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A Review of the Biological Characteristics and Ecological Functions Served by Corals, Sponges and Hydrothermal Vents, in the Context of Applying an Ecosystem Approach to Fisheries

Un examen des caractéristiques biologiques et des fonctions écologiques assurées par les coraux, les éponges et les cheminées hydrothermales dans le contexte de l'application d'une approche écosystémique aux pêches

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ABSTRACT

This paper was produced in response to a request for advice on a scientific basis for managing fisheries impacts on benthic habitats and communities, with an emphasis on coldwater corals, sponges, and hydrothermal vent (HTV) communities. Coldwater corals, sponges and HTV communities are consistently used as examples of ecosystem components that require special attention owing to their ecological importance. Departmental mandates of Fisheries and Oceans Canada (DFO) speak to Canada's commitments to manage anthropogenic impacts, including fishing, in a manner that insures sustainable utilization, conservation of biodiversity, no net loss of fisheries habitat and protection of species at risk. The legal precedence for this mandate is derived at the national level under the *Fisheries Act* and the *Species at Risk Act* (SARA), and under ratified international agreements such as the Convention on Biological Diversity (CBD) and the United Nations General Assembly (UNGA) Resolution 61/105. These regulations and international agreements provide the characteristics and definitions of what is legally "important". Although the importance of protecting fish habitat is well understood, the management of anthropogenic impacts has been inconsistently applied to various threats. Impacts often have unique, although sometimes overlapping pathways of effects, at both the species and the ecosystem functioning level. There are a number of ecosystem approaches to management (EAM) that have made progress on defining the key components necessary to quantify impacts, manage threats to ecosystem functions and the delivery of key ecosystem services like fisheries. The biggest problem that plagues existing EAM is the lack of appropriate data at the species and ecosystem levels. It is recommended that a holistic EAM be developed, which encompasses DFO's mandate to manage all threats under a common framework.

RÉSUMÉ

Ce document a été créé en réponse à une demande d'avis scientifique pour la gestion des impacts des pêches sur les habitats et les communautés benthiques avec un accent sur les coraux d'eaux froides, les éponges et les communautés des cheminées hydrothermales. Les coraux d'eaux froides, les éponges et les communautés des cheminées hydrothermales sont souvent pris comme exemples de composantes de l'écosystème qui exigent une attention particulière en raison de leur importance écologique. Les mandats ministériels de Pêches et Océans Canada (MPO) témoignent des engagements du Canada visant à gérer les impacts causés par les activités humaines, y compris les pêches, de manière à assurer l'utilisation durable, la conservation de la biodiversité, aucune perte nette de l'habitat du poisson et la protection des espèces en péril. Le précédent jurisprudentiel de ce mandat est obtenu au niveau national en vertu de la *Loi sur les pêches* et de la *Loi sur les espèces en péril* (LEP), ainsi que d'accords internationaux ratifiés tels que la Convention sur la diversité biologique (CDB) et la Résolution 61/105 de l'Assemblée générale des Nations Unies (UNGA). Ces règlements et accords internationaux fournissent les caractéristiques et les définitions de ce qui est « important » sur le plan juridique. Bien que l'on reconnaisse l'importance de la protection de l'habitat du poisson, la gestion des impacts causés par les activités humaines a été appliquée à diverses menaces de manière inégale. Les impacts ont souvent des séquences d'effets uniques, mais qui se chevauchent parfois, qu'ils s'agisse des espèces ou de la dynamique des écosystèmes. Plusieurs approches de gestion écosystémiques ont progressé dans le cadre de la détermination des composantes clés pour mesurer les impacts et gérer les menaces aux fonctions de l'écosystème et la prestation des services écosystémiques clés tels que les pêches. Le manque de données pertinentes concernant les espèces et les écosystèmes demeure le principal problème relatif aux approches de gestion écosystémiques actuelles. On recommande l'élaboration d'une approche de gestion écosystémique holistique qui englobe le mandat du MPO consistant à gérer toutes les menaces dans un cadre de travail commun.

INTRODUCTION

This paper was produced in support of a national Canadian Science Advisory Secretariat (CSAS) science advisory process, in March 2010, to address a request for science advice on the nature, extent and significance of fisheries impacts on benthic habitats and communities. This kind of advisory process could just as appropriately been convened to address potential ecosystem impacts of any other anthropogenic activities for which management falls within Fisheries and Oceans (DFO) mandate. The March workshop has limited its scope to review the impacts on coldwater corals, sponges, and hydrothermal vents (HTV), in correspondence with the focal habitats addressed in the FAM policy on sensitive benthic areas. This paper will address the following:

- Why are coldwater corals, sponges, and HTV the focus of this request?
- What are the regulatory authorities and the species and community properties that make them important?
- What are the pathways of effects of fishing and many other anthropogenic activities?
- What have other regulatory authorities done, both internationally and domestically, to address this issue?
- What recommendations might flow from the information to address these threats?

The Terms of Reference for the related scientific advisory process presents the drivers, goals, and objectives for the meeting with an emphasis on the impacts of fishing.

Canadian fisheries managers are being asked to develop management plans which address fisheries impacts on benthic habitats. This is occurring at both the international level through Regional Fisheries Management Organisations (e.g. NAFO) and domestically through the Sustainable Fisheries Framework *Policy for Managing the Impacts of Fishing on Sensitive Benthic Areas*. The over-arching policy agreement driving the development of provisions in fishery management plans to protect vulnerable marine habitats are paragraphs 80 and 83 of the United Nations General Assembly (UNGA) Resolution 61/105, which state:

80. *Calls upon* States to take action immediately, individually and through regional fisheries management organizations and arrangements, and consistent with the precautionary approach and ecosystem approaches, to sustainably manage fish stocks and protect vulnerable marine ecosystems, including seamounts, hydrothermal vents and cold water corals, from destructive fishing practices, recognizing the immense importance and value of deep sea ecosystems and the biodiversity they contain;

83. *Calls upon* regional fisheries management organizations or arrangements, with the competence to regulate bottom fisheries, to adopt and implement measures, in accordance with the precautionary approach, ecosystem approaches and international law, for their respective regulatory areas as a matter of priority, but not later than 31 December 2008:

(*a*) To assess, on the basis of the best available scientific information, whether individual bottom fishing activities would have significant adverse impacts on vulnerable marine ecosystems, and to ensure that if it is assessed that these activities would have significant adverse impacts, they are managed to prevent such impacts, or not authorized to proceed;

(*b*) To identify vulnerable marine ecosystems and determine whether bottom fishing activities would cause significant adverse impacts to such ecosystems and the long-term sustainability of deep sea fish stocks, inter alia, by improving scientific research and data collection and sharing, and through new and exploratory fisheries;

(*c*) In respect of areas where vulnerable marine ecosystems, including seamounts, hydrothermal vents and cold water corals, are known to occur or are likely to occur based on the best available scientific information, to close such areas to bottom fishing and ensure that such activities do not proceed unless conservation and management measures have been established to prevent significant adverse impacts on vulnerable marine ecosystems;

(*d*) To require members of the regional fisheries management organizations or arrangements to require vessels flying their flag to cease bottom fishing activities in areas where, in the course of fishing operations, vulnerable marine ecosystems are encountered, and to report the encounter so that appropriate measures can be adopted in respect of the relevant site;

WHY COLDWATER CORALS, SPONGES, AND HYDROTHERMAL VENT COMMUNITIES?

Restricting the emphasis of the advisory process related to this document to coldwater corals, sponges, and HTV communities reflects the current practice that these organisms and communities are consistently used as examples of ecosystem components that require special attention. FAO (2009) included these organisms and communities in the Annex to the Deep Sea Fishery Guidelines, as examples of ecosystems that are highly sensitive and vulnerable to impacts of fisheries using bottom-contacting gear. DFO managers from the Oceans sector have highlighted them in the establishment of the first DFO Marine Protected Area (MPA) at the Endeavour Ridge Hydrothermal Vents and through the development of coldwater coral and sponge conservation strategies in the Maritimes and Pacific Regions, as well as a National Center of Excellence for Corals and Sponges. Habitat and aquaculture managers are also keenly aware of these and other sensitive areas when they conduct their marine environmental assessments. In the USA, as part of their procedures to identify and manage Essential Fish Habitat, these organisms fall under their definition of Habitat of Particular Concern (HAPC). Coleman and Williams (2002) and Levin and Dayton (2009) classified corals and sponges as examples of ecosystem engineers which are species that create complex habitat either through their behaviour or owing to their morphology. Levin and Dayton (2009) also highlight the importance of HTV communities in our understanding of ecological and evolutionary processes controlling biodiversity and community structure, in systems driven by chemosynthetic food webs. The role of corals and sponges as bioengineers is also highlighted in the technical guidance for implementation of the EU Marine Strategy Framework Directive (ICES-JRC 2010). Establishing management principles and practices to ensure the sustainability of these organisms can easily be transferred to other organisms and communities.

HOW DO WE DEFINE IMPORTANCE?

In determining the “importance” of coldwater corals, sponges and HTV communities, we need to understand DFO responsibilities at the species level and at the ecosystem functioning level.

SPECIES PROPERTIES

Coral and sponge form major components of the biodiversity of Canada's Oceans, and as such DFO has the legal capacity to ensure their protection and conservation under the national *Species at Risk Act* (SARA), and *Fisheries Act*. Canada has also voiced its commitments to the conservation of biodiversity in ratified international agreements such as the Convention on Biological Diversity (CBD) and the UNGA. These international and national commitments apply to all species but are designed to be specifically effective in the protection of rare, endemic species and declining species that are highly vulnerable to damage by any form of anthropogenic threats (Glover and Smith 2003, InterRidge http://www.interridge.org/node/160).

***Species at Risk Act* (SARA)**

The *Species at Risk Act* was passed in June 2002. This Act is a key federal government commitment to prevent wildlife species from becoming extinct and secure the necessary actions for their recovery. It provides for the legal protection of wildlife species and the conservation of their biological diversity that have been identified at risk and listed under the Act.

To assess status and productivity, of non-harvested species and populations, requires the same data, procedures, and protocols used to evaluate the productivity and dynamics of targeted populations in a commercial fishery. However, data is often limited for non-target species, requiring the use of data-poor assessment methods (Piling et al. 2008, EU Poorfish Project: http://www.poorfish.eu/). Such approaches are being carried out to determine the sustainability of some of the fisheries in Australia on the Great Barrier Reef. In Canada, one of the tasks conducted to implement SARA is the development of a General Status Report for Canada's flora and fauna. The key components of this exercise include: the identity of the organisms; their distribution and the trends in these distributions; their population size and the trends in these population sizes; and finally the key biological characteristics that would define the populations' resilience to impacts.

Coldwater corals, sponges, and HTV communities are groups of animals that are taxonomically challenging and as such it is often difficult to identify which species are actually present. For example, of the 250+ species of sponges in the waters off the Pacific coast of Canada, there are at least 90 species that need to be described taxonomically before they can even be assessed in a General Status Report. The information that is coming in from observer sampling and research cruises has improved in the last few years, but is still deficient for all but a few species. The trends in distribution would be impossible to recreate from historical data as appropriate information was not collected. Surveys of the present status of coldwater corals and sponges would under-estimate historical distribution and abundance, due to impacts (particularly from past fisheries using mobile bottom-contacting gears) during past decades, from which recovery has not yet occurred. As a result, the only currently feasible way to evaluate a metric for trends in distribution is to use predictive species modeling (Finney and Workman 2010). Estimating population sizes and trends in populations cannot be completed owing to the same data problems encountered in trying to estimate distributions and trends in distribution. Moreover, owing to the extended life history schedules of essentially all coldwater corals and many sponges (Roberts et al. 2006, 2009), the sustainable rate of population loss is very small; certainly less than 5% per annum and in many cases 1% or less. Except for a very few particularly charismatic megafauna (usually endangered cetaceans or seabirds) we lack the ability to detect these small rates of change for any marine species, and particularly for incompletely surveyed benthic invertebrates. Hence, any management approach with actions triggered solely by quantified changes in estimates of population sizes of coldwater corals or sponges will be far to slow to respond to unsustainable impacts on those populations, therefore other approaches will have to be sought.

To estimate the ability of a population to recover from impacts, information on the key biological parameters of these organisms must be modeled against the nature and extent of the impact. Key biological parameters generally include: maximum age, age at first maturity, reproductive modes, potential reproductive outputs, ability to recolonize, dispersal mechanism of reproductive outputs, growth, ability to regenerate, ability to avoid the impact (mobility and where it lives). Appendix 2 outlines the diversity of these key biological traits that are found in coldwater corals and sponges.

Convention on Biological Diversity

The Parties to the CBD (1992) have adopted the goal to establish a global, representative system of MPA by 2012, in areas beyond national jurisdiction (WSSD 2002). The CBD has produced scientific criteria for identifying Ecologically or Biologically Significant marine Areas (EBSA) in need of protection in open-ocean waters and deep-sea habitats (CBD 2009). Here, the scientific selection criteria for MPA is related to coldwater corals and sponge habitat and HTV communities in order to examine whether such habitats can be considered EBSA and thus qualify for designation as MPA. Similarly, DFO developed EBSA criteria (DFO 2004a) that closely followed those developed by the CBD (see below) that could be considered when determining areas to be designated as MPA within Canadian waters under the federal *Oceans Act*.

1. Uniqueness or rarity – An area contains either (i) unique ('the only one of its kind'), rare (occurs only in few locations) or endemic species, populations or communities, and/or (ii) unique, rare or distinct, habitats or ecosystems; and/or (iii) unique or unusual geomorphologic or oceanographic features.

CBD (2009) does not set any limits to determining rarity or uniqueness, but indicates that the loss of such areas would be permanent. Rarity is subjective and must be evaluated on a relative scale against other similar habitat types at a range of scales. For areas containing coldwater corals and sponges, one can not say that all species and areas containing the animals are either rare or unique; however, there are certainly many species and areas of both that could and should be classified as such. For example, on the Canadian Pacific coast there have been discovered a number of rare and new species of corals and sponges; the Russian Hat population of sponges on the Scotian Shelf or the Glass Sponge Reefs in the Pacific (although in this latter case the reef-building species are not unique, it is ability to sustain reef-building in specific areas of the coast that is unique and rare). For HTV communities, the designation of Endeavour Ridge HTV as Canada's first MPA was based on the uniqueness of the area and the rarity of many of the animals comprising the HTV community.

2. Special importance for life-history stages of species - Areas that are required for a population to survive and thrive.

For coldwater corals and sponges this again depends on the species and its life history characteristics. With so little information available for most of these species and their related communities, it is difficult to identify these areas under this criterion. There is growing evidence that these isolated coral and sponge habitats are genetically isolated and so in one sense the habitat becomes essential for population sustainability. However, this criterion is easily applied to small, patchy biodiversity hotspots found in the deep continental margin areas like HTV communities (Levin and Dayton 2009).

Some coldwater coral, sponge, and HTV communities in their role as ecosystem engineers may well fulfil these criteria as habitat. Those which are large enough to be classified as ecosystem engineers appear to play an important role in local functional ecology. In particular, there is some evidence that many fish species are attracted to these benthic features, but the nature of this attraction is still poorly understood. CBD (2009) highlight the difficulties of applying the criteria in data-deficient situations such as in the deep sea and emphasize the need for a precautionary approach.

3. Importance for threatened, endangered or declining species and/or habitats – An area containing habitat for the survival and recovery of endangered, threatened, declining species or area with significant assemblages of such species.

Many of these species may actually fall into this category but until we deal with the issues in the aforementioned Criteria 1 and 2, it will be difficult to address this criterion except for the rare, endemic species within HTV communities. This criterion is very similar to Criterion 2.

4. Vulnerability, fragility, sensitivity, or slow recovery - Areas that contain a relatively high proportion of sensitive habitats, biotopes or species that are functionally fragile (highly susceptible to degradation or depletion by human activity or by natural events) or with slow recovery.

Here the concept of the resilience of the habitat to human pressures is raised. The CBD gives an example of this criterion under Vulnerable Species (i.e. species with structures providing biogenic habitats, such as coldwater corals, sponges and bryozoans). However, it is clear that within such broad biological groups such as corals and sponges that there will be some taxa which clearly meet this criterion and others which will not. NAFO reviewed the coral taxa within its Regulatory Area and concluded that soft corals and some cup corals (e.g., *Flabellum* spp.) did not meet this criterion, while gorgonian corals, black corals and sea pens amongst others, did (Fuller et al. 2009).

5. Biological productivity – An area containing species, populations or communities with comparatively higher natural biological productivity.

The CBD specifically mentions HTV as an example of this criterion. Levin and Dayton (2009) review this question as it applies to continental margin ecosystem and the processes controlling biodiversity and community structure. They highlight issues requiring further research including: latitudinal trends; the roles for protozoa and their greater importance in increasing water depth and decreasing oxygenation; competition and predation including territoriality, allelopathy, mimicry, refugia or propagule banks; and chemosynthesis-based food webs.

6. Biological diversity – An area contains comparatively higher diversity of ecosystems, habitats, communities, or species, or has higher genetic diversity.

Here traditional biological measures of diversity are included, that is indices that capture richness, evenness, taxonomic distinctiveness, and genetic diversity. Coldwater corals, sponges and HTV communities can be structurally complex habitat created site-specifically by a multitude of ecological engineers, with a large number of associated species and the capacity to create new habitat for the settlement of other macro- and megafauna.

7. Naturalness – An area with a comparatively higher degree of naturalness as a result of the lack of, or low level of, human-induced disturbance or degradation.

The criterion of naturalness gives higher priority to undisturbed or pristine habitats than to those which have been severely altered by human activities. However, as for some of the other criteria, naturalness is a relative state and even in heavily impacted areas relatively natural habitats may be found. These may be areas that are avoided by the fishing gear (as in the case of some of the sponge grounds within the fishing footprint of the NAFO Regulatory Area, or due to area closures (whether directed on the habitat or coincidental), which allow recovery to take place.

ECOSYSTEM PROPERTIES

Coldwater corals, sponges, and HTV communities have been also been designated as important owing to the special ecological contributions that they make.

HTV communities have many special ecological properties, primarily as the ecosystem structure is based on chemosynthesis rather than photosynthesis. These properties are reviewed by Banoub (2010).

Coldwater corals and sponges have functions in the trophic dynamics of their ecosystems but many also provide services as ecosystem engineers; that is, organisms that alter the structure of the seafloor in ways that are used by other organisms. The importance of the structural habitat they form to ecosystem function has been documented in many studies and reviewed in Freiwald and Roberts (2005), Valentine and Hecht (2005), and Roberts et al. (2006, 2009). Key functions of bioengineers include shelter from predation for small fish and invertebrates (ex. Grabowsky 2004, DeMartini and Anderson 2007, Pratchett et al. 2008, Wang et al. 2009), foraging centers particularly for grazers and predators with sit-and-wait predation strategies (Husebø et al. 2002, Costello et al. 2005, Auster 2007, Mumby et al. 2007, Rilov et al. 2007), resting sites from strong currents (Robinson et al. 2007, Johansen et al. 2008) and more generally serving as aggregation features for marine life (Hughes et al. 2002, Claudet and Pelletier 2004). In continental margins, where there is very little abiotic structure in the habitats, biogenic structures are fragile and patchy but provide these specialized habitats for often unique assemblages of animals (Levine and Dayton 2009). In particular, these functions combine to make coral communities among the most species-rich areas of marine ecosystems in most areas where they have been studied (Grassle 2007, Conservation International http://www.biodiversityhotspots.org/Pages/default.aspx), including Atlantic Canada (Buhl-Mortensen and Mortensen 2005, Edinger et al. 2007)

The protection of ecosystem functions falls within DFO's mandate at the national level under the *Fisheries Act* and under ratified international agreements such as UNGA Resolution 61/105.

***Fisheries Act* (Habitat)**

The *Fisheries Act* protects ecosystem engineers in their role as fish habitat, meaning that impacts which decrease their ability to serve their ecological functions may constitute 'Harmful Alterations' of habitat and these activities may either be prohibited or require compensation. The extent to how the ecosystem function served by these bioengineers varies with the relative density and quality of the corals and sponges has not been systematically quantified for any coldwater ecosystem. However, there is no reason to assume that the habitat functions served by these species vary in a different way than other types of habitat. In general, high quality habitat becomes a "hotspot" for species using the habitat features (Rahel et al. 2008, Honea et al. 2009), and thus are centers for biodiversity conservation. At very low relative densities of the habitat-forming features there is likely to be depensation, as it is unlikely that the larger ecosystem can have the relevant functions fully served by a very limited amount of a particular habitat type (Jennings 2000, Dulvy et al. 2003). Biodiversity conservation of rare species and communities may be a relevant consideration for rare habitat types; however, there is little scientific guidance on how to practically establish the relative density/ concentration of the habitat forming species at which the functions provided become important to ecosystem function (DeMartini and Anderson 2007, Belmaker et al. 2008, Kenchington et al. 2009). As habitat functions become important to the larger ecosystem, then initially the increase in functional significance is likely to be more rapid than the increase in amount of the habitat, but eventually begin to asymptote, as other factors become limiting on abundances of related species (ICES 2008, Rice 2009).

UNGA Resolution 61/105 (FAO guidelines)

The principles and directions outlined in the FAO Committee on Fisheries (COFI) *International Guidelines for the Management of Deep-Sea Fisheries in the High Seas* were adopted as the technical basis for actions by States and RFMO to implement those provisions of UNGA 61/105. These Guidelines were drafted by relevant experts to assist States and RFMO/A to sustainably manage deep-sea fisheries consistent with the precautionary approach and to guide the implementation of *UNGA Resolution 61/105"*.

In developing the aforementioned FAO Guidelines, the experts were particularly concerned with: "the sensitivity and vulnerability of some species, communities and habitats (i.e. Vulnerable Marine Ecosystems; VME) and the significance of direct and indirect impacts (i.e. significant adverse impacts; SAI) of fishing based on its ability to recover which is linked to key biological parameters including: the extreme longevity (100s to > 1,000 years) of individuals of some types of organisms or the long periods over which some habitats develop; the low resilience of particular species, communities and habitats; a high proportion of endemic species with risk of loss of biodiversity, including extinctions; distribution of some vulnerable seafloor communities as spatially discrete units often within a small area of the seabed so that small perturbations may have significant consequences; fragmentation and risk of loss of source populations; and poor current knowledge of the ecosystem components and their relationships."

Many of the ecosystems supported by coldwater corals, sponges, and HTV communities have been highlighted by FAO as VME that are susceptible to SAI. The 'International Guidelines for the management of deep-sea fisheries in the high seas' (FAO 2009) provide a range of recommendations on how to identify VME and assess SAI. The Guidelines also note that marine ecosystems should be classified as vulnerable based on the characteristics that they possess. States, RFMO/A, and as appropriate the FAO, should assemble and analyse relevant information on areas under the competence of such RFMO/A, or where vessels under the jurisdiction of such States are engaged or plan to be engaged in deep sea fisheries.

The following characteristics have been proposed by FAO (FAO 2009) as criteria to identify **VME** and **SAI**.

Vulnerable Marine Ecosystems (VME)

The criteria suggested to use to identify VME include:

- ***Uniqueness or rarity*** *- an area or ecosystem that is unique or that contains rare species whose loss could not be compensated for by similar areas or ecosystems. These include:*

- *habitats that contain endemic species;*
- *habitats of rare, threatened or endangered species that occur only in discrete areas; or*
- *nurseries or discrete feeding, breeding, or spawning areas.*

- ***Functional significance of the habitat** -are discrete areas or habitats that are necessary for the survival, function, spawning/reproduction or recovery of fish stocks, particular life-history stages (e.g. nursery grounds or rearing areas), or of rare, threatened or endangered marine species.*

- ***Fragility** - an ecosystem that is highly susceptible to degradation by anthropogenic activities.*

- ***Life-history traits of component species that make recovery difficult**: ecosystems that are characterised by populations or assemblages of species with one or more of the following characteristics: slow growth rates; late age of maturity; low or unpredictable recruitment; or long-lived.*

- ***Structural complexity** - an ecosystem that is characterised by complex physical structures created by significant concentrations of biotic and abiotic features. In these ecosystems, ecological processes are usually highly dependent on these structured systems. Further, such ecosystems often have high diversity, which is dependent on the structuring organisms.*

This list of criteria could be adapted and additional criteria could be developed as experience and knowledge accumulate, or to address particular local or regional needs. It is important to note that the guidelines, as stated by the UNGA Resolution 61/105, explicitly take a precautionary approach, emphasising that where site-specific information is lacking, other information that is relevant to inferring the likely presence of vulnerable populations, communities and habitats could be used. This will help lead to the identification of areas where VME are ‘likely to occur’. These criteria are dealt with in more detail in Appendix 1 as they relate to coldwater corals and sponges.

Significant Adverse Impacts (SAI)

21. Adverse impacts caused by fishing gear or other anthropogenic disturbances are impacts on populations, communities, or habitats that are more than minimal and not temporary in nature. The impact will be adverse if its consequences are spread in space or through ecosystem interactions and are not temporary, even if the ecosystem feature that is directly impacted shows rapid recovery.

22. Adverse impacts become significant when the harm is serious or irreversible. Impacts that are likely to take two or more generations of the impacted populations or communities or more than 20 years (whichever is shorter) to reverse are considered irreversible. Impacts that are likely to reduce the productivity of any population impacted by the fishery (whether intentional or accidental); or the productivity, species richness, or resilience of an impacted community or ecosystem; or the structural complexity of a habitat are considered serious. In this context productivity is intended to mean all aspects of a population’s capacity to maintain itself. In circumstances of limited information the assumption should be that impacts will be serious or irreversible unless there is evidence to the contrary.”

The FAO guidelines were established to address issues related to the potential to alter the functioning of ecosystems and the goods and services they provide to humanity. Ecosystem functioning is basically the processes that are occurring within the ecosystem that are driving the biogeochemical flow of energy and matter. Cooper et al. (2008) described it in the context of benthic organisms as ecosystem-level processes of transformation that include: all metabolism, catabolism; dynamic processes such as sediment bioturbation or active resuspension; as well as the production and transfer of food, oxygen, and nutrients, the recycling of waste material and the sequestration of harmful substances. The characteristics of these habitat forming taxa reviewed above provide a basis for considering that damage to these features could impair ecosystem functions. The issues to be resolved are how much alteration of a stand of coldwater coral or sponge constitutes "damage", and how much "damage" actually causes ecosystem functions to be impaired. These are complex science questions even for well-studied species and ecosystems, and there will be uncertainty associated with any conclusions for these marine ecosystem components. Scientists studying these questions, and managers with the responsibility of managing the activities in a sustainable manner, need to work with stakeholders to ensure that the proper information is being collected to reduce uncertainties and upon which management measures can be based. It is again important to note that the Guidelines, as stated by the UNGA Resolution 61/105, explicitly take a precautionary approach in the interpretation of a SAI.

WHAT ARE THE PATHWAYS OF EFFECTS FOR VARIOUS ANTHROPOGENIC ACTIVITIES?

The draft Pacific Coast Coral and Sponge conservation strategy provides a review of the human activities that are known to impact corals and sponges from the shallow intertidal to the abyss, in various ways and at various levels. It classifies these impacts into three types: direct removal or damage, indirect damage through ecosystem and habitat impacts, and/or climate change related threats. The consequences of these impacts may directly kill the organism, colony or parts of a colony; leave it more susceptible to disease or parasites; and or alter its habitat or the functional integrity of its ecosystem.

The following human impacts are known to impact on coldwater corals and sponges:

1) Fishing
    - Coleman and Williams (2002) discuss four potential pathways of effect of fishing on the ecosystem: unregulated bycatch; impacts of fishing gear on habitat; trophic effects (i.e. trophic cascades with the loss of keystone species); and indirect effects on both habitat and biodiversity by impacting marine habitat engineers.

    - The United Nations Environment Programme (UNEP) report considers active bottom-contacting gear (i.e. mobile gear such as trawls and dredges) a greater threat than other bottom-tending gears (e.g. hook and line, pots and traps, and gillnets) (Nellemann et al. 2008). A committee of the U.S. National Research Council Ocean Studies Board reviewed the ecosystem effects of trawling and dredging and concluded that biogenic and stable habitats were most vulnerable to these activities (National Research Council 2002).

    - All benthic-contacting fishing gear has the potential to be harmful to benthic environments, but the nature and extent of this harm appears to be dependant on gear type and the level or intensity of the fishing activity (Butler and Gass 2001, Gass 2003). While a number of papers have ranked impacts from mobile gear on benthic habitats to be generally higher than those from fixed gear (DFO 2006), However, the impacts of mobile gear on coldwater corals and sponges have been extensively documented (Freese et al. 1999, Brodeur 2001, Krieger 2001, Chuenpagdee et al. 2003, Ardron and Jamieson 2006), while the impacts of other gear types on coldwater corals and sponges are not as well studied.

2) Aquaculture
   - Finfish aquaculture, is a major industry in many provinces and as with other anthropogenic activities in the oceans, there are impacts. Many of these impacts and risks are mitigated though a series of operational policies and a multi-level regulatory review processes. The impacts pathways of effects include but are not limited to: organic deposition (e.g. food, feces, etc.) can alter substrate composition and quality and reduce interstitial water quality (Levings et al. 2002, DFO 2003, DFO 2004) and vectors for Aquatic Invasive Species (AIS) and large arrays of net pens can alter local currents (Cimberg et al. 1981, Cromey and Black 2005, Stucchi et al. 2005). Any habitat degradation caused by these disturbances may affect species of coldwater corals and sponges, but the degree of disturbance is likely dependant on the individual species susceptibility and proximity to impact (Cimberg et al. 1981).

3) Oil and Gas Exploration and extraction
   - The pathways of effect that exploratory or production drilling for oil and natural gas have on corals and sponges include but are not limited to: physical damage or destruction during drilling; siltation and pollution from the drilling muds; and/or damage resulting from anchoring of support and transport vessels, anchoring of semi-submersible drilling units, pipeline placement, platform installation and chains associated with moorings (Cimberg et al. 1981, Raimondi et al. 1997).

4) Marine log handling facilities
   - The pathways of effects for timber handling and transportation include but are not limited to: log handling practices result in debris fields (sunken trees, limbs, bark and bundling debris) in the marine intertidal and sub-tidal environment which bury benthos, alter water quality and physically abrade intertidal and shallow sub tidal habitats; barges, log booms and other structures can shade the water column and reduce primary production and growth; and decomposition of organic wood material can result in significant bacterial matting and reduced water quality. Depending on the duration of the operations and the size and depth of the sort the debris fields may be very large and thick and may persist for months to decades (Kirkpatrick et al. 1998, Williamson et al. 2000, Picard 2002).

5) Submarine Cables
   - Cables for telecommunications and electricity are regularly laid on or buried in the seabed. The pathways of effects for the installation, repair, and recovery of cables placed on or buried in the seabed may include but are not limited to: increased sedimentation and damage or destruction of benthic habitats and fauna from the cable itself or the support vessels (Butler and Gass 2001); impacts of electromagnetic field and temperature signature.

6) Mining
   - Seabed mining could have a significant impact on coldwater corals, sponges and hydrothermal vents, through pathways of effect including but not limited to: removal of habitat, siltation from mining operations, direct destruction or damage from anchoring facilities and/or support vessels.

7) Marine Transportation
   - Potential pathways of effect include but are not limited to: vectors for AIS; habitat impacts of anchoring; and discharge of chemicals.

   - Coles and Eldridge (2002) reviewed the pathways of effects that invasive species could have on marine benthic communities and they include: monopolization of energy resources, become voracious predators, out competing endemic species, or transmitting parasites and disease.

8) Directed commercial and research fisheries
   - Commercial harvesting of coldwater corals for jewellery and souvenirs presents a threat to their conservation through overfishing if the fishery is not properly assessed, managed, and enforced (Laist et al. 1986). Some coldwater coral species harvested for trade in other parts of the world are found in Canada's Pacific coastal waters although directed harvesting of coldwater corals and sponges does not presently occur.

   - Unregulated research collections in areas like the HTV which have rare, unique, endemic species is one of the major threats to the assemblage of animals in these regions.

9) Pollution
   - Land-based sources of pollution such as sedimentation, freshwater runoff, thermal and chemical pollution, sewage, dredging, and the presence of persistent organic chemicals have a variety of pathways of effects on coldwater corals including but not limited to: coral mortality (Laist et al. 1986; McAllister and Alfonso 2001; Cimberg et al. 1981; Rogers 1999; Etnoyer and Morgan 2004); suspended or re-suspended sediment can interfere with corals physiology and hinder feeding and respiration processes (Cimberg et al. 1981, Raimondi et al. 1997; Butler and Gass 2001; Gass 2003, NOAA 2004, Miller 2001); and persistent organic chemicals affect settlement, growth and/or long-term survival of corals (McAllister and Alfonso 2001, Fossa et al. 2002).

10) Climate change
   - The potential pathways of effect climate change on coldwater corals and sponges are not well understood, however they include but are not limited to: a reduction in the availability of carbonate ions essential to calcifying organisms such as hard corals through ocean acidification; corrosion of organisms' skeletons (Orr et al. 2005); ocean warming may reduce the availability of phytoplankton and zooplankton as prey items; rising ocean temperatures may also lead to a change in the depths where carbonate is biologically available causing coral populations to either change their depth distribution profile or perish.

WHAT HAVE OTHER REGULATORY AUTHORITIES DONE BOTH INTERNATIONALLY AND DOMESTICALLY TO ADDRESS THE PROTECTION OF SENSITIVE BENTHIC FISH HABITAT?

The importance of protecting fish habitat has been understood for a long time but the management of anthropogenic impacts has been inconsistently applied to various threats. This section will provide examples of how other regulatory authorities have addressed this issue.

ESSENTIAL FISH HABITAT IN THE USA

The United States *Magnuson-Stevens Fisheries Conservation and Management Act* (MSA) was promulgated to ensure the development of sustainable fisheries within the USA economic exclusion zone (EEZ). The focus of the act was initially on maintaining healthy fish stocks and rebuilding others. In 1996, amendments to the MSA required that National Marine Fisheries Service (NMFS) fisheries management plans describe and identify essential fish habitat (EFH), minimize fisheries impacts to the extent practicable and encourage protection and enhancement of these habitats. The MSA (October 11, 1996) states that "*One of the greatest long-term threats to the viability of commercial and recreational fisheries is the continuing loss of marine, estuarine, and other aquatic habitats*".

NMFS defined EFH as the area used by fish throughout their life cycle for spawning, feeding, nursery, migration, and shelter. They recognized that most habitats provide only a subset of these functions because fish may change habitats with changes in life history stage, seasonal migrations, abundance, and interactions with other species.

EFH designation is restricted to "waters and substrate within the following areas: depths less than or equal to 3,500 m (1,914 fathoms) to mean higher high water level (MHHW) or the upriver extent of saltwater intrusion, defined as upstream and landward to where ocean-derived salts measure less than 0.5 ppt during the period of average annual low flow". It also applies to seamounts in depths greater than 3,500 m as mapped in the EFH assessment GIS and areas designated as Habitats of Particular Concern (HAPC) not already identified by the above criteria.

An area (habitat) can be identified as a HAPC within EFH guidelines published in Federal regulations if it is considered to be ecologically important, sensitive, stressed or rare. Identified HAPC are also given particular attention when considering potential non-fishing impacts. Other agencies which regulate non-fishing activities that may impact HAPC within EFH must report the extent and nature of the impact to NMFS.

The amendments to the MSA afforded fisheries management plans the opportunity to incorporate habitat requirements and to a certain extent ecosystem requirements. Prior to the 1996 amendment habitat protection was only afforded to unique or critical habitats for a single species of concern. With these amendments it now applied to all commercial species (Copps et al. 2007). However, this has resulted in some real challenges - most of which were caused by the lack of infrastructure (data, assessment tools, policy) within the fisheries management process to include spatially explicit, habitat-based management.

The Pacific Fisheries Management Council chooses to address these challenges using a risk assessment framework built on three models: an EFH model, a HAPC model, and an Impact model (both natural and anthropogenic impacts).

The EFH model would ideally delineate habitat in terms of its contribution to spawning, breeding, feeding, growth to maturity, and production. However, the information to do this is generally not available so it usually only uses information on distribution and habitat-related densities. Information is generally limited to presence or absence data of late-juvenile and adult fish stages and their associated habitats or in some cases habitat-specific densities are only available in a few locations for a few species. To accommodate this lack of data, managers were provided Habitat Suitability Probabilities (HSP) based on a Bayesian Belief Network model that characterizes the association of various fish stages with habitat attributes: depth, latitude (proxy for bottom temperature), and substrate (both physical and biogenic substrate, where possible). For the purposes of the model, these three habitat attributes are felt to provide a reasonable representation of the essential features of habitat that influence the occurrence of fish. The data for the association of fish to habitat attributes came from the occurrence of fish species in NMFS trawl survey catches. For species not well represented in the trawl catches, information from the scientific literature was used. Within the HSP each location (a parcel or polygon of habitat in the GIS) is assigned a suitability value between zero and 100%.

The HAPC model is basically mapping those areas that have been identified as HAPC: seagrass beds, canopy-forming kelp, rocky reefs, estuaries and other areas of interest (e,g, seamounts, canyons, banks, etc.). In Amendment 18 and 19 to the Pacific Coast Groundfish Management Plan, HAPC also included: "Additional ecologically important habitat areas closed to specified gear types shoreward of the trawl footprint boundary. These are areas that are thought to be especially ecologically important or vulnerable to the effects of fishing based on information on substrate type, topography, and the occurrence of biogenic habitat." There is ongoing research on the inclusion of ecosystem engineers like corals, sponges, anemones etc. as HAPC on the Pacific Coast (Tissot et al, 2006).

A Bayesian Network Impact model was developed to measure cumulative anthropogenic impacts (fisheries and non-fisheries) on the habitat but the effort has been impacted because of lack of fine scale fishing efforts and information of fisheries effort and ecosystem impacts. The critical pieces of information that would be required for the model include: rates of impacts of specific gear of different habitats; detailed fishing effort on a spatial scale that allows geospatial analysis of footprints of multiple gear types; rates of recovery from chronic and acute impacts; quantifiable population and ecosystem effects of fishing impacts; trophodynamic changes resulting from impacts; evaluating the role of MPA in fisheries management; and evaluating the production from MPA in production, rebuilding, and long-term sustainability (Copps et al. 2007).

EUROPEAN MARINE STRATEGY FRAMEWORK DIRECTIVE

Prior to 2008, many European States, plus the relevant Regional Seas Organizations (OSPAR, HelCom, Barcelona Convention) and RFMO (NEAFC, IBFSC) provided protection to seafloor habitats, including corals, sponges, and HTV through a variety of legal tools and agreements, and to standards that varied widely among agencies. However the implementation Annexes to the EU Habitats Directive (1992) listed "reefs" as a fully protected habitat type, but there was a lengthy process for designation of particular areas as meeting the definition of "reef". (http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:31992L0043:EN:html)

Sponges and stands of coral that were not considered "reefs" were not protected under the Habitats Directive. However some degree of protection was offered through specific tools of individual States. For example, Cooper (2008) in assessing the impacts of marine aggregate dredging reviews the challenges in determining when an ecosystem has recovered from an impact. Historically managers considered a system had recovered when the assemblage of species was the same pre- and post- impact. This generally was carried out by measuring numbers of species and/or individuals in the assemblage. There are several problems with using this metric: i) if the impact changes the habitat it will probably never support the same assemblage of animals; ii) if the seabed is in a dynamic area then the assemblage of animals will naturally be constantly changing and fluctuating which affect the populations that are available for re-colonization; and iii) it is difficult to measure recovery in an ecosystem which never reaches equilibrium. To address these concerns, a number of approaches have been developed to characterize evenness and richness of ecosystem function (Diaz et al. 2004). These techniques recognize that some ecosystem functions can be undertaken by a variety of different organisms. One of the approaches being used in Europe is Biological Traits Analysis (Bremner et al. 2005, 2006) which uses life history, morphological and behavioral characteristics in the assemblage of animals as a metric of ecosystem function. It then uses change in the relative abundance of taxa exhibiting a certain trait to indicate the effects of human impacts on ecosystem function. These analytical techniques are finding their way into a number of EAM issues including measuring the impacts of fishing (Bremner et al. 2005, Kenchington et al. 2007); MPA designation (Frid et al. 2008); and marine aggregate dredging (Cooper et al. 2008). The development of the data base for the Biological Trait Characteristic is an online data base that is open to people using it and populating it with new species or filling the gaps of certain characteristics.

In 2008 the EU adopted the comprehensive Marine Strategy Framework Directive (MSFD - http://ec.europa.eu/environment/water/marine/index_en.htm) as the overarching policy for management of human activities in European Seas. Annex 3 to the MSFD lists 11 Descriptors of “Good Environmental Status” of the European Seas. States are allowed to develop their own regulations, targets, and reference levels for each descriptor, but States all must meet common standards that will be set over the coming year. EU DG-Environment contracted ICES and the Joint Research Council (JRC) to organize expert Task Groups for 10 of the 11 Descriptors. These Task Groups were to review the scientific basis for action on each descriptor, including a definition of terms, identification of attributes which make up the descriptor, delineation of “axes of degradation for each attribute, characterization of what constitutes “good” status on each attribute, guidance on selection of indicators for each attribute. One of the Descriptors is “Seafloor Integrity, for which the Task Group identified “substrate type” and “bioengineers” as crucial attributes. The report of the Task Group highlights that biogenic substrates and emergent structure-forming bioengineers are particularly important features of “seafloor integrity”, and deserve high levels of protection from harm. The report also concludes that direct measures of the status of these habitat features are costly on the regional scales where evaluations of “good environmental status” are to be conducted. However, indicators of the functions served by these features could be feasible on many scales, but particularly local ones. The measures that States will adopt to protect these attributes of Seafloor Integrity from harm are not yet resolved as implementation is not yet complete (deadline is the end of 2010). However, it is expected that application of the scientific guidance in the Task Group report and overarching Management Committee Report for the entire project will require stringent protection of areas where corals and sponges are common in densities high enough to contribute to ecosystem function.

DFO FISH HABITAT RISK MANAGEMENT FRAMEWORK

The Government of Canada has committed to implementing integrated management applying an ecosystem approach (IM/EAM) to managing human activities in the oceans while protecting the most important components of marine ecosystems. DFO Habitat typically manages habitat impacts based on the definition of fish habitat in the Fisheries Act. There are several guidelines that make reference to habitat parameters and management considerations related to essential/critical and important habitats but no "hard and fast" rules for their application. This means respecting sustainable development principles by ensuring that key features that sustain aquatic ecosystem health are not compromised by human activities. Habitat staff use the Risk Management Framework to assess project related habitat impacts and consider parameters/attributes related to scale of impact (e.g. extent, duration, and frequency) and sensitivity of fish habitat (e.g. species sensitivity, species dependence on habitat, rarity, habitat resilience). The Risk Management Framework is made up of three components which include: Aquatic Effects Assessment; Risk Assessment; and Risk Management. These components are a series of discreet steps in the overall process to review development proposals (http://www.dfo-mpo.gc.ca/oceans-habitat/habitat/policies-politique/operating-operation).

Aquatic Effects Assessment

Aquatic effects assessment is a means of identifying the potential effects an activity may have on fish and fish habitat. Documenting Pathways of Effects (PoE) is the central tool used in the Aquatic Effects Assessment to identify the cause-effect relationships that are known to exist, along with the mechanisms by which stressors lead to effects in the aquatic environment. For each cause-and-effect relationship, a pathway is conceived connecting the attributes of the stressor to some ultimate effect on fish and fish habitat. Each pathway represents an area where mitigation measures can be applied to reduce or eliminate a potential effect. Where mitigation measures cannot be applied, or cannot fully address a stressor, the remaining effect is referred to as a **residual effect**.

Risk Assessment

Risk Assessment is the process used to determine the level of risk that **residual effects** pose to fish and fish habitat. The Risk Assessment Matrix evaluates the **Scale of Negative Residual Effect** in the context of the **Sensitivity of Fish and Fish Habitat** to characterize the level of risk. The rationale used to locate the residual effects on the matrix forms the basis for decision-making and should be based on the best science possible.

Attributes, descriptions and examples of categories used to develop the **Scale of the Negative Residual Effects** are described in Table 1.

Scaling the **Sensitivity of Fish and Fish Habitat** can be carried out in the marine environment using: regional fish and fish habitat classification systems such as EBSA; Integrated Fish Management Plans (IFMP) that take fisheries management objectives into consideration and that integrate fish and fish habitat sensitivities into the plan. Where such plans are not available, additional information is required to determine the sensitivity of fish and fish habitat.

Attributes, descriptions and examples of categories for freshwater ecosystems used to develop the **Sensitivity of Fish and Fish Habitat** are described in Table 2.

Risk Management

Once the risk to fish and fish habitat has been characterized, managers then use a variety of common tools depending on the level of risk. These can include: 1) letters advising proponents of their obligations to protect fish habitat and the means to do so, and 2) *Fisheries Act* authorizations, which also include conditions for monitoring, compensation and possibly even financial security. These conditions are generally commensurate with the level of risk associated with the proposed development and ensure efficient use of resources; a comprehensive risk analysis process is being developed to help identify management priorities for oceans planning and decision-making.

Low Risks

Activities classified as Low Risk are not likely to result in HADD, providing appropriate mitigation measures are applied. An appropriate management option in this case would be to issue a 'No HADD Likely as Proposed' letter (see *Practitioners Guide for Writing Letters Used in Fisheries Act Reviews for DFO Habitat Management Staff*). Letters should include a list of those mitigation measures that formed the basis of the decision, or direct proponents to the appropriate guidelines, or best management practices where applicable.

Medium Risks

Activities classified as Medium Risk are likely to result in HADD, and a *Fisheries Act* authorization will be required. The purpose of the Medium Risk category is to recognize that some activities result in a HADD that are small-scale and/or temporary in duration, and have predictable outcomes with a low level of uncertainty surrounding potential negative effects. These works are routine and lend themselves to a stream-lined authorization process.

High Risks

Proposed developments that are High Risk will result in HADD over a long period of time and/or a broad geographic extent, and/or will take place in areas ranked high on the Sensitivity of Fish and Fish Habitat scale. Such development proposals will require a site-specific review and authorization under subsection 35(2) of the *Fisheries Act*. Within these authorizations, conditions concerning mitigation measures, compensation, monitoring, and financial securities should be commensurate with the level of impact associated with the project.

WHAT RECOMMENDATIONS MIGHT FLOW FROM THE INFORMATION TO ADDRESS THESE THREATS?

Management of the threats to coldwater corals, sponges, and HTV communities need to consider them as threats to the species and also threats to the ecosystem. These are not totally independent, as the relationship between biodiversity and ecosystem functioning has emerged as a central issue in ecological and environmental sciences during the twenty years (Loreau et al. 2001). As ecosystems collectively determine the biogeochemical processes that regulate the Earth system, the potential ecological consequences of biodiversity loss could be devastating.

The process to conserve and manage impacts to species that are rare or declining and their habitats are covered under national SARA legislation. Canada has ratified International agreements with requirements to protect diversity and productivity from serious harm such as: Agenda 21 of the Rio Convention; the CBD; and (for the seafloor) UNGA 61/105. The biggest risk to achieving these mandated conservation and protection requirements is that lack of information on the diversity of flora and fauna that occurs in Canada’s waters. By continuing to mange natural resources, in a framework that lacks baseline knowledge on the diversity of species and their trends in distribution and abundance, the mandated authorities are putting many species at an increased risk of extirpation or extinction, and reducing the overall biodiversity of the region.

Quantifying the impacts, and managing the threats on ecosystem functions and the delivery of key ecosystem services, like fisheries, is a much more difficult problem; but there has been progress in understanding what an appropriate assessment and management process might look like. The biggest problem that plagues all the approaches is the lack of appropriate ecosystem level data. Copps et al. (2007) discuss this and felt that one of the biggest benefits of having an assessment and policy framework for Essential Fish Habitat assessment is that proper data collection programs can now developed to feed into these frameworks, similar to what happened with Fisheries Stock assessment in the 1970's.

RECOMMENDATIONS

1. Coordinate the approach to EAM with all our sectors in DFO. This should include use of a common Ecosystem Risk Analysis Framework (ERAF).

2. Start building the data sets that are necessary to quantify the critical attributes within the ERAF, with a priority for the ecosystem functions served by bioengineers, including corals and sponges.

3. Start directed studies to understand how ecological function varies with the quantity and quality of bioengineers, and the nature and extent of specific impacts.

4. Review the approaches used in other jurisdictions, including the EFH process, the implementation of the MSFD, the Australian tiered approach, and others.

5. Develop a comprehensive approach to protection of VME, including coldwater corals, sponges, and HTV communities.

APPENDIX 1. EVALUTION OF SPONGES AGAINST THE FAO GUIDELINES FOR VULNERABLE MARINE ECOSYSTEMS

The 'International guidelines for the management of deep-sea fisheries in the high seas' (FAO 2009) provide a range of recommendations on how to identify vulnerable marine ecosystems (VME) and assess significant adverse impacts (see text). Here we evaluate corals and sponges against the list proposed by FAO (2009) as criteria to identify VME. The UNGA resolution 61/105 calls for a precautionary approach, emphasising that where site-specific information is lacking, inferences from other areas or through modelling can be used.

FAO 2009 CRITERIA

1. ***Uniqueness or rarity*** - *an area or ecosystem that is unique or that contains rare species whose loss could not be compensated for by similar areas or ecosystems. These include:*

   - *habitats that contain endemic species;*
   - *habitats of rare, threatened or endangered species that occur only in discrete areas; or*
   - *nurseries or discrete feeding, breeding, or spawning areas*.

A number of locations in Canadian waters meet this criterion, mostly as "*habitats of rare, threatened or endangered species that occur only in discrete areas*".

<u>Corals</u>

The major reef-building species of coral in the North Atlantic is *Lophelia pertusa*. It occurs along the continental slopes and banks (generally from 200 to 1000 m depth) of both Canada (as far north as the Laurentian Channel) and the United States (Hourigan et al. 2007). Off Norway, extensive reefs spread over hundreds of kilometers with the living coral growing over the skeletons of previous generations (forming structures called bioherms) (Rogers 1999, Friewald et al. 2004). To the south and west of Ireland several reefs have built mounds of 150 to 200 m high and about 1 km wide (ICES 2008). A small reef, heavily damaged by the redfish fishery, was found on the Scotian Shelf on the southeast Banquereau and has been protected as a Coral Conservation Area by Canada; this reef is unique to eastern Canada.

Kenchington et al. (2010) identified unique, dense aggregations of sea pens along the Laurentian Channel in the Gulf of St. Lawrence and of large gorgonian corals in the eastern Arctic and along the Newfoundland-Labrador slopes.

<u>Sponges</u>

Deepwater sponges generally do not meet this criterion, as most species are widespread (not discrete) and relatively common. However, there are a number of important exceptions where these species form dense aggregations. Exceptions include the glass sponge reefs off the coast of British Columbia (Conway et al. 1991) and Washington State (Bjorklund et al. 2008) which, although they occur along the length of the Canadian continental margin, are believed to be rare globally. On the east coast of Canada, sponge grounds are found along the continental margins north of the Laurentian Channel which are dense aggregations dominated by large structure forming genera such as *Geodia* and *Thenia* which host many other abundant but smaller sponge taxa (ICES 2009). The species forming these sponge grounds are not themselves rare and are widespread; however, it is the sponge grounds that are considered rare and require special oceanographic conditions to form (ICES 2009). The only confirmed glass sponge ground on the east coast of Canada is found in Emerald Basin on the Scotian Shelf south of Halifax, Nova Scotia (Kenchington et al. 2010). This area holds dense, mono-specific growths of *Vazella pourtalesi*, also known as Russian Hats for their barrel-shaped morphology.

2. ***Functional significance of the habitat*** *- discrete areas or habitats that are necessary for the survival, function, spawning/reproduction or recovery of fish stocks, particular life-history stages (e.g. nursery grounds or rearing areas), or of rare, threatened or endangered marine species.*

The functional significance of coral and sponge habitat has not been demonstrated to be *necessary* for the survival, function etc. of fish stocks if this is interpreted to mean an obligate relationship, however there is a growing body of literature that shows that these habitats support increased biodiversity and may have local enhance fish populations (see text in the main body of this report).

The nature of the relationships between sponges and associated taxa varies considerably; however, the majority of species associated with sponge communities are facultative rather than obligate associates, although many may be specific to certain sponge species (ICES 2009).

3. ***Fragility*** *- an ecosystem that is highly susceptible to degradation by anthropogenic activities.*

Most coral and sponge taxa meet this criterion, however, there are exceptions and some are not highly susceptible to degradation by anthropogenic activities. Fuller et al. (2009) rank large and small gorgonians and black corals ahead of sea pens on this criterion and conclude that many soft corals and some cup corals are not susceptible. Sponges also show a wide variety of susceptibility (ICES 2009).

<u>Corals</u>

The structural characteristics and long-lived nature of some coldwater corals make them especially vulnerable to damage by the mechanical impacts of bottom-contact fishing activities (Probert et al*.* 1997, Phillipart 1998, Freiwald et al. 2004). In the Norwegian Sea, it is estimated that 30 to 50% of the coral areas may be damaged or negatively impacted by trawling (Fosså et al. 2000, ICES 2008).

<u>Sponges</u>

Sponges, as a group, show varying degrees of fragility in response to human activities. ICES (2009) conducted a review of the response of individual sponges, other than direct removals, to pressures associated with trawling (Table 3). Due to their upright structure, the large structure-forming species are especially vulnerable to the impacts of bottom tending fishing gear (Freese et al. 1999). Experimental trawling, on sponge communities in the Gulf of Alaska, demonstrated that, in addition to the sponges directly captured in the fishing gear, another 30-60% of the *in situ* sponges of the dominant taxa were indirectly damaged. None of the damaged sponges in the trawl paths showed signs of repair or regrowth after one year, and damage to some had been so severe that they had subsequently died (Freese 2001). In another study of the impacts of trawling on sponge communities off Georgia, USA (VanDolah et al. 1987), the densities of large sponges greater than 10 cm in the trawl path were compared with adjacent control areas by SCUBA divers before, immediately after, and 12 months after trawling. The density of undamaged sponges showed a significant decrease immediately after trawling, similar to that observed by Freese et al. (1999). Of the total number of sponges remaining in the trawled area, 32% were damaged. Most of the effected sponges were the barrel sponges *Cliona* spp., whereas the finger sponges (*Haliclona oculata*) and the vase sponges (*Ircinia campana*) were not significantly affected. However, in contrast to the results from the Gulf of Alaska, twelve months after trawling, the abundance of sponges had increased to pre-trawled densities or greater.

The degree of damage is crucial to evaluating the indirect impacts of fishing. Sponges have a certain ability to regenerate tissue, which depends upon the size of the wound compared to the overall size of the sponge, and if this ratio is small, other factors may not be important. The key aspect of the wound in determining recovery rate is the wound perimeter, which positively correlate. Larger sponges showing an increased ability for regeneration (Henry and Hart 2005); smaller sponges tend to be younger and age is confounded with size in determining recoverability, as juvenile sponges may not be able to regenerate tissue (Simpson 1984, Henry and Hart 2005). Gross morphology also seems to influence regeneration ability and sponges with decreased morphological complexity are expected to regenerate less than more complex forms. Sponges that are brought up on deck and then returned to sea are not able to survive as air disrupts their aquiferous system and they are not able to reattach (ICES 2009).

Sponges are also vulnerable to smothering as they are unable to alter current inflow. Clearing accumulated sediments is energetically demanding and in extreme cases may disrupt the aquiferous system (ICES 2009).

It is important to note that the loss of the dense aggregations (i.e. sponge grounds or reefs) will be more difficult to replace than the loss of individual sponges owing to the long time period it takes to develop those features and the effect of microclimate that is created by the feature itself, allowing recruitment of sponges and other organisms to take place.

4. ***Life-history traits of component species that make recovery difficult**: ecosystems that are characterised by populations or assemblages of species with one or more of the following characteristics: slow growth rates; late age of maturity; low or unpredictable recruitment; or long-lived.*

The life-history traits of most coldwater corals and sponges meet this criterion. These are dealt with in detail in Appendix 2.

5. ***Structural complexity*** *- an ecosystem that is characterised by complex physical structures created by significant concentrations of biotic and abiotic features. In these ecosystems, ecological processes are usually highly dependent on these structured systems. Further, such ecosystems often have high diversity, which is dependent on the structuring organisms.*

Most of the structure-forming coral and sponge taxa meet this criterion. Marine megafauna over 5 cm in height, have been considered as structure-forming and can have a strong influence on biodiversity (Tissot et al. 2006), and species greater than 1 m in height can profoundly affect benthic community structure. However, factors such as complexity of morphology and population density, in addition to size determine whether a species can be considered habitat-forming (Tissot et al. 2006).

Corals

Coldwater corals can form important structural habitats that contribute to vertical relief and increase the availability of microhabitats (Tissot et al. 2006). Increasing complexity provides feeding opportunities for aggregating species, a hiding place from predators, shelter from high flow regimes, a nursery area for juveniles, fish spawning aggregation sites and attachment substrate for fish egg cases and sedentary invertebrates (Reed 2002, Fosså et al. 2002, Etnoyer and Morgan 2003, Etnoyer and Warrenchuk 2007), all of which have been reported for coldwater coral habitats. Aggregations of sea pens may provide important structure in low-relief sand and mud habitats where there is little physical habitat complexity. Also, these organisms may provide refuge for small planktonic and benthic invertebrates, which in turn may be preyed upon by fishes. They also may alter water current flow, thereby retaining nutrients and entraining plankton near the sediment (Tissot et al. 2006). Sea pens have previously been recognized by DFO as important habitat for both fish and invertebrates (DFO 2005). In general, coral habitats in deep water represent biodiversity hotspots for invertebrates (Reed et al. 1982, Jensen and Frederiksen 1992, Reed 2002, Freiwald et al. 2004, Mortensen and Mortensen 2005), and commonly support a high abundance of fish (Koening 2001, Husebo et al. 2002, Krieger and Wing 2002, Costello et al. 2005, Tissot et al. 2006).

Sponges

Where numerous large sponges aggregate, they tend to form a biotope or structural habitat of their own, exerting clear ecological effects on other local fauna (ICES 2009). Morphological forms such as thick encrustations, lumps, and branched, funnel- or fan-like bodies influence near-bottom current and sedimentation patterns. They provide substrate for other species and, displaying holes, crevices and spaces among branches, they offer sheltering places for associated fauna. Siliceous, hexactinellid sponges can form reefs as their glass spicules fuse together, such that when the sponge dies the skeleton remains. This provides settlement surfaces for other sponges, which in turn form a network that is subsequently filled with sediment, eventually creating mounds over 18 m high (Leys et al. 2004). These reefs support diverse deep sea communities that appear to be particularly vulnerable to deep sea fishing activities, particularly trawling. Although some of the siliceous spicules of non-reef-forming species dissolve quickly, there is a certain accumulation of shed spicules and spicules from dead sponges between and under the living ones. These spicules can form a thick sediment-stabilizing mat, which constitute a special bottom type and houses a rich fauna of small-sized species (ICES 2009).

APPENDIX 2: LIFE HISTORY TRAITS OF COLDWATER CORALS AND SPONGES

Coldwater corals and sponges are sessile multi-cellular animals that can occupy a range of substrate types, current rates, sediment types, and depth ranges. Coldwater corals and sponges also display a wide range of life history and reproductive strategies, both across and within their taxonomic groups. Despite their differences, as sessile organisms they are all vulnerable to mechanical damage, sediment smothering, toxicity, and potential climate change effects.

This section provides a brief overview of the life history traits of coldwater corals and sponges that FAO considers would make recovery difficult including: *slow growth rates; late age of maturity; low or unpredictable recruitment; and/or long-lived*.

COLDWATER CORALS

Reproduction

A basic understanding of reproduction and recruitment is required to develop appropriate management measures for activities that affect corals and for applying this understanding to develop methods that might support rehabilitation of damaged coral colonies, groves, and reefs (Richmond 1996). Coldwater corals employ reproductive strategies ranging from asexual budding to sexual fertilization with animals having either separate sexes or being hermaphroditic (Cimberg et al. 1981).

Asexual reproduction can occur in a number of ways including; among others, the division of an existing polyp (intratentacular budding) or the formation of a new polyp in the space between two existing polyps (extratentacular budding) (MacGinitie and MacGinitie 1968). This is particularly important in the growth of colonial species. Asexual reproduction can also occur by fragmentation, whereby pieces of a parent colony break off and form new colonies (Rogers 1999).

Sexually reproducing corals may have separate sexes (gonochoric), may be hermaphroditic, or may even display both strategies (Richmond 1996). Sexually reproducing corals exhibit two modes of fertilization and larval development: internal brooding or broadcast spawning (Cimberg et al. 1981). For internal brooding species, the eggs are fertilized internally and develop inside the animal into planula larvae prior to being released. These well-developed planula larvae are able to settle and metamorphose immediately, which may indicate that the larvae do not settle far from the parent colony. For broadcast spawners, the eggs and sperm are released into the water for fertilization. Free-floating fertilized eggs then require a few weeks to develop into larvae that are ready to settle, which may reduce the likelihood of fertilization, but potentially allows for settlement further from the parent colony. Some hermaphroditic corals may bundle packages of sperm surrounded by eggs and release these bundles into the water column for subsequent fertilization. This ensures that the sperm and eggs are in close proximity for fertilization. However, little is known about the size and age of first reproduction in boreal species. Based on research on the reproductive biology of tropical corals, colonies of 3 cm or less may have fertile polyps, but fecundity is low at these small sizes, both on a per polyp and colony basis (e.g., Torrents et al. 2005).

Recruitment

Site selection and metamorphosis have been identified as critical recruitment processes (Pawlik and Hadfield 1990). The selection of a site for coral larvae to settle can depend on a number of factors such as the texture of the substrate itself (most prefer a hard substrate) and chemical cues (Cimberg et al. 1981). Once the larvae settles it must then go through a successful metamorphosis into a juvenile with a mouth and feeding tentacles.

The process of metamorphosis in corals is a chain of reactions often triggered by chemical stimulus. The triggering process is very sensitive to pollution and the process can be impaired at chronic levels of pollution too low to be detected in acute toxicity tests (Cairns et al. 1978). Prevention of anthropogenic damage and protection of water and substratum quality are likely the most effective means of supporting successful reproduction and recruitment of corals (Richmond 1996).

Age and Growth

Most coral species aged to date are extremely long-lived and the oldest recorded living marine invertebrate (4,000 years) is the Antipatharian *Leiopathes glaberrima* (cf. Fuller et al. 2009). Sherwood et al. (2008) aged several species of gorgonians (i.e., *Keratoisis ornata*, *Primnoa resedaeformis*, *Paramuricea* sp., *Acanella arbuscula*, and *Paragorgia arborea*) which ranged in age from a few decades up to 200 years for a sub-fossil colony of *K. ornata*. *Paragorgia arborea* grew at the fastest radial growth rate of 800 µm/year.. Based on known slow growth rates recovery of gorgonian corals from fishing induced damage will likely take centuries (Fuller et al. 2009).

Black corals have low rates of growth, fecundity, recruitment, and mortality (Grigg 1989) and can be very long-lived. Sherwood et al. (2008) determined radial growth rates of 65-31 µm/year, and vertical growth at 1.34 cm/year, respectively, for black corals collected from the Grand Bank. Based on these extremely slow growth rates recovery of deep-sea corals from fishing induced damage will likely take decades to centuries.

Some cup corals, e.g., *Desmophyllym* spp. are very slow growing (0.5-1.0 mm/year) and long-lived (> 200 years; Lazier et al. 1999, Risk et al. 2002).

Sea pen stalks can be over 1.5 m long with larger species reaching up to 50 years (Wilson et al. 2002).

Corals have the capability of living for hundreds of years and generally have relatively slow growth rates (millimeters per year) (Risk et al. 2002, Roberts 2002, Rogers et al. 2007). Growth varies by species and is correlated to factors such as depth, temperature and current which generally combine to translate into available food (Cimberg et al. 1981). Little is known about the age of sexual maturity for most species of coldwater coral, though available information suggests generation times are quite long. For example, estimates range from 15-25 years for a family of Alcyonacean coral (Grigg 1976) and 10-31 years for some Antipatharians (Parker et al. 1997, Grigg 1976). Long generation times and slow growth rates reduce the capacity of coral to recover from damage caused by human or natural disturbances. The NOAA technical report on the deep water corals of the USA also points out that the age of sexual maturity can be as late as 32 years old for some species (Lumsden et al. 2007).

SPONGE GROUNDS

Reproduction

Sponges show a wide variety of both asexual and sexual forms of reproduction (cf. ICES 2009). Clonal reproduction occurs through broken fragments or specialized totipotent cells (archaeocytes). For sexual reproduction most sponge species are hermaphrodites. Spawning may be triggered by the spring bloom or temperature change. Sperm are released into the water column through the excurrent canals. Most eggs are fertilized within the ostule of the parent colony but in some cases eggs are also released into the water column on a mucus strand and fertilization is external. Larvae are lecithotrophic and settle only a few days after leaving the sponge (Ruppert et al. 2004).

Recruitment

Little is known about recruitment processes in coldwater sponges. Larvae are only free-living for 1 to 3 days so recruitment processes are most likely local, especially in deep water where bottom currents may not be strong.

Age and Growth

The dominant species of sponge grounds are long-lived and slow-growing; however they have an enhanced capability to regenerate tissue which can produce fast rates of new growth compared with the growth of undamaged tissue. Klitgaard and Tendal (2004) suggest that the dominant ostur species are slow growing and take at least several decades to reach the sizes commonly encountered. Leys and Lauzon (1998) report an average growth rate for the hexactinellid sponges on the British Columbia reefs to be 1.98 cm/year, but that regenerative growth rates were up to 20 times higher.

Little is known of the maximum age of sponges but some of the glass sponges off the coast British Columbia reefs are hundreds of years old (Leys and Lauzon 1998). Size is not a good indicator of age and thus size structure of a population is not a useful indicator. Sponge age can be determined by carbon and strontium isotopic dating (Xiao et al. 2005) and some sponges have been estimated at hundreds of years old (Leys and Lauzon 1998).

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TABLES

***Table 1**: Attributes Used to Describe the Scale of Negative Residual Effects*

Attribute	**Description**	**Examples of categories used qualify the attributes (in increasing order)**
1. Extent	Refers to the direct "footprint" of the development proposal, as well as areas indirectly affected, such as downstream or down-current areas.	Site or segment - localized effect Channel reach or lake region Entire watershed or lake
2. Duration	The amount of time that a residual effect will persist.	Short term (days) Medium term (weeks-months) Long term (multiple years - permanent)
3. Intensity	The expected amount of change from the baseline condition. Intensity is a way of describing the degree of change, such as changes in water temperature, salinity, flow, suspended sediment etc. The timing of works may have a major influence on intensity. Effects such as sediment release occurring during critical spawning periods will have a higher intensity.	Habitat still suitable but not as productive Habitat quality significantly reduced Habitat quality unusable

Table 2: *Sensitivity of Fish and Fish Habitat*

Attribute	Description	Scales for qualifying the categories in freshwater ecosystems. These are ordered from low sensitivity to high sensitivity for each attribute.
1. Species Sensitivity	Sensitivity of species to changes in environmental conditions, such as suspended sediments, water temperature or salinity.	Species present are resilient to change and perturbation (e.g. many cyprinid species) Species present are moderately resilient to change and perturbation (e.g. pike, walleye and some cyprinids) Species present are highly sensitive to perturbations (e.g. many salmonidae)
2. Species' Dependence on Habitat	Use of habitat by fish species. Some species may be able to spawn in a wide range of habitats, while others may have very specific habitat requirements.	No use by fish Used as migratory corridor only; feeding, rearing Spawning habitat; habitat critical to survival of species
3. Rarity	The relative strength of a fish population or prevalence of a particular type of habitat.	Habitat/species is prevalent Habitat/Species has limited distribution confined to small areas Habitat/Species is rare e.g. Listed species under SARA.
4. Habitat Resiliency	Habitat resiliency refers to the ability of an aquatic ecosystem to recover from changes in environment conditions. The flow and thermal regimes of the system as well as its physical characteristics are important considerations in describing freshwater ecosystems.	**Thermal regime** Thermal regime unsuitable for any fish species. Warm water thermal regime suitable for cyprinids. Cool water systems; coldwater systems that can buffer temperature changes Cold water systems that cannot easily buffer temperature changes. **Physical characteristics** System is stable and resilient to change and perturbation System is unstable and resilient to change and perturbation **Flow regime** Ephemeral - systems contain water only for short period after rain event Intermittent - system contains water periodically Permanent - system contains water year round

Table 3. *Summary of the Prognosis for Recovery of Structure-forming Coldwater Sponge Species According to Various Disturbance Types Associated with Fishing Activities. [Recovery assessment is individual-based as opposed to community-based]. From ICES (2009).*

Disturbance Type	**Comments**	**Prognosis for Recovery**
Mechanical Damage		
Minor tearing of body wall	Sponges showing tissue repair have been collected; increased risk of infection; distal wounds appear to heal faster than wounds on lateral surfaces	Excellent
Large wounds relative to body size	Incomplete regeneration; increased risk of infection; impaired reproduction and growth	Moderate
Breakage at base	No signs of recovery after 1 year during experimental trawling in Alaska	Very Poor or No Recovery
Dislodgement		
Minor change to orientation, position relative to currents not strongly affected	Sponges can lay new growth down to adapt to minor change in current direction	Unaffected
Significant change to orientation, position relative to currents strongly affected	Sponges likely to die if food availability is restricted as a result of dislodgement	Poor
Sponge dislodged on bottom, free-floating		No Recovery
Sponge brought up on deck and returned	When the aquiferous system is drained very few sponges can fill it up again; air in the chambers cause the sponges to float	No Recovery
Crushing	Turning over of substrate commonly seen in trawl tracks	No Recovery
Sedimentation		
Light accumulation of sediments in incurrent aquiferous system, no serious damage to aquiferous system	Ability to clear sediment; sediment accumulation can be viewed in cross sections with concentrations near ostiole	Very Good
Repeated accumulation of sediments in incurrent aquiferous system	Sponge death or impairment	No Recovery

FIGURES

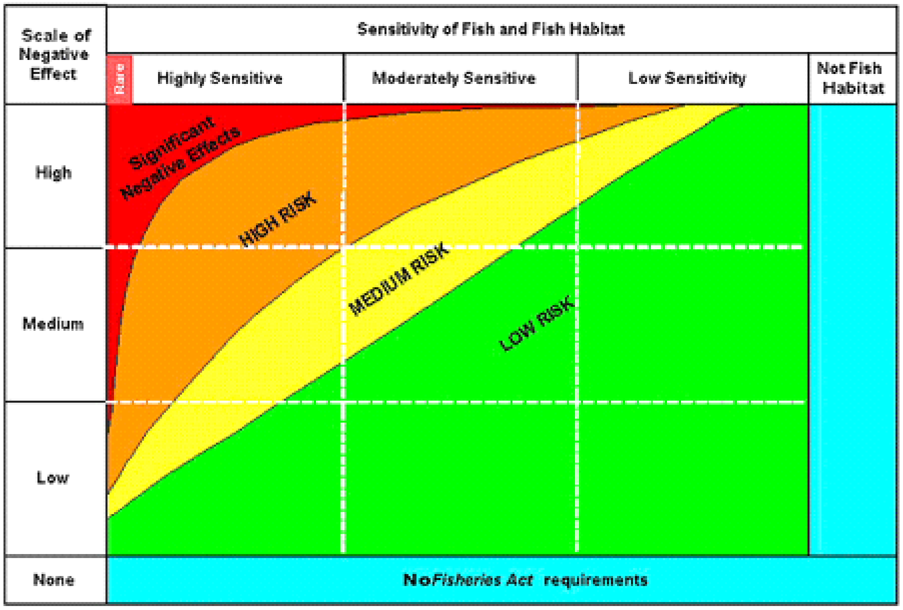

Figure 1. *Risk Assessment matrix used to illustrate various categories of risk. A red box labeled "Rare" located at the most highly sensitive end of the axis is meant to represent fish and fish habitats that are particularly rare and/or afforded special protection under the* Species at Risk Act *(SARA). The least sensitive extreme represents areas that are not considered fish habitat.*