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Developing an Ecosystem-Based Management Framework for Benthic Communities: A Case Study of the Scotian Shelf

O'Boyle, R., V. Kostylev, H. Breeze, T. Hall, G. Herbert, T. Worcester, D. Ricard,

and M. Sinclair

Bedford Institute of Oceanography, Dartmouth, NS, Canada

Abstract

Proclamation of Canada's *Ocean Act* in 1997 represented the start of a new management paradigm for the country's three oceans. Soon thereafter, a number of Integrated Management (IM) projects, including the Eastern Scotian Shelf Integrated Management (ESSIM) Initiative, were commenced by the Department of Fisheries and Oceans (DFO) to investigate how best to turn the principles of the *Oceans Act* into operational reality. A national approach to IM has subsequently emerged, including a suite of nationally defined ecosystem objectives and an IM planning framework. The planning framework describes how national objectives can be placed into a regional context and then linked to specific ocean industry activities through operational objectives (indicators and reference points) and management actions. Following this approach, ESSIM has developed a suite of regional ecosystem objectives based on the national model and is currently considering operational objectives for all ocean activities. Objectives related to the conservation of benthic community diversity are used to illustrate how national, conceptual, ecosystem objectives are being made operational. The process whereby the regional ecosystem objectives were developed is first described. Next, for each objective, the issues and impacted ecosystem components are considered and indicators, reference points and potential management actions outlined. A number of issues relating to the characterisation of benthic community sensitivity to human impacts are discussed as are strengths and weaknesses of a proposed methodology. Of interest are ways in which cumulative impacts can be addressed within a risk management setting, as well as options that are being considered for management actions. The lessons learned from this initiative will be of general interest to those involved in integrated management.

Keywords: ecosystem objectives, Integrated Management, benthic community diversity, cumulative impacts, decision rules

Contact Author: R. O’Boyle: Bedford Institute of Oceanography, P.O. Box 1006, Dartmouth, Nova Scotia, Canada B2Y 4A2 [tel: +1 902 426 3526, fax: +1 902 426 5435, e-mail:oboyler@mar.dfo-mpo.dfo.gc.ca]

INTRODUCTION

In December 1996, Canada enacted its *Oceans Act*, which outlined a new approach to managing oceans and their resources based on the premise that oceans must be managed collaboratively with stakeholders using new management tools and techniques. This Act responded to a number of international treaties and legislation (e.g. 1992 UN Conference on Environment and Development and 1995 Agreement for the implementation of provisions of the UNCLOS relating to the Conservation and Management of Straddling Fish Stocks and Highly Migratory Fish Stocks) which called for a new paradigm of ecosystem-based management of the world's oceans. While fishery management plans under the extant *Fisheries Act* continue to focus on target species, the *Oceans Act* changes the legislative basis for management and requires consideration of the impacts of human activities on Canada's ecosystems through the creation of integrated management (IM) plans.

When the *Oceans Act* was enacted, there was little concept as to what IM meant in practical terms. Much of the dialogue had been at a policy level with few linkages to implementation. Since then, Canada's approach to IM has started to emerge. In 1998, pilot projects were initiated on both the east and west coasts to investigate how IM could be implemented. The East Coast IM project is termed the Eastern Scotian Shelf Integrated Management (ESSIM) Initiative, the goal of which is the development and implementation of an integrated ocean management plan for the eastern Scotian Shelf area (Figure 1). Initial efforts focused on stakeholder engagement to build capacity and the necessary planning and management frameworks, but it was recognized that these initiatives would benefit from having objectives to guide their activities. In 2001, a national workshop was held to establish the ecosystem objectives for IM in Canada's oceans (Jamieson et. al, 2001). These were conceptual in nature and required translation into operational terms. For ESSIM, O'Boyle et al. (2004; 2005a) outlined a multi-step process by which the national ecosystem objectives could be operationalized to help manage human impacts at the regional level. It consisted of the development of an objectives hierarchy with conceptual objectives at the top and operational objectives controlling impacting human activities at the bottom. This approach has parallels to the IM framework discussed by Fletcher et. al (2005) for wild capture fisheries in Australia and has many of the features of an IM framework as proposed by de la Mare (2005). It was used to develop a set of ecosystem objectives that were included in the draft 2006 – 2011 ESSIM Plan (DFO 2005a), which was released in February 2005 for broad stakeholder review and discussion. More recently, national guidelines have been developed with the same intent – to define objectives for integrated management. The draft set of objectives in the ESSIM plan are currently being reviewed for consistency with these guidelines.

This paper investigates progress to date on the operationalization of the ecosystem objectives in the draft ESSIM plan related to one branch of the national ecosystem objectives' hierarchy – the maintenance of benthic community biodiversity (Jamieson et. al., 2001). It explores the 'unpacking' (O'Boyle and Keizer, 2003) of this objective and highlights recent theoretical advances. It considers current ocean activities on the Scotian

Shelf in relation to this objective and discusses potential management actions to achieve it. The paper ends by commenting on problem areas and next steps. It is hoped that the lessons learned will be of broad applicability within the ocean science and management community.

DEVELOPMENT OF REGIONAL ECOSYSTEM OBJECTIVES

Regional or IM Plan-Level ecosystem objectives are those that are based upon the national objectives' hierarchy but are still conceptual in nature. These need to be defined before they can be operationalized. The process outlined by O'Boyle et. al. (2004; 2005a) was used to develop these objectives for ESSIM, with some modification.

The first step in the definition of regional ecosystem objectives is to engage the oceans community (government and stakeholders) in the identification of conservation issues for an IM area. At this stage, issues will likely be a mixture of human pressures, ecosystem states, management responses, etc. For ESSIM, a multi-stakeholder working group (ESSIM WG) was established to develop this list for a small subarea (Sable / Banquereau Bank) within the larger ESSIM area as a test of the approach. The problem of how to prioritize these issues soon emerged and it was recognized that they needed to be merged within the national objectives framework, as described above by O'Boyle et. al (2004; 2005a). Subsequent discussions used the national objectives framework to help organize and contextualize further discussion of regional issues. Once the conservation issues had been described, the part of the ecosystem implicated in the issue, termed "ecosystem components", was identified and objectives for these were developed:

- Maintain the diversity of seascapes in the ESSIM area.
- Protect distinctive "hotspots" in the ESSIM area.
- Protect benthic communities susceptible to disturbance in the ESSIM area.
- Maintain high diversity benthic communities in the ESSIM area.
- Maintain identified pelagic communities or assemblages in the ESSIM area.

While not explicitly stated, the primary issues of concern for community biodiversity were the conservation of important, sensitive and representative benthic and pelagic communities, with a focus on areas or species aggregations that had previously been identified through other fora.

At this stage, O'Boyle et. al. (2004, 2005a) suggests that it is helpful to the ultimate formulation of operational objectives to state the characteristics (e.g., distribution, abundance) of each ecosystem component relevant to the objective. This is currently being explored by the ESSIM Science WG, a group in DFO Science specifically formed to aid ESSIM. It is important that stakeholders also have input on the characteristics of importance as this will assist agreement on the final suite of operational objectives.

After discussion within DFO, the list of ecosystem objectives developed by the multi-stakeholder working group were included in the draft ESSIM Plan (Table 1). These objectives refer to 'sensitive' and 'important' communities. The next section provides our interpretation of sensitivity. Importance is less easily defined unless one considers the wording in the 'ecosystem component' column. Terms such as 'highly diverse', 'unique', and 'productive' are used - terms also used in Section 35 of the *Oceans Act* in association with the Minister of Fisheries and Oceans authority to establish Marine Protected Areas (MPAs). DFO is currently undertaking an exercise to identify Ecologically and Biologically Significant Areas (EBSAs), which are to be used to guide ocean managers in decisions on what areas may need protection. We thus draw a distinction between these important or significant areas and sensitive areas. Significance can be the property of an area based on a number of criteria, including sensitivity. A sensitive area on the other hand has a specific property related to the ability of the biota in that area to respond to a human impact. It is possible to have areas that are significant and not sensitive and areas that are sensitive and not significant. The ESSIM draft plan identifies the need to define both sensitive and significant (i.e important) areas.

The ESSIM Plan-Level Ecosystem Objectives (Table 1) are considered draft or "interim" and are being used as such in planning and stakeholder review. Their development was initiated prior to dialogue on a nationally defined process to identify ecosystem objectives, which is being applied in each of the IM initiatives across Canada, including ESSIM. It too consists of a number of sequential steps:

1. Development of Ecosystem Overview Reports, which provide the background science information about the IM area. For the ESSIM area, this information is contained within Breeze et al. (2002)
2. Development of Ecosystem Assessment Report, which identifies the interactions between physical and biological components of the environment, including interactions with Human Activities. For the ESSIM area, this information is contained with Zwanenburg et al. (unpublished)
3. Identification of Ecologically and Biologically Significant Areas, which is in early stages for the ESSIM area
4. Development of IM Plan Ecosystem Objectives

The two approaches while different have many similarities and thus it is likely that the resulting regional ecosystems objectives will be similar. Following the national process, a small number of the ecosystem components that have been identified by both the Ecosystem Assessment Report and stakeholder engagement as particularly important for the ESSIM area will be selected and used to develop operational objectives within a formal science workshop setting.

The remainder of this paper pursues the operationalization of the two IM plan level ecosystem objectives related to the conservation of sensitive benthic communities:

- Identify and protect coral communities in the Gully and Stone Fence areas.

- Identify and protect other sensitive benthic communities.

OPERATIONALIZING PLAN-LEVEL ECOSYSTEM OBJECTIVES: CONSERVATION OF SENSITIVE BENTHIC COMMUNITIES

Indicators and Reference Points for the Conservation of Benthic Communities

Jamieson et. al (2001) discuss the process whereby conceptual objectives are made operational through a process termed 'unpacking'. The details of this are described elsewhere (O'Boyle and Keizer, 2003; O'Boyle et. al., 2004), are exploratory in nature and thus will not be outlined here. The primary features of an operational objective is that it consists of an indicator based on some measurable quantity and a reference point(s) of this indicator connoting the level at which some management action is taken. O'Boyle et. al (2004; 2005a) note the need to define operational objectives at the IM plan and industry levels. Operational objectives at the IM plan level control the cumulative effects of all industry activities impacting a particular ecosystem component while the industry – specific operational objectives control that industry's contribution to the overall impact.

Table 2 shows how the two plan level ecosystem objectives mentioned at the end of the last section might be operationalized for ESSIM. A direct way to control the impact of human activity on sensitive coral communities is to control the area of disturbance of this community. In other words, the indicator in the operational objective would be the area of disturbance of the human activity governed by the plan in question, in km^2. The level of control would be associated with a limit reference point (LRP) or the maximum allowable area of disturbance and a precautionary reference point (PRP) or the area of disturbance which invokes some precautionary management action. Given the sensitivity of corals, the LRP and PRP for disturbance of coral communities in the Gully and Stone Fence might be established as zero and the proposed management action would be to close these areas to potentially disturbing activities. In this case, the operational objectives at the IM plan level and at the industry level would be the same. In fact, area-based limitations on bottom fishing have been used for fisheries for many years and more recently as part of the IM strategy for both the Gully and the Stone Fence (Figure 2).

Currently under discussion is how best to manage human impacts on other sensitive benthic communities. For instance, one could determine the types and extent of sensitive benthic communities that exist, develop appropriate objectives with respect to allowable areas of disturbance and establish both a PRPs and a LRP for each community type. However, such an indicator for more widespread communities than corals implies that the area of disturbance can in fact be reliably estimated and controlled. This may be difficult to achieve in areas that are not entirely closed to impact. Until monitoring of human impacts can be improved through deployment of appropriate technologies (e.g. black box positional recorders), estimates of the area disturbed, either at the IM plan level or at the industry level, will have to rely on available information (e.g. log books for fisheries), which do not generally contain positional information at the required level of accuracy. For the purposes of management, it may not be appropriate to limit human impact to achieve some absolute area of disturbance reference point but rather to manage these impacts based on existing information to move the system in the right direction – reduce the overall area of disturbance. Thus, while we advocate use of the area disturbed as an indicator for an operational objective, we recognize that this indicator will be a measure of relative and not absolute impact. This has implications for the management action chosen to limit the human impact. Given the imprecision of estimates of the areas of disturbance, actions which allocate impact to industries would not be wise and it is more appropriate to utilize other forms of management actions such as gear restrictions, seasonal closures or closed areas to reduce the area of disturbance.

The need to conserve sensitive communities raises the issue as to what is ‘sensitive’. Communities with different levels of sensitivity will likely have different reference points of allowable impact. Even if we cannot be precise about the areas of disturbance allowable for these communities, we need to define what and where they occur to guide management actions. The next sections describe recent efforts to identify and characterise sensitive benthic communities on the Scotian Shelf.

The Classification of Benthic Communities of the Scotian Shelf

Following a 2000 regional workshop on the conservation objectives to be used for the ESSIM area (O’Boyle, 2000), dialogue within DFO Maritimes was initiated on a plan to conserve benthic communities on the Scotian Shelf. Three phases of this plan were outlined. The first was a review of existing approaches to the classification and characterization of benthic communities, the second was an application of a recommended classification scheme to the Scotian Shelf, while the last will be the development of management actions to meet the conservation objectives. At present, the first two phases are complete and planning is underway for the third phase. Much has been learned through this process, the main points of which are summarized here.

During the first phase, some 40 available benthic classification schemes were reviewed for their applicability to the management system on the Scotian Shelf. These could be categorized as being either deductive (create a classification model based on expected relationships and fit to available data) and inductive (create classification based on the available data) - top-down and bottom-up (Kostylev, 2002). Both approaches have their strengths and weaknesses and some combination of the two was recommended. Kostylev et. al. (2005) note that most classification schemes focus on determining the observed relationship between a species and parameters of its environment, without investigating whether or not there was broader ecological processes at work. In other words, are species of particular life history traits (slow growing, low fecundity, etc) found in similar areas? If so, this could assist management efforts as human impacts would be determined by the aggregate life history traits of a benthic community rather than the detailed species composition. Changes in species composition would not lead to a different benthic classification scheme as long as the community maintained similar life history traits.

The second phase started with a workshop (Arbour, 2004) that investigated a dramatically different approach to the classification of benthic communities, one which is based upon the life history traits of component species. The approach was considered promising and was developed further in two subsequent workshops (O’Boyle and Worcester, 2004; O’Boyle et. al, 2005b). There was general agreement that the life history approach to the classification and characterization of Scotia-Fundy benthic communities was a significant step forward and would be a valuable contribution to ESSIM. The next phase of the project will investigate how this classification scheme can be specifically used on the Scotian Shelf, although potential uses are already emerging.

As this life history traits approach to habitat classification is relatively new, it will be described briefly below. A more complete description of the approach, which represents a first application of a habitat template theory (Southwood 1977, 1988) to marine habitat mapping is in press, (Kostylev et. al, 2005).

An Evolutionary Approach to Benthic Community Classification

Southwood (1977, 1988) suggested that the environmental conditions of a particular area may select, in an evolutionary sense, for certain biological traits or life-history strategies of organisms 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. He proposed that there are certain life-history traits (migration, defence, number of offspring, longevity and tolerance) that can be used to characterize groups of species and act as indicators of environmental condition (Figure 3). 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. Southwood did not attempt to map these different environments. Rather, he was designing a periodic table of habitats.

During the phase two mentioned above, the disturbance axis was characterized by a suite of indicators such as grain size, tidal and wave driven bottom currents. The adversity axis was characterized by a suite of indicators related to the physiological processes of an organism (Figure 4). Participants of phase two considered that the term 'Adversity' tended to confuse understanding of the biological meaning of the axis and thus the term 'Scope for Growth' was suggested. How these axes combine to characterize habitat is shown in Figure 5. Benthic habitat can be classified as being Benign – Stable, Benign – Disturbed, Adverse – Stable and Adverse – Disturbed. Of course, these categories describe the extreme ends of two axes which represent a continuum of characteristics. Each point on the Scotian Shelf can be characterized by the interaction of the two axes, as seen in the benthic classification map produced during phase two (Figure 6).

Southwood (1977; 1988) did not discuss how human impacts would influence his habitat classification so this issue was discussed during the phase two workshops (O'Boyle and Worcester, 2004; O'Boyle et. al., 2005b). It was agreed that Scope for Growth (Southwood's adversity axis) would likely influence a population's rate of recovery from an impact. Organisms inhabiting adverse habitats would have relatively low Scope for Growth and thus only slowly recover from an impact. Similarly, organisms inhabiting stable habitats would be expected to be at a relatively high risk to a human impact. They would have evolved to that environment and thus would not withstand physical disturbances well. Overall, organisms in adverse – stable habitats would be at the highest risk to human impacts while organisms in benign – disturbed habitats would be at the lowest risk to human impacts.

As the ESSIM plan level objectives make explicit reference to sensitive benthic communities (Table 1), it is necessary to first define what sensitive means and how this definition relates to the Disturbance – Scope for Growth map discussed above.

Definitions of Sensitivity

A number of groups have developed definitions of sensitivity and rather than invent a new definition, some of these are reviewed here. The ICES Working Group on Ecosystem Effects of Fishing Activity (ICES, 2002) referred to sensitivity as 'structural fragility of the entire habitat in relation to a physical impact, or to intolerance of individual species comprising the habitat to environmental factors such as exposure, salinity fluctuations or temperature variation' based on work by McDonald et. al. (1996). In this definition, sensitivity is a function of both the structure (fragility) and function (tolerance) of an organism. The WGECO modified their definition the following year (ICES, 2003) based on OSPAR's Texel- Faial criteria (OSPAR, 2003) to describe sensitive habitat as that which is "easily adversely affected by human activity, and / or if affected is expected to only recover over a very long period, or not at all." . Importantly, the concept of recovery time had been added.

The Marine Life Information Network for Britain & Ireland (MarLIN) defines sensitivity as 'dependent on the intolerance of a species or habitat to damage from an external factor and the time taken for its subsequent recovery' where recoverability 'is the ability of a habitat, community, or species (i.e. the components of a biotope) to return to a state close to that which existed before the activity or event caused change'. Here, the term 'tolerance' appears to be similar to the 'vulnerability' term of ICES (2003).

From the definitions above, it is evident that sensitivity of a community, species, population or individual to an impact, be it natural or human, consists of the ability to recover to some previous state in a given amount of time (recoverability) and its existing condition and properties (vulnerability). Recoverability can be thought of a rate term related to physiological processes such as growth, recruitment, natural mortality, while vulnerability can be thought of as a state term related to structures such as body size and type and functions such as mobility and accessibility.

O'Boyle et. al. (2005b) discuss the relationship between sensitivity and the Disturbance – Scope for Growth axes of the habitat model. It would be convenient if the scope for growth were associated with recoverability while disturbance were associated with vulnerability. However, it is possible that elements of sensitivity are relevant to both axes and thus a one – to – one mapping may not be possible. This requires further investigation. Notwithstanding this, it was concluded that in general low scope for growth infers low recoverability while highly stable habitats would likely consist of organisms relatively vulnerable to physical disturbance. Thus, highly sensitive benthic communities would likely be found in stable, adverse environments while low sensitive benthic communities would be found in disturbed, benign environments. Moderately sensitive communities would be found in the other areas, the characteristics of which would be dependent upon the relative degree of scope for growth and disturbance.

A key component of operational objectives is the reference point. Using the area disturbed indicator mentioned above, it would be useful for management purposes to determine what the maximum area of disturbance would be allowed for each benthic community type (i.e. based on life history trait) (the X and Y of Table 2). The discussion above starts to set the theoretical basis for setting these reference points. However, as mentioned earlier, the exercise has not yet advanced to the stage where reference points can be provided and thus the sensitivity maps are to be used as guides to management actions.

Distribution of Sensitive Benthic Communities

O'Boyle et. al. (2005b) discuss ways to describe the distribution of sensitive benthic communities in the Scotia-Fundy region. Figure 6 is the current representation that was felt to be most informative. It shows that the most sensitive benthic communities, based upon predicted life history traits, will be found on the Eastern Scotian Shelf, particularly the inner basins to the west of Sable and Banquereau Banks and along the slope edge. Benthic communities on the Southern Scotian Shelf and in the Bay of Fundy would be less sensitive to human impacts, primarily due to the high food availability in this area. Ocean managers may want to highlight areas that are particularly sensitive to impact and thus other representations were explored. One such method maps the Euclidean distance of the habitat (disturbance x scope for growth) from the top right hand corner of the habitat matrix. These distances can be displayed as points with 75%, 50% and 25% of the most sensitive habitat (Figure 7). While some information is lost in this representation (i.e. distinct x and y characteristics are merged into a single vector described solely by its length), it draws attention to areas that might need the most attention by ocean managers. Other mapping products are being considered to assist ESSIM.

OPERATIONALIZING ECOSYSTEM OBJECTIVES WITHIN INDUSTRY ACTIVITIES

As stated above, operational objectives are required at the IM plan level to allow monitoring and control of the overall human impacts by various ocean industries on an ecosystem component, while each industry will have to develop operational objectives to control its impact. Sometimes within each ocean industry, control of sub-groups (e.g. fleets within the fishery) will be required. Each level of the planning hierarchy should have the means to control activity at that level while meeting the overall objectives established at the IM plan level, similar to the approach advocated by de la Mar (2005).

The industries that are known to impact sensitive benthic communities on the Scotian Shelf and that will be discussed further in this paper include:

- fishing industry (including a variety of gear types)
- oil and gas industry (exploration and developing drilling, pipelines, etc.)
- telecommunications industry (submarine cables)

Fisheries

There have been a number of recent contributions on the impact of bottom fishing on benthic communities worldwide (Kaiser et. al., 2003), as well as numerous regional contributions (Gordon et al., 2003; Gilkinson et al., 2005). While some studies have focussed on describing the impacts of individual gear types on different community types, others have attempted to evaluate the level of impact across a region. One approach has been to make estimates of the 'footprint' of each impacting unit on the bottom and then sum these over time and area. This approach has been applied to areas of the Scotian Shelf for a limited number of gear types (DFO, 2002; Kulka and Pitcher, 2001). However, divergent estimates of area of disturbance may be obtained when one examines fishing data using different assumptions on tow location (a single point or a line segment between start and end point), width, and grid size for aggregating the data (Sinclair, pers comm.). Thus, at present, only general indications of the impact of fishing activity on the Scotian Shelf can be obtained, a point made earlier. In order to determine the cumulative effects of fishing activity and assist in evaluation of the potential for future impacts, methodologies for ranking and comparison of gear types will have to be pursued.

For the Scotian Shelf, the distribution of fishing activities can be mapped based on reported activity. As examples, landings for 1999-2003 from three fisheries that use bottom gear were mapped: groundfish (otter trawl), groundfish (longline), and crabs (traps). These fisheries vary in extent, number of participants, and in amount of fishing effort. However, even without all this information, the maps of landings maps can be overlaid on the map of benthic sensitivity to show potential areas where management action may be needed in order to meet the plan-level objective of protecting sensitive benthic communities (Figure 8). More detailed assessments of activities and management efforts could then be focussed on areas where sensitive communities are most likely to be found, and where it is most likely that they are impacts from fishing activities. For example, there are few groundfish fishing activities on the eastern Scotian Shelf due to the moratorium on cod and haddock fishing, thus there are few interactions with areas considered "most sensitive." However, most of the crab landings occur on the eastern Scotian Shelf and a large portion of those come from the "most sensitive" areas. This area may deserve greater consideration by management in order to meet objectives.

On the central and western shelf, the fisheries landings maps show that most activities are occurring in moderately sensitive to least sensitive areas. However, longline activities occur on the edge of Georges Bank/mouth of the Northeast Channel and trawling takes place in the central shelf basins, areas which are more sensitive on the benthic sensitivity map.

Management actions that allow a particular sector of the fishing industry to meet the plan-level objectives would be outlined in fisheries management plans. Particular actions may also be put into conservation harvesting plans for particular fishing fleets, or within license conditions for individual fishers.

Oil and gas

Petroleum exploration and development may also impact the benthic environment. The placement of drill rigs and offshore pipelines cause disturbance in their immediate area, while disposal of wastes by the industry may both physically change the environment and result in physiological effects on organisms. Petroleum development on the Scotian Shelf is centred on Sable Island Bank, although there are exploration activities over a much wider area. As with the fishing activities, maps of petroleum development may be overlaid with the sensitivity map to identify areas of potential conflict. It should be noted that the sensitivity map does not identify areas that are most sensitive to chemical disturbance and this is an important consideration in evaluating impacts of this industry.

For this example, existing development wells and the offshore pipeline are shown (Figure 9). In the case of the existing activities, they are largely occurring in areas considered “least sensitive.” A section of the subsea pipeline travels through a more sensitive area. This type of overlay would be useful in assessing proposed new activities. In general, the physical disturbance footprint of drill rigs is small. If the general area of a proposed drilling activity falls within the “most sensitive” category, a more detailed examination of the area could be carried out to better understand if there will be impacts on the benthic environment.

Submarine cables

Many active and abandoned submarine cables cross the Scotian Shelf and are an important part of international telecommunications networks. Some of the abandoned cables are more than a hundred years old. Benthic impacts from submarine cables are largely from the physical disturbance caused by their placement or repair. Overlaying maps of submarine cables with the map of benthic sensitivity (Figure 10) will assist in planning cable routes and in identifying areas where particular care should be taken if repairs are needed. Several of the active cables cross through more sensitive areas of the middle shelf and management efforts could be directed to those areas.

Cumulative effects

An industry-by-industry evaluation of impacts may come to the conclusion that there are few activities and thus few benthic impacts in an area on an individual industry basis. However, the same area may be used by several industries, resulting in a large overall impact. Maps from different industries can be overlain to highlight areas where there are most likely to be cumulative effects. Overlaying groundfish fishing by otter trawl on the crab fishing map (Figure 11) shows that there are a few areas where benthic impacts may be greater than if only a single fishery was considered.

Addressing cumulative impacts may require that management actions be put in place for all the industries involved.

MANAGEMENT STRATEGIES AND ACTIONS

The draft ESSIM IM Plan (DFO 2005a) outlines the key management strategies and actions for the initiative over the next five years. It breaks them into broad thematic areas;

(i) multiple human use
(ii) marine ecosystem management and conservation
(iii) collaborative planning and management coordination

One of the priority strategies is the completion and implementation of the objectives-based ecosystem management framework. Initial work will require the identification of indicators, reference points and targets and develop a monitoring framework.

As this work is progressing, an effort will be made to evaluate impacts of human activities against ecosystem components and prioritize the issues associated. One of the strengths of the ESSIM process is the collaborative nature of the initiative which ensures that human use and institutional objectives are developed concurrently and that all three major components of the initiative are linked. Once the objectives, indicators and limits are established, the collaborative planning and management framework will be utilized to determine the most appropriate management actions needed to ensure the various ocean use activities meet the overall ecosystem objectives.

To ensure the most current and relevant information is available for decision –making in the ESSIM process, decision support tools are being developed. A detailed set of maps of human use on the Scotian Shelf have been developed, and these will be released in the form of an atlas in late 2005. The information will be utilized as part of an integrated GIS decision support framework that will cross-reference human use, ecological data and incorporate sensitivity and significance information that is being developed. This will include, in addition to the sensitive benthic communities, the identification of Ecologically and Biologically Significant Areas (EBSAs) of the Scotian Shelf. These areas will be based on criteria established at a national workshop held in 2004 (DFO, 2004).

All of these activities taken together will form the basis for a regional benthic conservation program as outlined in the draft ESSIM IM Plan (DFO, 2005a), which in turn forms a component of the overall planning and management strategy for the Scotian Shelf. The ESSIM process has made sure that all various components of the strategy are consistently moving towards effective ecosystem-based management.

FUTURE DIRECTIONS FOR SCIENCE

The Southwood (1977; 1988) habitat templet approach reported in the paper shows promise in providing a means to characterize the sensitivity of benthic communities and thus lead to better management of human activities. During workshops conducted which explored the approach (O'Boyle and Worcester, 2004; O'Boyle et. al., 2005b), a number of suggestions were discussed to further its utility. These involved improvements to the indices used in both axes, particularly food availability for Scope for Growth, additional analyses to those already conducted to validate the approach (e.g. map species of specific life history traits on the sensitivity maps), and investigation of the appropriate science products for a management decision support tool. In addition to these, work is required on appropriate reference points and directions for the various community types. Can absolute measures of allowable disturbance be produced for a benthic community of divergent species but similar life history traits. Finally, providing a theoretical, as opposed to empirical, basis for the classification of benthic communities opens the path towards linking this work with related biodiversity research (e.g. Hubble, 2001) as well as studying the relationship between biodiversity and productivity.

Another needed area of development is that of human impacts. There is a wide variety of activities that impact benthic communities – from physical disturbance by bottom trawling to chemical disturbance by oil and gas activities. Within each, there is also a range of impacts. Fishing activities can be of relatively short duration but frequent whereas the placement of submarine cables is of long duration, sometimes hundreds of years, but of low frequency. A means to classify and standardize these activities to manage cumulative impacts is necessary. This would take into account the intensity, duration, frequency and extent of the activity which would then be used to study its impact on sensitive benthic communities.

The endeavour presented here requires the collation and analysis of a wide variety of data types. The disturbance axis of the Southwood model is determined using numerous physical indicators. Predicted wind - and tide-driven current fields are calculated using physical oceanography models. Other inputs to the model consist in water temperature, chlorophyll concentrations derived from satellite imagery and water column stratification, among other. The Scope for Growth axis is similarly calculated using a series of physical and biological metrics. More details about the data requirements of the Southwood model can be found in O'Boyle and Worcester (2004). To ensure transparency in model development and to foster collaboration between researchers, a well-thought, efficient and accessible mechanism to share information is essential. As the project matures, it is expected that the data used in the model will become available to various practitioners through a central shared repository. Geographic Information Systems (GIS) provide a framework to store, retrieve and analyse such data and are an integral part of the project. It is also our goal to make the biological data from this project available on the Ocean Biogeographic Information System (OBIS), the principal information sharing mechanism for the Census of Marine Life.

CONCLUDING REMARKS

This paper summarizes the current status on the implementation of one aspect of the Scotian Shelf Integrated Management Initiative. Progress has been made on defining the overall planning framework, engaging the oceans community in setting objectives, establishing the scientific basis for operational objectives and considering consequent management actions. All of these are leading to changes in the current management system, including institutional changes within both DFO and oceans industries.

Thus far, much has been said about the need to manage how oceans activities are conducted. What is not so obvious are the changes required within DFO. A first step was creation of the Oceans sector in 1997. Subsequently, to better prepare itself to meet the obligations of the numerous acts and policies related to oceans activities, the department undertook a major review exercise, termed the Departmental Assessment and Alignment Project (DAAP). A key product of this exercise was the articulation of three strategic outcomes (Healthy and Productive Aquatic Ecosystems, Sustainable Fisheries and Aquaculture, and Safe and Accessible Waterways), each with priority program areas and an accountability framework, which would steer DFO over the longer term. Changes are also occurring within DFO Science to meet the new needs of integrated management. A major program review was conducted in 2004 which outlined required changes to the science advisory process, monitoring, data management, products and services and research. These are currently being implemented through a series of national science working groups.

Changes are also occurring within the DFO Fisheries Management sector. Fisheries on the Scotian Shelf are managed by approximately 40 fisheries management plans. In 2000, the sector undertook a national exercise to improve the form and content of the plans, in particular to ensure that each plan has explicitly identified objectives. The Objectives-based Fisheries Management (OBFM) initiative established pilot studies in each region. The Scotian Shelf pilot was the 2002 – 2007 groundfish management plan. The objectives used in this plan were based upon the national ecosystem objectives. There has also been dialogue with the scallop industry on the need to include ecosystem considerations into its planning. These pilots have pointed to the need for broader communication within DFO on the intent and requirements of integrated management. For this reason, a workshop is planned for October 2005 to ensure a consistent approach to integrated management within and amongst DFO sectors, ensure that the objectives of OBFM are consistent with those of integrated management, provide a common understanding of integrated management issues and initiatives and develop a work plan for the future.

It is evident that changes required to effectively implement integrated management outside of DFO are dependent on the changes within.

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Table 1. Issues, Ecosystem Components and Plan Level Ecosystem Objectives in the ESSIM Area associated with the National Ecosystem Objective on the Conservation of Community Diversity. Those in italics are the focus of this paper.

Issue	**Ecosystem Component**	**Plan Level Ecosystem Objective**
Important Benthic Communities	Highly Diverse or Unique Benthic Communities and Productivity Hotspots	Identify and Protect Important Benthic Communities (e.g. Highly Diverse or Unique Communities, Productivity Hotspots
Sensitive Benthic Communities	*Benthic Coral Communities in the Gully and Stone Fence Areas and other Sensitive Benthic Communities*	*Identify and Protect Coral Communities in the Gully and Stone Fence Areas*
		Identify and Protect Other Sensitive Benthic Communities
Important Pelagic Communities	Highly Diverse or Unique Pelagic Communities and Productivity Hotspots	Identify and Protect Important Pelagic Communities (e.g. Highly Diverse or Unique Communities, Productivity Hotspots
Sensitive Pelagic Communities	Sensitive Pelagic Communities	Identify and Protect Sensitive Pelagic Communities
Conservation of Communities	Pelagic Fish Communities / Assemblages (including Marine Mammals, Large Pelagics)	Maintain / Restore Identified Pelagic Fish Communities / Assemblages (including Marine Mammals, Large Pelagics)
		Maintain / Restore Identified Demersal Communities / Assemblages
	Benthic Communities / Assemblages	Maintain / Restore Identified Benthic Communities / Assemblages
	Seabird Communities / Assemblages	Maintain / Restore Identified Seabird Communities / Assemblages

Table 2. Operational Objectives to Protect Sensitive Benthic Communities at the ESSIM Plan Level

Plan Level Ecosystem Objective	**Operational Objective**	**Management Action**
Identify and Protect Coral Communities in the Gully and Stone Fence Areas	Limit Area Disturbed (km^2) of Coral Community Limit RP: 0 Precautionary RP: 0	Establish Closed Areas in Gully and Stone Fence
Identify and Protect Other Sensitive Benthic Communities	Limit Area Disturbed (km^2) of Each Benthic Community Type Limit RP: X Precautionary RP: Y	Allocate Area Disturbed to each impacting ocean industry

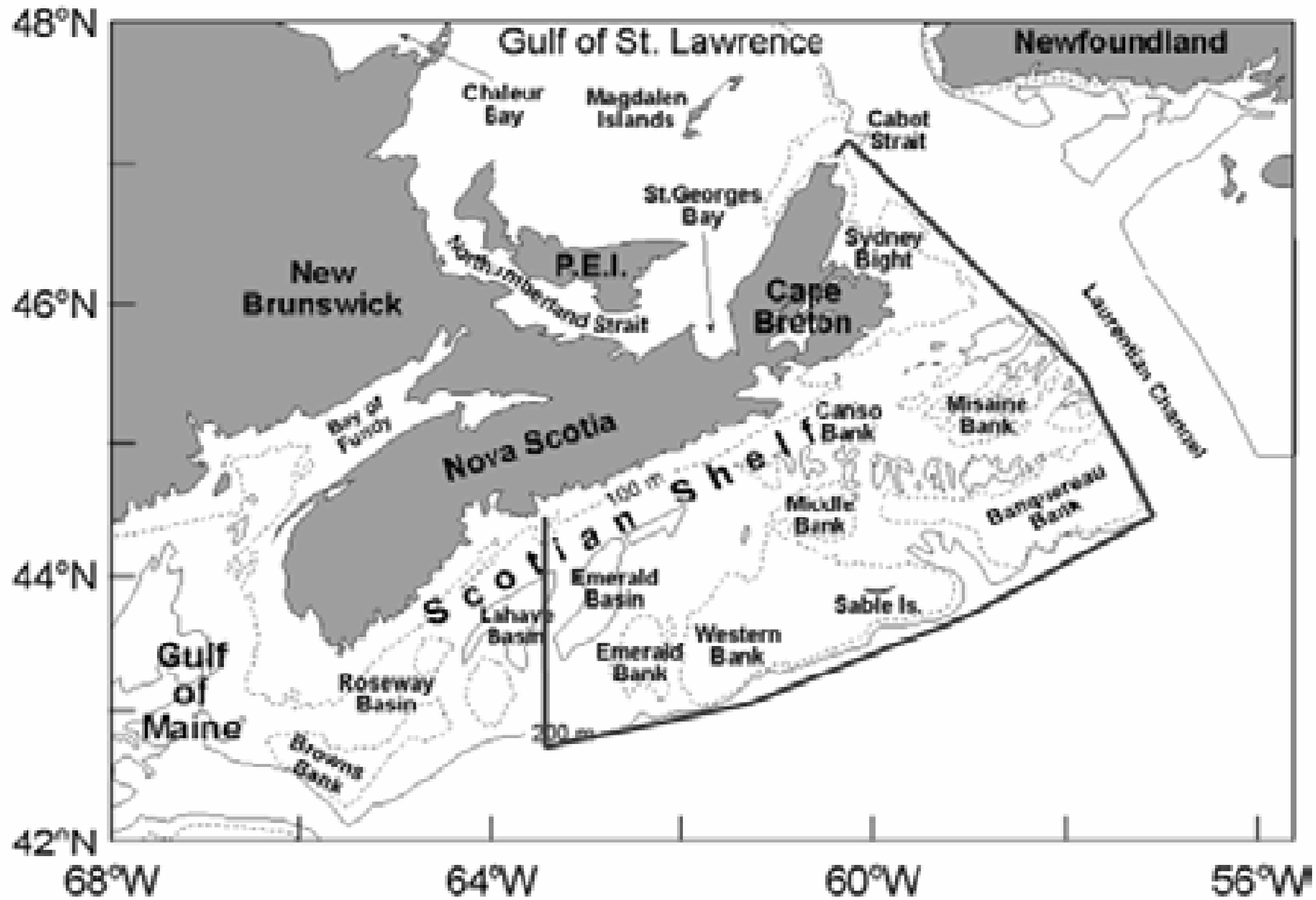

Figure 1. The Eastern Scotian Shelf Integrated Management (ESSIM) pilot area on Canada’s east coast, showing the main physical features.

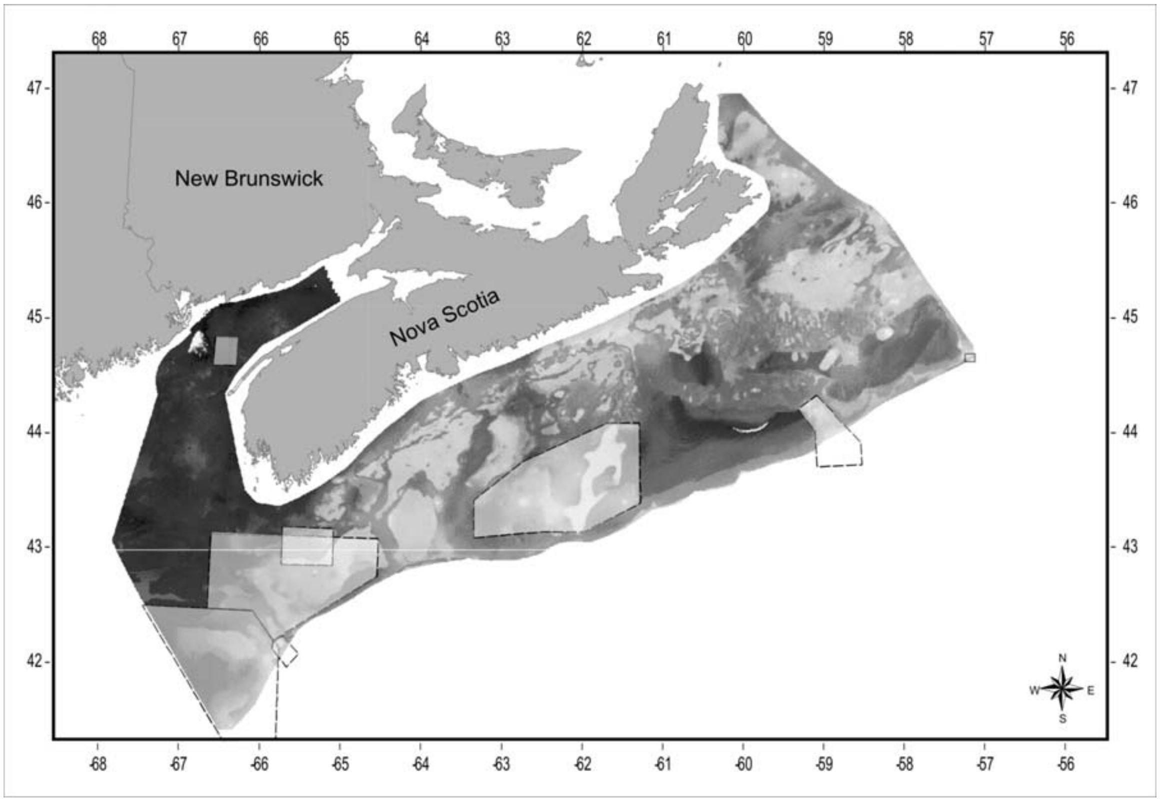

Figure 2a. Area Closures used on the Scotian Shelf, most of which are for Fisheries Management Purposes

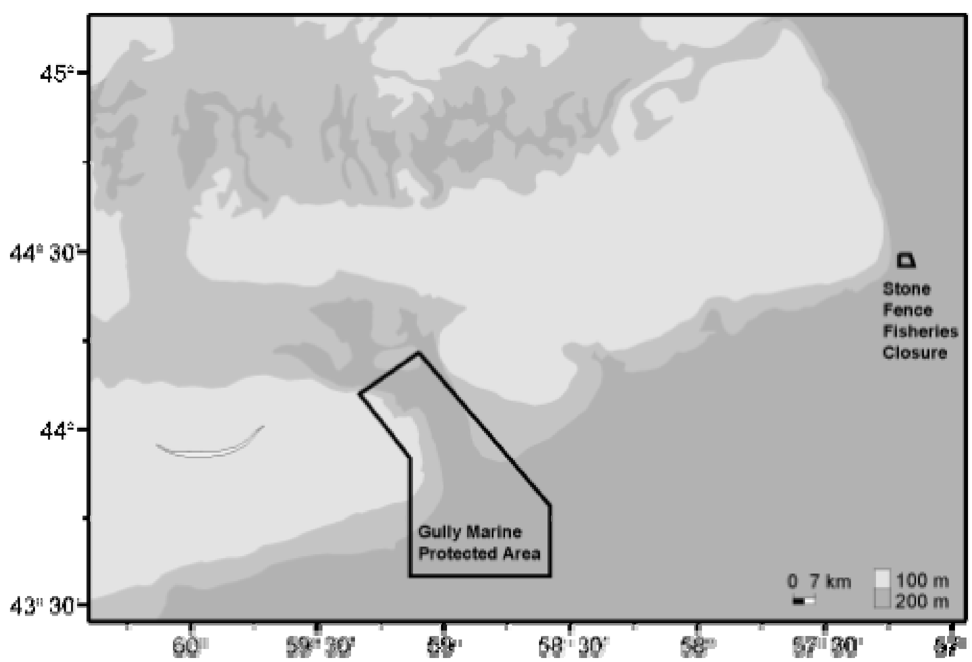

Figure 2b. Location of the Gully Marine Protected Area and Stone Fence Fisheries Closure within the ESSIM Area.

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

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 4. Physiological Energy Equation and its relationship to environmental indicators used in determining habitat adversity or Scope for Growth

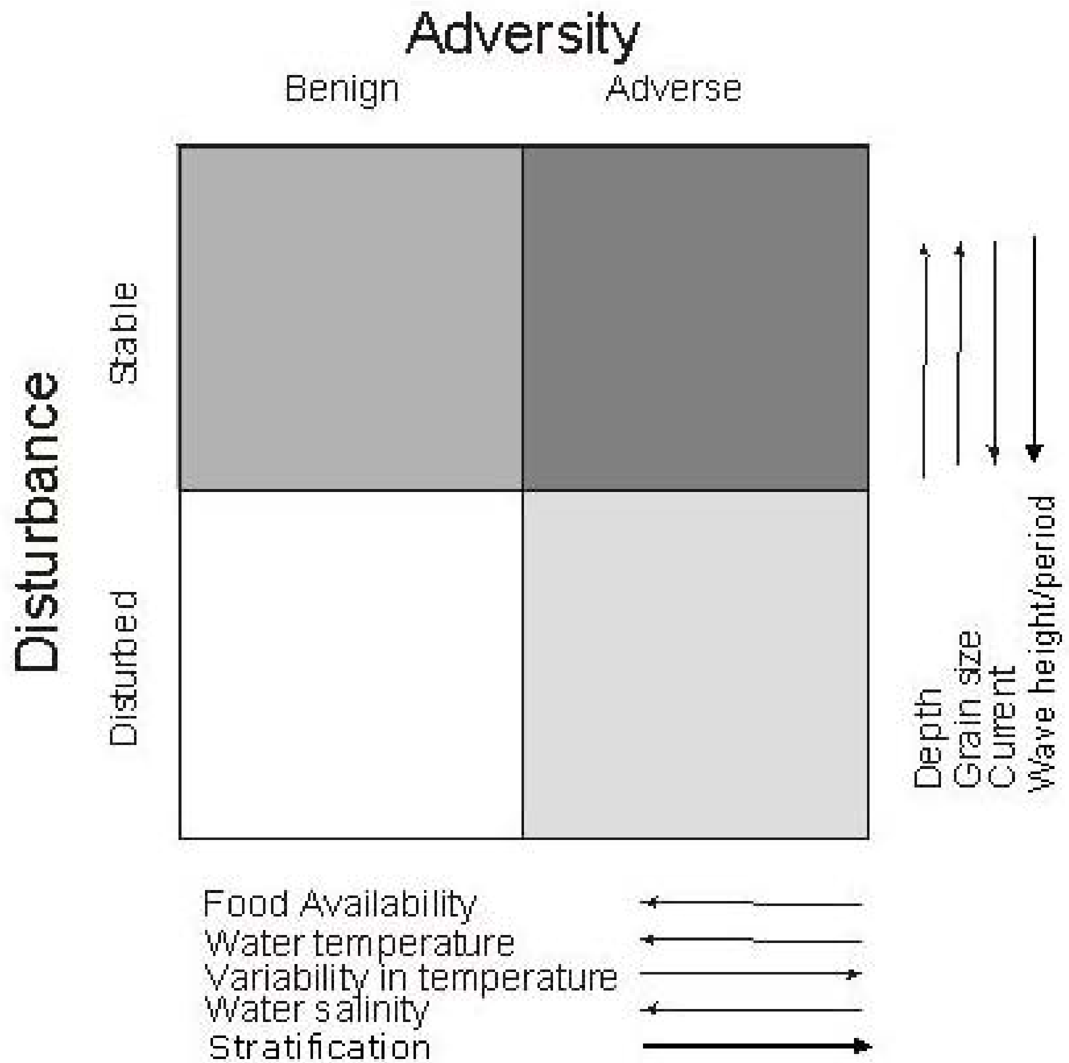

Figure 5. Indicators used in determination of the Disturbance and Adversity (Scope for Growth) Axes of the Southwood Model application to Scotian Shelf Benthic Communities

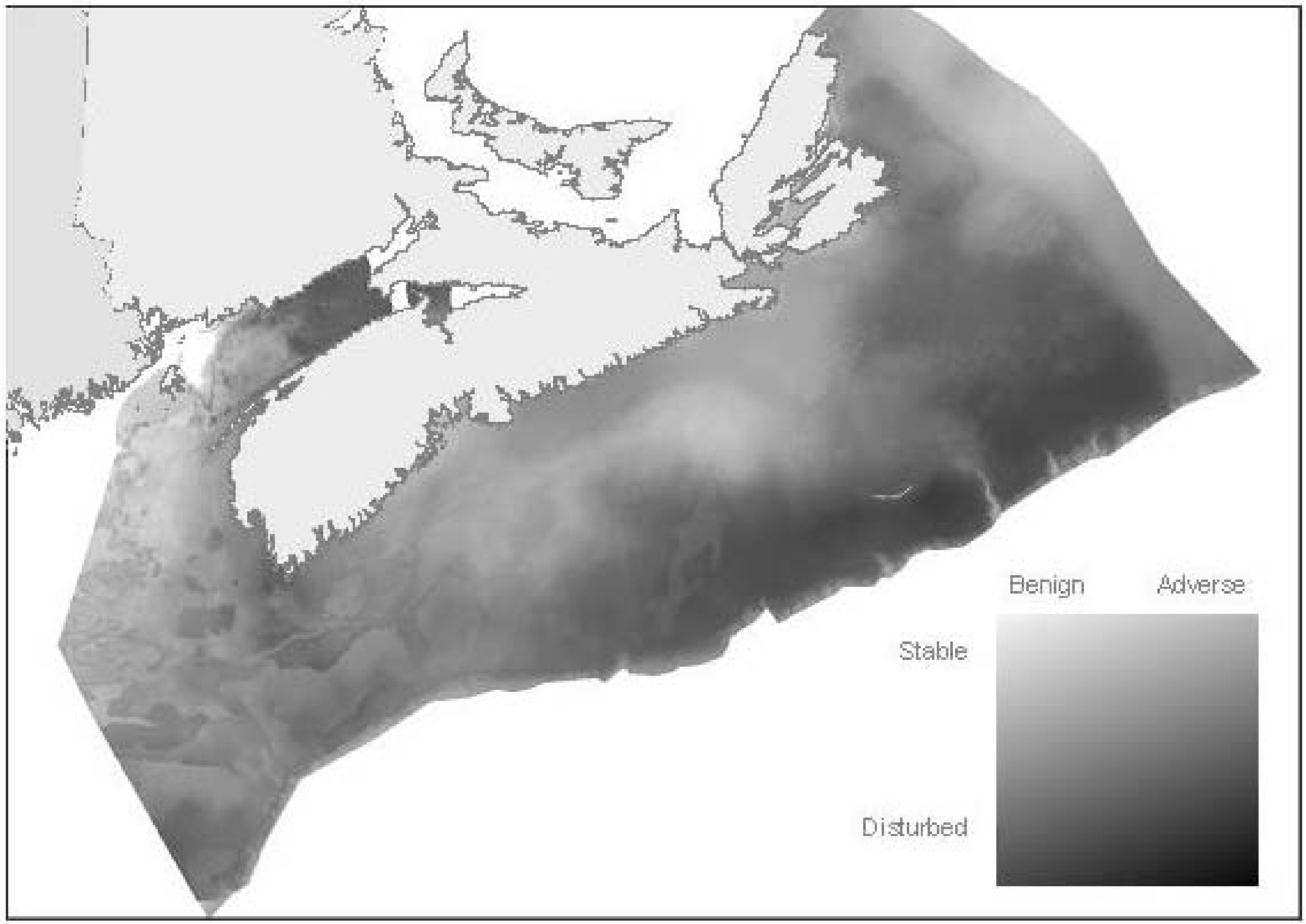

Figure 6. Classification of Scotian Shelf Benthic Communities based upon Southwood Model (produced by V. Kostylev and reported in O'Boyle and Worcester, 2005b)

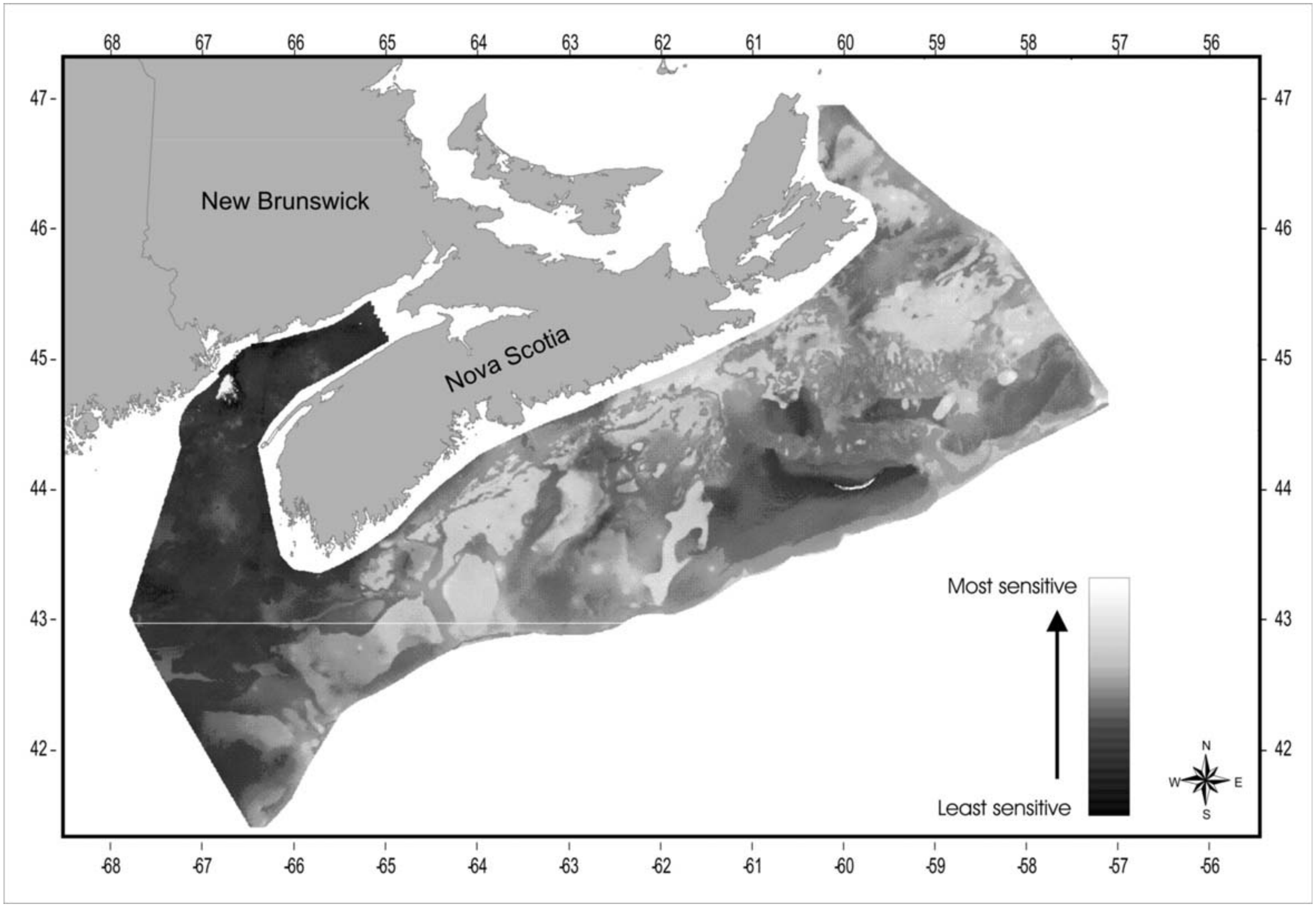

Figure 7. Areas of Sensitive Benthic Communities as Defined from Euclidean Distance for Most Sensitive Community (top right hand corner of habitat template)

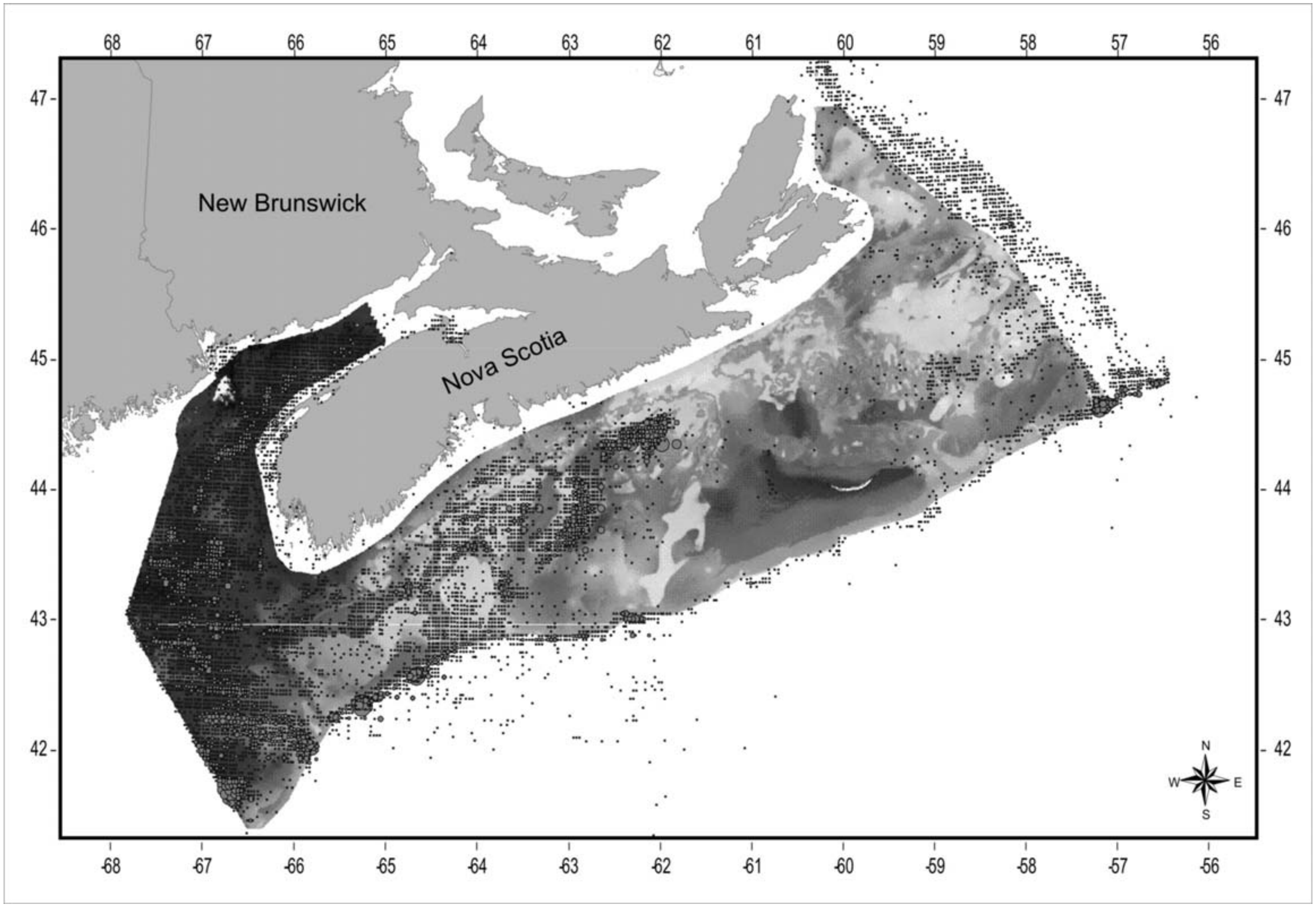

Figure 8 a. 1999 – 2003 Reported locations of Bottom Trawling from the Scotian Shelf Groundfish Fishery, overlaid on the Benthic Community Sensitivity Map (Figure 7)

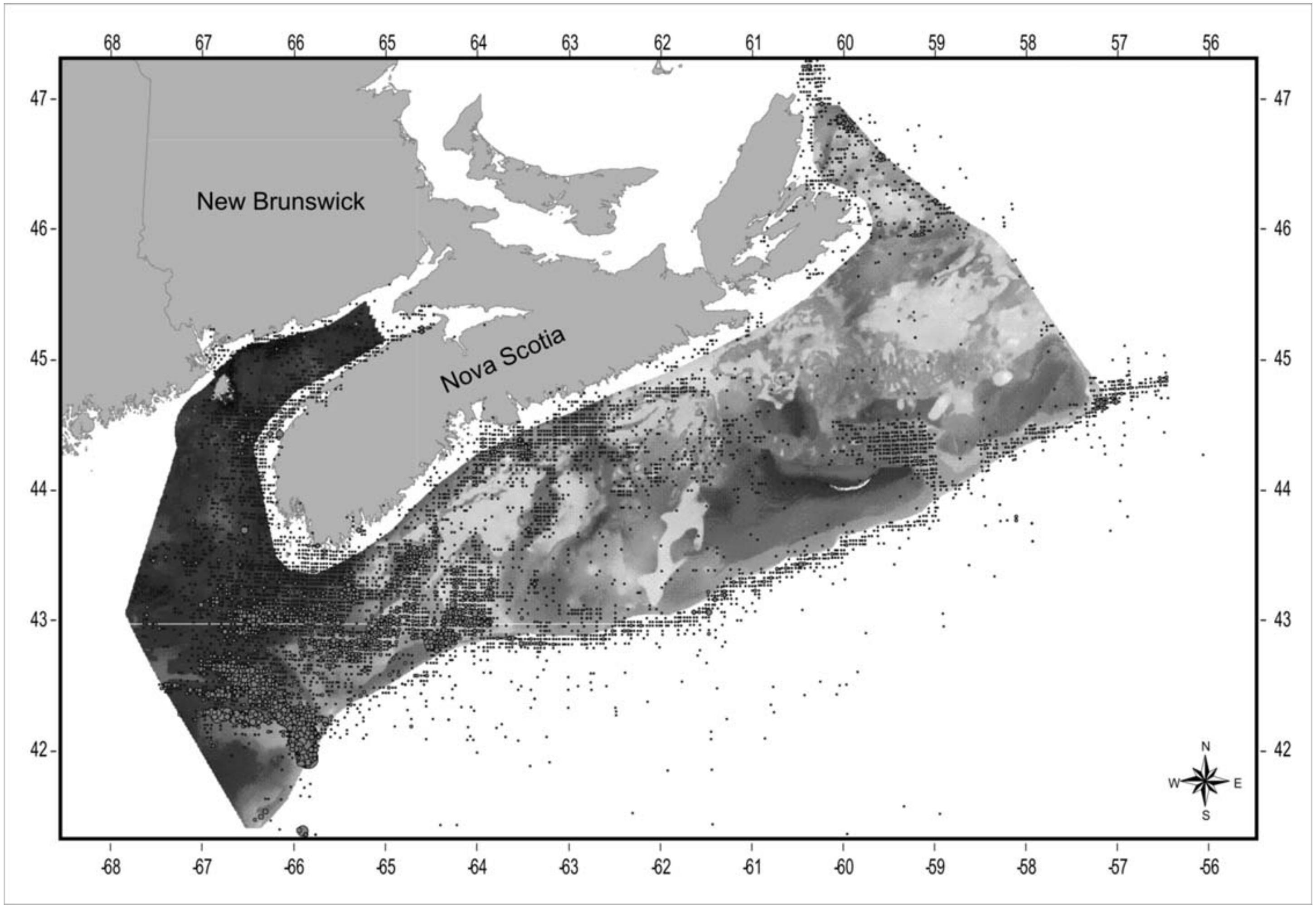

Figure 8 b. 1999 – 2003 Reported locations of Longlining from the Scotian Shelf Groundfish Fishery, overlaid on the Benthic Community Sensitivity Map (Figure 7)

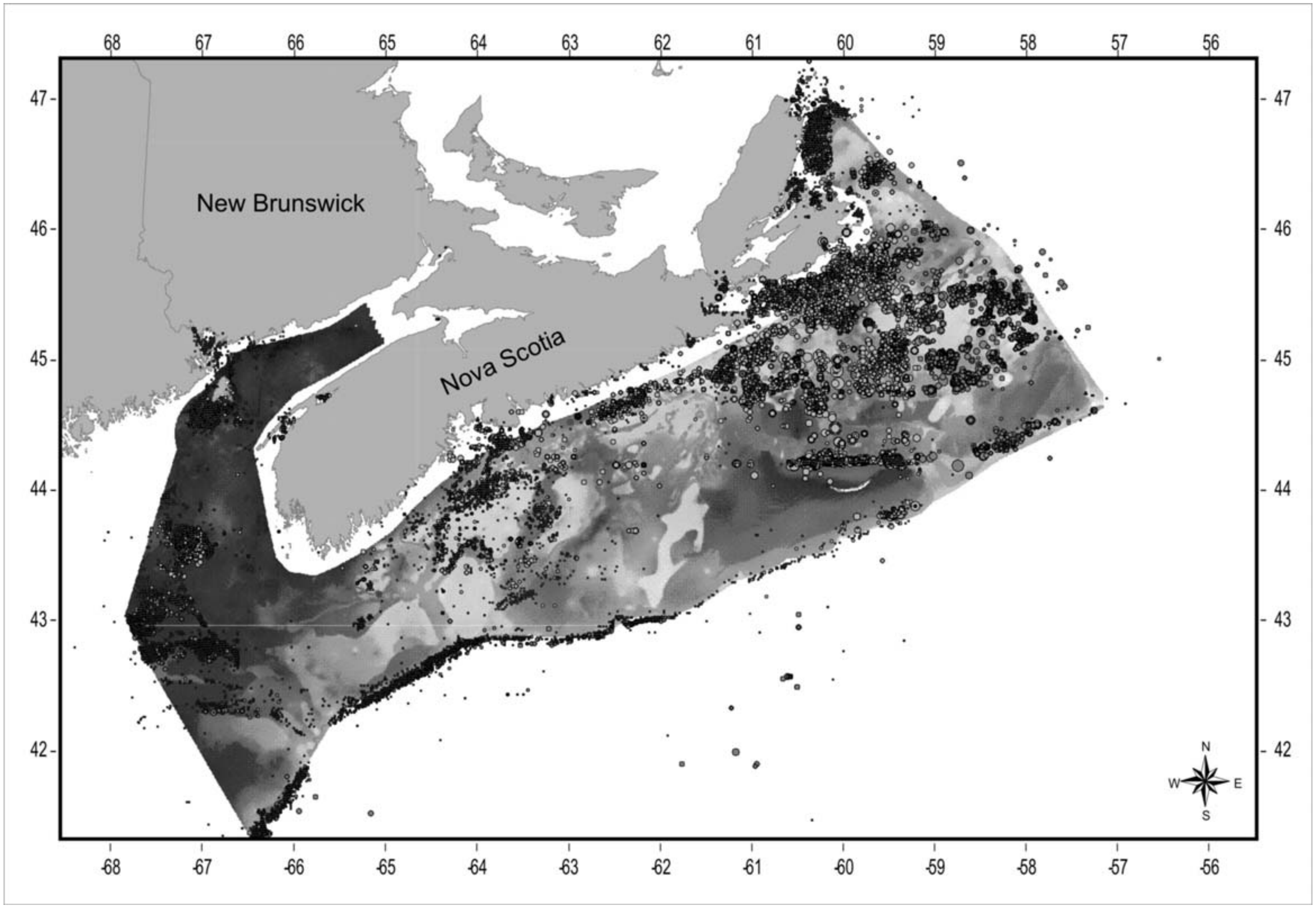

Figure 8 c. 1999 – 2003 Reported locations of Crab Fishing in the Scotian Shelf Crab Fishery, overlaid on the Benthic Community Sensitivity Map (Figure 7)

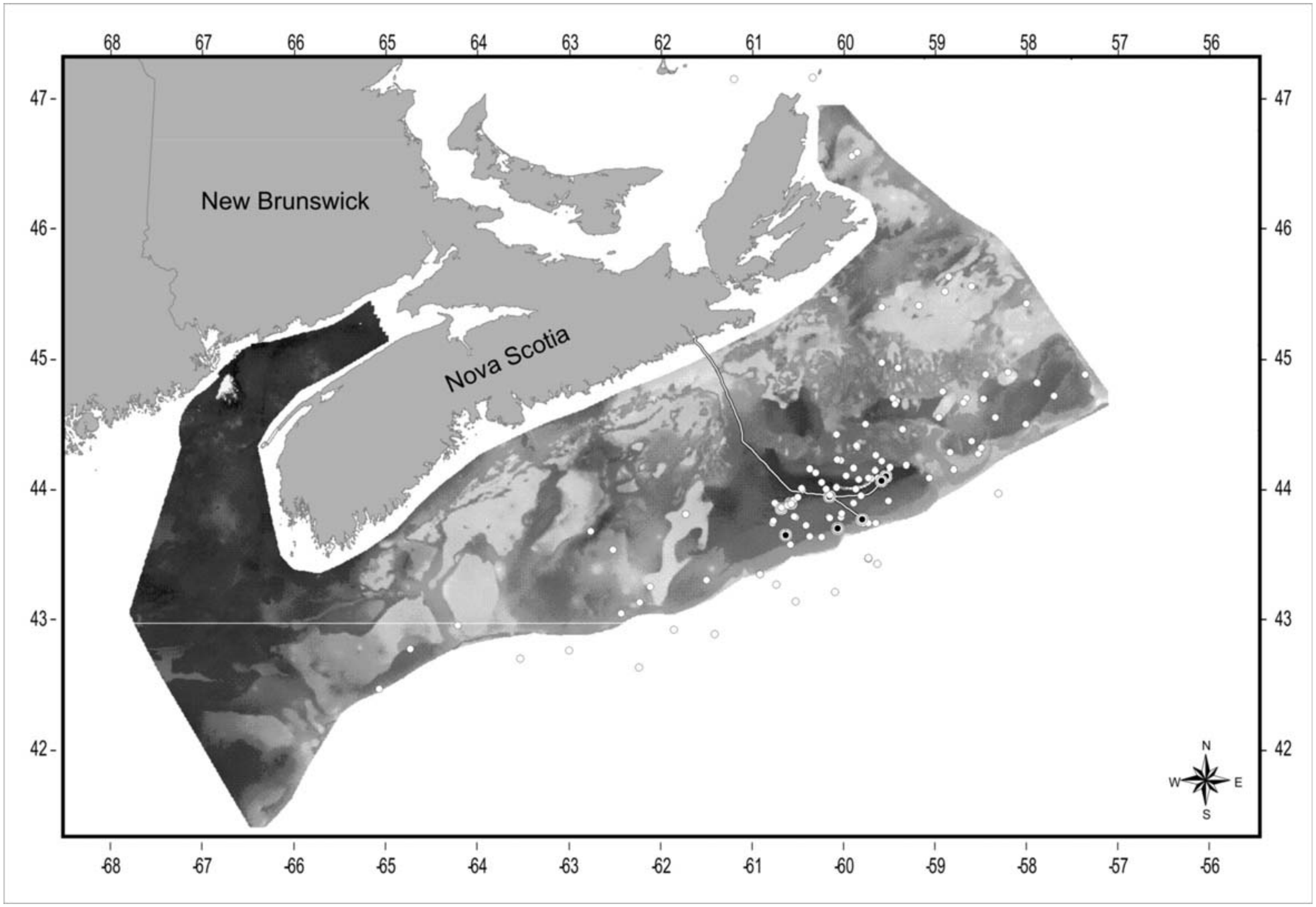

Figure 9. Locations of Current Oil and Gas Activities on the Scotian Shelf, overlaid on the Benthic Community Sensitivity Map (Figure 7)

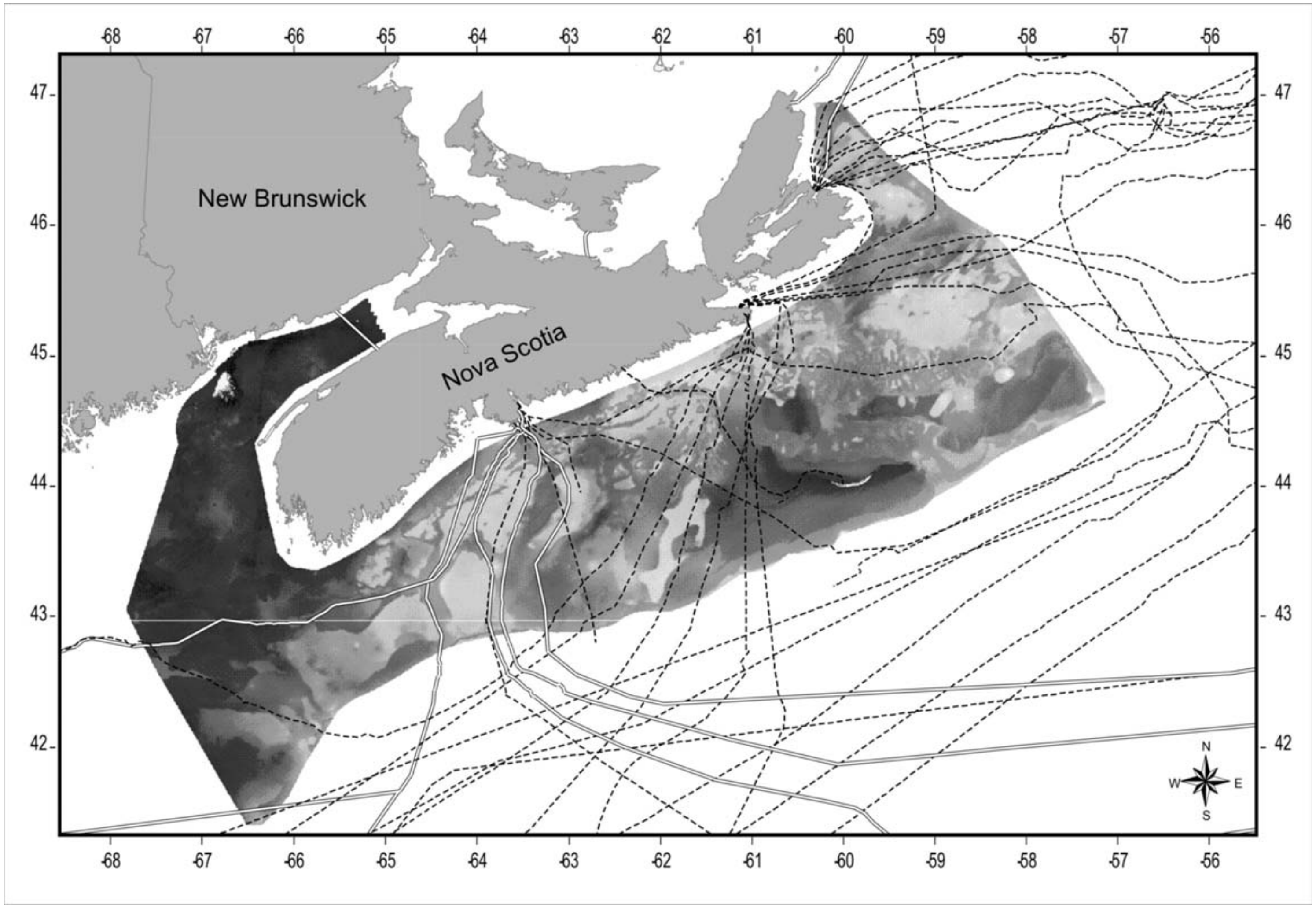

Figure 10. Locations of Active (solid) and Abandoned (dashed) Submarine Cables on the Scotian Shelf, overlaid on the Benthic Community Sensitivity Map (Figure 7)

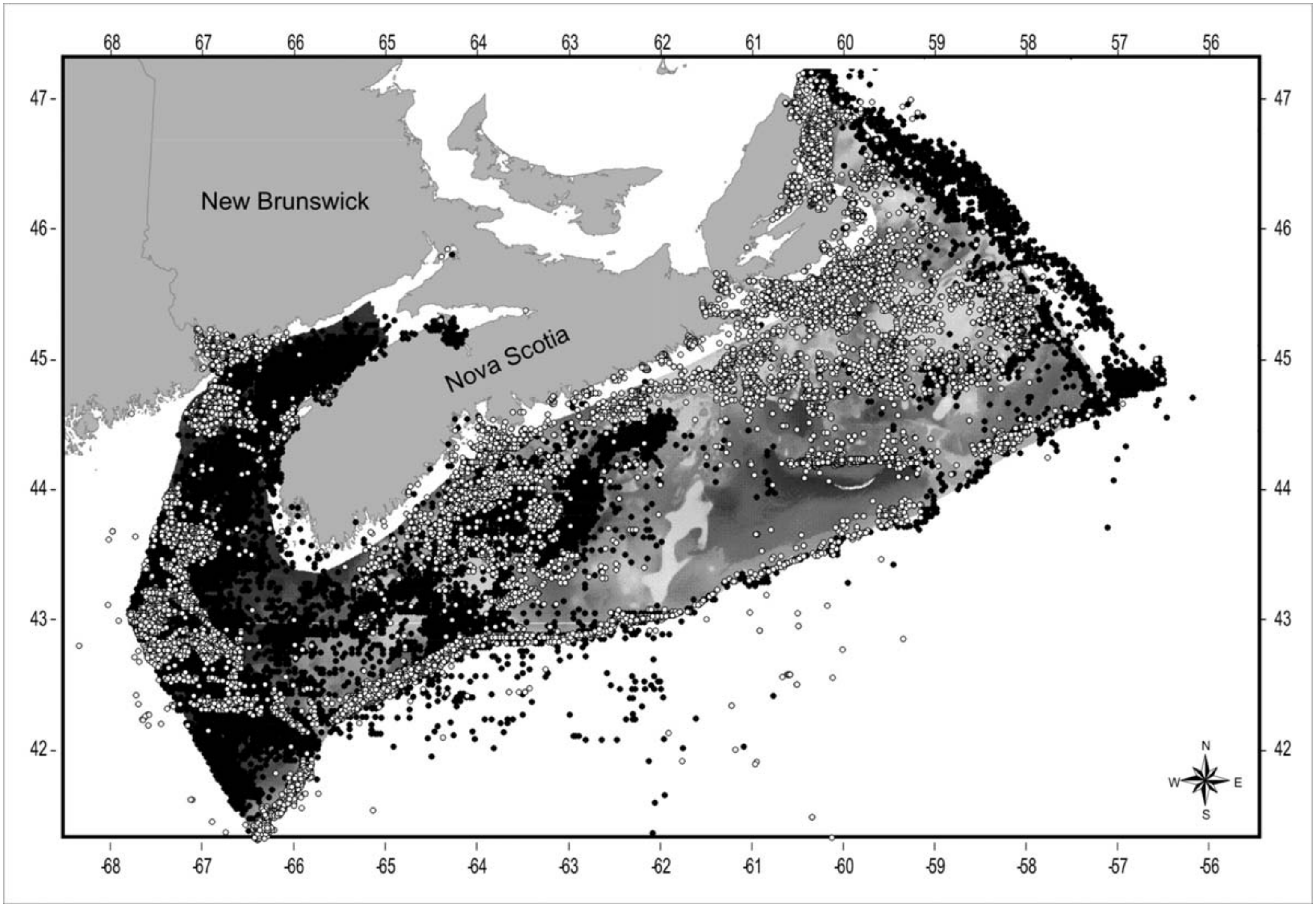

Figure 11. Crab and Groundfish Otter Trawl Fishery Locations overlaid on the Benthic Community Sensitivity Map (Figure 7)