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Habitat Plan Development Team Meeting Summary

May 28-29, 2009
Woods Hole, MA

The PDT met on Thursday and Friday, May 28-29, 2009 in Woods Hole, MA to continue work on the Swept Area Seabed Impact (SASI) model (previously the Fishing Gear Seabed Impact (FiGSI) model), which is part of Phase 2 of the Omnibus Habitat Amendment. The focus of the meeting was to discuss remaining issues surrounding implementation of the SASI model, with a specific focus on progress towards completion of the matrix-based vulnerability assessment.

The meeting started shortly after noon on Thursday with a presentation by the Chair on the SASI model. This presentation highlighted the change in the name of the model from FiGSI to SASI: the latter had previously referred only to the fishing effort representation as area swept portion of the analysis. Other topics raised by the presentation included: (1) assumptions of the SASI model, (2) the function used to combine susceptibility and recovery to generate sensitivity, (3) the method for combining the sensitivity scores of geological and biological features into a composite score for a particular habitat, (4) the method for combining geological and biological sensitivity scores for a particular habitat, and (5) the need to defend assumptions and methods using ecological theory. Discussion on these topics occurred throughout the two-day meeting, so conclusions reached are presented topically below, rather than chronologically.

To be explicit, the Chair presented a mathematical representation of the SASI model (updated to reflect decisions made at the meeting) as follows:

$$SASI = A * \Omega$$

A represents contact-adjusted area swept by a tow k of gear type i, comprised of individual gear components j, as follows:

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

where w is the linear effective width and c is the contact index for the *jth* gear component of gear type *i;* d is the distance the *kth* tow of gear type *i* travels in one tow over substrate s and energy environment *e*; and *i, s,* and *e* are each elements of bound sets: $k = \{k1, k2, \dots \infty\}$; $i = \{i1, i2, \dots i9\}$; $j = \{j1, j2, \dots \infty\}$; $s = \{s1, s2, \dots s5\}$; $e = \{e1, e2\}$. Gear types include generic otter trawl, squid trawl, shrimp trawl, raised footrope trawl, scallop dredge, hydraulic dredge, trap, gill net, and longline; and substrates include mud, sand, granule-pebble, cobble, and boulder; and energy environments include high and low.

Ω is the sensitivity index applied to each tow:

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

where h is a habitat component and 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*. Habitat components h_1 and h_2 refer to geological and biological, respectively.

Simply put, using this function to calculate Ω means that impacts to geological features and biological features are weighted equally by the SASI model. An alternative form was proposed that would have weighted the geological sensitivity index more heavily: $\Omega = \omega_{h_1} * \left(\omega_{h_2} + 1\right)$, where ω_{h_1} is geological sensitivity and ω_{h_2} is biological sensitivity. The team discussed this at some length, and felt that the equal weighting function was more appropriate, while acknowledging that, due to the model grid being substrate based, that there is a probably a more direct ability to infer geological features as compared to biological features for a given substrate-based unstructured (Voronoi) grid cell. Alternative weighting schemes are of course possible, or, either geological or biological sensitivity could be used without the other. A team member questioned whether two separate representations of sensitivity could be used by the Council, rendering moot the need for a function to combine geological and biological sensitivity. However, this seems to conflict with the advice given by the SSC.

Combining the functions for *A* and Ω, SASI becomes:

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

The above does not specify how to calculate the sensitivity index itself. This particular issue has been revisited repeatedly by the team over recent months. S and R are whole numbers ranging from 0-3. The sensitivity index, ω, is allowed to range from 0-1, and equals zero when susceptibility equals zero. Between the last meeting and this one, staff investigated the properties of various functional relationships between S and R. For the time being, the following functional form was determined to be the most appropriate for combining S and R:

$$\omega = \sqrt[3]{\frac{(S+R)_{i,s,e}}{y}}$$

In this formula, y is the number of unique combinations of S+R from the S / R matrix (seven, in this case).[1]

Related to the need to estimate sensitivity from S and R was the need to combine feature-level sensitivity estimates from the matrices into a habitat-component level estimate, specified for each gear, substrate type, and energy environment combination. Ideally, the usefulness of geological and biological features to managed species would be known, and the relative abundance of those features in particular cells would also be known. This would allow feature sensitivities to be combined based on a meaningful weighting, either in terms of the features' usefulness to fish, or in terms of their relative abundance in the substrate/energy-defined environment. Absent this information, it would be helpful simply to know what features occur (i.e. presence/absence) in particular grid cells.

Lacking <u>this</u> information, reasonable inferences about the features expected to occur in a particular substrate/energy environment can be made, based on the literature in combination with empirical data when available (i.e. from the SMAST video survey). Given that this is the level of data available on feature distribution and relative abundance, feature-level sensitivities will be determined by individual team members and then habitat-level sensitivities for geological and biological features in each substrate/energy environment will be determined in plenary by the team.

This discussion raised an important general issue. While in the near-term, the goal of the team is to develop a tool that can be of immediate use to the Council, that the long-term goal is to develop the best tool possible, simplifying where necessary for current implementation. This approach is consistent with the expressed desires of the Habitat Committee. As long as the proper framework is in place, the model can be adjusted in the future if better data become

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[1] Subsequent to the PDT meeting, the parameterization of Ω (i.e. the combination of S and R scores into a sensitivity coefficient) changed significantly. These changes were not discussed at the meeting, but are central to the model and therefore summarized here. S and R were intended to be comparable in magnitude but were measured using different scales (% and time, respectively), making their integration conceptually difficult. However, whichever function was chosen to combine S and R, sensitivity had a consistent property that for a given susceptibility value, longer recovery timescales resulted in higher sensitivities, and shorter recovery timescales resulted in lower sensitivities. Unfortunately, the properties of a sensitivity coefficient derived in this way meant that fishing effort added to the model would not be removed over time as recovery occurs. While an inelegant solution would be to run the model in annual time steps, a better one is to model every S and R combination as a decay function. This allows the model to run from 1996-2008 and into the future.

available. In the case of habitat-level sensitivity values, for example, once the model for the entire domain is up and running, it may be useful to look at specific spatial areas for which there is better data that could be used to generate empirical feature weightings.

Model assumptions

The SASI model makes a number of simplifying assumptions related to the nature of the habitat being impacted and the fishing gear and its operation.

1. Within a tow, it is assumed that fishing gear impact is constant. In particular, the **abundance of geological and biological features is uniform**, **substrate type and energy environment are constant**, there is **constant impact along the entire length of a gear component**, **otter board angle of attack is constant**, **ground cables are straight along their entire length**, and the **impact of each gear component is cumulative**. These were not discussed in detail by the team, except that the assumption of constant substrate and energy within a tow may not be required if the spatial grid is implemented differently so that tows can be split over multiple grid cells (obviously this will only effect model output if the grid cells differ in substrate and/or energy, and thus in sensitivity). This is discussed further below.

2. SASI smoothes over differences in gear configuration within a gear type, except to the extent that the effective width of the gear components is allowed to vary. In other words, **the susceptibility of a particular habitat feature to fishing effort may vary between gear types, but not within a gear type**. Put another way, the impact of a gear and its components as represented by S (susceptibility) does not vary by its size/length, weight, design or rigging, unless this combination of factors causes the gear to be classified as a different type.

   For example, fishing events classified as belonging in the generic otter trawl category may have used a variety of gear configurations (in particular, various types of sweeps), but susceptibility of a particular feature does not vary on this basis. Rather, analysts considered the possible types of gear configurations that might influence susceptibility when assigning the score (although see discussion in the matrix section, below). In contrast, although both generic otter trawls and raised footrope trawls have the same components (ground cables/bridles, doors, and sweep), habitat features may have different susceptibilities to these two gears, because they were determined to be sufficiently different to be specified as two gear types. Furthermore, **the contact index for a given gear component is specified categorically by gear type and does not vary**. For example, the contact index for generic otter trawl sweeps might be 0.8. Regardless of fishing vessel or sweep width, this contact index is the same for all fishing effort classified as generic otter trawl. In addition, **contact index does not vary based on towing speed** (although towing speed does influence the distance, d, covered by a tow).

3. Other assumptions relate to the cumulative impacts of multiple tows over time. In particular, SASI assumes **that the impact of multiple tows is additive, i.e. it does not assume a greater impact due to the first vs. subsequent passes**. In addition, SASI assumes that **both the presence and abundance of geological and biological features in a model cell is independent of past fishing effort in that cell**. Related to these assumptions, the team wondered if the ecology of fished areas comes to some new equilibrium or alternate stable state. One possible way to accommodate the ability of habitats to recover from impact would be to implement susceptibility, S, and recovery, R, separately, and use a decay function to represent R. This would remove effort/area swept from the model after a recovery period.

   Finally, **data of different ages used to code for the substrate type in a particular cell are weighted equally**, e.g. recent data are not prioritized over older data. In other words, substrate type in a particular cell is assumed constant over the period during which substrate data were collected.

Incorporating heterogeneity in model

The above model specification and assumptions don't factor in habitat heterogeneity. One team member in particular was concerned that the influence of habitat patchiness/heterogeneity on, for example, biological recovery was not being captured. Theory indicates that highly heterogeneous areas recover slower than homogenous areas. Spatial scale is critical to this assumption. In particular, another team member felt that while this theory applied on very large scales (zoomed in), that it might not be applicable to small scales (zoomed out), and thus, while worthy of mention, did not need to be incorporated explicitly in the model.

Another concern about heterogeneity is that heterogeneity at the substrate level can't be explicitly represented using the current grid structure, except that adjacent cells can be examined visually to determine whether they are similar or different. If we assume that heterogeneous environments are important, it is useful to be able to visualize on a map where these areas are. In addition, a single unit of fishing effort (e.g. a tow, or string of traps) may occur within areas that have multiple dominant substrates, but currently the model cannot accommodate this.

One team member worked on two ways to represent heterogeneity visually. The first, the so-called 'net' approach, overlays a 10 km x 10 km grid on the Voronoi grid (cracking Voronoi cells as required). This allows the model user to estimate the percentage of the 10x10 grid covered by the various substrate types, based on the dominant substrate coding in the Voronoi cells. Fishing effort that occurs in the 10x10 grid could then be scaled with the appropriate sensitivity coefficients for the substrates that occur, in proportion to the substrate's occurrence. The second, the so-called 'buffer' approach, would assign sensitivity values for multiple neighboring unstructured grid (Voronoi) cells to a unit of fishing effort based on anticipated distance covered in a unit of fishing effort (for most gear types, one tow). The Team's preferred approach was to apply the 10x10 grid and assume that fishing effort within each grid was distributed to the dominant substrates in proportion to the size of the (cracked) underlying voronoi grid cells.

Vulnerability Assessment

The feature/matrix-based vulnerability assessment and accompanying literature review was the method selected by the team to evaluate the susceptibility and recovery of habitats to fishing. Recently, the team has focused on integrating biological and geological habitat components in the assessment. Between the last PDT meeting and this one, a subset of the team refined the vulnerability assessment methods to incorporate biological features that represented broad taxonomic categories into the vulnerability assessment matrices. The inclusion of prey features is discussed separately below.

Currently, each matrix is specific to a gear type and dominant substrate, with separate recovery columns for high and low energy environments. Only geological and biological features expected to occur in a particular dominant substrate were added to each matrix. In nearly all cases, the same features were expected to occur in both high and low energy, given a particular substrate type. To ensure that all analysts had the same conception of the features, in particular the biological features, descriptions were written that included example species and factors that would influence susceptibility and recovery.

Prior to this meeting, team members individually re-reviewed the literature and filled in S and R values for select mobile gear matrices. At the meeting, the team discussed some of the values, and discussed some general issues with the matrix approach.

Team members wondered if generally, susceptibility and/or recovery would be independent of substrate. Some team members argued in favor of stating this independence as an assumption of the vulnerability assessment, while others thought that while it might be a likely result of the assessment, that there was no need to specify this at the outset.

The team also wondered if the distribution of biological features was energy-driven, perhaps via increased/decreased larval delivery, secondary dispersal, or food delivery. While this would likely be true at an individual species level, because the features specified are generic, they would not be expected to differ in their distribution by energy environment.

Regarding trawls, one team member noted the difficulty he was having in assigning susceptibility values given the different effects of particular trawl components (doors, cables, sweep). The team discussed this at length, and it was noted that SASI was originally intended to have gear component-specific sensitivity coefficients. The idea was presented of expanding the trawl matrix to include more specific gear configurations, particularly sweep configurations, and a number of team members supported it. The Chair noted that he could investigate the specific gear configurations noted in the observer data, and determine whether this level of disaggregation was practical, noting that observer data is biased in its sampling of the otter trawl fishery. Currently, a single susceptibility value is generated for each gear/feature/substrate interaction, considering all gear components together. Averaging susceptibility values at this stage may introduce error, but applying the wrong sensitivity coefficients to a tow because of uncertainty in the gear configuration would also introduce error. Additionally, only a portion of the fishing impacts literature specifies the gear type to this level of detail or considers gear components separately. The team decided to keep the matrices as-is, but noted that individual analysts could choose to record different scores by gear component.

For this round of matrix evaluations, studies from the literature review were narrowly applied to matrix cells if they evaluated the interaction between a particular gear type and feature in the appropriate substrate (e.g. scallop dredge gear/bryozoan feature/cobble substrate). However, if susceptibility and recovery were more closely related to the specific gear configuration, rather than to the substrate or energy environment, this would indicate that gear configuration, rather than substrate and energy, might make a particular study in the literature review more or less applicable to a particular matrix cell. The team was encouraged to consider this during future S/R evaluations, and staff will make an effort to specify gear configurations in the database where this information was reported. On a related note, staff asked whether studies conducted in muddy sand belonged more appropriately with mud or with sand, and, the team agreed that muddy-sand studies should be referenced in both the mud and sand matrices.

Shell debris was singled out as a challenging feature to evaluate. A distinction was made between occasional shell debris and more substantial shell deposits, and it was noted that some types of fishing gear might increase the availability of this feature. These two features will be disaggregated going forward.

Staff asked whether it would be appropriate to grey out unlikely matrices entirely. The team agreed that this would be a good idea, and the Chair noted that the joint AP/Ctte workshop would be a good place to test these assumptions. In particular, the team determined that cobble and boulder matrices were not necessary for squid trawls, raised footrope trawls, or hydraulic clam dredges.

Prey

The PDT spent a considerable amount of time last summer considering how prey, a component of essential fish habitat, could be incorporated in the impacts analysis. As currently conceived, the vulnerability assessment only considers structural, geological and biological features, although prey features were coded during the literature review.

A few questions were raised, none of which have clear answers at this stage.

1. How do impacts to prey (infaunal or epifaunal) affect managed species?
2. To what extent does a particular prey group have to be affected before managed species are impacted?

3. Do infaunal prey change the nature of the substrate such that the habitat might no longer support the same epifauna (i.e. are the biological and prey components of habitat interrelated)? Conversely, do changes in geological and biological components effect prey?

The team saw three main alternative approaches for including prey in the analysis:

1. Consider impacts to prey during a post-hoc analysis, paying particular attention to the needs of managed species that are specialist feeders.
2. Undertake a more comprehensive analysis of impacts to prey via the matrix-based assessment and bring sensitivity values forward into the SASI model.
3. Include prey in the matrix-based assessment but do not bring sensitivity values forward into the spatial model.

The team decided on option 3, which would require an inference about the substrates in which particular prey features are found. Given the generic nature of the features, it seemed likely that all prey features would be found in all substrates, and an on-the-spot review of the SMAST video survey data seemed to lend credence to this. The team felt it was important to include both infaunal and epifaunal prey items, but that it was appropriate to limit the analysis to benthic invertebrates and not consider benthic or pelagic fish at this time.

Tasking/moving forward

The meeting concluded with a discussion of tasking. As usual, the team managed to make definite progress on many issues while managing to create lots more work for itself. The team agreed to prioritize the generation of sensitivity scores for geological and biological components and then consider prey. Major ongoing work includes:

- Summarize ecological theory used to justify SASI model assumptions, and decide how to test the sensitivity of model output to these assumptions
- Revise matrices to include prey
- Assign matrix responsibilities to team members (at least two per matrix)
- Generate maps of sensitivity by gear type, and then add fishing effort surfaces

The meeting adjourned at 1:30 p.m. on Friday.