing		n/a	*(0-3)*	*(0-3)*	n/a	
Geological	Shell debris	burying, crushing, displacing			*(0-3)*	*(0-3)*	*(0-3)*	
Biological	Hydroids	breaking, crushing, dislodging, displacing			*(0-3)*	*(0-3)*	*(0-3)*	
Biological	Anemones, burrowing	breaking, crushing, dislodging, displacing			*(0-3)*	*(0-3)*	*(0-3)*	
Biological	Sea pens	breaking, crushing, dislodging, displacing			*(0-3)*	*(0-3)*	*(0-3)*	
Biological	Epifaunal bivalves	breaking, crushing, dislodging, displacing			*(0-3)*	*(0-3)*	*(0-3)*	
Prey	Amphipods	breaking, crushing, dislodging, displacing			*(0-3)*	*(0-3)*	*(0-3)*	
Prey	Decapod shrimp	breaking, crushing, dislodging, displacing			*(0-3)*	*(0-3)*	*(0-3)*	
Prey	Decapod crabs	breaking, crushing, dislodging, displacing			*(0-3)*	*(0-3)*	*(0-3)*	
Prey	Polychaetes	breaking, crushing, dislodging, displacing			*(0-3)*	*(0-3)*	*(0-3)*	
Prey	Infaunal bivalve mollusks	breaking, crushing, dislodging, displacing			*(0-3)*	*(0-3)*	*(0-3)*	
Prey	Echinoderms	breaking, crushing, dislodging, displacing			*(0-3)*	*(0-3)*	*(0-3)*	

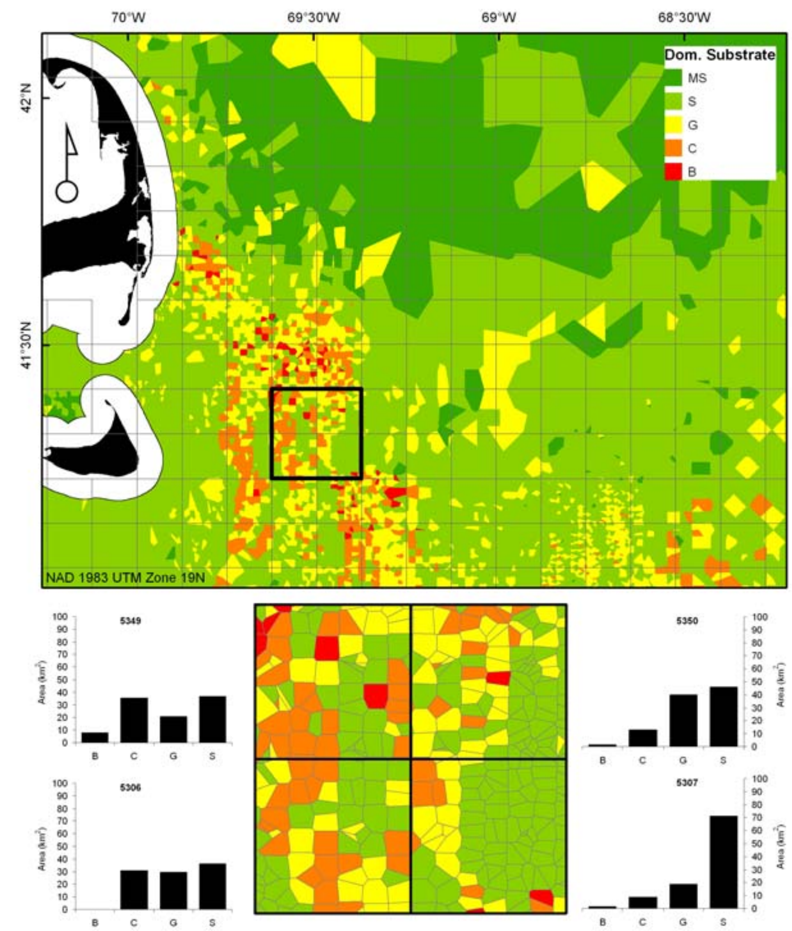
Susceptibility is a measure of the percentage by which a feature is reduced in functional value due to the impact of a particular fishing gear, and recovery is a measure of the amount of time it would take for the functional value of the diminished habitat feature to be restored following the cessation of impact. Recovery is evaluated separately for high and low energy environments. Both susceptibility and recovery are scored from 0-3. Values are assigned using knowledge of the fishing gears and habitat features combined with results from the scientific literature on gear impacts. To facilitate use of the literature in matrix evaluations, research relevant to regional habitats and fishing gears was summarized in a database, which can be updated as new results are published.

Once all the matrices are evaluated, an overall vulnerability score for each structural habitat component (geological and biological) will be estimated from the feature level susceptibility and recovery scores in each matrix. This vulnerability information is carried forward with the area swept estimates into the spatial model.

Model grid

To be useful for spatially explicit management strategies, SASI outputs must be spatially referenced. A substrate-based model grid was developed to provide a surface on which to overlay vulnerability and area swept estimates. Two sources of substrate data, usSEABED and SMAST video survey, were used to generate the grid. Across both data sets, substrates were classed based on particle size (using the Wentworth scale) into mud, sand, granule/pebble, cobble, and boulder.

Figure 3 – A portion of the model grid. MS=mud/silt, S=sand, G=granule/pebble, C=cobble, B=boulder.



An unstructured grid was generated from the raw substrate data using a Voronoi tessellation procedure (see the colored grid cells in Figure 3). Depending on the arrangement of samples in space, the grid cells vary in shape and may be larger or smaller, as shown. As new substrate data becomes available, it can be added to the model and the grid can be updated. Each of these grid cells was classified as having a high or low natural disturbance (energy) regime using critical shear stress and depth-based criteria. Habitat vulnerability estimates are then assigned to each cell based on these substrate and energy attributes.

Next, a 10 km^2 grid was overlaid on the unstructured grid, and the substrate composition of each 10 km^2 grid cell was calculated based on the attributes of the typically smaller unstructured cells as shown in the lower panel of Figure 3. This allows for estimates of substrate heterogeneity within each 10km^2 grid cell. (Such heterogeneity may have implications for habitat recovery rates.) Area swept effort estimates are assigned to the 10km^2 cells.

A mathematical representation of SASI

Swept area seabed impact can be represented using the following simple equation, where A represents the area swept and Ω represents vulnerability:

$$SASI = A * \Omega$$

A may be further specified as follows:

$$A = \sum \left(\sum (w * c)_j * d \right)_{k,i,s,e}$$

Here, *w* is the linear effective width and *c* is the contact index for the *jth* gear component of gear type *i*. The variable *d* is the distance the *kth* tow of gear type *i* travels in one tow over substrate *s* and energy environment *e.*

Ω may be further specified as follows:

$$\Omega = \left(\omega_{h_1} + \omega_{h_2} \right)$$

Here, ω is a function of a susceptibility vector, S, and a recovery vector, R, such that $\omega = f\,(S, R)_{i,s,e}$ for gear type *i*, substrate *s* and energy environment *e*, and *h* is a habitat component (geological or biological).

Combining these two functions, SASI becomes:

$$SASI = \sum_{\substack{s=1 \\ e=1}}^{\substack{5 \\ 2}} \left[\left[\sum_{\substack{i=1 \\ k=1}}^{\substack{\infty \\ 9}} \left(\sum_{j=1}^{\infty} (w * c)_j * d \right)_{k,i} \right] * \left[\left(\omega_{h_1} + \omega_{h_2} \right) \right] \right]_{s,e}$$

Alternatively, SASI can be shown as a flowchart (Figure 4).

Figure 4 – SASI model flowchart