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Workshop on the Maintenance of the Diversity of Ecosystem Types: Benthic Community Distributions of the Scotian-Fundy Area

7 – 9 December 2004

Atelier sur le maintien de la diversité des types d'écosystème : distribution des communautés benthiques dans la région de Scotian-Fundy

Du 7 au 9 décembre 2004

R. O'Boyle and T. Worcester

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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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TABLE OF CONTENTS

ABSTRACT

On 7-9 December 2004, a small group of scientists, managers, and academics met at BIO, Dartmouth, Nova Scotia, to review the theoretical basis of a proposed benthic classification system for the Scotian Shelf. Presentations were made on the Southwood model, progress to date on the application of this model to the Maritimes Region, and efforts to test the model using known species distributions. Presentations were also made on the ICES approach to defining sensitive species in the North Sea, as well as a proposal for identification of sensitive species and habitats in the Maritimes Region. There was general agreement that good progress had been made in both these areas but that additional work was needed. In terms of the benthic classification scheme, it was felt that alternative measures for the food availability index should be sought, relative weighting of input variables should be rationalized, and the limiting approach (as opposed to an additive approach) to data layer compilation should be pursued, including development of appropriate “flex points”. In terms of the sensitive habitats and species work, it was agreed that a consistent definition of sensitivity was required and that development of a sensitive species database for the Maritimes Region, building on international experience, would be useful for both science and management purposes. Concerns were raised about the length of time required to develop products that would be useful for management and the need to advise on conservation measures in the short-term. Participants made a series of recommendations on next steps, including suggestions to establish working groups to guide progress, to strength linkages with related regional and national initiatives (e.g. critical habitat for species-at-risk, ecologically and biologically significant areas, etc.), and to proceed with publication of results.

RÉSUMÉ

Du 7 au 9 décembre 2004, un petit groupe de scientifiques, de gestionnaires et d’universitaires se sont réunis à l’IOB, à Dartmouth (Nouvelle-Écosse) afin d’examiner la base théorique d’une proposition de système de classification benthique pour le plateau néo-écossais. Les participants ont entendu des présentations sur le modèle Southwood, sur les progrès accomplis à ce jour dans l’application de ce modèle à la Région des Maritimes et sur les expériences de mise à l’épreuve de ce dernier à partir de ce qu’on sait de la distribution des espèces. Ils ont également entendu des présentations sur l’approche du CIEM en matière de définition des espèces vulnérables dans la mer du Nord, ainsi qu’une proposition d’identification des espèces et des habitats vulnérables dans la Région des Maritimes. On s’est entendu sur le fait que des progrès importants avaient été réalisés dans ces deux domaines, mais que de plus amples travaux étaient nécessaires. En ce qui a trait à la classification benthique, les participants ont estimé qu’il faudrait rechercher des mesures de rechange pour l’indice de disponibilité de la nourriture, que la pondération relative des variables d’entrée devrait être rationalisée et qu’on devrait envisager une approche limitative (par opposition à une approche additive) à la composition des couches de données, comprenant l’élaboration de « points de flexion » pertinents. Pour ce qui concerne les espèces et habitats vulnérables, il a été convenu qu’une définition homogène de la vulnérabilité était nécessaire et qu’il serait utile à la fois pour les scientifiques et pour les gestionnaires d’élaborer une base de données sur les espèces vulnérables pour la Région des Maritimes, en se fondant sur l’expérience internationale à cet égard. On a soulevé la question du temps qu’il faudrait pour élaborer des produits susceptibles d’être utiles à la gestion, alors qu’il est nécessaire de donner des avis sur les mesures de conservation à court terme. Les participants ont présenté une série de recommandations sur les prochaines étapes, suggérant notamment d’établir des groupes de travail pour guider la progression des efforts, de renforcer les liens avec les initiatives régionales et nationales connexes (concernant, p. ex., l’habitat essentiel des espèces en péril, les zones d’importance écologique et biologique) et de publier les résultats obtenus.

INTRODUCTION

After welcoming participants (Appendix 1), the chair (R. O'Boyle) provided a brief background to the workshop. There are a number of human activities (e.g. fishing, oil and gas exploration) that can impact benthic community diversity. The 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 habitats 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 (DFO 2002) at which various classification approaches were discussed. The second phase was initiated with a RAP meeting on 6 – 8 January 2004 (DFO 2004) to review a proposed benthic classification scheme for the Maritimes Region, which was based on a model developed by Southwood (1977, 1988). The proposed classification scheme integrated a wide array of biophysical variables into two independent axes of *disturbance* and *adversity*, which were then used to delineate benthic habitat. Consensus on disturbance indicators was achieved at the January 2004 meeting but consensus was not reached on indicators of adversity, for which further work was recommended. The present workshop was to consider and discuss on-going scientific work as part of phase II of the RAP.

As provided in the workshop terms of reference (Appendix 2), the objectives were to consider and discuss:

- The Southwood model and the indicators used for the adversity axis
- Definitions of resilience and sensitivity used elsewhere
- Maps of benthic habitat distribution based on maps of the disturbance indicators overlaid with empirical observations of sensitive benthic species
- Comparison of the above maps with those produced using the Southwood model to further insight on modeling approaches to habitat mapping

The chair then reviewed the agenda (Appendix 3), noting that he would encourage on-going discussion and debate during the workshop and be open to changes in the agenda as deemed necessary. A list of documents considered and/or presented is in Appendix 4.

These Proceedings are the only product of the workshop. The workshop rapporteur was Tana Worcester.

SOUTHWOOD APPROACH AND APPLICATION TO MARITIMES REGION

The Southwood Model as a Basis for Habitat Classification
Vladimir Kostylev

Presentation Highlights

Three years ago, DFO Science Branch embarked on an initiative to classify the benthic habitats of the Scotian Shelf. At a RAP meeting held in January 2004 (DFO 2004), relevant biophysical variables for which there was available information and reasonable coverage across the Scotian Shelf were described and discussed in detail. The presentation demonstrated that there was no single factor that could be used to adequately characterize the Shelf's benthic habitats. Instead, a proposal was made to condense the most relevant environmental variables into two axes of *disturbance* and *adversity*, using theories developed by Southwood (1977, 1988). The benefits of this approach were thought to be its usefulness as a model for predicting the distribution of habitat types in the absence of extensive empirical surveys and as a management tool for evaluating the likelihood of benthic impacts associated with ongoing human activities. While the approach was supported in principle at the January meeting, additional work was suggested. The purpose of this presentation was to reintroduce the Southwood model, describe modifications made to the benthic classification scheme since the January 2004 meeting, and show preliminary results of model testing based on datasets available for the Scotian Shelf.

Southwood's approach is based on evolutionary theory, which suggests that the environmental conditions of a particular area may select for certain biological traits or life-history strategies over time. The two major forces that Southwood predicts will influence species' life-history characteristics are disturbance and adversity, where disturbance is a mechanical force while adversity can be described in terms of the energy that is available for a species to spend on reproduction and adaptation.

Southwood proposed that there are certain life-history traits (migration, defense, number of offspring, longevity and tolerance) that can be used to characterize groups of species and act as indicators of environmental condition (Figure 1). For example, long-lived and slowly growing species may be sensitive to disturbance, and are therefore considered more likely to occur in low disturbance (stable) environments. However, a species that reproduces frequently may be more immune to disturbance and therefore more likely to occur in a highly disturbed environment. It is important to note that Southwood did not attempt to map these different environments. Rather, he was designing a periodic table of habitats.

Disturbance Axis		Adversity Axis: Benign	Adversity Axis: Adverse
	Stable	Defense medium Migration low Offspring medium and small Longevity medium Tolerance low	Defense high Migration low Offspring few and large Longevity great Tolerance high
	Disturbed	Defense low Migration high Offspring many small Longevity small Tolerance low	Defense high Migration high Offspring medium large Longevity medium Tolerance high

Figure 1. Relative importance of different life-history tactics in various habitats as predicted by Southwood (1988).

Discussion

After the presentation, the discussion initially focused on whether or not species life-history traits determine the geographic distribution of species. Ecologists have differing opinions on whether or not this is a valid theory. It was felt that there is a difference between agreeing with the theory of optimization and agreeing that the Scotian Shelf is currently at some optimized state. For the Scotian Shelf, we are looking at a relatively recent colonization process (only 6000 years old). The distribution of species that we find now may not have anything to do with current environmental conditions. Also, when considering changes over time, we don't have to consider changes just over evolutionary time but also decadal changes, e.g. in temperature. It was noted that the Scotian Shelf may not now be in equilibrium or in an evolutionarily "optimum" state. The distribution of species on the Scotian Shelf does however reflect some pattern of colonization. Species occur where physical and biological conditions allow them to. In general, there was agreement that the distribution of species across habitat types will be influenced by their life-history traits.

Regarding Figure 1, it was felt that the grouping of traits in each of the quadrants was not intuitive. In particular, the relationship between adversity and defensive traits was not clear. In response, it was pointed out that these were intended as extreme examples.

Comments were made that it would be possible to find different species that are characteristic of stable and disturbed environments in a single location, e.g. Banquereau Bank. Species will have different ranges in tolerance to influential conditions, and what is benign for one species may be adverse for another. Given the difference in species responses to adversity and disturbance, there was confusion on how this model would help to classify habitat types. It was suggested to focus on those species which have narrow tolerance ranges, and to use these as indicators of habitat type.

The suggestion was made that the words "*benign*" and "*adverse*" be dropped, particularly as they might apply to species and not the habitat. Rather, the concept of overall community productivity should be applied. It was reiterated that the adversity axis was not meant to be subjective but rather that it is a measure of the energy available to the benthic species for production.

The comment was made that physiological forcing derived from physical factors would only be one determinant of species distribution. Competitive interactions may make species distributions different from what the model would predict. It was suggested that this model was just one way of organizing physical indicators for the purpose of generating geographic patterns. The hope was that by grouping physical indicators in this manner, emergent geographic patterns that are realistic for what we know about the Scotian Shelf might become apparent.

It was felt that one of the problems with using the Southwood model was its geographic limitations, i.e. lack of sensitivity to small-scale changes. Ideally, the model would be used to compare tropical with temperate regions. On the Scotian Shelf, there is a hint of biological response to the driving physical factors, but the differences between areas are subtle.

Application of Southwood Approach to Maritimes Region
Vladimir Kostylev

Presentation Highlights

Since the January 2004 RAP meeting, work has been undertaken to improve the data layers used as input into the benthic classification scheme and new approaches for combining and scaling the revised data layers have been developed. A summary of these revisions were provided according to the two axes of Figure 1.

<u>Disturbance Axis</u>

The indicators used in the model to determine natural physical disturbance to the benthos include: grain size, tidal bottom currents, and maximum significant wave heights and periods.

The grain size (mm) is an important indicator of disturbance. For example, highly disturbed environments on the Scotian Shelf, such as Sable Island Bank, tend to consist of well sorted sand. It was noted that the grain size (mm) data layer presented at this meeting was the same as that presented in January 2004; however, further improvements were underway. NRCan databases have been thoroughly investigated, bad data discarded, and additional analyses initiated. Through this process, three distinct, statistically well-defined textural classes have been identified for the Maritimes Region: 1) sand, 2) sandy gravel, and 3) sandy mud. There appears to be a correlation between these revised grain size classes and depth. However, there is poor correlation with the geological formations developed by Gordon Fader at BIO.

No major changes have been made to the tidal current (Residual Mean Square of the velocity in cm/sec) map as none were needed; it adequately captures the main current features within 10 m of the bottom. However, changes were needed to the wave – based current map. For the January 2004 meeting, the wave-based current had been mapped using the maximum significant wave height occurring on the Scotian Shelf during 1958-1999. This map showed the outer shelf to be more disturbed than the inner shelf, which does not agree with observations. Therefore, Charles Hannah ran Environment Canada's wave climate hindcast model using the detailed bathymetry available from CHS; the new wave-based current map is considered more physically valid. For example, it shows that the tops of the banks as more disturbed than previously calculated. The new wave and previous tidal current information was then combined to produce a new average current map. This shows that the outer banks and the Bay of Fundy are most affected by currents. Unfortunately, the results for the nearshore are not accurate, and thus are excluded from further consideration.

The next step was to determine how current is related to grain size. Major problems are encountered when modeling substrate mobility. For example, it is hard to model poorly sorted sediments. Most of the interest in sediments is in relation to those that are being eroded. Therefore, a current velocity of 50 cm/sec (upper limit of Hjulstrom diagram) was chosen as the threshold to produce a critical current (cm/sec) map. This is based on the assumption of well-sorted sediments.

Finally, the new disturbance map was produced as the ratio of the observed / critical current. It would have been possible to subtract the critical from observed current, but the ratio estimator provides a finer level of detail.

Adversity Axis

It was reiterated that adversity is a measure of the physiological stress on an organism to grow and reproduce. Thus, it is a measure of the amount of energy that an individual needs for physiological growth and reproduction. The more adverse the habitat, the more energy needed to maintain physiological processes. The indicators of adversity (temperature, salinity, chlorophyll a, and stratification) are representative of stresses on different aspects of the physiology and are thought to be the primary factors influencing adversity in the Maritimes Region's offshore environment. To assist in understanding the meaning of the adversity axis and facilitate inter-regional comparisons, it is instructive to utilize the physiological energy equation to relate the indicators to adversity (Figure 2).

Physiological Energy Equation

Production = Ingestion – Respiration – Feces – Excretion.

Relationship to Indicators

Component of Energy Equation	Process & Example Indicators
Ingestion	Food availability (chlorophyll a & Stratification)
Respiration	Metabolic rate (temperature & oxygen saturation)
Feces and Excretion	Osmoregulation (salinity)

Figure 2. Physiological Energy Equation and its relationship to environmental indicators used in determining habitat adversity.

Food Availability is obviously an important indicator of physiological stress. Two indicators were combined to provide an index of food availability to the benthos in the study area: spring chlorophyll a concentrations and the sigma-t difference between surface and 30m water depth. Chlorophyll a concentrations (mg/m^3) in the spring were used as a measure of production because in offshore areas, phytoplankton provides the greatest contribution to primary production. While data are available for the whole study area, nutrients from the spring peak were considered most likely to reach and therefore influence the benthos. The sedimentation process is influenced by stratification and thus the sigma-t (density) difference

(kg/m^3) between the surface and 30m water depth was selected as an indicator of stratification during July-September. This period was used as it was thought to be the most likely quarter during which the spring bloom was being transported to the benthos. Data were taken from the BIO data archives.

Bottom temperature (degrees Celsius) is generally depth related. Three separate indicators of bottom temperature were utilized: 1) average annual bottom temperature, 2) seasonal temperature range, and 3) interannual temperature variability. Few modifications were made to these indicators since January 2004.

The use of salinity (ppm) as an indicator of adversity (influence on metabolic cost) was debated in January 2004. Maps of salinity distribution on the Shelf are based on oceanographic models and are well correlated with depth and temperature. This information is not expected to be controversial. However, salinity was not thought to be influential on the Shelf and thus was not used to create the new adversity map.

Oxygen saturation (%) information for use in the adversity map was explored with the help of Peter Strain. Observations from the BIOCHEM database (approx. 30,000 samples) were used with some analysis and extrapolation. The limitations of these data were acknowledged, including its age, the lack of bottom depth information for many samples, and the variability in collection methods and seasons. As a result, there may be inconsistencies related to seasonal and annual variation.

Two methods were considered to combine the adversity indicators. The first is the 'Additive Approach '. In order to combine the different indicators (chlorophyll a, sigma-t, temperature) into a single adversity map, each was related to adversity using a linear approximation (Figure 3; scale from 0-1). Once each of the indicators had been converted into comparable and unitless measures of adversity, these were then combined additively and averaged: Adversity = average (Aa, Ab, Ac, Ad, Ae).

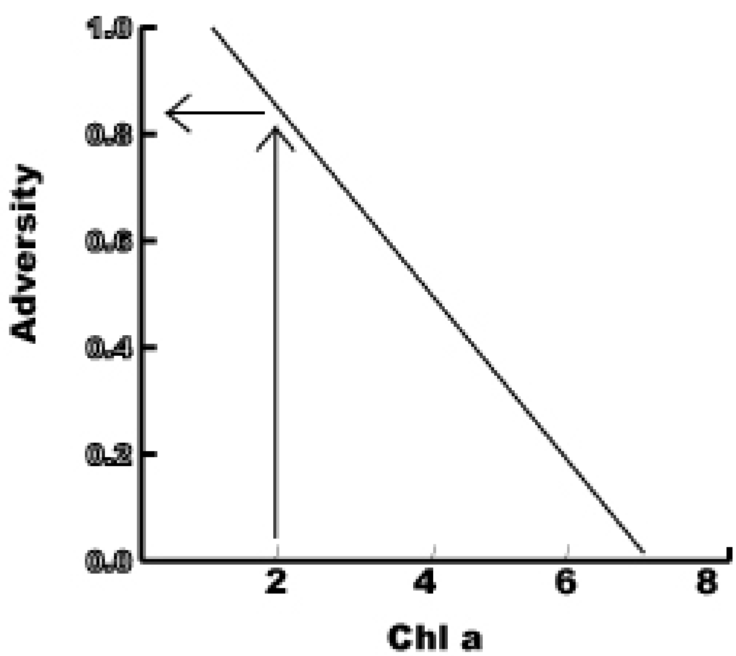

Figure 3. Relationship between adversity and chlorophyll a.

A problem with the additive approach is that it doesn't take into account limitations that each indicator separately places upon the organism. Using the second 'limiting approach' might be more ecologically meaningful. In the limiting approach, rather than adding the independent measures of adversity, they are multiplied and subtracted from one: Adversity = 1 – (La*Lb*Lc*Ld*Le). This allows the indicator which is the most restrictive in terms of adversity to dominate. Using the limiting approach, the model still displays a pattern of adversity from east to west across the Scotian Shelf; however, there are some differences from the additive approach. For example, using the limiting approach, more of the Gulf of Maine is rated as benign.

Mapping Adversity versus Disturbance

To produce the final benthic classification map (Figure 4), the results of the disturbance and adversity calculations are combined and mapped across the Maritimes Region.

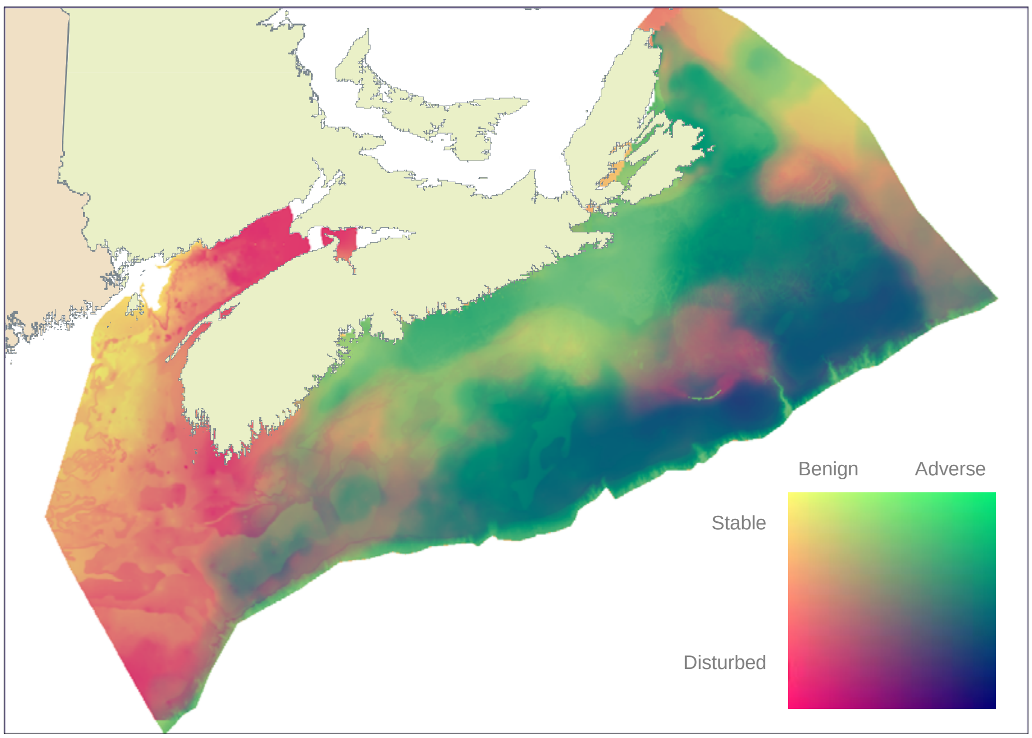

Figure 4. Classification of Maritimes Region Benthic Habitat based upon Southwood Model.

For discussion purposes, Figure 5 is used to describe the four extremes in habitat type.

Adversity
Low → High

Disturbance High → Low		
	Benign and Stable	Adverse and Stable
	Benign and Disturbed	Adverse and Disturbed

Figure 5. Intersection of Adversity and Disturbance: the four extremes.

It is important to recognize that these cells don't represent four distinct habitat types, but rather the extremes in a continuum of habitat characteristics. An example of a disturbed and benign habitat would be Georges Bank, where there is relatively high level of productivity and mixing. Adverse and stable habitats may be found on slopes and in canyons, where there *may* be relatively lower levels of productivity and bottom mixing. The inner Shelf appears to be a mix of habitat types. Differences between Western and Sable Banks appear to be related to the level of disturbance rather than adversity. A large proportion of the Maritimes Region is characterization as stable and adverse.

Discussion

There was a question on why an aggregated as opposed to individual map layer approach was needed. It was responded was that the alternative would result in multiple maps, which would be difficult for managers to interpret and apply in a consistent manner.

The rest of the discussion is provided below as per the axes of the Southwood Model.

<u>Disturbance Axis</u>

The comment was made that a lot of the variability in the disturbance map appeared to be strongly influenced by the grain size data layer. Discussion ensued on the characterization of grain size on the Scotian Shelf. Three processes control grain size: 1) flow conditions, 2) history, and 3) supply. History and supply were seen to be responsible for the conditions observed on the Scotian Shelf. The Scotian Shelf is characterized as sediment starved, erosional, and dominated by the presence of glacial till. There was a comment that grain size would not only indicate the level of disturbance of an organism but also the ability of the organism to burrow. It was felt that grain size should also be used in the adversity axis, but consensus was not reached on this point. A question was asked about how boulders were classified. It was responded that the data were collected using grab samples, so boulders would not be sampled, although boulders would fall into the "sandy-gravel" category. It was then queried how bedrock was classified. There is no information on bedrock in grab samples and the model assumes that there is sediment everywhere. There may be bedrock in areas of steep relief, e.g. in the Gully but most of the Shelf is unconsolidated. Areas that are not covered in sediment are important ecologically but are not shown here. It was asked whether a map of areas known to consist of hard bottom would be a useful addition to the model. It was suggested that a crude way to do this would be to compare a sediment map with a multibeam map, where available, and estimate the percent coverage of the Scotian Shelf by bedrock. In response, there were no plans to trace every multibeam for bedrock. It was suggested that this might be a more pressing issue in the coastal environment. A question was asked about potential deposition areas on the Scotian Shelf, e.g. the Gully, and whether these would be indicated in the final map. Such areas would not be readily apparent in the final map. It was noted that there were no major sediment inputs into this system, though some sediment transport was expected from St. Lawrence estuary. Sediments are accumulating in places like Emerald Basin. It was acknowledged that this model only considered deposition of inorganic matter, not organic matter. Neither is resuspension of material taken into account. There was general agreement that the efforts to revise the grain size information, which has not been incorporated at this point, should be utilized in the model.

A question was asked about the wave driven as opposed to the tidally driven current. In response, there is agreement that these are different types of disturbances with different temporal scales; however, the method used represented the best available information at the present time. It was mentioned that if one removed the extreme observations in the upper Bay of Fundy, more variability and pattern would be seen on the rest of the Shelf. If a different scale is used, it would also show more variation. The response was that, in general terms, the current map was adequate. If the scale was altered, the map would show more fine-scale variability, but this would not significantly affect the utility of the model in management. Revisions to this data layer would depend on the provision of additional data.

It was asked whether the disturbance map represents average steady state or whether it includes extreme events, e.g. hurricane conditions. The response was that the wave data were generated from daily observations and thus included extreme events. Discussion followed on how extreme events can impact benthic communities, including examples from Western and Grand Banks. Observational data on Western Bank after hurricane Juan showed that there were some changes observed but the background pattern remained. In the Grand Banks experiment (three years of data), interannual variation was observed. When a storm passed through, it completely changed the bottom. It was reiterated that the existing model uses the average of 90% of wave height and that using a different methodology would not generate a different pattern. Species abundances may change after an extreme weather event, but it would still be the same community type.

A question was asked on the level of confidence in the disturbance map. The results are dependent upon the quality of data that went into creating the data layers, which was considered to be adequate for these purposes. Some fine scale modifications may have to be made, but this would not be expected to change the overall, broad scale patterns. Discussion ensued on the relationship between the model results and participants' personal experience with and understanding of the Scotian Shelf. There was surprise that Banquereau Bank was shown as a "disturbed" environment, and suspected that this was related to the presence of gravel. It was also surprising that there wasn't more disturbance on Georges Bank. It was asked why there was not more structure to LaHave Bank. It was replied that this structure was captured by the model, but that the map scale selected was not able to display this level of detail. Discussion ensued on the ability of the map to convey fine-scale variability, such as demonstrated in the grain size data layer, and suggestions were made for possible improvements. For example, one could use the log of ratios, which would be symmetric around zero. It was replied that a linear scale was selected for presentation purposes to better demonstrate the relative importance of various data layers used to generate the disturbance map. In addition to being concerned about how the results of the model are portrayed, there should be care taken to ensure that the use of the data layers (relative weighting, etc.) reflects the importance of various physical processes in the distribution of benthic communities. It was asked whether the map represented the ratio between what we find and what we expect to find, i.e. variability from the mean that we would expect. The response suggested that the map represented the temporal persistence of structure, i.e. if you were to examine the Scotian Shelf in a thousand years, the places that changed the most would be the ones displayed in red (most disturbed).

A concern was raised that the disturbance map did not adequately convey the frequency of disturbance events, i.e. that there was no temporal dimension to the model. Disturbance frequency would play an important role in the ability of organisms to recover after a perturbation (recovery time). It was suggested in reply that the temporal component of disturbance is captured through use of the critical current.

It was mentioned that the disturbance map only portrays natural disturbance and that we need to compare this to human-induced disturbance. The data exists to consider human disturbances; however, it may be difficult to convert these into units that can be compared with natural disturbance. It may be possible to use energy as a comparable measure of disturbance, though chemical impacts may be difficult to translate into energy units. Discussion ensued as to whether one could calculate fishing disturbance for 500 m squares across the Shelf, which is the spatial resolution of the model. This method has been applied by Dave Kulka and independently this method has been applied and reviewed for Georges Bank. It has been suggested that at least 50 different variables are important in determining fishing disturbance. The frequency of impact is also an important consideration. In response, it was suggested that the model has some predictive power in terms of what effect human activities might have as compared to natural disturbance.

Adversity Axis

Concern was expressed that the high levels of suspended sediment observed in the Bay of Fundy may interfere with analysis of the chlorophyll data. The results for the Bras d'Or Lakes were also questioned. It was replied that the fine-scale variability displayed in this data layer may not be an accurate reflection of reality, as there are still problems with data quality. It was commented that the model resolution ($500m^2$) was a quarter of the resolution of the remote sensing methods used to derive chlorophyll. A question was asked on the relationship between chlorophyll a and the benthic community. Chlorophyll a is used as an indication of primary productivity, which is transported to the seafloor to become food for the benthos. The link is weak but the flow of organic matter to the bottom has not been measured or modeled for the Scotian Shelf and thus chlorophyll a was chosen as a proxy for productivity in the offshore. For the inshore, there is a need to consider macrophytes and other sources of primary production. It was queried why the spring peak of chlorophyll was used instead of annual estimates (totals or averages). In previous discussion, it was agreed that the spring peak correlated better than other seasons with the delivery of food to the benthos, since spring rates are "leakier." However, it was acknowledged that this might be more applicable in the Gulf of Maine where there are high rates of production year round. It was then asked if zooplankton has a role in the food supply for the benthos, for which data is available. The timing of the zooplankton biomass in relation to phytoplankton blooms would need to be taken into consideration. It was felt that the patterns in the distribution of benthic habitat types would not likely change as a result of these considerations.

There was general consensus that the sigma-t data layer provided a good representation of stratification on the Scotian Shelf. There was a discussion on the use of stratification as an indication of the transport of organic matter to the benthos. Where there is mixing, one typically sees good transport to the bottom. However, this doesn't take into account classic sedimentation processes.

Regarding the overall measure of food availability, concerns were raised about the combination of summer stratification with spring chlorophyll a as the indicator for transport of organic matter to the benthos. If the spring phytoplankton bloom is of primary interest, using summer stratification may be too late as the spring biomass may reach the benthos well before July. An additional concern was expressed about the additive approach to combining these data layers. It was suggested to use an average sedimentation rate to indicate flux of organic matter to the benthos, particularly since it may be difficult to predict where surface organic matter may reach the seafloor. It was replied that some indication of surface biomass production would still be required. While the distribution of deposit feeders may be a good indicator of food availability, this distribution is in fact what the model is trying to predict. However, known locations of deposit feeders could be used as a test to validate the model. It was agreed that further development of the "food availability" indicator (or indicator of organic matter transport to the benthos) was required, and it was suggested that Ocean Sciences Division be engaged to provide additional expertise and advice.

The comment was made that temperature influences the growth of benthic organisms, that there may be changes in temperature over decadal timescales, and that it might be interesting to study benthic communities in relation to temperature changes over a 10-20 year period. It was asked if summer maximum temperature is a potential limiting factor to growth, e.g. for scallops. It was replied that information on summer maximum temperatures had not been readily available, so it had not been used in this model. A question was raised as to whether the temperature ranges experienced in the Maritimes Region would be adverse enough to influence the distribution of benthic communities across the Scotian Shelf. In the intertidal zone, temperature ranges can be very extreme. For subtidal organisms, temperature is not as much of a limiting factor. Generally, the deeper, the more stable temperature is. The tops of banks may experience some fluctuation but at 300m, one would expect very little fluctuation. It was replied that that temperature range is not typically a lethal factor, but it does influence the metabolic cost of normal functioning and thus its inclusion in the adversity axis.

A question was asked as to whether salinity was considered important in influencing the distribution of benthic communities offshore. In response, salinity is strongly related to temperature in this region and thus could be considered as another proxy for temperature. While salinity may influence normal metabolic functioning, it was agreed that salinity would play a more important role in the coastal zone.

Concerns were expressed about the small-scale variability in oxygen saturation that is generated by the model, which may not accurately reflect the level of spatial resolution that can reasonably be extrapolated from the data. Clarification was requested on the definition of "bottom" for the purposes of this data layer, and whether the data layer was derived entirely from empirical data. The responsible scientist indicated that data included samples taken within 10 m of bottom (or the lower 4% of total depth), and that while the data layer was based upon empirical data, some extrapolation and modeling had been used. An analysis had also been conducted for silicate, which might help to explain the distribution of glass sponges. It was asked about why oxygen saturation was used instead of oxygen concentration. The scientific expert indicated that oxygen saturation seems to be more important physiologically. A comment was made that oxygen saturation may be a more limiting factor for demersal fish species than for infauna, which typically have high tolerances for low oxygen conditions.

There was discussion on the ‘additive’ approach in the combination of the adversity information. Concerns were raised about the use of a linear scale for the adversity map. Expectations were that adversity would best be represented by a bell curve for most parameters, i.e. high and low values would be adverse while middle values would be benign. It was reiterated that adversity was not a subjective measure of environmental conditions, which might vary from species to species. Rather, it was meant to represent the energy available for growth (scope for growth), which would be a linear measure. Concerns were also raised about the relative weighting of data layers used to generate the adversity map. It was felt that chlorophyll a and sigma T should not be added separately, but rather that a single indicator called “food availability” should be utilized. There was concern that temperature effects were over-represented by the inclusion of three separate data layers related to temperature. It was agreed that a logical and conscious approach should be used when weighting the relative importance of data layers. It was noted that if one removed the oxygen saturation data layer, one would see less small-scale variability in adversity across the Scotian Shelf.

Regarding the ‘limiting approach’, it was felt that it enhanced how adverse habitat of the Scotian Shelf was compared to the additive approach, while Georges Bank remained benign. This seemed to correspond with what we know about the productivity of these areas. It was reiterated that, for bivalves, the maximum summer temperature would be a limiting variable. It was generally agreed that the limiting approach was a more logical and biologically meaningful approach to the development of an adversity map. The use of “flex points” was seen to be useful in fitting the model to reality.

Discussion ensued on the term “adversity.” It was suggested that it be replaced with the term “scope for growth” to better reflect the intent of the axis. Concern was raised that the adversity component of this benthic classification model encompassed a large range of variables, and that it was still unclear how these variables were related. This would make relative weighting difficult. It was suggested that more use be made of the physiological equation as a way of organizing and explaining the role of each variable used as an indicator of scope for growth. A suggestion was also made to investigate global variation in the ranges of variables selected, plug these into the energy equation, and come up with an absolute scale. It was asked as to whether any variables were missing from consideration, e.g. current parameters are of primary importance to animals, and new ones, including parameters relevant to plants, may be required for the coastal zone.

Suggestions included:

- Contaminants - could be a physiological stress or energy source, some are distributed shelf-wide; however, are a human input so may not be applicable for this model
- Particulates – shelf-wide information not thought to be available
- Rugosity – could represent a positive contribution of structure, but bathymetry data is not considered adequate. Slope may be easier to calculate but is a different concept
- Nitrogen – understanding how nitrogen supply effects spring bloom is limited, could potentially used in calculations of food availability index but not as an independent variables
- Silicate – could be important for distribution of glass sponges
- Light – may be more relevant in the coastal environment

It was noted that Southwood's third axis of species interactions is not explicitly addressed within this model, i.e. there are no maps showing the likelihood of competitive interaction, as these interactions can not be predicted based on physical factors. The suggestion was made to use biodiversity as a possible indicator of species interaction. Metrics of biodiversity could potentially be used as input to the model or as a test of the model.

There was discussion on the limitations of mapping model output, particularly with regards to the portrayal of uncertainty and temporal variability. It was replied that every data layer has uncertainty associated with it; however, the overall variance could be potentially be calculated and described. A suggestion was made to generate a data layer that portrays the distribution of variance.

A discussion of alternatives to the proposed benthic classification model included suggestions and rebuttals as follows:

- Draw lines around bathymetry – depth is only one variable that influences the distribution of benthic habitat types
- Provide individual data layers without further integration – would be difficult for managers to apply in any consistent manner
- Provide a selection of models and maps for use by management – see comment above
- Use a sensitive species approach rather than model habitat
- Map community types directly – this may be possible in areas where multibeam data is available; however, there is not adequate information available for the Scotian Shelf

In conclusion, it was agreed that using the proposed benthic classification model would make decision-making processes more transparent and defensible by providing a single, unifying approach. It was also generally agreed that while Southwood's theory formed the basis of this benthic classification model, the model was not dependent on it. Therefore, one did not have to support Southwood's theory in order to utilize the model developed from it. A suggestion was made that while the model itself may not represent an adequate ecosystem model, it may prove useful in identifying predictive variables. It was acknowledged that disturbance and physiological processes aren't the only processes that influence biogeography; however, we do not have sufficient data on processes, such as species competition, to readily incorporate these into the model. It was acknowledged that physical factors that limit species distribution on the Scotian Shelf, e.g. temperature on eastern shelf, may not be limiting in other places.

Testing of the Southwood Model

Vladimir Kostylev

Presentation Highlights

Aggregate biological characteristics, such as turnover time and total biomass, were extracted from various DFO databases and mapped across the Scotian Shelf. These characteristics were compared to the disturbance / adversity map described above to evaluate if the predicted patterns were observed.

Average turnover times across the study area were calculated using thirteen species whose distribution and sampling densities provided good coverage. Average turnover time was calculated as the ratio of respiration to biomass in calories. However, comparison of average turnover times with the disturbance / adversity map yielded no clear patterns. Thus, no clear relationship between turnover time and adversity / disturbance could be established.

Total biomass was considered as a potential indicator of benthic well-being. In comparison to the adversity / disturbance map, minor patterns were detected. For example, the biomass of small, rare species tended to increase in stable, benign habitats. Polychaetes tended to be more ubiquitous, with a slight increase in adverse habitats. Crustaceans seemed to be more likely to occur in benign habitat, while echinoderms were more likely to occur in adverse environments. However, overall, no clear relationship between total biomass and adversity/disturbance could be established.

In order to evaluate the spatial uncertainty in model predictions of benthic habitat type, a Similarity Analysis was conducted to compare empirical data from a variety of databases to the disturbance / adversity model results. The Similarity Analysis was conducted on a number of DFO and NRCan databases, including NRCan photo stations, NRCan grab samples, DFO grab samples, and DFO multispecies survey stations (limited to the 80 most abundant species recorded) (Table 1).

The distributions of sample species were compared to the distribution of habitat types as predicted by the model. In general (Figure 6), the following species tended to be located in the following “habitat types.”

- Snow crab, flabellum, brachiopods: stable, adverse
- Potamilla: stable, benign
- Scallops: disturbed, benign
- Sand dollars, mactromeris: disturbed, adverse

However the range of habitat types occupied by a particular species was found to be quite broad in most cases.

Table 1. Overview of Datasets used in Testing Application of Southwood Model to Maritimes Region.

Database	**Spatial Scope**	**Comments**
NRCan Grab Samples	Misaine, Georges Bank, SW Nova	Frequency of occurrence of species per station was assessed; samples covered large range of adversity types (as determined by the model); samples did not provide much range in species richness
DFO grab samples	Banquereau, Sable Island Bank, Western Bank and Emerald Bank	Grouped samples from Western Bank together, samples from Sable Bank together, and differentiated between two groups from Banquereau Bank; temporal variations were less pronounced than spatial variations
DFO Sable Island Bank survey	Sable Island Bank	Similarity between stations seemed to correlate better with habitat type (based on model predictions) than on proximity; similarity between stations decreased quickly with distance; appeared to be relationship between species richness and disturbance
NRCan Photo stations	Patchy distribution across Scotian Shelf, no samples from Georges Bank.	Biomass of select species was extracted from NRCan photos and compared to disturbance/adversity model; samples appeared to cover large range of both adversity and disturbance types (as determined by the model)

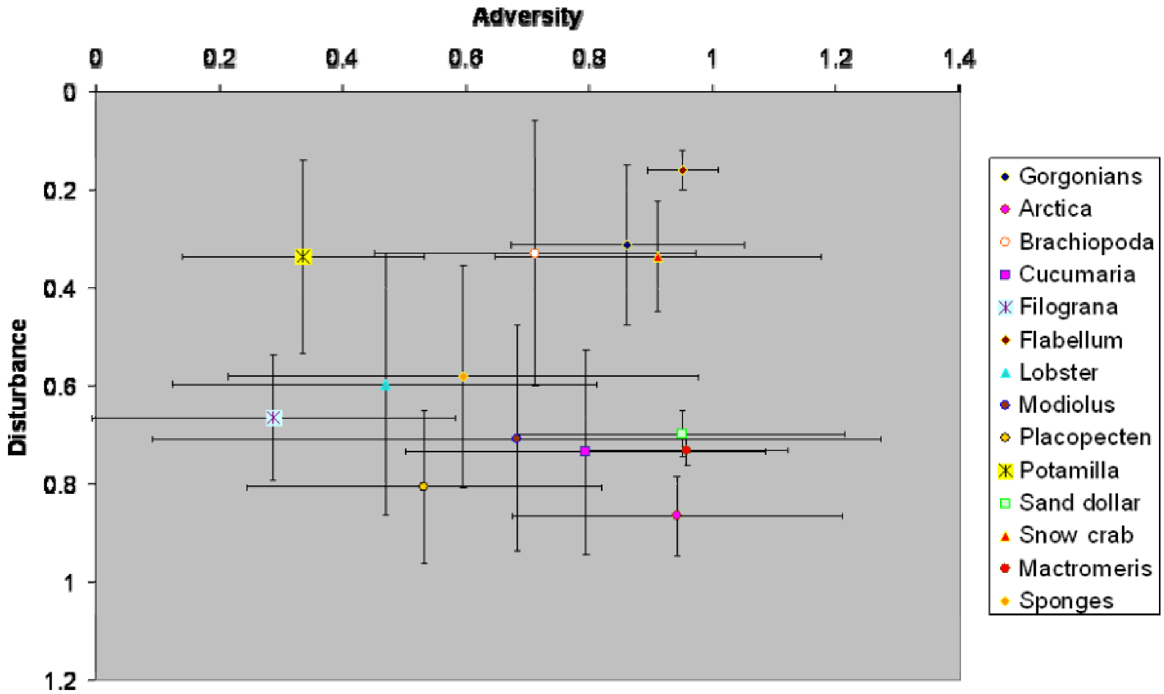

Figure 6. Relationship between species distribution and habitat type as defined by Southwood Model for a select number of indicator species

Species traits have not been mapped against the model output for the Scotian Shelf. However, efforts were made to compare traits of species presented in Figure 6 to the species traits / habitat relationships identified in the Southwood (1998) habitat template (Figure 1), upon which this model is based.

Discussion

The comment was made that the Similarity Analysis of the samples had been conducted in the past. However, very few species were found to be associated with one another. To get similarity, one needs associations, but there is almost no indication of associations in the datasets.

Regarding Figure 6, a number of observations were made - snow crab was a multiple outlier and didn't seem to fit model well, sessile animals were present in every quadrant, corals seemed to fit well but other species usually associated with corals didn't seem to fit as well, and brachiopods fit well. Species found in a small number of locations, e.g. Gorgonians, tended to show less variability in habitat type. Species that were widespread would require some analysis of abundance data to demonstrate differences in habitat preference. The importance of the adversity axis in determining habitat type was queried. It was replied that corals seemed to be influenced by the adversity axis. The relationship between sensitive species and habitat type was also queried. The sensitive species considered in Figure 6 appeared to be correlated with the adverse, stable quadrant. It was agreed that, overall, the model appeared to work well for the species selected. It was recommended however that a more objective way of testing the correlation between the species distribution and the model predictions be developed. For example, Primer could be used to plot species against habitat.

The comment was made that the use of indicator species to test the model would depend on data quality and spatial coverage. A concern was raised that a species distribution would correlate better with sediment type than with the results of the adversity / disturbance model. A suggestion was made to include abundance data in the analysis rather than just presence / absence data. Patterns may become more evident when abundance information is considered. It may also be useful to focus on a subset of species that have a direct relationship to communities and biogenic structure, perhaps those with narrow physiological ranges. It was commented that Figure 6 indicated either 1) that most species have very broad niches within the habitat classification scheme or 2) that the Scotian Shelf is homogeneous. Alternatively, habitat patterns on the Scotian Shelf are more subtle than the model can depict. It was noted that the distribution bars may shrink if the quality of the data layers can be improved.

A suggestion was made to take three benthic community types, e.g. high energy sand, mud, and rock communities, and conduct a pixel by pixel sensitivity analysis to determine the ability of a particular attribute to predict their occurrence. This testing approach is similar to that used for remote sensing to provide confidence in classifications. Concern was expressed about this suggestion since the model was not designed to operate at this scale. It was reiterated that data were not available to conduct this type of analysis.

A suggestion was made to use the list compiled by Ellen Kenchington of thirty-eight species with 7-8 associated life-history traits to test their general correspondence with the model.

SENSITIVE SPECIES AND HABITATS

Resilience and Sensitivity: An International Perspective

Ellen Kenchington

Presentation Highlights

This is an alternate approach to benthic classification that is being used widely elsewhere in the world. It may be useful to merge this approach with the benthic classification being pursued in the Maritimes Region to determine if one couldn't use sensitive organisms to detect habitat patterns. It is first necessary to establish some definitions. Here are some definitions based upon recent work in ICES (WGEO):

Sensitive species

- Determined by vulnerability and recoverability
- Susceptible to human disturbance and take a long time to recover from disturbance
- "Sensitive" can refer to individuals or colonies
- Recoverability can be determined empirically or through known or suspected life history traits (reproduction annual, fecundity, longevity, regeneration ability).

Example: Icelandic scallop is sensitive due to its long lifespan and infrequent reproductive period. Also it is sensitive to high temperatures

Fragile species

- Related to body size, mobility, and accessibility
- Not linked to recoverability; therefore, can be fragile without being sensitive
- Fragile benthic species are those which are sessile or slow-moving, have rigid bodies, and are present on the sediment surface (epifauna) or near the surface (infauna)

Example: corals

Habitat forming species

- Individuals may not be sensitive, but colony as a whole is sensitive

Example: habitat forming tube worm, which form mats

A recent study surveyed the North Sea for benthos in soft sediments using a van Veen grab and assigned sensitivity designations to each species based on its life-history characteristics and morphology (size, etc.) using the above definitions. Each species was characterized as either sensitive, fragile, habitat forming, opportunistic, etc. A total of 250 taxa were classified. Of these, 130 taxa were considered fragile, including 22 in the “sensitive” category and 57 in the “extensive and characteristic mats or structures” category. Sensitive species included cnideria, mollusca, pogonophora, priapulida (no crustacean, annelids). It is important to note that many of the species surveyed live in the Maritimes Region and if they do not, congeneric species do live here, so it is possible to extend the approach to this region.

Another initiative relevant to Maritime Region is the Marine Life Information Network for Britain and Ireland (MarLIN: see www.marlin.ac.uk for details). A review panel has developed benchmark criteria related to recoverability and tolerance, which include current state/status and changes in state/status of populations. The species characterizations include both individual and population sensitivities. Overall, the results of this work (can be viewed on the above website) have some agreement with that of ICES.

Regarding applicability of the above work to the Scotian Shelf, they allow us to add to the current list of sensitive species list using local scientific knowledge (e.g. trawling studies, decadal change studies). From what has been observed, there has been a shift from fragile, sensitive, habitat forming species to motile scavengers. A list of sensitive species list could be used to both test the predictions of the Southwood model and guide management action.

Discussion

It was asked why the ICES definition of sensitivity only considered human disturbance. This appears to have been an organizational focus. In a broader context, any type of reaction, including reaction to environmental disturbance could be considered. It was also queried whether the ICES definition of recovery differentiated between recovery due to recruitment and recovery due to in-migration. In response, only recruitment was considered.

There then followed a more general discussion on the ICES approach. The comment was made that the objective of the approach appeared to be to reduce the large list of potentially sensitive species to a small, manageable, number. However, it was confirmed that ICES didn’t start with the intention of identifying only 25 sensitive species. They started with a list of 500 species, applied the sensitivity criteria, and were surprised that only 25 species were identified as sensitive. General agreement was reached that the criteria used to identify/define sensitive species would be key. Positive comments on this approach included:

- it is a logical way to move towards a tractable solution without being prescriptive
- it has a proven track record, and
- it is logical to benthic ecologists

Concern was expressed however, that it would be difficult to predict where sensitive species would occur without conducting extensive sampling. No one felt that there were any contradictions between this approach and the proposed benthic classification scheme. However, the benthic classification scheme provided a “top down” approach that was useful when site-specific information on benthic communities was not readily available, and the ICES approach was “bottom up” and perhaps more applicable in a data-rich setting.

Discussion ensued on the similarity in the results of different approaches. ICES and MarLIN appeared to generate similar lists of sensitive species but this is understandable as there is overlap in the science expertise involved in each process and both are based on information provided by world experts on the individual species. The comment was made that the sensitive species identified in the ICES approach made sense, and they would be a good starting point for work in the Maritimes Region as at least half of species selected by ICES were also present here. It was generally agreed that the lessons learned elsewhere should be applied, where possible, to the Maritime Region.

The comment was made that MarLIN, while providing some ecologically neutral statements about sensitivity, included statements which were value judgments. For example, change (increase or decrease in some attribute) is typically considered to be negative. It was asked whether MarLIN reflected the relative importance of individual sensitivities versus the sensitivity of a population, i.e. were individual sensitivities described separately from population/community sensitivities. The response was that MarLIN appears to be clear in its description of individual versus population sensitivities. It is also consistent in its rankings, since it is a relatively recent initiative (one year) and the same group of people has been involved in the project to date. It was mentioned that recoverability appeared to be a primary driver in the sensitivity designation, so it would be important to examine the criteria for recoverability further.

It was noted that distribution maps are available for some Maritimes species that have been identified by ICES and others as sensitive. It was offered that once sensitive species had been identified for the Scotian Shelf, their distribution alone (as opposed to the use of the benthic classification scheme) could be used as the basis for conservation measures. It was further suggested that we could extrapolate what we know about the role of these sensitive species as indicators to validate the predictions of the benthic classification scheme. A suggestion was made to investigate the recurrent characteristics of sensitive species and ensure that these were reflected in the model. It was recommended that a table of sensitive species be developed, including distinguishing characteristics and vulnerability to specific human activities, for use in the validation and further development of the benthic classification scheme.

It was agreed that, at the very least, a process for identifying sensitive species for the Maritime Region be developed, including the development of criteria for defining sensitivity. The Oceans Branch staff at the workshop agreed that information on sensitive species would be useful for many purposes, and work in this area is being pursued through other venues.

Sensitive Species and Habitats of the Scotian Shelf

Don Gordon

Presentation Highlights

The purpose of identifying sensitive species and habitats is to identify the most sensitive areas, to manage human activities, and to gain a better understanding of the large scale and wide range of habitats and organisms in the offshore environment. Impacts depend on type of habitat, scale, intensity, and frequency and sensitivity to these impacts is related to the level of natural disturbance, i.e. naturally disturbed habitats are generally more resilient and have faster recovery. Stable habitats on the other hand tend to be more complex, easier to disturb, and take longer to recover. Pristine habitats tend to be easier to disturb.

A number of habitat complexity ranking methodologies exist (Auster and Langton, 1999; Collie et al., 2000; NRC, 2002). In general, the sensitivity to disturbance depends upon life mode (infauna / epifauna), size and fragility while recovery depends on mobility, range, reproduction, and growth rate. Most sensitive species are epibenthic, sessile, large, slow-growing, with low or irregular recruitment and are associated with more stable and complex habitat. Those that add biological structure increase complexity even more e.g. Lophelia reefs, mussel reefs, aggregations of seafans, beds of fan mussels and sponges such as Gorgonians, soft corals, Filograna, encrusting bryozoans (Kaiser et al., 2003).

There has been a fair bit of DFO research in this area. Here is a quick synopsis:

- Grand Banks otter trawling experiment
    - Detected impact, but showed recovery within one year
    - No long term effects above natural variation
    - Impact on large epibenthos (drop in biomass), but no impact on polychaetes.
- Western Bank otter trawling experiment
    - Detected less of an impact because of the gravel environment, but recovery took more than a year
    - Impact on epifaunal species, but few impacts on colonial epifauna (hydroids, sponges, bryozoans), which may be protected by microstructure
    - Damaged organisms were preyed upon by fish
    - No long-term effects above natural variation
- Banquereau Bank experiment
    - Detected dramatic impacts on sand habitat and recovery will take many years to recover
    - Large organisms were removed by the dredge; there was an immediate decrease in most species, polychaetes and amphipods recovered over two years, but there is no sign of recovery of target mollusc species over two years
    - Not seeing an increase in burrows using photographic surveys
    - Would like to go back during the ten year anniversary of the experiment.
- Deep-water coral studies
    - Detected heavy damage from fishing gear to Lophelia reef near Stone Fence and moderate damage to Gorgonians
    - Very little evidence of recent fishing damage was detected in the Gully and along slope.
- Drill waste studies
    - Sea scallops were found to be sensitive to fine sediment
    - Their feeding and growth rate can be reduced under realistic drilling scenarios.

Other regional studies include work on large sponges (Fuller, pers comm) and Filograna (Collie et. al, 2000).

Sensitive benthic habitat types generally include sand (dredging only), cobble and boulder laden bottom with abundant physical and biological structure. This implies that sensitive areas for Scotia – Fundy would include areas of 1) extensive gravel lag, 2) high abundance of boulders and 3) areas used by species for a critical part of their life-history, especially where limited in spatial extent, e.g. spawning areas and nursery areas. When defining sensitive benthic species, there are hundreds of candidates, so one needs to be selective, taking into consideration their vulnerability to disturbance, recovery potential, abundance and distribution, role in ecosystem (habitat, predator, prey), and commercial importance. Proposed sensitive species for Maritimes Region include:

- Gorgonian corals: epibenthic, large, sessile, fragile, create habitat, slow growing, localized distribution.
- Lophelia: same characteristics as above.
- Sponges (particularly Russian hats): same characteristics as above.
- Surfclam: infaunal, non-mobile, slow growing, provide habitat (burrows and shells), pulsed recruitment, harvested.
- Ocean quahog: same as surfclam.
- Horse mussel: epibenthic, large, non-mobile, slow-growing, provide reef habitat.
- Sea scallop: epibenthic, large, provide habitat, sensitive to fine sediment, harvested.
- Brachiopods: epibenthic, sessile.
- Staked tunicates: epibenthic, sessile.
- Filograna: tube building polychaete, epibenthic, provide habitat.
- Potamilla: tube building sabellid polychaete, epibenthic.

The distribution of each of these species was mapped by identifying appropriate databases, extracting data and building a file for each species, and plotting the results. The focus here was on the species rather than the habitat. A wide variety of datasets was accessed:

- Groundfish surveys
- Observer program
- Fishery bycatch data
- Sable Bank benthic survey
- NRCan grab samples
- NRCan photos
- DFO grabs from gear impact studies
- Campod photos and video from Gully
- Photos from Browns Bank study
- OBIS
- Hunstman Lab database (available through CMB website)
- DFO coral database, 1997-2003
- DFO fish habitat project, 2002
- Prena et al. (1996) study of Western Bank
- Peer et al. (1980) study of Lower Bay of Fundy
- Wildish et al. (1983) study of Upper Bay of Fundy
- Kenchington, Fuller and Caddy work on Bay of Fundy
- Messieh el. al (1991)

One needs to be aware of the limitations in the data in interpreting the distribution maps. The sampling gear e.g. (trawl vs. grab) varied across datasets and sample analysis generally depended upon taxonomic expertise. One of the biggest issues was sampling intensity with many ‘holes’ in the distribution due to a lack of sampling. Given the differences in sampling, only presence, not abundance, could be mapped. Finally, not all datasets could be accessed in time for this workshop.

Keeping in mind that some species have not yet been analyzed (sea urchins, blood worms, Macoma, surf clam, propeller clam, stalked anemones), below are comments on the individual species maps:

- Identification of functional habitats: e.g. herring spawning sites and haddock nursery areas. Not evenly distributed. Used Ken Frank's data to set "hot" and "cold" sites for further study.
- Lophelia and Gorgonian corals map: Doesn't include historical data or sightings data, just plots from the Mortenson's database and video work. Corals show up on southwest corner of channels, where there is net outflow and potentially more food particles.
- Sponge map: Included all sponges, not just Russian hats, though a map of Russian hats could be made available (based on video, etc.)
- Mactromeris: Found on the eastern part of the shelf, primarily Banquereau and Sable Banks. Two outliers could be artifacts. Missing data from Haddock Box. Can add inshore data.
- Ocean quahog: Found on Western Bank and Banquearau. Again, no data from the Haddock Box. Records from southwest Nova. Some records from Georges Bank.
- Horse mussel: Widespread. In the Bay of Fundy, form reefs. On the shelf, don't appear to form reefs.
- Scallops: Widespread, but there are areas where scallops are concentrated/abundant. These are sites of commercial fisheries.
- Brachiopods: Widespread throughout area of interest.
- Tunicates: Found in western part of study area, e.g. SW Nova, Bay of Fundy. Based on few records.
- Filograna: Found in western part of study area, e.g. mouth of Bay of Fundy, SW Nova. One record on Emerald Bank. One record on Cape Sable.
- Potamilla: A few records on Western Bank. Mostly Bay of Fundy and western areas.
- Flabellum (cup) corals: More widespread. Found on soft sediments along slopes. Abundant in Gully and Laurentian Channel. PERD proposal to conduct work on sensitivity to drilling wastes.
- Sand dollar: Eastern shelf, e.g. Sable and Banquereau Banks. Some records to west.
- Sea cucumber: Eastern shelf. A few records from SW Nova. None from Georges Bank. Some from Bay of Fundy.
- Snow crab: Widely distributed, particularly on the eastern shelf.
- Lobster: Found primarily on the western shelf, e.g. Gulf of Maine and Bay of Fundy. Also found along the slope to the east.

When one overlays all species maps, it indicates that there was little coverage of the Northeast Channel and the Haddock Box on Western Bank, although the latter was sampled by the groundfish research vessel survey. Sensitive species could be found across the study area, i.e. there are no areas that stand out as completely barren of "sensitive" species (though the definition of sensitive used here is quite broad). On the Eastern Scotian Shelf, surf clam, quahog, sand dollar, sea cucumber, and snow crab are all present, while on the Western Shelf, horse mussel, tunicates, polychaetes and lobster are dominant. Corals, sponges, scallops, and brachiopods are found throughout. Further work on the dataset includes plotting the individual species distributions on the disturbance / adversity template, completing the analysis of all species and comparing distributions across species.

Discussion

It was asked whether resilience referred to recovery or sensitivity. It was replied that commonly used definitions of sensitivity include consideration of resilience, which was done here. Resilience can refer to both the ability to resist perturbation and the ability to return to a pre-perturbation state. These two definitions tend to be linked. Related to this, it was asked if habitat forming species would be included as a category of sensitive species. They should be included, perhaps as secondary, biogenic habitat. The comment was made that the definition of sensitivity should include references to evolutionary adaptation, human perturbation or value to humans. Overall, it was agreed that the definition of sensitivity used for the Maritimes Region should be reconciled with the ICES and MarLIN definitions. Interestingly, it was noted that the selected sensitive species, without a clear definition of sensitivity, were similar to those listed using the ICES approach. However, sponges were not identified as sensitive species in the ICES list because of their ability to recover from perturbation. It should be noted that different species of sponges have very different recovery rates, and some, such as glass sponges, may be slow to recover. It was recommended that a definition of sensitivity be developed and applied more rigorously to species present in the Maritimes Region.

Regarding habitat complexity, the comment was made that the National Research Council's (2002) ranking of bottom types was more intuitive than other approaches. It was asked whether these authors had a rigorous definition of complexity, to which the response was that complexity was based solely on a structural definition and did not include consideration of community types. It was noted that it is difficult to find empirical observations for physical habitat type, such as areas with high abundance of boulders or gravel lag. The 1991 - 1995 East Coast of North America Strategic Assessment Project (ECNASAP) attempted to assemble this type of geological data but couldn't combine the Canadian and US data due to differences in definition of substrate data.

Questions were asked as to whether the recovery observed in the Grand Banks project was likely due to in-migration. The area studied was small, so the potential for in-migration was high; however, the recovery process was not clearly identified. The spatial scale of drilling mud impacts according to the benthic boundary layer transport (bblt) modeling scenarios, was queried. Here, impacts were mostly limited to within one km of the drill site, though some drilling scenarios produced drill mud concentrations that could potentially result in a few days of lost scallop growth out to five km. It was noted that international studies have demonstrated broader impacts of drilling discharges over hundreds of kilometers, though these results were typically for multiple well scenarios. The drill mud experiments presented here only considered impacts of a single exploration well.

There were questions on the quality of the observer and multispecies survey dataset. The observer data provides information on more than just the abundance of fish. Have observers and multispecies survey personnel been trained to identify sensitive species? An identification sheet has been developed for corals and offers had been made to meet with observers. Overall, the identification and recording of benthic species has improved over the last few years, particularly on the multispecies surveys.

Regarding the spatial extent of data on sensitive species available for the Maritimes Region, the multispecies survey provides extensive geographic coverage and other datasets are available, e.g. archived photos. It was mentioned however that while the spatial coverage appeared extensive, it still represented sampling of only approximately 1% of the bottom. It was suggested that the location of null samples of sensitive species be indicated on the distribution maps, i.e. include all stations rather than just positive samples. It was noted that absence of a species in a particular sample would not necessarily mean absence of a species at that location. It was asked whether abundance information was available for sensitive species, and whether plots of this information would be useful in detecting more subtle patterns of habitat use. The response was that most of the data used for this analysis was obtained from observer and research survey databases, which only provide an indication of presence / absence. Other datasets may contain abundance information, which may be useful. The suggestion was made to exclude the distribution of lobster, snow crab, and other abundant species from the final compilation map of sensitive species since they tend to dominate and give the impression that sensitive species are located everywhere. In addition, maps showing the abundance distribution of these species across the study area might be more useful than simply presence / absence.

Reference was made to a paper on nutrients in the Gully (Strain and Yeats, 2005), which suggests that the Gully acts as a miniature estuary where accumulation of nutrients leads to higher productivity. This might explain the presence of corals in this area. Reference was made to a map produced by Breeze et. al. (1997) that documented the observer sightings of corals. This map and that compiled from DFO datasets appeared to show a similar pattern of coral distribution. Different coral species have different habitat characteristics; large octocoral and reef-building species are not widespread.

It was asked whether most of the sponges indicated on the map were likely to be glass sponges. Sponges were not identified by species on this map although a sponge specialist would be able to provide more detailed information.

A comment was made on the partitioning between *Arctica islandica* (Atlantic surf clam) and *Spissula solidissima* (ocean quahaug) on Georges Bank, with the suggestion that partitioning may be related to substrate type.

The linkage of this project to other initiatives was discussed. Concerns were raised on the possible overlap between this initiative and the work being conducted by the Species-at-Risk Offices, particularly with regards to development of new definitions for sensitive species or habitats. It was felt however that this work is distinct and would not result in significant overlap, particularly since none of the species being discussed were currently included in the species-at-risk listing process. For example, corals are not yet on any candidate list. It was noted that management attention and science advice is currently provided on commercial species, and that the intent of this initiative would be to extend this to other non-commercial species. Discussion ensued on the need for consideration of non-commercial species that may be harmed by human activities, by determining what these species are sensitive to and what processes are currently influencing them. It might be useful for Oceans Branch to have a list of 7-8 sensitive species available when conducting environmental risk assessments of proposed activities. However, if such a list were to be provided, the concern is that it might not be consistent with criteria established by others (e.g. COSEWIC).

Discussion ensued on how information on Maritimes Region sensitive species and habitats might best be compiled by Science and utilized by Oceans Branch. A number of follow-up actions were suggested. The North Sea information, which was compiled by a few people in ten days, as well as other information available in the literature should be brought to bear on this issue. Similar initiatives had been attempted in the past, e.g. Marine Invertebrate Diversity Initiative (MIDI) species profiles. All sensitive species, and not just benthic species, should be considered. The suggestion was made to explore the possibility of developing a MarLIN-like system for the Maritimes Region which would be used as a decision-support tool.

It was reiterated that the key to the sensitive species exercise is the evaluation of the criteria used to define sensitivity, which determines which species are important. At present, we have not yet established the criteria for what we map and why. What we've done is to define the datasets available for the Scotian Shelf, and how you might manipulate them. We still have to determine what is the purpose -- what are you going to show and why.

GENERAL DISCUSSION AND RECOMMENDATIONS

The remainder of the meeting was devoted to discussion on the Southwood model (concepts, improvements, etc) and sensitive species, the needs of management and next steps. This discussion is presented below not necessarily in the order discussed but rather by theme.

Conservation of Habitat and Species Diversity

Initial discussion focused on the need for various habitat and species conservation measures, and whether the protection of representative habitat types would in itself be sufficient to conserve species diversity. It was suggested that protecting representative habitat types would serve to protect some sensitive species, but additional measures may be required to protect other vulnerable species. It appeared likely that some combination of the two approaches (protection of representative habitat and sensitive species) would be needed.

Whatever approach is taken, management tools are required that would enable an effective response to existing and potential threats to habitat and species diversity. There was general agreement that it would not be sufficient to create a benthic habitat scheme that merely documented or described benthic habitat. It is important that some sense of the human – induced impact on this habitat is required. From this perspective, the proposed benthic classification scheme is a significant conceptual advance and could be very useful as a guide to predicting and evaluating the impact of human activity on the benthic environment. There was some discussion regarding the role of disturbance and adversity at the individual, population and community scales. Adversity may play more of a role at the individual level, while disturbance may play more of a role at the population scale. Community-level interactions, e.g. species interactions, are not specifically addressed through this application of the Southwood model.

The model may also help management understand the complex interactions between physics, chemistry and biology and thus lead to a greater appreciation of the ecological consequences of human impacts. This led to a discussion on the types of products needed for management. The following were seen as desirable:

- seascape scale map for the protection of seascape diversity types
- sensitive species maps for the protection of sensitive species
- biogenic habitat map layer to add to existing physical habitat maps
- model to predict benthic community types
- model to predict life-history traits or strategies
- benthic habitat sensitivity map to assist in evaluating the impact of human activities on benthic habitat

Notwithstanding this, more work is needed to demonstrate how the proposed benthic classification scheme could be used to assess the sensitivity of various benthic habitats to human activity. A number of alternatives were discussed. One suggestion was to overlay maps of known distributions of sensitive species on the empirically derived physical data. A second alternative was to provide the results of the Southwood model to Oceans Branch as guidance for their use, being sure to communicate that it is in development and requires updating on an on-going basis. It was generally agreed that the Southwood Model is useful for mapping species traits that can guide management activities but the individual sensitive species maps are also required. The rest of the discussion pursued improvements to both products and how to achieve these.

Improvements to Southwood Model

A number of suggestions were made to both improve the data inputs and utility of the model.

Disturbance Axis

A general understanding of the disturbance axis was achieved through the workshop. The only subsequent work that needed to be pursued was that on grain size, which should continue as planned.

Adversity Axis

The workshop provided a much better appreciation and understanding of the intent of the adversity axis than had existed after the January 2004 meeting, particularly the realization that it is related to physiological processes. Certainly, use of the physiological equation (production = ingestion – respiration – feces – excretion) to rationalize and standardize interpretation of the components of adversity was thought to be helpful. There was still some discomfort with the term itself and use of ‘Scope for growth’ was suggested.

A number of suggestions were made to improve the indicators making up the adversity axis. It was suggested that Ocean Sciences Division be tasked with providing a better indicator of food availability. For temperature, further improvements were suggested, particularly in terms of weighting of the various series. Regarding oxygen saturation, it was suggested that small-scale variability be eliminated where this is not ecologically meaningful. Regarding silicate (e.g. sponges), this should be incorporated if felt useful. It was noted that in coastal environments, it may be necessary to incorporate additional variables such as suspended particulates, light and nitrogen.

It was recognized that temporal variability was addressed to some degree through the selection of the input variables; however, it was agreed that further consideration of temporal variability was warranted, although no specifics could be provided.

As a general comment, both for this and the disturbance axis, research on the effects of weighting, scaling and the relationships among variables was encouraged.

Testing of Southwood Model

Further testing of the model is required. A number of suggestions were made as to how this might be undertaken. It was thought useful to tabulate as many of the benthic species of the Maritimes Region as possible and characterize their life history traits. Their distribution would then be mapped to examine the correspondence of these distributions with those predicted by the model. It was acknowledged that the tests conducted thus far were promising. For widespread species, it was suggested to consider using abundance data where available to differentiate between habitats (e.g. high density vs. low density usage). Overall, as much as possible should be done to test the concepts underlying the Southwood Model and its consistency with other approaches.

Sensitive Species and Habitats

A number of suggestions were made to enhance the utility of the sensitive species information. The definitions and criteria of the following need confirmation:

- Sensitive species (should we adopt the ICES definition which implicates fragility and recovery?)
- Habitat forming species
- Recovery (perhaps based upon observation and life history traits such as reproductive schedule, fecundity, generation time, etc.)

There is a need to categorize human-induced impacts by species. It was suggested to list the sensitive species that we know of along with the level of sensitivity to type of impact. This might have to be based on expert judgment as well as being guided by the results of the Southwood Model.

It was suggested that the sensitive species maps of the known distributions be provided to Oceans managers to aid ongoing management needs. It might be possible to expand the interpretation of some of this information by considering the relationship between species sensitivity and substrate grain size.

It was suggested that a joint Science – Oceans project on sensitive species be initiated with the intent to develop a sensitive species and habitats database similar to that of MarLIN. Such a database would be an important resource to all aspects of the work discussed at this workshop.

Ocean Management Applications

As stated above, there was general agreement that the Southwood model is useful, with future potential, for mapping species traits (life history strategies), which could be used to guide Ocean Management, particularly in identifying threats and potential impacts of human activities. Interpretation of the disturbance / adversity grid in terms of impacts was particularly insightful (Figure 7) and illustrated possible usage of the model results.

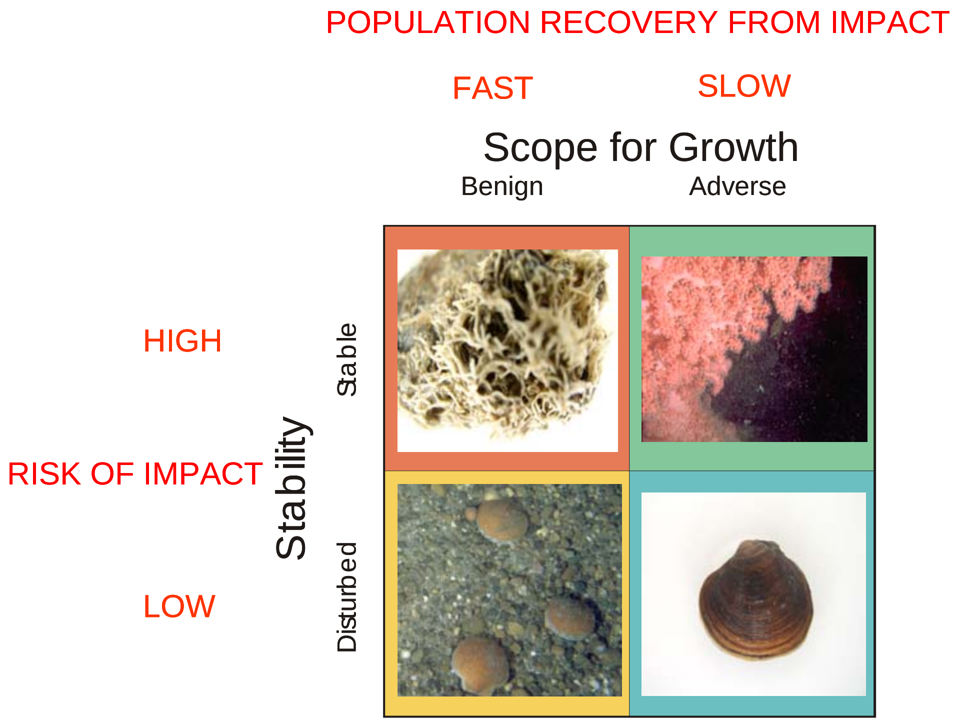

Figure 7. Relationship of Southwood Model to Recovery Potential and Risk of Impact.

This discussion raised issues as to how different types of impacts, e.g. fishing, chemical, etc. could be compared, particularly when one wishes to consider cumulative effects. One suggestion was to investigate the use of energy as a common denominator. It might be possible to translate all impacts into this common scale. This highlighted the difference between disturbance-type impacts and adversity-type impacts and the need to take this into account. Related to this is the relationship between natural scales of adversity / disturbance and habitat vulnerability, also worthy of further research. Overall, research is needed to translate the products identified to date into tools usable by managers.

Linkage to Related Initiatives

A number of other regional and national initiatives are currently underway, which it will be important to coordinate with. Nationally, coordination is required with the Ecologically and Biologically Significant Areas (EBSA) initiative and the determination of critical habitats under the *Species at Risk Act.*

A workshop on Ecologically and Biologically Significant Areas (EBSA) was held in 2004 to develop criteria for the evaluation / ranking of significant habitats. The relationship of the current workshop to this initiative was discussed. It was noted that mapping the habitat of sensitive species was a subset of classification of ecologically and biologically significant areas. These were not thought to be mutually exclusive exercises. Regarding use of the Southwood Model, it was noted that there may be some overlap with the EBSA initiative, which highlighted the need for on-going communication both within and between DFO regions on benthic classification approaches. This is an active field of research and developments elsewhere should not stop progress here but rather should encourage dialogue on benthic habitat classification and management.

Comment was made on the linkage between the work on benthic classification or sensitive species and the determination of critical habitat under SARA. The end objective is to provide a management tool with the capacity to provide science information in a meaningful way. Efforts to identify critical habitat for Northern Abalone have used empirical data (e.g. substrate, water depth and kelp distribution), which has been collected in coastal surveys. It was suggested that the benthic classification model discussed at this meeting would be a good surrogate where survey data is not available or is difficult / harmful to conduct, e.g. deep waters of the Scotian Shelf where damage to corals may be a concern.

Other DFO regions are also conducting research in this area. The suggestion was made to share our approach to benthic classification with scientists in Newfoundland, as they are dealing with similar issues and ecosystems. The same holds true for the eastern US. DFO Pacific region has been very interested in developments at BIO, where efforts are underway to investigate the use of this benthic classification scheme in the coastal environment (>20m depth). Bloom effects, temperature stratification, and salinity may be more important in coastal waters compared to the offshore.

In general, there was recognition of the need for on-going communication with scientists both within and outside DFO on benthic habitat classification, sensitive species and ocean management.

NEXT STEPS

The workshop ended with discussion on how best to proceed. The project thus far has depended upon the scientific efforts of a limited number of individuals (e.g. V. Kostelev on the Southwood Model). Future progress will depend upon the formation of teams to formally bring a wider scope of expertise to bear on realization of the project's objectives.

It was recommended that the following occur:

- Science Branch form a Benthic Classification Working Group to modify and test the proposed benthic classification scheme as described in these Proceedings. The results of this WG would be reviewed at the final phase II RAP meeting, tentatively planned for summer 2005.

- Science and Oceans & Habitat Branches form a working group to plan phase III of the benthic classification RAP, which is to develop tools for managing human impacts on the benthic environment, based upon the results of the phase II RAP. The review meeting is tentatively planned for fall 2005.

- Science Branch form a Sensitive Species and Habitats Working Group to establish working definitions and criteria for sensitive species and habitats in the Maritimes Region, produce distribution maps of species/habitats that meet these criteria, investigate development of a sensitive species and habitats database (including defining life-history characteristics), and contribute a list of species with narrow distribution ranges and distinguishing life-history characteristics to help test the benthic classification model. This WG would also form a focus for collaboration with Oceans Branch on the creation of a MarLIN style database for the Maritime Region.

The chair offered to bring these to the attention of DFO Science line management.

CONCLUDING REMARKS

The chair closed the meeting by thanking participants for two full days of animated discussion on benthic habitat classification and sensitive species. The workshop provided an excellent exchange of ideas and concepts and will lead to further improvements on our approach to the management of these ecosystem components. To ensure steady progress on these issues, it will be essential in the coming year to obtain the commitment of regional staff to pursue the research areas discussed at the workshop as well as to broaden discussion outside the region to test the wider applicability of the concepts and develop the approach further.

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APPENDICES

Appendix 1 : List of Participants

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Appendix 2. Meeting Terms of Reference

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 guidelines and best practices 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 was initiated with a RAP meeting 6 – 8 January 2004 to review a proposed benthic classification for the Maritimes Region based on a model by Southwood. The classification considered two sets of indicators – one set relating to physical bottom disturbance and the other to the biological habitat as separate axes of a benthic community classification. Consensus on the disturbance indicators was achieved but not on those for the biological habitat, for which further work was recommended. This workshop is to consider and discuss on-going scientific work as part of phase II.

Objectives

The workshop will consider and discuss:

- The Southwood model and the indicators used for the adversity axis
- Definitions of resilience and sensitivity used elsewhere
- Maps of benthic habitat distribution based on maps of the disturbance indicators overlaid with empirical observations of sensitive benthic species
- Comparison of the above maps with those produced using the Southwood model to further insight on modeling approaches to habitat mapping

Products

- Proceedings reporting the discussion

Participation

- DFO: Science, with some Oceans involvement
- Other Government Departments: NRCan, External Experts

Appendix 3. Meeting Agenda

7 December (Tuesday)

13:00 – 13:15	Introduction / O'Boyle The background to and objectives of the meeting will be provided
13:15 – 15:00	Southwood Model and Application to Sites on Scotian Shelf / Kostylev We will spend the afternoon on Southwood's disturbance/adversity model. We will start with a brief review of the theory and available data bases as presented at the January 2004 RAP. Then, we will review how both disturbance and adversity indices have been calculated for the Scotian Shelf - variables used, weighting, averaging, changes since January 2004, etc. The results of the Southwood model will then be presented for both indices separately and combined. This will be followed by a presentation on recent results of comparing model output with empirical data (e.g Campod photos, Videograb, etc.) considering how the theory fits the observations.
15:00 – 15:15	Break
15:15 – 17:00	Southwood Model (cont'd)

8 December (Wednesday)

09:00 – 09:30	Reflections of Day 1 Observations & conclusions of first day's discussion
09:30 – 10:15	Definitions of Resilience & Sensitivity / Kenchington The ICES and perhaps other perspectives on how habitat resilience and sensitivity can be defined will be presented and discussed.
10:15 – 10:30	Break
10:30 - 12:00	Identification of sensitive habitats and species on the Scotian Shelf and mapping their spatial distribution / Gordon The distributions of a number of sensitive species and habitats on the Scotian Shelf will be presented. This will further the discussion held on the first day.
12:00 – 13:00	Lunch
13:00 – 15:00	Considerations of Scientific Uncertainty / Kostylev Issues concerning the use of the Southwood Model in areas not well sampled will be presented and discussed.
15:00 – 15:15	Break
13:00 – 17:00	General Discussion on all presentations

9 December (Thursday)

09:00 – 09:30	Reflections of Day 2 Observations & conclusions of second day's discussion
09:30 - 12:00	Discussion on next steps (action items, scheduling, etc)
12:00	Adjournment: we will aim for noon but smaller group discussion can follow into the afternoon depending on people's availability

Appendix 4. List of Documents

Kenchington, E. 2004. Defining Sensitive Species in Marine Conservation. RAP Working Paper 2004/36.

Keizer, P. 2004. Notes from the NAP on the Identification of Ecologically and Biologically Significant Areas.