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MEMORANDUM

DATE: January 21, 2011
TO: SASI Peer Review Panel
FROM: NEFMC Executive Committee
SUBJECT: Terms of reference for SASI peer review

What is the SASI model?

The Swept Area Seabed Impact (SASI) model is a geo-referenced analytical tool that estimates the adverse effects (*Z*) of fishing on seabed structures by combining fishing effort data, seabed substrate and energy data, and gear-specific habitat vulnerability parameters. The model domain extends from 3 nm offshore to the edge of the EEZ from the Maine/Canada border to the North Carolina/South Carolina border, and includes the Gulf of Maine, Georges Bank, the Mid-Atlantic Bight, and the associated slope regions. The SASI model was developed by the New England Fishery Management Council (NEFMC) Habitat Plan Development Team (PDT) between fall 2007 and spring 2010.

The gear-specific vulnerability parameters are decomposed into susceptibility, which refers to the percentage of a particular structural habitat feature removed or damaged by a single pass of the gear, and recovery, which refers to the number of years required for the feature to return to its pre-impact state. Different suites of structural seabed features (e.g. sponges, biogenic burrows, bedforms, etc.) were inferred to each of the ten possible combinations of substrate (mud, sand, granule-pebble, cobble or boulder) and energy (high or low). Vulnerability evaluations were evaluated for each gear type individually based on a combination of literature review and professional judgment. Fishing effort estimates were individually calculated for each of ten bottom tending gear types, including four types of trawls, three types of dredges, and three types of fixed gears.

Fishing effort data and SASI model outputs are provided at a 100 km^2 grid resolution, while seabed substrate and energy data are incorporated at higher or lower resolutions than this, as dictated by the distribution of raw data points. Both fishing effort inputs and model outputs are given in km^2 units. Model runs were completed for hypothetical, even distributions of fishing effort (simulated runs, output referred to as Z_∞); realized, historical distributions of fishing effort (realized runs, output referred to as $Z_{realized}$); and to obtain spatially-specific practicability/opportunity cost estimates (practicability runs, outputs referred to as Z_{net} and e). Because the recovery parameters are modeled using a decay function, Z_∞ and $Z_{realized}$ estimates for given year include residual adverse effects from past years, and current year adverse effects. However, because the practicability runs incorporate both the adverse effect estimates (Z_{net}) and profits, and profits are realized immediately following a fishing event, the Z_{net} values are instantaneous. Specifically, Z_{net} can be thought of as an instantaneous version of $Z_{realized}$.

Clustering of Z_∞ outputs was examined using spatial statistics (specifically, Local Indicators of Spatial Association, LISA) in order to draw the Council's attention to locations estimated to contain highly vulnerable structural habitats, thus providing a starting point for spatially-specific habitat management.

Why was SASI developed?

The Magnuson Stevens Fishery Conservation and Management Act (MSA) has included provisions requiring fishery management plans (FMPs) to minimize the adverse effects of fishing on Essential Fish Habitat (EFH) since the 1996 reauthorization.

The Council initiated EFH Omnibus Amendment 2 in 2005 with two main goals, the first of which was to review and update EFH designations for all managed species. EFH is defined as 'those waters and substrates necessary for spawning, breeding, feeding, and growth to maturity'. EFH is designated on a species-by-species basis, and may be specific to the egg, larval, juvenile, and adult lifestages, as appropriate. The designations include a spatial component and a descriptive component. **Because we do not have adequate information on how specific types of habitats or specific habitat locations contribute to the productivity of managed stocks, the EFH descriptions are by necessity fairly general.** In most cases, the spatial distribution of EFH is based largely on the spatial distribution of the species/lifestage to which the designation applies. As might be expected, there is a high degree of overlap in the EFH designations of the various species managed by the Council.

The second major goal of EFH Omnibus Amendment 2 was **to optimize the minimization of adverse effects across FMPs.** This requires both a method for estimating adverse effects, and a strategy for minimizing those effects. **Previous to SASI, EFH evaluations conducted for NEFMC FMP actions were ad-hoc, and could not be compared across plans in a straightforward manner. One important way in which the SASI model improves upon previous adverse effect analyses is that it allows for a comparison of the magnitude of adverse effects across different fishing gear types and FMPs.** This comparison can be made because all fishing effort is converted into area swept units, regardless of whether trawl, dredge, or fixed gears are being evaluated. In addition, a single range of susceptibility and recovery values were selected from to parameterize the model, no matter which gear type was being evaluated, so the magnitude of Z_∞ estimates can be compared across gears.

It is worth emphasizing some key assumptions and limitations of the SASI approach. Because of the spatial overlaps in EFH designations, and due to the general nature of the EFH designations, EFH was considered holistically by the PDT for the purpose of estimating adverse effects. In addition, although the EFH designations include information such as preferred water temperature, and the entire water column may be designated EFH depending on the species and lifestage, the SASI adverse effects evaluation focuses on the seabed, in particular on various structural features of interest. This is because seabed structures were assumed to be the most heavily impacted by fishing operations. Obviously, non-fishing stressors on habitat might have significant effects on water quality, especially in near-shore environments, but because the Council has a direct ability to control fishing operations, and a mandate to minimize the impacts of fishing operations on habitat, SASI focuses on fishing impacts on seabed structures.

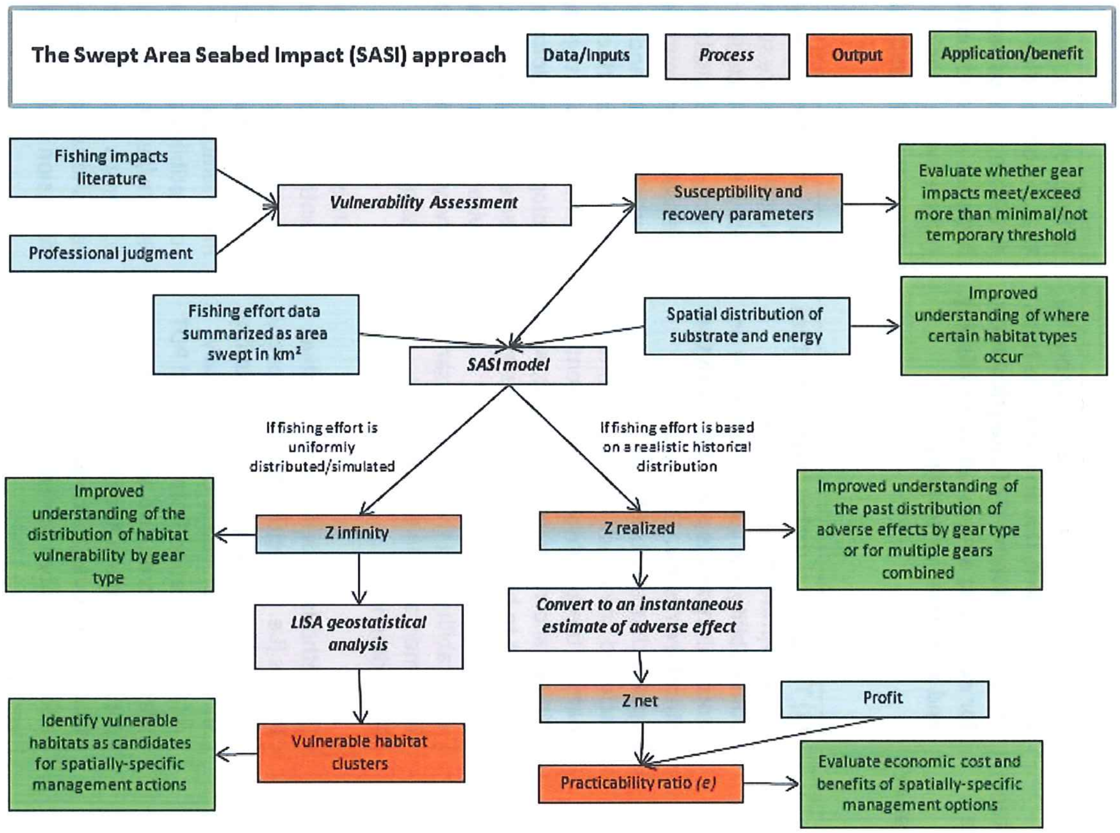
How is SASI being used?

For the Omnibus EFH Amendment, SASI is being used both to develop alternatives, and to analyze alternatives. The flowchart below diagrams the data inputs, processes, outputs, and applications/benefits associated with the SASI approach. Note that some outputs are inputs to other processes.

Some SASI outputs fulfill the basic EFH requirements of the MSA, i.e. to make a determination as to whether the effects of fishing on habitat are adverse (susceptibility and recovery parameters), and to describe the magnitude of those effects and the need for further action ($Z_{realized}$ outputs). Others (Z_∞ outputs, vulnerable habitat clusters, Z_{net} and *e* (practicability ratio)) are used to guide the Council as it develops appropriate alternative to minimize adverse effects.

Once suites of measures to minimize adverse effects are packaged into discrete alternatives (this is projected to happen during the first few months of 2011), the model will be used to generate projections of $Z_{realized}$ across all gear types that can be used to compare between the various alternatives and the status quo in terms of their habitat benefits/impacts. In the future, it is anticipated that SASI will be used in a similar way to evaluate the habitat impacts of management measures and fishery specifications in various FMP amendments.

Figure 1 – The SASI approach.



<u>**What were previous terms of reference and reviewer comments on the SASI approach?**</u>

The SASI approach has been reviewed three times by the Council's Scientific and Statistical Committee (SSC). The first review in March 2009 was conducted when the basic features of the approach were in place but when the details of these features and how they fit together were not yet finalized. The second review in December 2009 was conducted after the model inputs and structure were largely finalized, but few results were available. The third review in August 2010 was conducted after all model inputs were finalized and results were available. In addition, the August review was conducted after the geostatistical/spatial analyses and practicability analyses were developed. Concurrent with the August review, the results of those analyses were available to the Habitat Committee and in the process of being applied to development of management options. Currently, the Council's Habitat Committee has approved a series of management options for analysis, based in part of the LISA cluster outputs and in part on recommendations from the PDT and Habitat Advisory Panel. As appropriate, these options will be packaged into management alternatives, and the cumulative and interaction effects of the various options as combined will be evaluated by the PDT as described above. The table that follows summarizes the TORs from previous reviews, SSC feedback on those TORs, and PDT adjustments to the approach and responses to the feedback. Note that in some cases terminology differs from the original TOR memos and SSC response memos in order to be consistent with currently used terminology.

Table 1 – Previous terms of reference for SASI reviews, including SSC and PDT feedback.

Review date	SASI component	TOR	SSC feedback	PDT response/follow-up
March 2009	Vulnerability Assessment – literature review	Is the literature review comprehensive and well developed? Does the literature review provide an adequate basis for the Vulnerability Assessment? Does the literature review adequately capture sources of uncertainty?	**While the literature review may not be comprehensive, it is an adequate basis for the development of analytical tools for evaluating adverse effects of fishing and associated uncertainty.**	In addition to the fishing impacts studies that were formally reviewed and coded in a database, various works related to the life histories and distributions of biological features were considered during estimation of susceptibility and recovery parameters.
March 2009	Vulnerability Assessment – matrix-based estimation of susceptibility and recovery parameters	Is the matrix-based structure appropriate to its intended use? Are the results consistent with the published literature? In cases where results are extrapolated are these cases treated appropriately? Are sources of uncertainty in the assessment adequately carried forward from the literature review?	**(1) The general matrix-based structure is appropriate for evaluating vulnerability, includes information on uncertainty and is consistent with the literature review.** However, the approach presented to the SSC only included one major aspect of habitat, namely the geophysical component. The biological components of habitat, which have yet to be addressed, are essential elements for the evaluation of vulnerability, and they are necessary for implementation in the Omnibus Amendment. (2) Methods for deriving quantitative indices (i.e. susceptibility and recovery values) from subjective determinations should be explored to more formally retain information from individual PDT members' scores, and analyzed in a statistically sound and repeatable way that includes variability among scores and uncertainty in derived decision variables.	(1) At the time of the March review, only geological feature susceptibility and recovery was included in the model. Later, structural biological features were added to the assessment matrices, and their susceptibility to and recovery from particular gear effects were evaluated based on the results of the literature review. Geological and biological features were inferred to particular substrate and energy environments based largely on literature survey, informed by empirical data when possible. (2) More formal methods for deriving quantitative indices were explored but ultimately a consensus-based approach was selected by the PDT. Small groups of 3-4 PDT members per gear type evaluated susceptibility and recovery for each feature/gear combination, decided on a consensus value, and then brought these values forward to the entire team for discussion and approval. (3) Sensitivity analyses were conducted to

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			(3) Some of the categories in the matrix-based approach are arbitrary or subjective, and results may not be repeatable by a similar group of experts. Sensitivity analyses would be an informative approach to evaluating uncertainty in results. (4) The proposed matrix approach considers susceptibility and recovery of different habitats, but not their relative values for fishery resource production or ecosystem services. Future developments should consider habitat value. For example, 'mature' benthic communities (i.e., the climax stage of ecological succession for each physical habitat type) should be considered a high-value habitat.	evaluate the terminal recovery year assumption, the effect on outputs if susceptibility and recovery scores were biased away from the lowest and highest values, and the relative contribution of geological and biological feature scores to total adverse effect. (4) The PDT acknowledges that a model based on fishery production would be useful, but notes that there is inadequate information about the influence of habitat features on productivity to develop such a model at this time.
March 2009	Fishing effort data	Is the area swept model structure appropriate for its intended use? Are the data inputs characterized appropriately?	(1) The analytical approach of swept area of fishing effort is appropriate for evaluating seabed impact, but some modifications to the characterization of fishing effort should be considered to refine the method. (2) The calculation of swept area assumes additivity of fishing effort. For the same gear type, there is no consideration of the relative impact of multiple passes. Similarly, interactive effects of different gear types on the same bottom are not considered.	(1) Models for fixed gears were updated after the March review, and contact indices were refined with input from the Habitat Committee and Advisory Panel. Information about buoyancy and hydrodynamic lift, as well as information about footrope types, was considered when assigning both susceptibility values and contact indices, but neither were formally incorporated into the area swept models. (2) Vulnerability and effort were both assessed at a tow-by-tow level, and the impact of multiple tows was assumed to be additive. While the PDT recognizes that cumulative impacts may be either greater or

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				less than this additive approach, this fundamental assumption of SASI remains unchanged.
March 2009	SASI Model	Is the Critical Shear Stress Model appropriate for its intended use? Are the substrate data inputs characterized appropriately?	Several methodological refinements are needed to more accurately characterize habitat, including analysis of heterogeneous data and the inference of energy levels from shear stress. However, the general approach to overlaying habitat and fishing effort is appropriate.	In March, the SSC had concerns about combining substrate data from different sources in a single unstructured grid cell when multiple data points fell within the previously specified minimum cell size of 3 km^2. The model grid was updated such that substrate data are represented by the smallest unstructured cells possible, given the spatial distribution of sampling. However, rather than assigning fishing effort to these small, unstructured grid cells, it is assigned to regular, 100 km^2 grid cells. Substrate- and energy-specific S and R parameters are then applied to fishing effort in the 100 km^2 grid cells in proportion to the area of the unstructured grid cells that fall within each 100 km^2 cell. Also, a deeper 60 m depth threshold was selected to distinguish between high and low energy environments, and trawl survey hangs were eliminated from the data set as a proxy for boulder habitat. Finally, additional substrate data were added to the Gulf of Maine region of the model.
March 2009	SASI Model	Do the model results make sense in the context of fishery management decision making? Are the uncertainties previously noted adequately addressed?	The proposed method for evaluation of impact of fishing on habitat has the potential to provide sensitivity-adjusted fishing areas for specific management alternatives. However, a more formal and transparent method is needed for the derivation of the sensitivity criterion used by the model and its uncertainty as	Previously, susceptibility and recovery scores for each feature were combined into a single sensitivity parameter, which was then used to scale area swept. The approach eventually selected keeps these parameters separate, using the susceptibility value to initially scale fishing effort and the recovery value to determine the number of years over which that effort decays. Both

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			a function of susceptibility and recovery. Higher spatial resolution of fishing effort is also needed.	the percentage reduction and number of years are drawn from a distribution of values consistent with the parameter definitions. The PDT acknowledges that more highly resolved fishing effort data would be useful, but given the size of the model domain, the variety of gear types evaluated, and the number of years considered, vessel trip reports, which are fairly coarse in terms of their spatial resolution, are the only practical data source.
December 2009	General SASI approach	Evaluate the ways in which the Swept Area Seabed Impact (SASI) model can be used as a basis for crafting and analyzing alternatives to minimize to the extent practicable the adverse effects from fishing on Essential Fish Habitat.	(1) **The SSC compliments the PDT on their efforts to provide a tool that uses the best information available to evaluate the effects of fishing on habitat. The SSC concludes that the SASI model is useful for evaluating alternative management options that have substantially different habitat impacts.** However, several model limitations were identified that should be considered in applying the method. (a) Given the low resolution of some input data (e.g., location of fishing effort from logbooks, few substrate samples in some areas), the current SASI model results may not be well-suited to evaluate subtle differences in relative impacts among gear types. Some measure of uncertainty in impact (Z) is needed to evaluate the power of SASI for evaluating differences in habitat impact. Until a measure of uncertainty can be	(a) SASI results indicate large (order of magnitude) differences in realized area swept and adverse effect (Z) by gear type, which should allow the Committee and Council to focus their efforts appropriately on the most adverse gear effects. In addition, the areas identified as having high vulnerability (i.e. high Z_∞ scores) are significant outliers as compared to other locations throughout the model domain, and are in most cases cluster into groups of grid cells. Finally, the PDT has produced maps depicting the relative uncertainty in substrate data inputs and thus in resulting model outputs, in order to guide decision makers about where, spatially-speaking, to use the most caution in applying model results. (b) The PDT acknowledges the validity of the SSC's concerns about additivity of adverse effects, but given the substantial uncertainties inherent in estimating both

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			provided, the SASI is considered only capable of detecting large differences in relative habitat impact. (b) The assumption of additive impact of fishing effort (e.g., accumulating impact of multiple passes of gear or gear deployments) may be more reasonable for some gear types (e.g., fixed gear) than others (e.g., mobile gear). The location of mobile gear effort may overlap within fishing trips, while the location of seabed swept by fixed gears do not overlap within trips. As result of this difference, it is reasonable to assume that mobile gear area swept is not as additive as fixed gear area swept. Therefore, it may be appropriate to compare among mobile gears or among fixed gears, but not between fixed and mobile gears.	fixed and mobile gear area swept, as well as the large differences in the magnitude of the fixed vs. mobile estimates, it will be necessary to interpret all model results with caution.
August 2010	General SASI approach	Evaluate the application(s) of the SASI model for use in developing management alternatives for Phase 2 of Omnibus Habitat Amendment 2.	The PDT's methods are the most appropriate measure of habitat alteration for the information available to support fishery management decisions. The Habitat PDT's analyses may be the most technically advanced attempt to evaluate fishing impacts on habitat, and could be the basis for a broader research and monitoring program. The SSC has reviewed the PDT's methods and results at several stages, and no major technical flaws were identified. However, the process would benefit from a more formal peer review of the methodology.	The PDT agrees that more research is needed, and will include specific research recommendations as a component of the Omnibus EFH Amendment. Also, the PDT agrees that additional peer review is likely to identify ways in which the approach can be improved. The PDT is currently drafting peer-reviewed journal publications covering various aspects of this work.

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August 2010	General SASI approach	Evaluate the appropriateness of the LISA spatial analysis methods for defining clusters of high Z_∞.	The PDT's analyses are useful for identifying areas of habitat that are vulnerable to alteration from fishing and for evaluating area closures. The SASI model identifies locations with habitats that are altered by fishing effort, and the LISA analysis evaluates contiguous areas of these habitats. The analysis could be expanded to evaluate the ecological value and role of different habitats in ecosystem and fishery production, but the SSC agrees that the PDT's current analysis is the most appropriate approach for the data that is available at this time. Although alternative spatial methods could be considered, the PDT's analyses appear to be appropriate for the spatial properties of information that is available. The SSC recognizes that habitat data are limited, and data availability varies geographically. Therefore, the PDT's existing measures of data support should be routine diagnostics for determining the information content of spatial results.	See comments above regarding data support maps. Also, a similar spatial analysis was recently published for the Georges Bank region (see Harris, B. P. and K. D. E. Stokesbury (2010). "The spatial structure of local surficial sediment characteristics on Georges Bank, USA." Continental Shelf Research **30**: 1840-1853.)
August 2010	General SASI approach	Evaluate the appropriateness of the Z_{Net} Stock model for comparing practicability among management alternatives.	The PDT's comparisons of practicability among management alternatives are promising, but can be improved in several areas. The economics of multispecies tradeoffs and utilities are complicated, and anticipating changes in fishing behavior is difficult. Alternative approaches to modeling the effects of closed areas on redistribution of fishing effort for area closure scenarios should be explored. The PDT's methods may	The PDT agrees that fisheries site choice models are complex and that forecasting the redistribution of fishing effort into areas that are currently unfished is challenging. Constructing a fully-developed site choice model for use in this action is not a practical option at this time, and would likely add years to the analysis. The purpose of the practicability work is to provide a coarse assessment of whether or not various habitat management options are reasonable

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			help to inform some specific management decisions but are not adequately developed for general application.	from an economic standpoint. All assumptions and uncertainties inherent in this approach will be fully documented as results are presented to the Committee/Council.

To establish a common understanding from which to consider the TORs below, part of the review meeting will include presentations on the various components of the SASI approach, in particular:

- Literature review, vulnerability assessment, and estimation of susceptibility and recovery parameters
- Characterization of fishing effort, substrate, and energy inputs, and their combination with susceptibility and recovery parameters in the spatial/temporal model framework
- Types of model outputs produced (i.e. Z_{∞}, $Z_{realized}$, Z_{net}) and analyses of those outputs, specifically:
    - Spatial/geostatistical analyses of Z_{∞} outputs
    - Practicability analyses of Z_{net} outputs

Terms of reference:

1. Is the SASI approach a reasonable way to estimate the magnitude and location of adverse effects of fishing on EFH, as required by the MSA? In particular,
    a. Considering the availability of other tools used by Fishery Management Councils, is SASI -- without additional modification -- a valid approach to evaluate the adverse effects of fishing on EFH?
2. Is the SASI approach, including the geostatistical and practicability analyses, a reasonable way to develop and analyze spatially-based management alternatives to minimize the adverse effects of fishing on EFH? In particular:
    a. Have uncertainties in SASI inputs and resulting limitations of SASI been appropriately characterized for the Committee, Council, and members of the public?
    b. Is the spatial scale of the model outputs (i.e. 100 km^2 grid) appropriate for fishery management applications? What ecological processes are missed by estimating adverse effects at a 100 km^2 grid resolution? What implications does this have for development of alternatives?
    c. Are the practicability analyses appropriate to use for eliminating options at the alternatives development stage, or should they be reserved for a later stage when the impacts of various alternatives are being compared?
3. Existing gaps in data and theoretical understanding of habitat-related processes have been identified during model development.
    a. Review and evaluate research priorities that have been identified during the model development process.
    b. Review and evaluate updates to the structure of the model that could be made in the future, given additional data or understanding of habitat-related processes.

Background documents

1. TOR memo (this document)
2. SASI methods document – contains detailed information about vulnerability assessment, SASI model, LISA geostatistical analysis, and Z_{net}/e practicability analysis.
3. SASI results (Z_{∞}, $Z_{realized}$, LISA, and Z_{net}/e map outputs and summary tables)