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Proceedings of a Benthic Habitat Classification Workshop Meeting of the Maritimes Regional Advisory Process

Maintenance of the Diversity of Ecosystem Types

Phase II: Classification and Characterization of Scotia-Fundy Benthic Habitats

20 – 22 July 2005
George Needler Boardroom
Bedford Institute of Oceanography,
Dartmouth, Nova Scotia

R. O'Boyle (Chair)

Compte rendu de l'atelier du Processus consultatif régional des Maritimes sur la classification des habitats benthiques

Maintien de la diversité des types d'écosystèmes

Phase II : classification et caractérisation des habitats benthiques de Sotia Fundy

20 – 22 juillet 2005
Salle George Needler
Institut océanographic de Bedford,
Dartmouth (Nouvelle-Écosse)

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P.O. Box 1006, Dartmouth, Nova Scotia
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June 2006 — **juin 2006**

Canada

Foreword

The purpose of these proceedings is to archive the activities and discussions of the meeting, including research recommendations, uncertainties, and to provide a place to formally archive official minority opinions. As such, interpretations and opinions presented in this report may be factually incorrect or mis-leading, but are included to record as faithfully as possible what transpired at the meeting. No statements are to be taken as reflecting the consensus of the meeting unless they are clearly identified as such. Moreover, additional information and further review may result in a change of decision where tentative agreement had been reached.

Avant-propos

Le présent compte rendu fait état des activités et des discussions qui ont eu lieu à la réunion, notamment en ce qui concerne les recommandations de recherche et les incertitudes; il sert aussi à consigner en bonne et due forme les opinions minoritaires officielles. Les interprétations et opinions qui y sont présentées peuvent être incorrectes sur le plan des faits ou trompeuses, mais elles sont intégrées au document pour que celui-ci reflète le plus fidèlement possible ce qui s’est dit à la réunion. Aucune déclaration ne doit être considérée comme une expression du consensus des participants, sauf s’il est clairement indiqué qu’elle l’est effectivement. En outre, des renseignements supplémentaires et un plus ample examen peuvent avoir pour effet de modifier une décision qui avait fait l'objet d'un accord préliminaire.

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SUMMARY

In 2001, a Maritimes Regional Advisory Process (RAP) was initiated to classify the benthic communities of the Scotian Shelf and provide fisheries and oceans managers with guidance on the use of this classification system. Three phases to the RAP were planned: 1) review of existing classification systems and recommendation of an approach for the Scotian Shelf, 2) application of the recommended approach to the Scotian Shelf and 3) development of management approaches. The first phase was completed at a June 2001 RAP meeting. The current meeting completes phase two, for which there have already been a RAP meeting (January 2004) and workshop (December 2004). The current meeting discussed and agreed to improvements to the benthic classification model made since the January 2004 RAP meeting, outlined limitations and constraints to its use, provided a definition of habitat sensitivity that was linked to the classification model, and considered a number of mapping products that fisheries and oceans managers could use to guide management actions. These outputs will be considered during the phase three of the RAP, planning for which is currently underway.

SOMMAIRE

En 2001, on a fait appel au Processus consultatif régional (PCR) des Maritimes pour classifier les communautés benthiques du plateau néo écossais et guider les gestionnaires des pêches et des océans relativement à l’utilisation du système de classification. Ce PCR devait se dérouler en trois phases : 1) examen des systèmes de classification existants et recommandation d’un système pour le plateau néo écossais; 2) application du système recommandé pour le plateau néo écossais et 3) mise au point d’approches de gestion. La première phase s’est terminée lors d’une réunion du PCR de juin 2001. La réunion en cours met fin à la phase deux qui avait déjà fait l’objet d’une réunion du PCR (janvier 2004) et d’un atelier (décembre 2004). Lors de cette réunion, les participants ont examiné et approuvé les améliorations qui ont été apportées au modèle de classification des habitats benthiques depuis la réunion de janvier 2004; ils ont également inventorié les limites et les contraintes relatives à son utilisation, donné une définition de la vulnérabilité des habitats en rapport avec le modèle de classification et examiné plusieurs produits de cartographie que pourraient utiliser les gestionnaires des pêches et des océans pour guider les processus décisionnels. Les résultats de cette réunion seront pris en compte lors de la phase trois du PCR portant sur la planification, phase qui est maintenant entamée.

INTRODUCTION

The chair, R. O'Boyle, welcomed the group (Appendix 1) and provided background to the meeting (Appendix 2). The DFO Maritimes Region initiated a Regional Advisory Process (RAP) in 2001 to classify the benthic communities of the Scotian Shelf and provide fisheries and oceans managers with guidance on use of this classification approach. A three phase set of meetings were planned to accomplish this:

> Phase I: Review existing approaches to classifying and characterizing benthic communities and recommend a method for classifying the benthic communities of the Scotian Shelf; RAP Meeting held in June 2001 (Arbour and Kostylev, 2002)
>
> Phase II: Apply the recommended classification approach to the Scotian Shelf and produce a map of the benthic communities; Initial RAP meeting held in January 2004 (Arbour and St-Laurent, 2004) and subsequent workshop held in December 2004 (O'Boyle and Worcester, 2005)
>
> Phase III: Assess the sensitivity to human activities of the benthic communities occurring on the Scotian Shelf as classified by the recommended approach, and develop management approaches (planned to start in the fall of 2005)

The present meeting is to finalize phase II. As described in the remit for the workshop, the objectives were to:

- Review the benthic classification model
  - Consider model enhancements
  - Test model including tabulation of indicator species life history traits and compare to model predictions
  - Present model limitations and constraints

- Develop maps of the sensitivity of benthic communities to human impacts including
  - Definition of sensitivity
  - Characterization of sensitivity of different Scotia-Fundy benthic seascapes
  - Zonation of areas of sensitivity

Background materials for the workshop included the proceedings from the previous meetings referred to above and papers provided for this or previous meetings of this RAP series. These included the papers by Southwood (1977, 1988), who was the originator of the habitat template model.

The chair reviewed the agenda (Appendix 3). The first day was to be devoted to presentations and discussion on improvements made to the Scotia-Fundy benthic classification model since the January 2004 RAP meeting, the main conclusions of which are provided in Appendix 4. The second day would be devoted to discussion on mapping products for management purposes. The content of the status report would be discussed on the last day. The chair noted that the report would likely not be finalized at this meeting but would be subsequently drafted and discussed at a specially arranged status report review meeting. He noted that the products from the meeting would include a CSAS Science

Advisory Report, Proceedings, and a Research Document containing the technical details discussed at the meeting.

A TEMPLATE APPROACH TO BENTHIC CLASSIFICATION

Vladimir Kostylev

Theoretical Basis

V. Kostylev described the approach to benthic classification used in phase II of the RAP. Details can be found in the proceedings from the January 2004 and December 2004 meetings (Arbour and St-Laurent, 2004; O'Boyle and Worcester, 2005).

Presentation Highlights

Southwood's 'habitat template' model (1977, 1988) defines habitat along two axes: disturbance (the durational stability of habitats) and the general level of adversity (physiological stress). Southwood proposed a third axis, interspecies competition and predation, which he suggested had the most influence in habitats with a low level of disturbance and adversity (1988). Communities with particular life history traits would be found at different points along the axes. Theoretically, this model could be used to predict areas of the Scotian Shelf where there are communities with particular life history traits.

Environmental variables corresponding to the disturbance and adversity axes were identified for the Scotian Shelf, combined and mapped to derive the benthic classification model. The third axis, corresponding to interspecies interactions, is not included in the Scotian Shelf model. At previous meetings in the series, there was general agreement that the disturbance axis developed for the Scotian Shelf was appropriate. However, the adversity axis was not completely accepted and various refinements and enhancements were suggested. In addition, the word "adversity" did not seem appropriate and it was suggested that a new label for this axis be found. As a result, the term "scope for growth" was proposed and is used throughout this meeting (Figure 1).

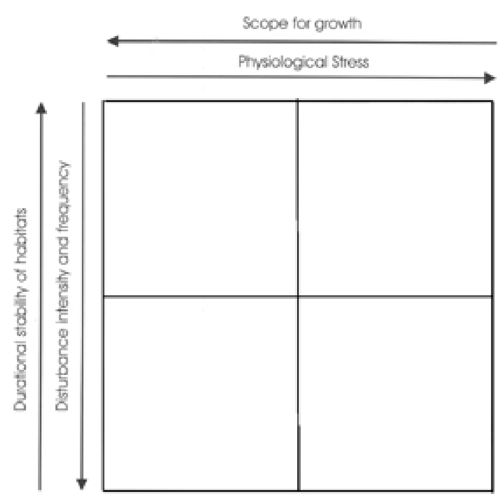

Figure 1. Blank habitat template.

Southwood proposed that various habitats would have communities with different life-history traits (Figure 2).

		Adversity (Scope for Growth) Axis	
		Benign	**Adverse**
Disturbance Axis	**Stable**	Defense medium Migration low Offspring medium and small Longevity medium Tolerance low	Defense high Migration low Offspring few and large Longevity long Tolerance high
	Disturbed	Defense low Migration high Offspring many small Longevity short Tolerance low	Defense high Migration high Offspring medium large Longevity medium Tolerance high

Figure 2. The relative importance of different life-history strategies in various habitats as predicted by Southwood (1988; Figure 8)

At the December 2004 workshop, consideration of other ecological models and approaches to habitat was encouraged. Once examined, it was found that other ecological models had many characteristics that were similar to the Southwood approach. Huston (1996) came to similar conclusions as Southwood, e.g., that disturbance and productivity were the main drivers of biodiversity. This is different than the equilibrium theory of biodiversity proposed by MacArthur and Wilson (1967).

Using Southwood's model, we would expect diversity to increase toward the centre of the habitat template, i.e., highly productive, undisturbed habitats would have lower diversity than more disturbed, less productive habitats (Figure 3). Huston (1996), who began by looking at patterns of diversity, predicted the same distribution of life-history patterns as Southwood, who started with life-history traits. This provides support for the theoretical underpinnings of the habitat template used here.

In the pelagic domain, Margalef et al. (1979) developed an approach to predict species characteristics and adaptive strategies. They used two axes, with nutrient dissolution on one axis (similar to the productivity element of Southwood's adversity axis) and turbulent mixing on the other (comparable to physical disturbance in the Southwood model). Reynolds' (1999, 2001) approach modified Margalef's template by grouping elements into two categories: resource limitations and process limitations. He then identified about 16 life history traits and placed them on the template. These functional groups have been proven to work but are difficult to transfer to the benthic realm. Grime (1977) proposed three axes for his triangular habitat template: environmental disturbance, environmental stress (adversity), and competition. Figure 3 shows various the habitat templates with the exception of those of Grime.

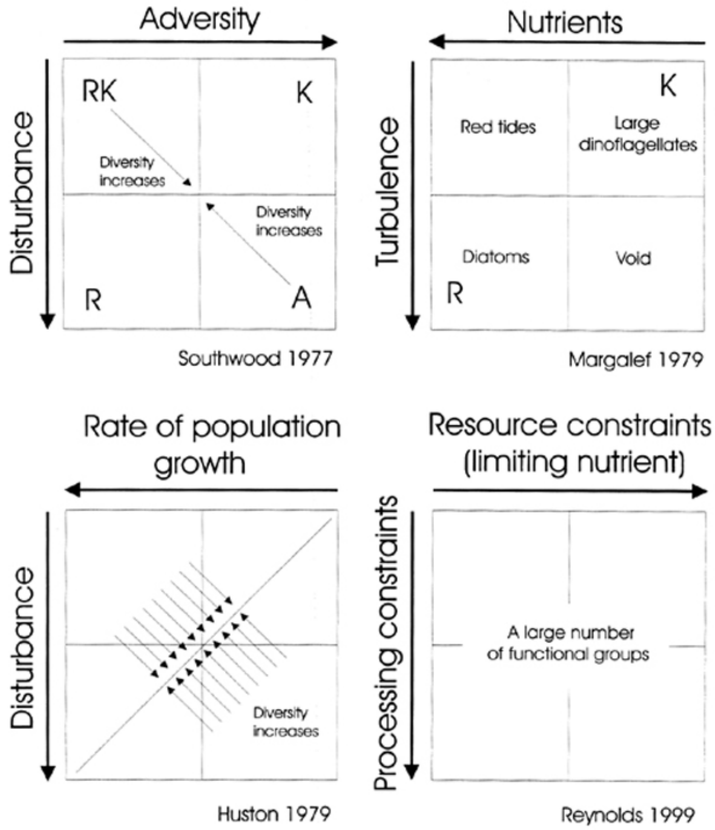

Figure 3. Various habitat templates (Kostylev and Hanna, in prep.)

Discussion

Southwood's template of life history characteristics was shown with the relative position of r, K, and A species identified (Figure 3, above). It was noted that species are not classified by Southwood's model; it is their life history traits that are. It was noted that the scope for growth axis was an attempt to portray functional groupings. It was noted that the benthic habitat classification is for cold-blooded species living on the seabed and does not work for chemosynthetic animals or marine mammals.

It was asked what species or communities would benefit from the approach. While looking at the traits and the fitness of the environment is important, at some point, species and population information is needed. The bridge between the two is not clear. The habitat template provides a means to understand why species are distributed the way they are. The species mix would be specific to a geographic location. Corals are not found on Georges Bank and scallops are generally not found in stable, unproductive environments. If we consider an array of organisms from viruses to whales, there would be some in those groups that have the characteristics corresponding to the template. It was noted that our focus has been on macro-organisms, but if we looked at very small organisms such as protists, there is another ecosystem that fits into the template that we are currently not concerned about. There are more dimensions to the system than we have looked at, particularly the elements making up the Scope for Growth axis. This failing is common to most approaches; bacteria and micro-organisms that drive the system are missing. It was reiterated that the focus of the model was on benthos, particularly the macro-benthos.

Data management issues associated with the project were identified, such as the limited availability of data layers, such as critical velocity, for others to use. It was agreed to return to the data management issue on the last day of the meeting.

Application of the Template Approach to the Maritimes Region

Presentation Highlights

Disturbance Axis

The disturbance axis corresponds to the natural physical habitat disturbance of the ocean bottom. Hjulstrom (1935) developed a model of physical disturbance of rivers, with current speed and particle size as the main defining factors. The model identifies areas of sediment erosion, transportation and deposition and thus stable and non-stable habitats. It can be used to define the disturbance axis of the Southwood model, i.e., it is possible to transfer the locations of erosion, deposition, etc. on the Hjulstrom diagram to locations on the disturbance axis.

Disturbance is related to the ratio of frictional velocity at the seabed relative to the critical shear stress for a given particle size (critical current). Frictional velocity was determined from the synthesis of four data products: (1) high resolution bathymetry of the region, (2) 42-year hindcast of the wave height and period (Swail and Cox, 2000), (3) near-bottom estimates of tidal current extracted from various models; (4) grain size estimates. These were all used as inputs for the calculation of bottom stress (friction velocity) using the SEDTRANS96 software (Li and Amos, 2001). Critical currents were calculated from the Hjulstrom empirical relationship between grain size and the current velocity required for mobilization.

The mean grain size distribution was developed by examining Geological Survey of Canada (GSC) databases, based on grab sampling. The actual measurement of grain size was used. Grab sampling is not considered the best way to examine grain size, e.g., bedrock cannot be sampled and this is missing from the model. The information was considered to be inaccurate for the inner shelf area and thus was removed from the model. It was noted that previous surficial geology maps compiled by the GSC are of limited use to marine ecologists as they focused on the origin of surficial sediments, rather than the grain size. A surficial sediment category used on the GSC maps may include many different grain sizes. However, existing geological boundaries were used in some cases to constrain the data interpolation for the grain size model. Based on observations of German Bank, Browns Bank, and Georges Bank, there is confidence that the grain size map matches the actual grain size.

The Hjulstrom diagram discussed above is an important concept that accounts for many different factors related to disturbance, such as different flows and different grain sizes. Hjulstrom used real data to define the critical currents. In some areas of the Scotian Shelf, the critical current is very high and it may be achieved very infrequently, if at all, during storms. For example, on the north of Georges Bank, a lot of current would be needed to achieve disturbance. This suggests that the scallop fishery on the northern portion of Georges Bank might be an issue for consideration by management.

The disturbance map from the December 2004 workshop was compared with the new disturbance map (Figure 4). The December 2004 map, based on tidal currents only, showed very little pattern; more patterns are obvious in the new map. The new disturbance map represents a characteristic state based on root-mean-square tidal currents and the 90th percentile wave heights and periods. It is expected that at each point the disturbance exceeds the plotted value about 10% of the time (about 1 month per year). In the map below, yellow and orange areas can be considered disturbed; green and blue areas are not disturbed.

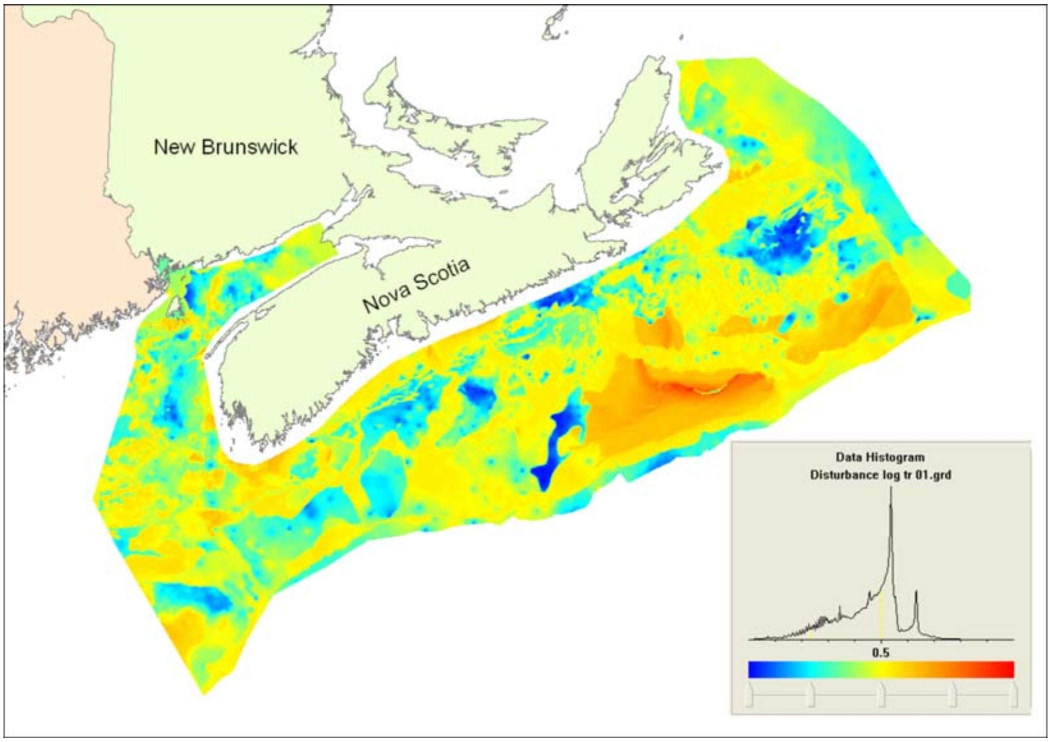

Figure 4. New disturbance map (July 2005).

<u>Scope for Growth Axis</u>

As discussed in December 2004, food availability was considered to be the most problematic element of this axis. The spring distribution of chlorophyll a based on satellite images, normalized from 0 to 1, is combined with the summer stratification (density difference from surface to 30 m). Chlorophyll observations for the inner Bay of Fundy may be an artefact of turbidity and the final map will not include coastal areas.

Temperature is included in the scope for growth axis as a factor affecting metabolic rates rather than as a factor in determining the distribution of species, i.e., as a limiting factor in determining species range. Temperature is related to energy, e.g., animals living in warm-water environments have higher respiration rates than those in cold-water environments. In general, the bottom temperature regime on the Scotian Shelf is warm in the west and cold in the east. Also, the Scotian Shelf has high annual temperature variability in some areas – up to 18 degrees. This is potentially an important stressor as it takes a lot of energy to accommodate this variability. In terms of interannual variability, some areas are stable while others have high variability due to the Gulf Stream.

Salinity was not included in the scope for growth axis as it does not appear to be a stressor over its range in open water of the Scotian Shelf. In coastal areas, salinity is more of an issue.

A new map of oxygen saturation was created based on data provided by Brian Petrie, replacing the one used at the December 2004 workshop. The blue areas on the map are limiting for benthos during summer stratification events.

The Scotia-Fundy Scope for Growth map (Figure 5) is based upon the additive combination of the separate indicators; linear relationships were preserved. All the Scope for Growth indicators were rescaled from 0 to 1, combined by adding or subtracting (some were positive, some were negative), and averaged. However, whether or not the indicator is a physiological stressor depends upon the sign of the indicator. Average bottom temperature, chlorophyll a concentration at the surface, and oxygen saturation were positive factors (less stress); the yearly temperature range, interannual temperature variability, and stratification were negative factors (more stress).

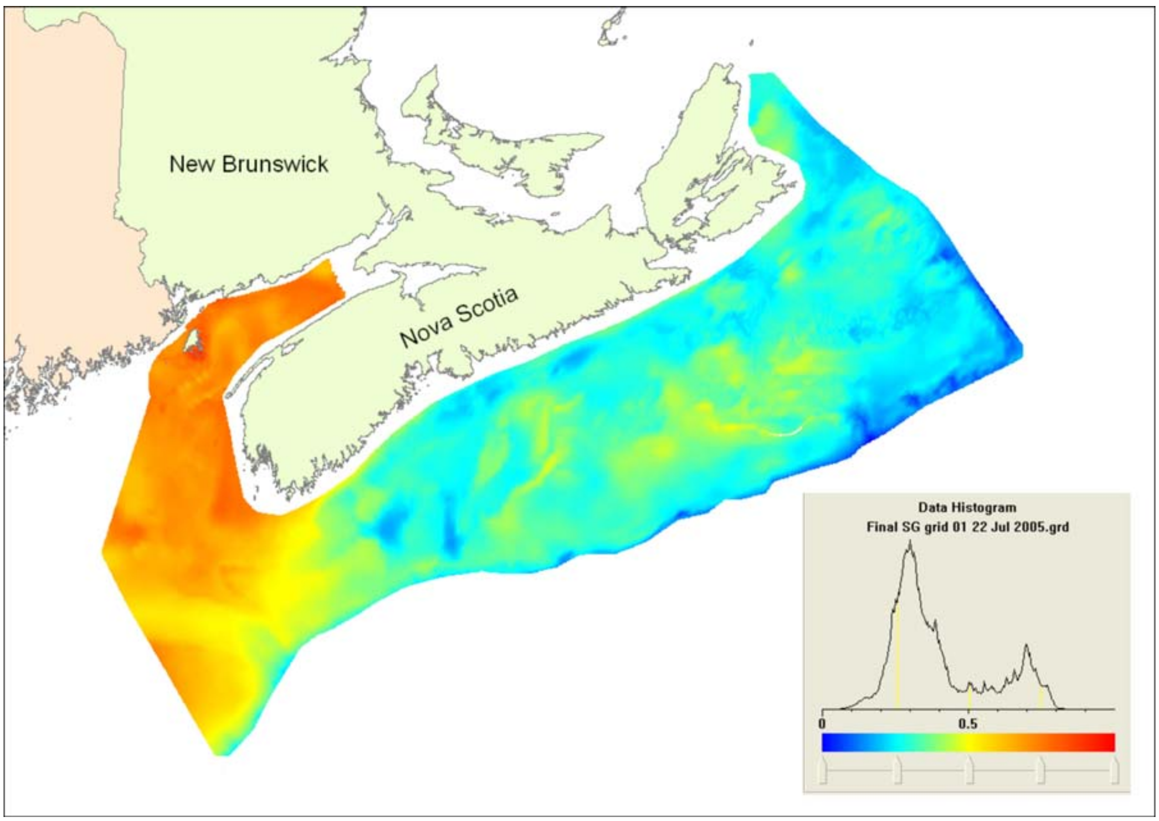

Figure 5. New Scope for Growth map.

Mapping Scope for Growth versus Disturbance

In developing the habitat template, there has been some debate on whether to use an additive or limiting approach in combining the axes. The additive approach has been used for the maps shown above. With the limiting model, if one index is unfavourable, it is considered limiting. With the additive model, if one index is unfavourable and others are not, organisms can still live there (they will adapt). However, as an example of the limiting model, if oxygen is low, it doesn't matter how much food is in the system. The results of the limiting model were compared with the additive model. There were similar patterns, although there were also some obvious differences. Overall, it was felt that the additive approach was more appropriate.

Discussion

Disturbance Axis

Participants asked for clarification on the definition of the disturbance axis for the Scotian Shelf. The new calculation of frictional velocity, or bottom stress, is quite different from that used at the December workshop (see presentation highlights for new data inputs). The values corresponding to the 90th percentile wave heights and periods were computed on the roughly 1 degree mesh of the hindcast and then interpolated to the grid points of the habitat map. Wave heights and wave period were calculated separately, with values corresponding to the 90th percentile of wave height considered characteristic. Higher percentiles did not make sense in some areas as high winter wave heights were combined with long wave periods in the summer. The wave hindcast model does not include effects due to shallow water and thus likely overestimates the heights (and thus the stress) in shallow water.

There were comments that, based on the ratio of frictional velocity to critical current, there appeared to be very few disturbed habitats on the shelf. It appears that for most of the shelf, most of the time, the sediments are not going to move. If the sediments are relatively stable, the present indices do not appear to be a very good measure of disturbance and there must be another determining factors related to disturbance. Perhaps this is one layer of disturbance, but others should be considered, such as currents or rugosity. However, it was felt that the critical value itself was not that important. What is more important is the direction of change. The map generalizes the average state; during severe events more sediments will move throughout the entire area. For everything that's yellow to orange to red, the bottom moves at least once per year. Thus, the critical value is not 1, but somewhat less than one. Areas that are red are likely moving one month per year; yellow areas may be moving three weeks of the year. It was suggested that calculating the average number of times the bottom sediments move each year would be useful. This could not be completed in the short term but would be good to pursue.

It was asked if resuspension altitudes for different size particles could be calculated. There may be areas of the Scotian Shelf where resuspension is a concern. If that was combined with bottom currents, it would be a good tool for predicting silting such as in relation to bottom trawling. This has been a concern in the Skagerrak, where there are contaminated sediments. The response was that the map shows the area without human activities. If ocean mining, drilling and other human activities were added, the map would be different. However, it was mentioned that an activity such as otter trawling would not likely add much disturbance to most areas of the shallow banks, based on the disturbance map. In the north of Georges Bank, it would be a large new disturbance, but in the centre of Georges Bank, it would not add much to the overall disturbance level.

It was asked where exposed bedrock would show up on the disturbance axis: would it be have a value of 0 (stable) or 1 (disturbed)? The response was that it was likely to be 0. It was suggested that things that grow on disturbed bedrock would likely not show up in the proper area. The response was that bedrock would be in the right area (stable). The sediments in the very disturbed area are most likely to be coarse sand.

It was noted that Disturbance was very closely linked to sediment type (e.g., very calm environment with mud, and very energetic environment with sand), suggesting that this had limited usefulness in terms of certain human activities. A comment was made that disturbance was not the same as sediment type but was more closely related to the energy present in the environment. In response, it was noted that the distribution of surficial sediments was a reflection of the energy of the environment.

Overall, there was agreement that the improvements made since the January 2004 RAP meeting were good and formed an appropriate basis for the Scotia-Fundy Regional Disturbance axis.

Scope for Growth Axis

It was suggested at the December 2004 workshop that using spring stratification may be more appropriate than using summer stratification to produce the food availability map. The response was that on examining the spring stratification, no patterns were found. It was suggested that Trevor Platt's group at BIO may be able to develop an indicator of productivity. The response was that this group was already involved with providing and interpreting the satellite date. The data were a five-year average of the spring bloom from SeaWiFS.

It was asked why stratification was added to the model. Stratification is an indicator of the amount of chlorophyll reaching the seabed and thus can be used to develop the food availability index. It was observed that this was based on the assumption that food gets to the bottom by sinking. Many other assumptions are also being made implicitly when using this index: it doesn't account for grazing and doesn't account for currents, among other things.

A comment was made that chlorophyll a is often found in areas with good upwelling but zooplankton can be found in quite different areas, perhaps where chlorophyll a is being transported. The response was that the map's best feature is the broad pattern it shows from west to east. West (Bay of Fundy-Gulf of Maine) is more productive than east. The question we should ask is 'are there more organisms growing on the bottom on Banquereau than in the Gulf of Maine'? Food availability was just one of the factors in the Scope for Growth axis.

It was observed that Georges Bank is well known to be more productive than Banquereau Bank. If the Gulf of Maine basins were compared with the Scotian Shelf basins, the Gulf of Maine basins would probably be more productive too. If you looked at cod and haddock growth rates, cod growth rates are probably higher in Gulf of Maine than the eastern shelf. However, relative growth rates may depend on the species being examined.

It was commented that currents are a factor and may play a larger role than stratification in food availability. This is one of the weaknesses of this axis. Food transport processes should be investigated. It was recognized that more modeling work is needed.

It was asked if depth was related to food supply on the bottom. One response was that depth was considered from the perspective of light availability. It was also commented that depth was particularly related to food supply since food is respired and remineralized during its decent to the sea floor and, therefore, food supply is generally inversely proportional to depth. Although there are many factors that influence this, in general there is less food availability at greater depths.

A comment was made that nitrates reaching the bottom don't show the same pattern as chlorophyll a reaching the bottom. The response was that the source of nitrates at depth in deep water is the North Atlantic, not recycled nitrate from the surface. A data layer related to nitrates had been added to the model at an earlier meeting, but it seemed to add little and was removed.

It was asked if the contribution of food availability to the overall axis had been assessed. The response was that some correlations had been run and presented at the December 2004 workshop. In the case of some elements of the axes, there was no consistent pattern between measurements of benthic pattern and structure. Analyses presented at the December 2004 workshop showed that chlorophyll a was positively related to epifauna biomass and epifauna richness (significant relationship).

The best index of food availability may be carbon present on the bottom. It was asked if data on carbon flux was available to use for the food availability element. In response, information was sought from Barry Hargrave's work (Hargrave, 2001). Hargraves found that organic carbon burial is a function of primary production (PP_0 in g C m^{-2} y^{-1}) and depth (Z in m):

$$C_B = 8.4\ [PP_0 / Z]^{1.37}$$

The comment was made that this equation may be different in different areas and does not account for other variables mentioned previously (e.g., horizontal transport).

The comment was made that fecal pellets from zooplankton can be an important source of carbon to the benthos that was also not accounted for. In response, it was noted that the food availability layer has been simplified because of what data were available. The information has to be available for every pixel on the map. To further refine the map, a working group that considered the benthic-pelagic coupling would be needed.

It was asked how the map for the Gully, which shows low scope for growth, could be interpreted. The response was that Sable Island Bank has more food supply than the Gully, which makes sense in general.

The classification model focuses on benthic invertebrates and it was asked if it could be used for other species, e.g., groundfish, upper trophic level fish, pelagic zooplankton, etc. Groundfish would likely have some relationship with this classification. Questions were raised on the standing biomass as estimated from groundfish research surveys. Is there more biomass of non-groundfish species in the west than the east? It was not clear that this would be a good measure as the survey is designed to catch groundfish. Analyses (see below) were conducted at the meeting on groundfish distributions. One participant felt that groundfish assemblage patterns were comparable to those in the scope for growth map.

It was noted that some animals are adapted to low-oxygen environments and would not be limited by these conditions. This is true; however, oxygen saturation is considered here in terms of metabolic cost (i.e., energy expenditure) rather than as a limiting factor to distribution. It was asked how the oxygen saturation map was developed. The map was gridded by Brian Petrie using data from 1991 to 1996, likely from CTD casts (DFO, 2004a).

Overall, addition of the oxygen index to the scope for growth axis was seen as an improvement.

It was suggested that this axis is influenced too much by temperature - three temperature layers contribute to the axis. The response was that some parts of the map seemed to be largely driven by oxygen saturation. However, the question about temperature is important and it was suggested that the three layers be combined. In response, it was noted that the three layers contributed different things to the model. It was asked if temperature reached points that were critical. It was commented that the temperature variability layers could be rescaled to have them count once instead of twice; however, it was also noted that these two layers are very different. Overall, combining the temperature layers is not likely to change the overall pattern much and thus the suite used was agreed to for current purposes.

Revisions to Food Availability Index

Based upon the above discussion, there was agreement that the food availability index of the scope for growth axis should be revised, if possible. Discussion focused on how to improve this index.

It was suggested that the food availability layer could be refined based on an earlier suggestion, where the carbon that reaches the bottom is reduced according to depth. Another suggestion was to look at carbonate content in sediments. This has been shown to be a good proxy for carbon reaching the bottom. There was agreement that we should try scaling the chlorophyll and stratification elements of the scope for growth axis by depth. The food availability map does not account for horizontal transport of food via currents. There are many currents that occur and the productivity has to travel from the surface to 100 metres or more. Currents tend to concentrate and carry zooplankton. For example, corals (filter feeders) are found on the southeast corners of channels, in areas where large volumes of water are coming off the shelf. The response was that sediment traps show a relationship between pelagic processes and the bottom. In areas that are very hydrodynamic and variable, this relationship may be weak or non-existent. However, at scales of 50 kilometres or more, this relationship is likely to occur.

It was suggested that the food availability map be divided by depth minus 20 metres. This would help to account for the likelihood that areas less than 20m deep would be well mixed. In areas that are shallow, food is getting to the bottom faster (and there is more of it); in other areas, food reaching the bottom is influenced by biological processes. A new map of food availability was generated [old food availability layer/(depth-20 m)]. Shallow portions of the shelf were shown as having lots of food availability while the basins and channels had little food availability. There were few differences over large areas. It was suggested that this map was the result of inconsistent scaling among the different elements. It may be possible to fix some of the scaling problems with the chlorophyll/depth map in the interim. There was general agreement that this element should be revisited and efforts should continue to make a more realistic model of how food is getting to the bottom. A number of food availability maps were produced using different data inputs and depth treatments.

It was asked what formula was used for food availability attenuating at depth. The response was that the equation was based on work by Barry Hargraves. Other formulas have been used elsewhere and there was some discussion as to which was most appropriate.

The new food availability map was compared with the old one. Few changes were obvious. The Gully appeared to have lower food availability while the variability that had been apparent over Banquereau on the previous map was smoothed. It was noted that it would be useful to plot how the maps change, as this would show what areas are sensitive to the different food availability parameters.

It was agreed that the food availability index was important to the model and more research was needed on food availability and food transport to the bottom. Notwithstanding this, the current index of food availability provides general patterns and while it doesn't deal with all food transport to the bottom (e.g., horizontal transport), there was agreement that the new scope for growth axis, incorporating depth in the food availability index, was preferred.

Mapping Scope for Growth versus Disturbance

It was asked if the various elements were weighted when they were combined. The response was that ideally, they would be weighted; however, there is not enough information to do so. The basis for changing the weighting would also need to be established. There is no strong theoretical basis upon which to select a weighting scheme. A comment was made that the three indices for temperature were in some ways a weighting. However, it was noted that although there are three indices, two are considered negative and one positive. Overall, the current combination of the indices to form the scope for growth axis was accepted.

It was suggested that the limiting and additive models be compared to provide an idea of robustness of the model. The response was that they had been compared and broad-scale patterns were the same. It was then noted that how the model maps life history patterns of biota would provide a better validation. Comments were made that there was no weighting problem for the limiting factor model, it was necessary only to identify the levels at which it is limiting. The response was that at the December 2004 meeting, there was an attempt to relate the different indices with actual physical processes rather than using linear relationships. For temperature, this should be a log relationship, not a linear curve. For metabolic rate and salinity, there are physical break points that could be used in a limiting model. In the end, Scope for Growth used linear scaling and the additive model.

It was asked how this map compares with the map prepared in December 2004. The response was that they are very similar.

It was asked how areas on the map related to the four-celled template (Figure 2). In response, each of the four cells was described in relation to particular areas. Disturbed, productive (lot of energy, lots of food, potentially easy to recover) areas would be in the Gulf of Maine, parts of Georges and Browns Banks. Disturbed, adverse areas would include Banquereau, Sable Island and Middle Banks, as well as other patches (i.e., populations there would have a limited ability to recover). Stable, productive areas would be most of the Gulf of Maine and northern Georges Bank. Stable, adverse areas would be most of the Scotian Shelf – they don't have enough energy to recover from large disturbances (parts of Browns Bank, LaHave, Emerald and Misaine Banks, middle shelf basins). A comment was made that the map showed general trends but it was difficult to pick out details. Scale is also an important factor to consider: what is the temporal and spatial scale for the model? How meaningful are some of the differences – could animals distinguish between a yellow and a red area? As well, categories such as stable, adverse, etc. which are relative can be interpreted differently in different areas. The relative nature of the categorization was acknowledged but was still felt useful as a general guide to management. It was asked how the axes were broken into groups. The median point was used in each axis.

A comment was made that this map does not appear to reflect observed conditions, for example, there are many basking sharks on Banquereau in the summer, suggesting it is a productive area. The response was that the model was for the benthic, not the pelagic environment. It was noted that the strong link between the benthic and pelagic realms had just been mentioned. However, Banquereau is very strongly stratified in the summer, limiting this link.

It was asked how the classification had been verified. A graph, presented at the December 2004 workshop, was shown that related the similarity composition of samples at particular stations and distance. Even in closely related samples (in terms of distance between stations), there is large variance (and this is an argument for not using samples to look at similarity). Distance-based similarity was used as a way to test the template. If the habitat conditions are the same, as predicted by the template, the species should be the same. Efforts were made to determine if similarity in species composition depended on distance or the similarity of the habitat factors. It was determined that if the habitat factors were the same, species composition was likely to be similar, independent of the distance between stations. The conclusion was that the habitat template is providing better information than using distance. Comments were made that you would not expect the classification to work on a species or habitat level. If you looked at functional groups, this should work. However, it was suggested that within 1000 kilometres or some kind of minimum size, even species may work. At some minimum size, the similarity between the species and template would begin to increase.

It was commented that many of the sampling points were from areas where the habitat mapping classification is similar. At longer distances, there is no similarity in habitat composition. In response, it was argued that in fact there was similarity at longer distances. The similarity test is testing community structure through the similarity of species composition. The samples from the Sable Island Bank survey were from one year of sampling effort and it was suggested that these samples may be better to use than the ones from the NRCan grab samples, which were from many different years. It was observed that there appears to be a strong relationship between diversity of species and similarity of habitat type.

A more valid test of the approach would be to have species classified as dominantly r or dominantly K and then plot their distribution according to the habitat template. A limited list of species was provided at the December 2004 workshop and their distributions plotted on the template. In general, the resulting pattern supported the template and model. For example, snow crabs and gorgonians were found in stable, adverse environments, while scallops were found in disturbed, productive environments. It was recognized that further testing would be advantageous.

There are many options for adapting the model. Different analyses can be conducted on the depth and food availability information; the template could be compared with other benthic data and so on. It was noted that some of these have been done, but there is scope to do more. It would also be useful to expand the classification to the pelagic realm.

It was suggested that categorizing species groups into functional groups could provide very useful information, depending on what the management needs are. However, while it is important to consider functional diversity, managers want to consider compositional diversity as well. It was suggested that a list of species be developed that would link function and composition.

Scotia-Fundy Groundfish Assemblages

K. Zwanenburg and A. Sinclair

Presentation Highlights and Discussion

During the discussion on the habitat template, it was asked whether the groundfish research survey data had been considered in assisting to validate the model. The response was that the invertebrate bycatch data had been examined but the quality of the data was considered poor. The groundfish distributions have not been compared to the model. It therefore may be useful to consider work that has been done on groundfish assemblages with these data. K. Zwanenburg thus presented an excerpt from a paper (submitted) that he wrote with Andres Jaureguizar on groundfish assemblages. They analyzed groundfish research vessel data over four decades and derived assemblages for the Scotian Shelf. The map of groundfish assemblages (Figure 6) suggests good relationships with the habitat template; demersal fish have strong links to the factors used in the habitat template model.

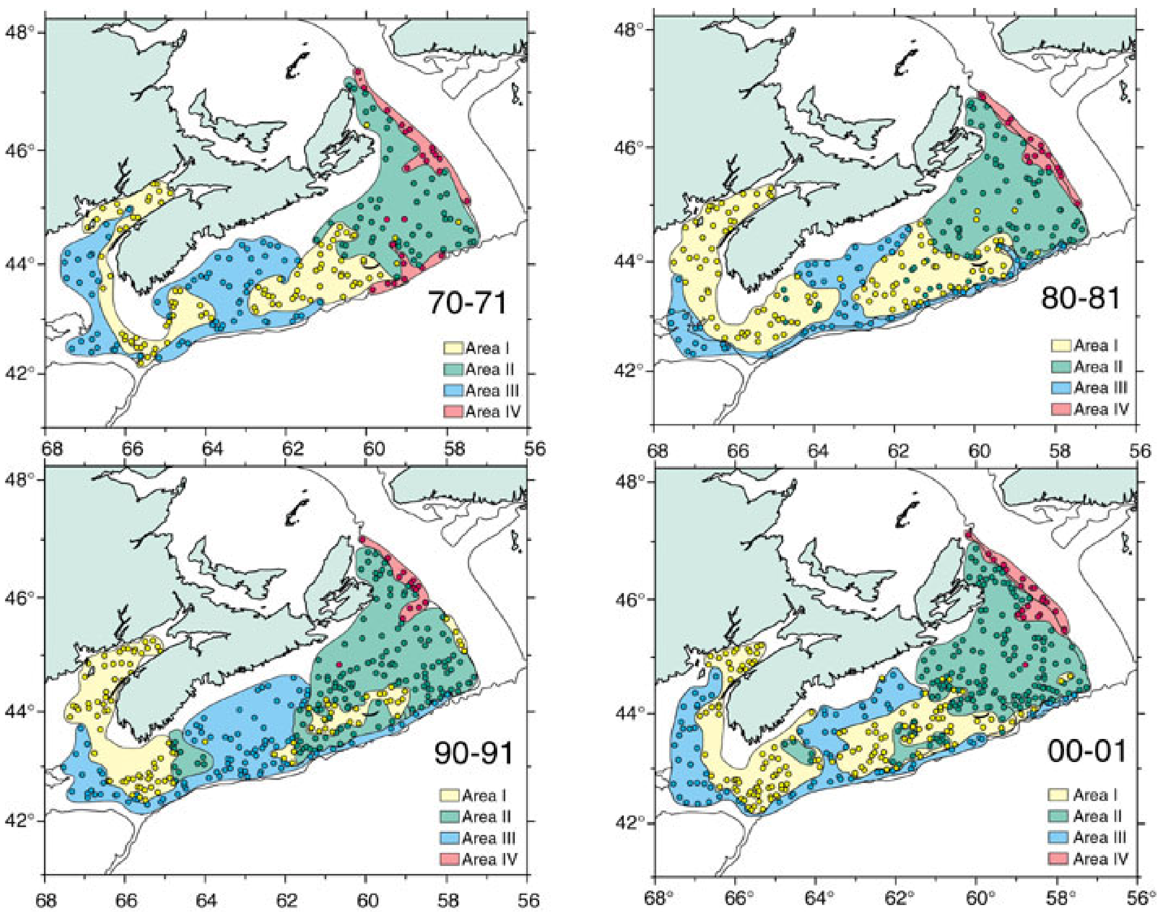

Figure 6. Map of groundfish assemblages (Zwanenburg and Jaureguizar, submitted 2005).

A comment was made that populations of snow crab and shrimp on the eastern Scotian Shelf have been increasing. This trend doesn't fit with the model. The response was that groundfish are cueing to the variables in the model, as well as other variables. The variables used in the model are helping to structure the groundfish community.

A slide was shown of biomass of all species, per standard tow, from the summer groundfish research vessel survey for 1970-1979 (Figure 7). In general, this shows more biomass per tow on the eastern Scotian Shelf than in the Bay of Fundy. The comment was made that there seems to be larger biomass in areas where the model is saying there is less food availability. It was noted that a previous look at the surveys had found that fish increase in biomass with latitude while benthos decrease.

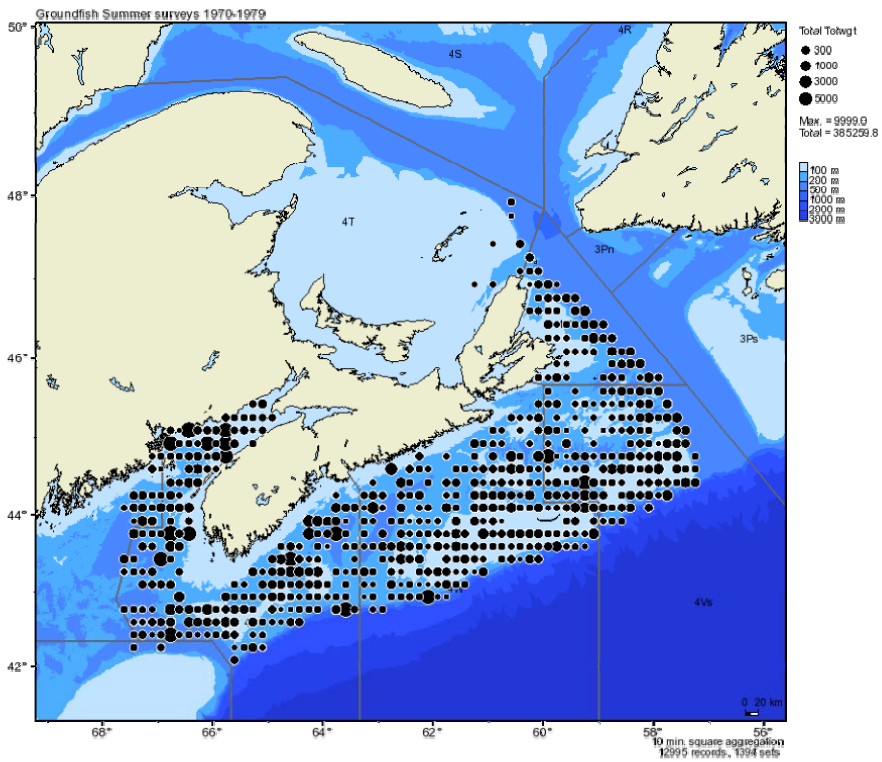

Figure 7. Biomass per standard tow, DFO summer groundfish research vessel survey, 1970-1979 (provided by Alan Sinclair, from Jerry Black).

The groundfish biomass map is important to consider in relation to the model. While groundfish are one level removed from the communities the model is supposed to map, they feed on benthic communities. It was mentioned that it would also be interesting to look at production rate rather than standing biomass to see if this apparent anomaly remains

An Alternate Model of Biodiversity

Tom Noji

Presentation Highlights

A section of a paper from GEOHAB 2005 was presented (Cogan and Noji, in press). It proposed a model that combines the elements of biodiversity - thematic, spatial and temporal – to form an ecosystem. The spatial scale ranges from landscapes to genes; the thematic elements of structure (e.g., complexity of habitats and community), composition (e.g., species, populations, genes), and function (ecological processes) operate within this hierarchy (Figure 8).

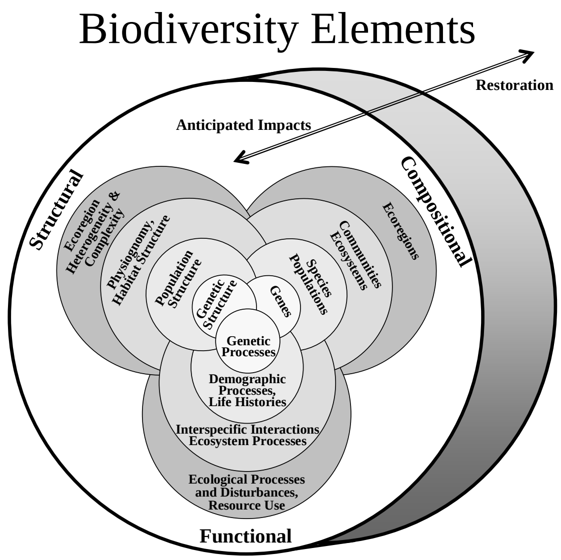

Figure 8. Diagrammatic elements of marine biodiversity showing multiple thematic scales (structure, composition, and function), multiple spatial scales (from outside to inner core of diagram), and multi-temporal dimensions which may direct a range of biodiversity applications from restoration to anticipated future impacts (Cogan and Noji, in press).

Diversity can be examined at many different levels, depending on what the concern is. Genetic diversity is important for some people. Should we be thinking about different levels of organization when we think about sensitivity? For example, genetic variability of individuals may be very important and may show impacts from anthropogenic stresses.
The intent of the paper is to indicate to managers what should be considered for marine protected areas and conservation.

Discussion

It was noted that various approaches to the organization of ecosystems have been developed, e.g., Jamieson et al. (2001), and all share many common elements. It was suggested that the method of organization itself is not critical as long as the main elements are included.

LIMITATIONS AND CONSTRAINTS OF THE APPROACH

The discussion suggested that the benthic classification model is in agreement with theory presented in other similar models and is describing large scale patterns of the benthic community in Scotia-Fundy Region that would be useful as a guide to management. It is a useful step forward in that it provides a theoretical basis supported by observation, a means to consider the sensitivity of habitats to human activities, as well as a way to organize our thinking on how benthic communities function and are distributed. It also could facilitate research prioritization. However, there is still uncertainty associated with some of the elements. The Scope for Growth axis, in particular, generated much discussion and suggestions for future enhancements, perhaps even annual consideration of model improvements. Notwithstanding this, it would be useful to look at the model from the perspective of how it can be used in its current form and what its limitations are for management purposes.

At the January 2004 RAP meeting, there was much concern about the Scope for Growth axis. Since then, this axis has been extensively investigated and now appears to be a useful concept to incorporate into the template. However, it has been difficult for the meeting participants to understand the impact of the different indices and weighting on the overall model. Notwithstanding this, there was agreement that the current formulation of the Scope for Growth axis was the best that can be done at the moment. It was reiterated, however, that at some point transport by currents should be added to the food availability index of the Scope for Growth axis. This is a limitation of the model.

Another limitation is that it is focused on life-history traits of benthic invertebrates. It cannot be used as a proxy for the distribution of species.

It is an equilibrium model – based upon nature before human intervention – but the current ecosystems are very disturbed and probably far from equilibrium. For instance, the food web on the Scotian Shelf has dramatically changed since the 1980s. The counter to this was that the equilibrium assumption would be a serious problem if the model is used for species; it however is used to map life-history traits. While the species composition might change, the model predicts that the same functional groups should be there.

A comment was made that some of the anthropogenic disturbances, e.g., hydraulic dredging for clams, may make it difficult to test the model. These changes would make it difficult to reach an equilibrium state. The response was that the template predicts what areas would take a long time to recover if disturbed.

It was suggested that it would be useful to account for the uncertainties in the model. For example, uncertainty in the maps could be colour-coded, based upon Monte Carlo simulation. The response was that different ways to map uncertainty were attempted. However, there are different types of uncertainty associated with each layer; this is difficult to quantify. This is a limitation of the current model. In lieu of this, it was recommended that the construction of, and uncertainties in, the final map product be well documented.

MANAGEMENT APPLICATIONS OF THE MODEL

Benthic Habitat Classification Model and Integrated Oceans Management

Tim Hall and Heather Breeze

Presentation Highlights

The 1997 Oceans Act gave a broader mandate to DFO in relation to oceans. It mandated DFO to lead and facilitate integrated management (IM) initiatives, and gave it the ability to create marine protected areas (MPAs) and develop regulatory standards for marine environmental quality. Canada's Oceans Strategy (DFO, 2002a) and the Policy and Operational Framework for Integrated Management (DFO, 2002b) gave further guidance on the implementation of the Oceans Act. The 2005 Oceans Action Plan (DFO, 2005a) makes further commitments in relation to Canada's oceans program.

Regionally, the two focal points for integrated management activities have been the Eastern Scotian Shelf Integrated Management (ESSIM) Initiative and the Bras d'Or Lakes Collaborative Environmental Planning Initiative. This year, an integrated management initiative will commence in the Gulf of Maine. The region has also been active in marine protected area planning and implementation (the Gully MPA, Musquash proposed MPA).

A draft integrated management plan (DFO, 2005b) for the eastern Scotian Shelf has been developed. The plan includes a series of ecosystem (conservation) and human use objectives. Activities are being or will be carried out in support of these objectives or other commitments within Canada's Oceans Strategy or Oceans Action Plan, including a Deep Sea Corals Conservation Plan, marine protected area system planning, identification of EBSAs, and depending on the results of this RAP meeting, the identification of sensitive species.

The ESSIM Planning Office coordinates and supports the integrated management process. The office brings groups together to discuss common issues of interest and also carries out and supports research to meet information needs, develops tools in support of integrated management, and seeks and provides expert advice. The ESSIM Planning Office has made efforts to develop decision-support tools for integrated management, with a focus on the spatial planning aspects of decision-making. Multiple factors are involved in making decisions, and complete information is not available. Decision-making tools provide a consistency of approach and a framework for decision-making. Some examples of decision-support tools using GIS were presented. When the information is relatively simple, basic overlays of activities and habitats may provide sufficient information for decision-making. For example, the extent of areas closed to bottom fishing to protect corals could be compared with the area proposed for a new bottom fishery. This is directly linked with the draft ESSIM objective: "Identify and protect coral communities in the Gully and Stone Fence areas."

More elaborate analyses are possible, for example, a risk matrix could be developed. Risk is defined as the interaction between the likelihood of an undesirable event occurring and the significance or severity of that event. A risk matrix defines levels of severity or significance, as well as levels of likelihood, and sets out management actions related to particular events.

For certain activities, it is necessary to aggregate information or analyze it differently to assess risk rather than simply to portray the spatial extent of the activity. For example, pelagic longline fishing uses very long lines (20 miles or more in length) that drift, yet only one latitude and longitude point is entered in the commercial landings database for each longline set. To better deal with the uncertainty in this data, it could be grouped to units of uniform size. In this example, the pelagic longline data were grouped to cells on a 4-minute grid; however, a larger or smaller grid may be considered more appropriate. By aggregating data, managers may also have a better indication of the importance of the area (e.g., sightings of turtles or marine mammals) or level of use by a particular activity.

Spatial analyses will look not only at interactions between the environment and human activities, but at interactions between different human activities. One such interaction – one that both parties wish to avoid – is the interaction between bottom fishing activities and submarine cables. Use interactions are linked to the draft ESSIM objective of reducing actual and potential multiple use conflicts. While a basic overlay of cables with bottom fishing activities may indicate obvious areas of overlapping activity, an analysis using defined criteria may result in better information for management.

To assist in making decisions, managers need information on the extent, impacts and vulnerabilities (or sensitivities) of human activities, and the extent and vulnerabilities (sensitivities) of particular habitats and species distributions. There are some activities at present to address these information needs, but more work needs to be done, such as on the impacts and extent of impacts of particular human activities, the distribution of sensitive species, EBSAs, etc.

Three options for using the benthic classification model in management were proposed:

1. Benthic protection based on the model (e.g., x % of habitat area type 1 to be protected, y % of habitat area type 2, etc.).
2. Activity-based zoning (e.g., no activities causing benthic disturbance in habitat area type 1, benthic disturbance allowed throughout habitat area type 3, limited benthic disturbance in area 3, etc.)
3. Planning using a variety of tools, including the classification model but also the distribution of sensitive benthic species, EBSAs, materials resulting from unpacking the ecosystem objectives, and other available information.

A multi-stakeholder workshop will be held in fall 2005 to further discuss the application of the benthic classification model to management.

Discussion

It was asked if critical habitat identified under the Species at Risk Act (SARA) fell under EBSAs. The response was that critical habitat for at-risk species would be considered another factor in identifying EBSAs.

A question was asked if DFO was required to take into account new stakeholders as a result of the Oceans Act. In response, it was suggested that involvement of new stakeholders was less of an issue then the fact that the traditional regulatory framework did not address inter group conflicts (e.g., interaction between fisheries and submarine cables).

It was asked how cumulative effects would be taken into consideration. In response, it was suggested that this could be considered through decision-support tools.

For the bottlenose whale sighting map, it was suggested that areas of low risk and areas with no observational effort be distinguished. In response, it was noted that GIS allows one to do this, e.g., colour areas with no data as blue to distinguish them from areas with data. It was asked if the Center for Offshore Oil and Gas Environmental Research (COOGER) data were used for the whale sightings map. They were not. It was pointed out that the interactions between northern bottlenose whales and pelagic longline fishing had a low risk tolerance. The response was that risk tolerance can be adjusted depending on management objectives. For example, for a species at risk, a low risk tolerance may be appropriate.

It was suggested that fuzzy logic would be useful in carrying out some of the analyses, particularly as the information becomes more complicated. For example, the benthic classification model could be combined with species information using fuzzy logic.

It was asked why a multi-stakeholder workshop on the model's application was proposed instead of a RAP meeting. A RAP provides science advice and if no science advice is being provided, then the meeting should not be a RAP. However, if the discussion will be on impacts of a particular activity on the environment and science advice is required in relation to that, then the meeting would be a RAP. The third phase of the benthic classification work may be advanced by a combination of different meetings. A comment was made that multi-stakeholder workshops are important, but DFO Science needed to address some of the questions about human impact and provide scientific advice on that. The international literature and studies in other areas can provide guidance on impacts. It was suggested that having a group of stakeholders discuss impacts will have limited value and that the multi-stakeholder workshop be held after a RAP. It was mentioned that a National Advisory Process (NAP) meeting on the impacts of fishing may be held in the fall. This may provide guidance for the Maritimes regional process.

A comment was made that management was going to have to be adaptive. What will managers do when version two of the benthic classification is produced in six months and version three in 18 months? What will happen as the map evolves? The response was that information is always changing, and decisions are made based on what is available at the time.

A question was asked about drawing boundaries – what if management lines were drawn based on the classification; could they be changed? Drawing lines is a management process: lines are not used to manage ecosystems; they're to manage human activities. We can be more confident about drawing lines in some areas than in others and perhaps considering probabilities of change for areas of the map would be a useful concept. It might be useful to say what areas we can be confident about that will not change in the short-term. The benthic classification model is only one tool in decision-making. Perhaps one day there will be a zoning map for the shelf, but we are not there yet. It was noted that in the US, managers (e.g., fisheries councils) are urging scientists to draw lines in relation to managing human activities. Scientists are reluctant to do this, since every six months or so there are improvements to individual models and we gain a better understanding of life history needs of individual species. It is difficult to say what would be the best model for establishing management lines – there may be one best model for one species and a different one for another. If we only offer a model that is changing all the time, it will be difficult for managers.

There were questions on the three options on the use of the benthic classification model. The first two showed distinct ways of how the model could be used, but the third option (using the classification as one of a number of tools) did not specify how the classification would be used. Will boundaries be set under the third option? The response was that all the characteristics of a particular area would be looked at, perhaps using planning areas to look at the characteristics. The benthic classification would be one of many characteristics.

It was asked what the final product would be: the flat map or the model? It was suggested that if the product is the model, then the expertise needs to be transferred to management.

The haddock box (Emerald-Western Bank juvenile haddock nursery area) was brought up as an example of how science information was used to set a boundary. This boundary has persisted even though there have been suggestions that it should be changed. Comments were made that management boundaries should be re-evaluated at some point using updated scientific information.

A comment was made that habitats change constantly. Even in areas where there are no or very few activities, habitats change. The benthic classification model seems to be more of a climate zone map like those used in gardening and does not respond to seasonal variations.

Some species will exist in all areas – they might not be happy in some of them, but they will be there. This tool will tell you what the climate will be but there are many other factors to consider. It could be used to identify areas where there may be long-term damage from human activities. But what's going on in the day-to-day weather might be more important to management than the climate. In response, while the model has 'climatic aspects', it incorporates more than that.

It was asked what part of DFO should be responsible for risk assessment – Science or Oceans? It would involve both branches as well as others. There are both ecosystem and socio-economic issues that are part of risk assessment; some aspects involve management science. It was noted that other government departments, e.g., Health and Agriculture, have scientists that are more involved in this field than in DFO.

Definition of Sensitivity and Relationship to Benthic Classification Model
Tana Worcester and Robert O'Boyle

Presentation Highlights

The protection of sensitive and significant habitats is an important focus of the Eastern Scotian Shelf Integrated Management (ESSIM) initiative. The draft 2006 – 2011 ESSIM IM plan identifies objectives to 'identify and protect' important and sensitive benthic communities (DFO, 2005b). Important benthic communities are those of ecological and biological significance and are the focus of an independent exercise from the current one. The present meeting is focused on sensitive benthic communities. Vlad's application of the Southwood model does not explicitly describe sensitive habitats but rather maps habitat in relation to Disturbance and Scope for Growth. Intuitively, there are linkages between this approach and sensitivity but these need to be explicitly investigated. It is first necessary to agree on a definition of sensitivity.

A number of organizations have considered the definition of sensitivity. The ICES (2002) working group on Ecosystem Effects of Fishing considered sensitivity as (based upon McDonald et al., 1996) a function of the structural fragility and tolerance of a habitat to disturbance. In 2003, the working group expanded this definition (adapted from OSPAR, 2003) to include recoverability. The Marine Life Information Network for Britain & Ireland (MarLIN) considered sensitivity to be a function of both habitat tolerance and recoverability. In general, current definitions of sensitivity include aspects of both recoverability and vulnerability, the latter composed of both structural fragility and functional tolerance to disturbances. It was proposed that sensitivity to an impact, be it natural or human, be defined as a function of recoverability (rate of response to an impact) and vulnerability (existing property or condition of the habitat). Recoverability is related to the physiological potential for additions (e.g., recruitment, growth) and losses (e.g., natural mortality) as well as perhaps to recolonization. Vulnerability is related to the properties of the species or habitat (e.g., body size and type, mobility) and its existing condition or state.

The relationship between sensitivity and disturbance (both physical and chemical) was discussed. MacDonald et al. (1996) described this as being linear, although this was questioned. How would sensitivity change with the level of disturbance? Cooke and McMath (2001) describe the relationship between chemical disturbance and sensitivity as non-linear. A threshold point is reached after which the physiological capacity to buffer disturbance is exceeded, again assuming that sensitivity changes with the level of disturbance. These relationships require further investigation.

Linkages between the identification of sensitive habitat and the identification of Ecologically and Biologically Significant Areas (EBSA) were described. Criteria for identifying EBSAs have been defined (DFO, 2004b) in which sensitivity is one component. Thus, it is possible to define sensitive areas that may not be significant according to the criteria for EBSAs and significant areas that may not be sensitive. The current meeting of identifying sensitive habitats will therefore inform the EBSA process.

Discussion

A participant drew attention to a recent paper that described diversity as having three properties: compositional, functional, and structural. Fisheries managers focus primarily on the functional properties; the habitat template appears to be more associated with function rather than structure. For biodiversity, the compositional properties are important. While Scope for Growth might be related to recoverability, this may not meet our needs for the protection of compositional diversity.

Comments were made that vulnerability appeared to be closely related to the Disturbance axis; however the Disturbance axis does not include the chemical sensitivity or tolerance aspect of vulnerability. It was suggested that this could be acknowledged as one of the limitations of the model.

A comment was made that human impacts should not be considered in the definition of sensitivity. Many papers refer to sensitivity in relation to human impacts, yet habitats can be sensitive to environmental factors. The response was that we are interested in sensitivity because of human impacts. We wish to know if an area is susceptible to irreversible change.

It was noted that the upper right corner of the benthic habitat template describes areas with the most sensitive communities. In this area, time to recovery is long. In terms of the sensitivity of the other three quadrants, the lower left corner has high recoverability and is the least sensitive. It was asked if the other two quadrants are in the middle. In response, the scope for growth axis is relevant for populations, while the Disturbance axis relates more to habitat.

It was agreed that recoverability is related to physiological processes but it is also related to population level processes such as recruitment, which is not obviously incorporated in the Scope for Growth axis. Regarding vulnerability, the fragility (structure) element of it works well with the Disturbance axis, but tolerance (function) does not. In response, it was argued that the term “fragility” is typically applied to structures, i.e., a shell or a coral can be described as fragile, but is not used as a property of the broader habitat, i.e., a sand community is not typically described as “fragile.”

The presentation noted that the condition of a habitat can be measured in relation to some desired state. Questions were asked about what would this desired state might be. Conceptually, if the impact stops, the habitat would return to this state; it thus implies the pristine state of the habitat. It was then noted that the assumption is being made that habitat can in fact return to some previously defined state. Would alleviation of an impact result in some form of recovery? Is there evidence that this has happened? Some felt that for the model to be useful in management there should be evidence to show that recovery can in fact occur. Some empirical studies have shown that when one disturbs a community, it can come back but in a different compositional state. There was then an extended discussion on the lack of evidence for recovery of the eastern Scotian Shelf cod population. It was offered that cod on the eastern shelf might not be expected to recover, according to the benthic classification model - the eastern Scotian Shelf is not a benign, stable area. In contrast, areas with high Scope for Growth will have potential for recovering populations. The level of disturbance to the cod populations was large and mortality was greater than the resource could sustain. It was suggested that these impacts have changed the underlying benthic system, particularly since trawling began in the 1940s and 1950s. In response, it was argued that the current benthic system is not considerably different than before. The fact that the population has not yet recovered does not invalidate the theory and the benthic classification model. There is good evidence that ecosystems can recover. Terrestrial systems take a long time to recover, but they do recover.

Comments were made on the characteristics of recovered communities. What could a disturbance mean to the properties of a community? As an example, after dredging, the most recoverable species may take over and the whole community might not recover. The model may apply to communities that have succession. The community might not come back to the same composition, but may come back to the same function. Animals that replace other animals should have the same traits as the one they replace. Rather than a community in terms of species, it’s a community in terms of life-history traits.

A concern was raised that it should be clearly stated that recoverability means the recoverability of life-history traits, not that the same community or assemblage would be there. The species that are there will have similar life-history traits to the species found there previously. Also, “recoverability” does not mean that recovery will definitely occur, simply that the conditions for recovery are better at one end of the Scope for Growth axis than the other. The potential for recovery is there.

It was reiterated that recoverability and vulnerability is in relation to populations, individuals and habitats. Biogenic structures, such as structure-building fauna, are not part of this. Habitat means the habitat of the physical seabed.

The comment was made that we appeared to be using different terms for the axes of the habitat template. Recoverability was being used for Scope for Growth, while vulnerability was being used for Disturbance. It was reiterated that recoverability and vulnerability may correspond to different axes at different organizational levels.

After considerable discussion, the group reached agreement on several items related to sensitivity. There was general agreement that sensitivity is a function of recoverability and vulnerability but that mapping sensitivity to the Southwood model is complicated. While the Scope for Growth axis generally relates to recoverability (except for physical habitat) and Disturbance generally relates to vulnerability, the correspondence between the recoverability and Scope for Growth axes on one hand and the vulnerability and Disturbance axes on the other may not be one-to-one. However, in general, adverse, stable environments (upper right corner of template) have biota that are the most sensitive while disturbed, benign environments (lower left corner) have biota that are the least sensitive. The upper left corner (benign, stable) is more sensitive to physical disturbance but is also more likely to recover quickly. The lower right corner (disturbed, adverse) is less sensitive to physical disturbance but slow to recover. The other two quadrants could not be ranked over one another: it depends on what is being considered. Figure 9 shows these properties as related to the template.

Scope for Growth
High ← Low

Disturbance High ← Low

High recoverability and High vulnerability to physical disturbance	**Low recoverability and High vulnerability to physical disturbance**
After disturbance, a community may recover quickly, but it may go through a number of semi-stable states and end up with a different species composition. Example: Bank top gravel habitats, such as the gravel lag on Georges Bank.	After disturbance, the community may slowly come back to the similar state. Some species may be lost because some populations may not recover Example: Deep sea coral communities.
High recoverability and Low vulnerability	**Low recoverability and Low vulnerability**
Communities are likely to recover quickly from disturbance and return to a similar state. Example: Communities dominated by scavengers and mobile species, such as on tops of banks.	Communities, while highly resistant to disturbance, will likely take a long time to recover once disturbed. Example: Slow growing species tolerant to physical disturbance, such as quahog communities on Banquereau Bank.

Figure 9. Predicted response of different benthic community types to (primarily physical) disturbance.

One of the main comments made was that the terminology was complex and it is important to define terms clearly and use them consistently. Also, we should not be inventing new definitions but using what exists. This point came up several times in the discussion.

Management Uses of the Benthic Classification Model

Following the presentations, there was a general session on the potential uses of the benthic classification model in integrated management. These focused on particular visualizations and mappings to facilitate interpretation by ocean managers.

Mapping

If we wish to know the relative stability of an area, this could be determined in relation to the point of highest stability and adversity within the template (i.e., the top right hand corner of matrix). Every other point on the template could be given a value relative to this as a Euclidean distance from the corner, with both axes weighted equally (Figure 10a). A map could then be plotted showing the likelihood of each point belonging to that set (nearness to the corner). Similar maps could be plotted relative to each corner of the template. The result would be a map of the likelihood of how much each point belongs to each of the four corners. The middle of the template is expected to portray areas of high diversity, so a map of distance from the middle might also be useful.

As another approach, the template could be divided into different quadrants and points could be mapped according to which quadrant they fall into (Figure 10b).

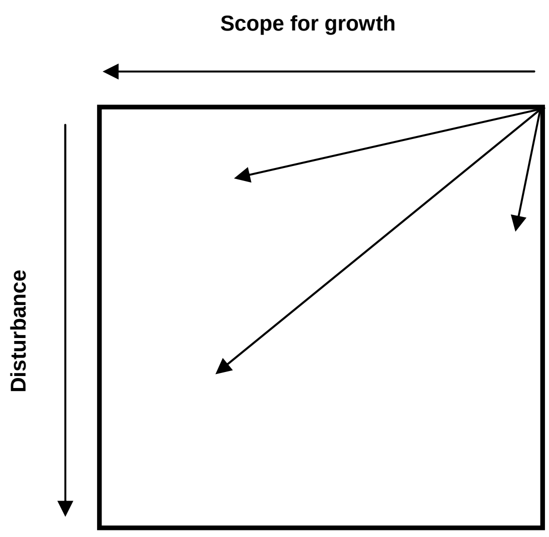

Figure 10a. Sensitivity as determined by the Euclidian distance from the top, right corner of the disturbance / scope for growth template.

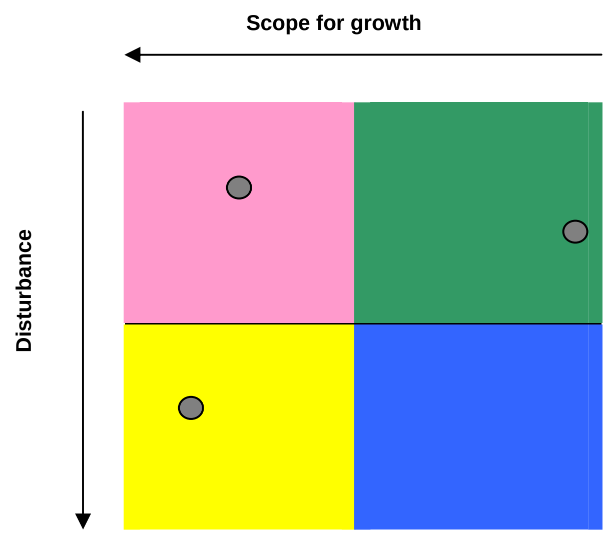

Figure 10b. Sensitivity as determined by location within a particular quadrant of the disturbance / scope for growth template.

The utility of the Euclidean distance maps was discussed. It was asked if ocean managers were satisfied with the maps portraying no zonation of sensitive areas. In general, it was felt that there were important characteristics related to each of the four corners of the template that were valuable for management to consider.

A map showing distance from the stable-adverse corner (lowest disturbance, lowest scope for growth) was generated. It was noted that the selection of the inflection points is critical to how the map appears. When mapped as equal area, the same amount of the shelf appears to be stable-stressed as disturbed-productive. However, a linear scale would show most of the Scotian-Shelf as stable-stressed (the scale went from 0 to 1.21 and only 1.6 percent of the values were between 0.53 and 1.21). It was suggested that this may be an artefact of how this particular map was derived, thus most of the points are found in the top-right corner (stable-adverse). Another map was created based on Euclidean distance from the top right corner (stable, adverse). This differed from the previous map in that the disturbance and adversity axes were log transformed, normalized 0-1. The breaks in the scale were by percentiles: 25th (i.e., 25% closest to the corner), 50th, 75th and beyond 75th. Hypothetically, the most sensitive areas would be within the 50th percentile (Figure 11). It was suggested that natural breaks be used instead of percentiles. This was done; however, it was noted that this was not a more valid way to divide the data because the data were not actual observations.

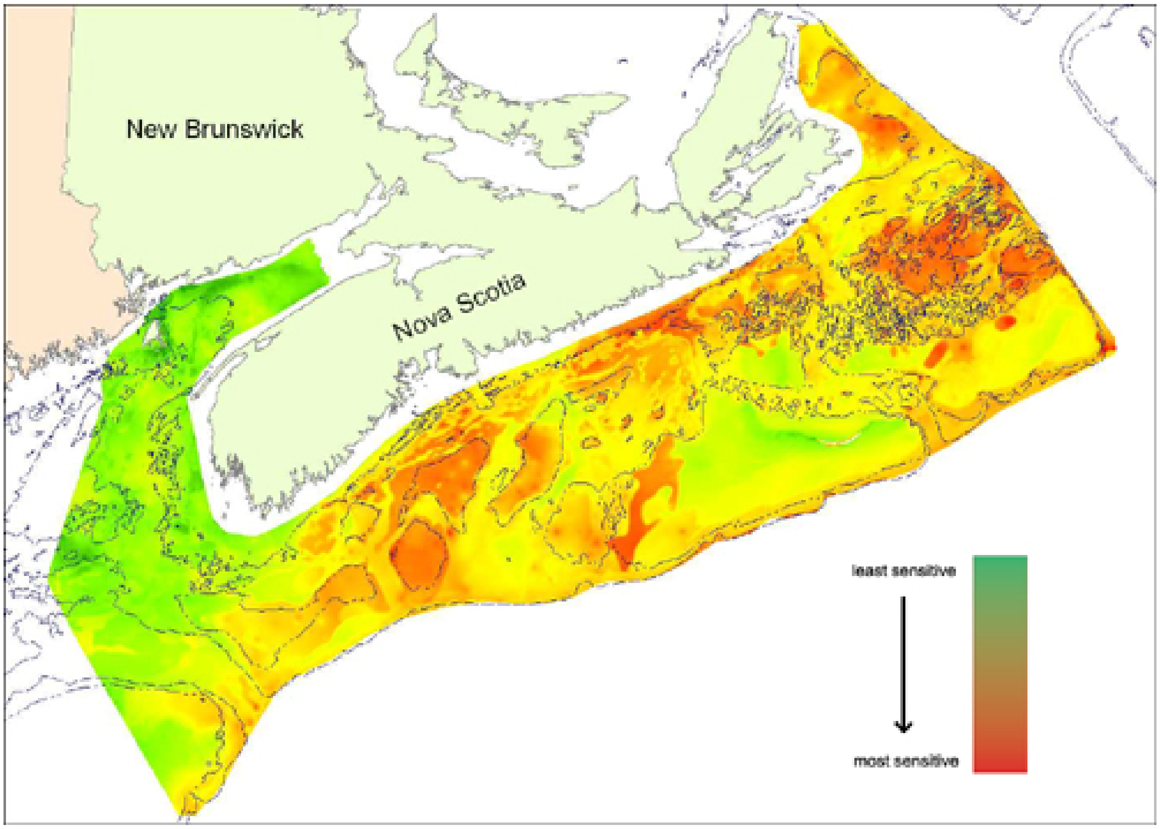

Figure 11. Habitat template, as mapped by Euclidean distance from stable-adverse corner.

It was suggested that the least sensitive areas (i.e., distance from disturbed benign corner of template) could also be mapped. There was some discussion as to whether or not this would be the inverse of the previous map; the result was the inverse of the previous map.

It was asked why all the coral areas did not correspond to the most sensitive areas on the map. The response was that they did show up as more sensitive than other areas. It was asked whether structures such as coral forests should be in the same area as other species groupings. In response, it was stated that this would not be the approach to take in mapping which areas are most likely to have a coral species such as Lophelia. The present map shows not only sensitive species, but habitats.

It was suggested that as the two axes provide different information, the Scope for Growth map and the Disturbance map should also be products of the RAP, separate from the combined map. A comment was made that there may be difficulties in using the model to predict vulnerability and recoverability. People will have expectations related to these words and there will be many exceptions. It was suggested that the concepts of recoverability and vulnerability seemed to work well and could be used separately in management. Areas that are considered highly sensitive are highly sensitive based on a combination of both axes. However, in some instances, we may be more concerned about recoverability than we are about physical disturbance, or vice versa. This should be considered by management.

Overall, how the maps would be used still needs to be worked out. Many different ways of portraying the habitat template on maps were discussed, such as different combinations of colours for the quadrants and different Euclidean distance maps. We may learn over time how best to use them. It was noted that many different maps could be created. A combined map could be made with four colours, each colour corresponding to a quadrant, and shades of each colour representing distance from the corner. As well, the Scope for Growth map and Disturbance map should be produced separately. In addition, there could be one or two examples of the Euclidean distance map. It was evident that no one map will answer all the questions; however, particular illustrations of how individual maps could be used would be helpful for oceans management.

Levels of Ecosystem Organization

There was a general discussion on how the two components of sensitivity (recoverability and vulnerability) apply at different levels of biological organization - habitat, communities, populations, and individuals. There was agreement that the level of organization (related to the structure of the ecosystem) was an important consideration in evaluating sensitivity. For instance, if one is considering the physical structure of a habitat, it has properties of both vulnerability and recoverability. For example, the sandy tops of banks are vulnerable in that they are easy to disturb, but they will recover. This also applies to the population level. At the level of individuals, fragility becomes more important. The community level is the most complex one to sort out. To aid conceptual thinking, a matrix was developed showing the relationship between vulnerability and recoverability (descriptors of sensitivity) and the axis of the benthic habitat template for four levels of organization (habitat, community, population, and individual) (Table 1). The cells corresponding to community were not completed at the meeting.

Table 1. Relationship between vulnerability and recoverability (descriptors of sensitivity) to disturbance and scope for growth (habitat classification) for four levels of ecosystem organization (physical habitat structure, community, population and individual).

	Physical habitat structure	Community	Population	Individual animals
Vulnerability	disturbance axis		scope for growth axis	interaction of two axes structure and body shape of animals
Recoverability	disturbance axis		scope for growth axis	interaction of two axes

Comments were made that management interest was probably at the level of communities in particular areas. It is difficult to see how the template will work for these. For instance, it does not appear to work well for the groundfish community, particularly as they may live in different areas corresponding to several different quadrants throughout their lives. Further, management is interested in conservation of communities and the application of the template for these. It was pointed out that communities are collections of species and individuals, which, from the template, will share certain life-history traits and thus sensitivity characteristics. As discussed earlier, this can be used as a general guide for management.

REVIEW OF STATUS REPORT

A draft status report was distributed which included points from the meeting's discussion. Changes to the report were agreed to with the following assigned to re-write sections of the report:

Management Context: Tim Hall and Heather Breeze
Description of the issue – sensitivity element: Tana Worcester and Bob O'Boyle
Description of model (equilibrium model): Vladimir Kostylev and Tom Noji
Energy equation: Vladimir Kostylev, Charles Hannah
Defining sensitivity: Tana Worcester and Bob O'Boyle
How sensitivity relates to the model: Vladimir Kostylev, Charles Hannah, Kees Zwanenburg, Nell den Heyer
Sources of uncertainty: Vladimir Kostylev, Charles Hannah
Domain of application: Tana Worcester, Bob O'Boyle
Conclusions and advice: Tana Worcester, Bob O'Boyle
Management considerations: Heather Breeze, Tim Hall
Examples of management applications: Vladimir Kostylev, Tim Hall
Glossary: Tana Worcester, Bob O'Boyle

A teleconference was to be arranged by the Maritimes RAP Office subsequent to compilation of the completed Science Advisory Report.

It was noted that data management was a critical issue that had not been addressed. It was recommended that a sub-group be formed to develop recommendations on data management in relation to the model.

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APPENDICES

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Appendix 2. Remit

Background

There are a number of human activities (e.g., fishing, oil and gas exploration) that can impact benthic community diversity. Maritimes Region initiated a RAP review in 2001 to provide fisheries and oceans managers with guidance on the management of these human activities. The three phases of the review include 1) investigation of potential benthic classification schemes, 2) classification of the benthic communities off Nova Scotia and 3) development of management approaches to ensure their conservation. To address the first phase, a RAP meeting was held 25 – 26 June 2001 (CSAS Proceedings 2002/023) at which various classifications approaches were discussed and recommendations made. The second phase included an initial RAP meeting 6 – 8 January 2004 (CSAS Proceedings 2004/004) to review a proposed benthic classification for the Scotia-Fundy and a follow-up workshop 7 – 9 December 2004 to investigate specific elements of the proposed classification. A final meeting is required to complete the review of phase II.

Objectives

The final meeting of RAP II has the following objectives:

1. Review of the benthic classification model
    a. Consideration of model enhancements
    b. Testing of model including tabulation of indicator species life history traits and comparison to model predictions
    c. Presentation of model limitations and constraints
2. Development of maps of the sensitivity of benthic communities to human impacts including
    a. Definition of sensitivity
    b. Characterization of sensitivity of different Scotia – Fundy benthic seascapes
    c. Zonation of Areas of Sensitivity

Products

- Status Report providing overview of benthic classification model and maps
- Proceedings reporting the discussion of RAP meetings
- Research Documents summarizing the technical basis for the conclusions in the Status Report

Participation

Participation will be by invite, based upon expertise and knowledge, and include the following:

- DFO Science, Oceans and Fisheries management
- NRCan
- External Experts
- Scotia – Fundy stakeholders

Appendix 3. Agenda

<u>20 July 2005 – Wednesday</u>

09:00 – 09:30 Welcome and Introduction (Chair)
09:30 – 12:00 Benthic Classification Model: Enhancements & Testing since January 2004
Presentation & Discussion

12:00 – 13:00 Lunch

13:00 – 17:00 Model Limitations and Constraints
Presentation & Discussion

<u>21 July 2005 – Thursday</u>

09:00 – 11:00 Definition of Sensitivity:
Presentation & Discussion
11:00 – 12:00 Sensitivity and Mapping of Benthic Communities to Human Impacts:
Presentation & Discussion

12:00 – 13:00 Lunch

13:00 – 14:00 Sensitivity and Mapping of Benthic Communities to Human Impacts:
Presentation & Discussion (cont'd)
14:00 – 15:00 Application of Model in Integrated Management: Presentation & Discussion
15:00 – 17:00 Zonation of Sensitivity Maps: Presentation & Discussion

<u>22 July 2005 – Friday</u>

09:00 – 12:00 Status Report Review

12:00 – 13:00 Lunch

13:00 – 15:00 Status Report Review
15:00 Adjournment

Appendix 4. Synopsis of Discussion on Day One of Workshop

Model

Theory

- Agreement that model was useful step forward
- Theoretical basis supported by observation
- Organizes thinking on how benthic communities function & are distributed
- Assist linkage to evaluation of human impacts
- Facilitates research prioritization

Data & Usage

<u>Disturbance</u>

- Improvements made to axis good; general agreement with derivation of disturbance
- Issue of frequency of disturbance

<u>Scope for growth (SFG)</u>

- Food availability
  - recognition that more work would be useful
  - current use of chl a /stratification debated; other suggestions provided (e.g., carbon loading) but these are not going to be available in short term
  - depth could be more easily used as proxy
  - current indicator of food availability provides general pattern; doesn't deal well with food transport
- Temperature
  - concerns of overweighting
  - suggestion to combine 2 measures of seasonal & interannual variability
  - overall current suite agreed to for current purposes
- New oxygen data
  - o good improvement
- Development of SFG indicator
  - discussion on weighting
  - do not have strong theoretical basis for weighting
  - current weighting accepted

<u>Testing</u>

- Nothing new since Dec 2004

Limitations and Constraints

- Focus of benthic inverts; doesn't deal with carbon transport well
- Equilibrium; may not be problem with functional groups
- No measure of uncertainty; need to have to judge robustness
- Anthropogenic change: limitation to testing of model

Next Steps

- Data management issues