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# Proceeding of the national peer review meeting on impacts of trawl gears and scallop dredges on benthic habitats, populations and communities.

**March 22-24, 2006**
**Queen Elizabeth Hotel**
**Montreal (Quebec)**

**Jake Rice – Chairperson**
**Jean G. Landry - Editor**

**Canadian Science Advisory Secretariat**
**Fisheries & Oceans Canada**
**200 Kent Street**
**Ottawa, Ontario, K1A 0E6**

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# TABLE OF CONTENTS

**SUMMARY**

A national science peer review was held 22-24 March 2006 at the Queen Elizabeth Hotel, Montreal, Quebec. The purpose of the meeting was to review the scientific information available from international studies and Canada's research in relation with the impacts of mobile bottom gears on Canadian benthic habitats and communities. This meeting considered only the mobile bottom-impacting gears, specifically otter trawls (defined broadly), scallop dredges, and hydraulic clam dredges. The main working paper submitted at this peer review was a synthesis from five major international reviews or symposia conducted on the impacts of mobile bottom gears on seafloor habitats, species, and communities, in the early part of the 2000's. Seven other working papers dealing with the recent research done in Canada on trawl impacts on seafloor habitats, or describing what is presently known about the nature and distribution of benthic habitats in Canada were also presented.

A total of 46 persons attended this meeting, including 10 external experts from various groups (Academia, Fishermen associations, Conservation groups, etc.) and people from various sectors of DFO (e.g. Science, Fisheries and Aquaculture Management, Ocean and Habitat Management, Policy). These proceedings summarize the discussions at the peer review. The specific advice resulting from the peer review meeting is documented in the Science Advisory Report produced by the Canadian Science Advisory Secretariat (http://www.dfo-mpo.gc.ca/csas/Csas/status/2006/SAR-AS2006_025_E.pdf). The information issued from this meeting represents the science basis on which Canadian policy regarding the management of mobile fishing gears could be based.

**SOMMAIRE**

Un examen scientifique national par les pairs s'est tenu du 22 au 24 mars 2006 à l'hôtel Reine Élizabeth, à Montréal (Québec). La réunion avait pour but d'examiner l'information scientifique provenant d'études internationales et de la recherche canadienne relative aux impacts des engins de fond mobiles sur les habitats et les communautés benthiques du Canada. La réunion n'a porté que sur les engins de fond mobiles, particulièrement les chaluts à panneaux (au sens large), les dragues à pétoncles et les dragues hydrauliques à coquillages. Le document de travail principal qui a été présenté à cet examen par les pairs est la synthèse de cinq examens ou congrès internationaux importants tenus sur les impacts des engins de fond mobiles sur les habitats, les espèces et les communautés benthiques au début des années 2000. On a également présenté à cet examen sept autres documents de travail ayant trait à la recherche récente effectuée au Canada sur les effets qu'ont les chaluts sur les habitats benthiques ou décrivant ce que l'on sait actuellement au sujet de la nature et de la répartition des habitats benthiques au Canada.

Au total, 46 personnes ont assisté à la réunion, parmi lesquelles dix spécialistes indépendants issus de divers groupes (universités, associations de pêcheurs, groupes de conservation, etc.) et des personnes issues de divers secteurs du ministère des Pêches et des Océans (p. ex. Sciences, Gestion des pêches et de l'aquaculture, Gestion des océans et des habitats et Politiques). Le présent compte rendu résume les discussions tenues à la réunion de l'examen par les pairs. L'avis qui découle de la réunion est documenté dans l'Avis scientifique 2006/025 qui a été produit par le Secrétariat canadien de consultation scientifique (http://www.dfo-mpo.gc.ca/csas/Csas/etat/2006/SAR-AS2006_025_f.pdf). L'information découlant de la réunion représente l'assise scientifique sur laquelle pourrait reposer la politique canadienne sur la gestion des engins mobiles.

DAY 1, MARCH 22, 2006

# INTRODUCTION

*(J. Rice)*

**Participants**: The chair welcomed the participants. A total of 46 persons attended this meeting, including 10 external experts from various groups (Academia, Fishermen associations, Conservation groups, etc.) and people from various sectors of DFO (e.g. Science, Fisheries and Aquaculture Management, Ocean and Habitat Management, Policy - List of participants, Appendix 1).

**Terms of reference, agenda and approach for the meeting:** The Chair invited the group to look at the terms of reference (Appendix 2) and the proposed agenda for the meeting (Appendix 3). The key objectives of the meeting were reconfirmed and it was suggested to add one more presentation to the agenda (*Bottom-Contact Fishing in Atlantic Canada, Spatial & Temporal Overview of Area Fished by Offshore Groundfish Sector, B. Chapman*). The list of the Working papers submitted at this meeting is available in Appendix 4.

The proposed approach for the review was to first examine the working paper 1 (*Review and synthesis of selected international reviews on the impacts of mobile bottom gears on seafloor habitats, species, and communities*) prepared by J. Rice. For this specific part of the meeting, it was proposed that Hugh Bain be the chair of the review given the fact that the author of the first working paper was also the chair of the meeting. The objective was to establish if this WP represents a fair amalgamation /summary of the advice from international studies and if the participants accepted this as our starting point. The default was that we accept the existing expert advice unless there is sound reason not to do so. We will look first at the science conclusions and then at the management recommendations. Once the presentation and initial discussions of WP 1 are completed the group will examine the other working papers dealing with recent research done in Canada on trawl impacts on seafloor habitats, or on what is known at present about the nature and distribution of benthic habitats in Canada. The objective is to identify any features of the Canadian benthic communities and habitats, or any particularities related to the Canadian context of the fishery, that are sufficiently different from the conditions considered in the international reviews (WP1) that conclusions of these reviews would not apply to the management of activities (particularly fisheries) affecting Canadian areas.

Finally, the chair reminded the participants of the rules of the advisory process to the group. We will try to reach a consensus but that does not mean that we all have to resolve every possible differences. We can agree that there is a range of interpretations and we may identify the evidence in support or against each of them.  It was also mentioned that this is not a policy or a management meeting and the participants are asked to focus on the science basis that is available.

**Context justifying this peer review meeting:** In response to a question from a participant, it was mentioned that the international context/debate (e.g. United Nations meeting in fall 2005) on trawling impacts has likely precipitated the conduct of this meeting.  There is a need for Canada to produce a report on this issue at the international scale. The advisory report issued from this meeting will represent the science information on which Canadian policy could be based, not the Canadian policy by itself.

**Specific products from the meeting:** Many publications of the Canadian Science Advisory Secretariat (CSAS) are expected. A Science Advisory report (SAR) will be produced. The participants should be able to agree on key conclusions (point form conclusions) by the end of the meeting and these will be used in the elaboration of the advisory document. The Advisory report should be available in early May 2006.

A Proceeding report will also be produced (rapporteurs: C. Allen; H, Bain and J. Landry). The persons giving presentations are asked to provide CSAS with a short summary of their paper/presentation for the proceedings. Finally, it is recommended that each working paper submitted (and accepted) at this peer review meeting be the source of a formal CSAS Research Document.

# PRESENTATION OF THE WORKING PAPERS

## WP1 - Impacts of Mobile Bottom Gears on Seafloor Habitats, Species, and Communities: A Review and Synthesis of Selected International Reviews

*(J. Rice)*

**Abstract:** No abstract is provided. However, given the fact that this working paper was central in this peer review meeting, the whole WP is available in Appendix 5. This approach will help the readers to look at the details related to the context, the approach taken and the key findings and recommendations from the various international studies on which the WP1 is based.

**Sources of information:** This WP is based on five major international reviews or symposia conducted in the early part of the 2000's. These are as follows:

1. International Council for the Exploration of the Seas (ICES) – 2000
2. US National Academy of Science – 2000
3. US National Marine Fisheries Service (NMFS) – 2002
4. United Nations (UN), Food and Agriculture Organisation (FAO) – 2005
5. American Fisheries Society (AFS) – 2003 (Book 2005).

The FAO publication does not include any specific management recommendation and the AFS publication was not a "review" in the sense of the other four studies. However, the last two documents are included to make sure that the results summarized in this WP reflect the most recent findings.

**Strategy adopted for the elaboration of WP 1:** The context/mandate and the process conducted for each of the sources of information vary. The approach taken for the review of each study is as follows:

- Review the mandate, context and approach of the study
- Extract the conclusions and recommendations
  - Number within each study
  - Acknowledge qualifications, and limits placed by mandate
  - Rely on quotations as much as possible
  - Commentary on whether the qualifications are thought to restrict the relevance of the conclusion or recommendation to Canadian contexts.
- Highlight points of emphasis.

The approach taken to provide a cross-comparison and synthesis of the material from the five studies was to tabulate a final set of conclusions by:

- effects on habitat;
- effects on species and communities;
- mitigation measures; and
- management recommendations.

A judgment call was sometimes necessary to present the final conclusions on a common basis as the various groups rarely used the same words to describe same/similar things. Finally, the conclusions were examined to see if they were relevant to the Canadian context.

## KEY POINTS FROM WP1 AND DISCUSSION

This section gives a general description of each of the five studies (context, mandate and approach) and makes the relevant links to the working paper (Appendix 5) in order to help the readers to identify the key findings and recommendations from each study and to understand better how they were compared and integrated in this peer review process. This section also highlights the key points that were discussed during or following the presentation of WP1.

International Council for the Exploration of the Seas

**Context/mandate:** Request from European Commission DG of Fisheries to consider the effects of different types of fisheries on the North Sea and Irish Sea benthic ecosystems (Lindeboom and de Groot report) and to formulate management advice as to how effects of the gears discussed in the report on benthic ecosystems could be measurably reduced, without unduly reducing the possibilities of catching commercially important species.

**Approach:**

- Independent peer review of Lindeboom and de Groot ‘s report (also referred as the IMPACT II report) conducted by ICES Working Group on Ecosystem Effects of Fishing (WGECO) in December 1999. The IMPACT II report represents the product of a three year research programme, conducted by over 40 scientists working in 13 research centres around the North Sea and Irish Sea. This peer review involved 26 experts (all major scientific disciplines were covered) from 14 countries.
- Second-level independent review of WGECO report and elaboration of management recommendations done by the Advisory Committee on Marine Environment (ACME) of ICES in its 2000 meeting (19 national experts plus the chairs of various working groups reporting to ACME).
- Advice developed specifically for the types of otter trawls and beam trawls used in the North Sea and Irish Sea.

**Key findings and recommendations:** The key findings from ICES review were synthesyzed in the WP 1 via two tables (Tables 1 and 2 in Appendix 5) describing respectively the possible effects of trawl gears on seafloor habitats and communities, and ICES judgements of the effectiveness of various possible mitigation measures in addressing the priority habitat and species impacts of mobile bottom gears. The possible effects were tabulated by the strength of evidence and by the relative seriousness of the effect. “Relative seriousness” was judged on three criteria: temporal scale, spatial scale and direction of change.

ICES produced general considerations in developing its advice on mitigative measures (nos 14-19 in Appendix 5) and identified six priority management measures (nos 20-25, presented in ranked order, with the most important measure first). It also recommended four immediate actions for the northeast Atlantic (nos 26-29). In the recommendations, it was stressed that "the advised Priority Management measures should not be viewed as universally applicable remedies, to be applied without further thought. They should be developed as well-planned mitigation programmes to address well-specified problems".

**Discussion:** This information was briefly discussed by the group as described below.

- It is mentioned that it would help to have more information about where data of various studies come from. Maybe some Canadian data are already included in those studies. The presenter is asked to give more precisions on this aspect in the ongoing presentation.
- The table 1 could be improved by adding more details in the column entitled "type of effect". This would help to orient the reader (even though it is explained in the text) who would not have to flip back and forth when reading the table.
- A clarification is requested about habitat complexity in table 1. This refers more to fine scale changes (e.g. furrows, etc.) rather than any major net habitat reduction.
- There is a need to clarify the context of the proposals of gear substitution and reduction of effort i.e. for both benthic species and some targeted species. For example, a modification of a gear could make it less efficient to catch fish but you may have to trawl more often so that the benefits for habitat could be lost.
- The recommendation for a reduction of effort is more related to the specific context in Europe where the study was conducted and does not necessarily apply in Canada where an important reduction already occurred.
- What was the basis to choose 30% below recent historical levels? ICES picked 30% as a starting point for reduction. At the time of the study, ICES knowledge was only on 30x30 nautical miles squares where fishery was (now their knowledge is on a finer scale). This recommendation is also related to the need for a substantial reduction of fishing effort in order to have a sustainable industry (effort was high and catches were low). If only 10-20% there would not likely be any observable change. This recommendation was seen to contribute to both objectives (protecting habitat and having a sustainable industry) at the same time.
- We must be prudent with the concept of closed areas because it may simply means an effort displacement (in Europe it seems to be always the situation). It is also mentioned that tables 1 and 2 are not linked as closely as assumed and this should be made clear.
- The group agrees that the conclusions represent an accurate interpretation of the information that was available at that time. The participants recognize that the ICES report was restricted to otter trawl and beam trawls, and did not consider other gears like scallops dredges. Moreover, this study did not look at long-term effects (e.g. North Sea has been fished for a very long time and should represent one of the best long-term data bases of changes in benthic communities). Finally, it is clear that priority management measures should not be viewed as universally applicable measures; nothing is uniform and we must look at each situation on a case specific basis.

US National Academy of Science

**Context/mandate:** The reauthorization of The Magnusson-Stevens Fishery Conservation and Management Act (1996) was associated with the addition or strengthening of many provisions to give greater focus to protection of "essential fish habitat". The implementation of these provisions proved to be problematic and consequently, recommendations for management measures to minimize any detrimental effects of fishing on such habitat were required.

The mandate of the study was essentially to summarize and evaluate the existing knowledge on 1) the effects of bottom trawling on the structure of seafloor habitats and on the bottom-dwelling species (relative to the type of gear, the method of fishing, etc.), 2) the changes in seafloor habitats with trawling and cessation of trawling and 3) the indirect effects of bottom trawling on non-seafloor species. Recommendations were needed on how the existing information could be used more effectively in managing trawl fisheries and on the research needed to improve understanding of the effects of bottom trawling on seafloor habitats.

**Approach:**

- The National Oceanographic and Atmospheric Administration (NOAA) contracted the Ocean Studies Board (OSB) of the National Research Council to conduct several reviews of information on how fishing affects marine communities and habitats, and provide recommendations for management measures to minimize any detrimental effects.
- OSB appointed a panel of twelve experts.
- A review of the scientific literature was completed and three open sessions were conducted. The report from the panel was reviewed by six independent experts.
- A consensus report was released in 2002. This report addresses various topics (e.g. characteristics of fishing gear, habitat mapping and distribution of fishing effort in the US, etc.). For the purposes of this DFO peer review, the emphasis was put on the key findings and recommendations with regards to the effects of trawling and dredging on seafloor habitats and species.

**Key findings and recommendations:** The main potential effects of trawling and dredging issued from the Panel's report are described in the WP1 (points no 1 to 8). Other indirect effects of bottom trawling (nos 9-12) and some factors affecting the recovery from a perturbation (nos 13-16) are also identified. This study confirmed that the acute, gear-specific effects of trawling and dredging on various types of habitat are well documented. However, to assess the risks that these types of fishing pose to seafloor habitats and communities also requires information on the spatial distribution of fishing effort and the distribution of habitats and benthic communities, and the knowledge of the latter factors was considered incomplete. This meant that general recommendations regarding trawl impacts and mitigation measures could be made (nos 17-22, appendix 5) but few recommendations were possible regarding how specific fisheries should be managed in particular places.

**Discussion:** The information from this study was briefly discussed by the group just after the presentation in order to proceed with the review of the findings from other international studies. The points below refer to this discussion.

- Some parts of the US reports are vague and that might illustrate the difficulty to reach a consensus of some aspects of the report. Most of the management recommendations (nos 17-22) represent pretty high level ones but they are considered very similar to ICES' recommendations (especially no 19). On this specific recommendation, it is mentioned that the US report also referred to "gear substitution" and it is suggested that the author verify this point.

- The recommendations of the US study on mitigation measures are considered as relevant to areas that are used year after year but it would be necessary to put more emphasis on areas that were not submitted to bottom trawling ("Frontier areas", pristine populations/habitats) like in the Arctic. A lot of results from Alaska were used in this study (a lot of new areas) then the information is available and should be highlighted adequately. It is mentioned that we have many areas that were not submitted to bottom trawling in Canada and we should consider mitigation measures as recommended by ICES (no expansion of activities in those new areas).
- This study may be seen as an endorsement of habitat classification systems.
- Recommendations on recovery (nos 13-16) are based on a bunch of parameters. Recovery means both physical (habitat) and biological processes and these are very different.

<u>US National Marine Fisheries Service</u>

**Context/mandate:** The purpose of the review was to assist the New England Fisheries Management Council (NEFMC), the Mid-Atlantic Fisheries Management Council (MAFMC) and NMFS with 1) evaluating the existing scientific research on the effects of fishing gear on benthic habitats; 2) determining the degree of impact from various gear types on benthic habitats in the Northeast; 3) specifying the type of evidence that is available to support the conclusions made about the impacts; 4) ranking the relative importance of gear impacts on various habitat types; and 5) providing recommendations on measures to minimize those adverse impacts.

**Approach:**

- A workshop involving 23 experts (academia, fishing masters, conservation groups) was conducted. Nineteen specific questions given by the Steering Committee and many working papers were available. ICES recommendations were used as a starting point by the group.
- The workshop considered several fishing gears but only the results on otter trawls and scallop dredges are reported in the WP1. In this workshop, it was made clear that "habitat" was to be interpreted in the context of "essential fish habitat" under the Magnusson-Stevens Act (1996). As such it only considered benthic species and communities in the narrow context of prey for commercially exploited fish stocks. The treatment of the physical impacts is considered as similar compared to other reviews but not the biotic impacts.
- All conclusions were produced in plenary sessions but it was not possible for all participants to reach consensus on a number of the conclusions and those cases are identified in WP1.

**Key findings and recommendations:** The key conclusions on the impacts of scallop dredges and otter trawls are presented respectively in tables 3 and 4 of WP1. The NMFS report also identifies a number of possible effects of dredges (nos 9-20) or potential/indirect effects of otter trawls (33-37) but these may not correspond to consensus conclusions of the workshop, or the effect may not have been linked specifically to one of the gear of concern. Few statements related to management options (nos 20 and 37) are identified but no particular emphasis was put on any of the conclusions of this report.

**Discussion:**

- The limitations of this study (species composition not within its mandate, unclear if consensus was reached on all the recommendations, etc.) are acknowledged by the group.
- The different types of gears used in the various studies were also the subject of a discussion. For example, the beam trawls used in our shrimp fishery are not like the beam trawls used in groundfish in Europe and US. In Canada, we are also starting to use beam trawls for sea cucumber fishery in some areas - we call them a dredge, but they are more like a beam trawl. This led the group to a general recommendation that our advisory report should include some explanations regarding the various gears studied and how they were used. However, it is also recognized that this is a very complex issue involving many factors (e.g. gear weight, width of path, frequency of use, type of contact on the bottom, etc.) and we do not have the time and all the relevant information to address this issue adequately at this meeting.

United Nations - Food and Agriculture Organisation

**Context/mandate:** Critical evaluation of the methodologies utilized in impact studies, and uses it to make conclusions about what lessons have been learned to date of how benthic communities have been affected by towed fishing gear activities.

**Approach:**

- ➢ Review of more than 35 studies of trawl and dredge impacts published since 1990.
- ➢ Single contracted author but the overview went through the standard FAO process of extensive internal review and external review by selected experts.
- ➢ The review focused particularly on critical evaluation of the methodologies used in impact studies, finding many shortcomings in published works.
- ➢ No mitigation measures or management recommendations.

**Key findings and recommendations:** Many kinds of design problems have been identified in the trawl impact studies available. The review concludes that the net tendency is for studies to often overestimate short-term effects of trawling by including natural variation in the treatment effect but to underestimate long-term effects through the limited time span of many studies. Despite these common tendencies, the FAO report does contain a number of conclusions regarding physical and biological effects of trawl gears and scallop dredges. These key conclusions are presented in WP 1 (physical effects – nos 1-9, biological impacts – nos 10-16 and overall conclusions – nos 17-19; Appendix 5).

**Discussion:**

- The overall conclusions of the report were considered by the group as generally comparable to other reports.

- It was mentioned that very few studies are available on long-term effects and it would be important to highlight (in WP1) the studies that are considered as good for this particular aspect.

<u>American Fisheries Society</u>

**Context/mandate:** Proceedings of an American Fisheries Society Symposium entitled “Benthic Habitats and the Effects of Fishing” edited by Barnes and Thomas (2005).

**Approach:**

- Scientific Symposium conducted in 2002 but many of the 59 full papers and 99 abstracts submitted at the symposium were updated further and contain more recent information.
- 29 papers of 7 theme sessions were considered as relevant to this peer review meeting.
- A standard journal peer review was applied to all papers, but the conclusions and recommendations cannot be taken as a consensus of the Symposium participants following the standard discussions/debates of a peer review meeting.
- No specific management recommendation provided in this report.

**Key findings and recommendations:** The factual information in many of the presentations that was considered as relevant to the deliberations at this meeting is resumed in points nos 1-29 in WP1.

**Discussion:**

- The group acknowledged the fact that the conclusions of this symposium do not represent a consensus but rather the author’s conclusions that withstood journal review and this will have to be taken into account in the overall conclusions of this peer review. It was suggested to see which of these conclusions reinforce those already made in other reports and which correspond to new ones.

SYNTHESIS AND OVERALL CONCLUSIONS FROM THE FIVE INTERNATIONAL STUDIES

The conclusions and management recommendations of the five studies were presented to the group. The results of the cross-comparison of these five studies are found in Table 5 of WP1 (Appendix 5). This table begins with the ICES list, with the other reviews tabulated according to the approach/wording used in ICES report. Many judgement calls were needed to present the key conclusions on a common basis because the various groups rarely used the same words to describe same/similar things. Some “conclusions” were also inferred from other conclusions that were made explicitly. Finally, findings or conclusions of one report that were in contradiction with other reports (only few cases) were put in bold.

Many similarities have been found in the conclusions of the five review sources with regard to impacts of bottom trawling on habitats, species and communities, and on the mitigation measures and management recommendations. These conclusions, based on table 5, are presented in four categories in WP1: Impacts of Bottom Gears on habitats (nos 1-7), impacts on benthic species and communities (nos 8-15), considerations in the application or adoption of mitigation measures (nos 16-21), and recommendations for management of mobile bottom gears (nos 22-27). They are listed in an order reflecting their relative breadths and strengths of support in the studies.

**Discussion:** The participants proceed with a first examination of the overall conclusions of WP1. It was agreed that the participants will not necessarily go deeper in each aspect of these conclusions before having the possibility of looking at the other working papers dealing with Canadian's research and context. Once done, the group will have the opportunity to revisit the conclusions of WP 1 and determine what should be produced in terms of scientific advice. As a first step, the group was asked to focus on two key aspects regarding WP1: 1) is there anything present in the international studies that was missed in the conclusions of WP1? 2) is there anything that was not in the international studies and that is important to us (e.g. frontier area)? The key points from this preliminary discussion are as follows:

- More emphasis should be put on the difference between short-term and long-term effects. Some recommendations (e.g. no 14) are clearly related to short-term, others not.
- The conclusion no 5 on the gradient of impacts, with greatest impacts on hard, complex bottoms and less impacts on sandy bottoms is maybe not exactly true. The effect on sandy bottoms can be greater in some cases and it may depend on the type of gear (e.g. dredge clam).
- One suggests that what is missing is perhaps the identification of cases where mitigations were necessary (mitigation measures may not be needed in all cases). No group was asked to address specifically what level of perturbation (for each case) is large enough to justify mitigation measures. The studies did not address either the threshold that would inform about levels from which recovery would not be possible. The studies rather focused on what are the impacts, the potential mitigation, etc.
- The definition of "mitigation" should be clarified. In the ICES context, mitigation was more related to a decrease of impacts on habitat and species, not in a context of recovering habitats that were damaged.
- Most of the studies are in areas that have been fished for many years. We should also look at frontier areas.
- There is little information about productivity in those studies. The link with the concepts of Ecologically and Biologically Significant Areas or Species (EBSA, EBSS) should be made more clear.
- There seems to be very few studies of hydraulic gears.
- The numbering system used in WP1 could be improved (when we produce the Research Document) in using a given number only once for all studies.

## WP2 - A Review of Maritimes Region Research on the Effects of Mobile Fishing Gear on Benthic Habitat and Communities

*(Donald C. Gordon Jr., Ellen L.R. Kenchington and Kent D. Gilkinson)*
*Presenter: D. Gordon*

ABSTRACT
(provided by the authors)

In collaboration with the Newfoundland & Labrador Region, the Maritimes Region has conducted an extensive field program to provide quantitative information on the effects of bottom-contacting mobile fishing gear on benthic habitat and communities. This research has included carefully designed manipulative experiments as well as observational studies. The three major gear types used in Atlantic Canada have been studied (otter trawls, scallop dredges and hydraulic clam dredges). Impact on both sand and gravel habitats have been investigated, but not mud habitats. Geographic areas considered include the Bay of Fundy, Northeast Channel, Western Bank, Banquereau, Laurentian Channel and the Grand Bank. The results provide information on immediate impacts, recovery times and long-term impacts. With just a few exceptions, the results have been subjected to peer review and published in the scientific literature (the last few reports are being drafted). They illustrate that the impacts of bottom-contacting mobile fishing gear are extremely variable and depend upon many factors including the kind of gear, how it is used, the return period of the disturbance, the kind of physical habitat and the species composition of the benthic community. Sandy habitats are easier to disturb but are faster to recover than gravel habitats. The most sensitive species are large epibenthic forms, especially those that are sessile and have slow growth rates. The results are in general agreement with the conclusions reached from recent international reviews on this issue with the exception that gravel habitats may not be as sensitive as generally thought. The impacts of bottom-contacting mobile fishing gear is an important issue that needs to be considered as Canada moves to adopt an ecosystem approach to fisheries management. The most effective management measures are effort control, gear modification and substitution, and establishment of closed area. The best course for action needs to be decided with input from all stakeholders (i.e. scientists, fisheries managers, habitat managers, industry, coastal communities, NGOs, etc.)

KEY POINTS FROM WP2
*(based on the presentation at the meeting)*

**Historical:** This was a long-term program initiated in 1990 to investigate impacts on benthic habitat and organisms. It involved many collaborators (DFO Newfoundland & Labrador, universities, industry, etc.) and considered all major gear types used in Atlantic Canada. Most of the results from this study have already been peer-reviewed and published in the international scientific literature.

**Development of three sampling gear:** three sampling gears were developed in the context of this program: the Videograb (for sampling seabed, with video and with acoustic device); the Campod (to get video/photography of the bottom, especially the rough ones); and, the Towcam (towed platform that can be flied just over the bottom to get pictures).

**Sources of information:** This WP is based on nine different sources of information (specifically designed field experiments and observational studies). The characteristics and the key findings related to these sources are briefly described below.

<u>Minas Basin otter trawling experiment (1990-1991)</u>

- Intertidal zone
- Benthic diatoms, meiofauna and polychaetes
- Overall impacts minor
- High energy environment (waves and ice) with few large epibenthic organisms.

<u>Grand Banks otter trawling experiment (1993-1995)</u>

- Sandy seabed (120-146 m).
- The site chosen had not been disturbed for at least 13 years and contains a rich benthic community (246 taxa).
- Applied heavy trawling disturbance with Engel 145 otter trawl. Three corridors were each trawled 12 times three years in a row.
- Very low catches (fish and invertebrates)
- Immediate impacts on sandy habitat: decrease in complexity, impacts on some epibenthic organisms (mostly the large and mobile).
- Few immediate impacts on infauna and no detectable impacts on mollusks
- Recovery from disturbance in 1 year
- Little evidence of long-term impacts (3 y) above natural variability

<u>Western Bank otter trawling experiment(1997-99)</u>

- Gravel seabed (70 m).
- Undisturbed site for at least 10 years with a rich benthic community (341 taxa)
- Applied heavy trawling disturbance (same trawl as Grand Banks)
- Large fish catches (mostly haddock)
- Habitat disturbance is evident on gravel lag but less than observed on sandy bottom
- However, recovery takes longer (furrows still evident after two years)
- Few detectable immediate effects on abundance or biomass
- Immediate minor damage to some surface dwelling organisms (molluscs, polycheates, brachiopods), related to number of trawl passes
- Increase in fish catch during trawling and changes in prey
- Impacted organisms grazed by demersal fish
- No significant impacts on colonial epifauna
- Long-term decline (3 y) in the proportion of epibenthic biomass (horse mussels)

Banquereau hydraulic clam dredging experiment (1998-2000)

- Sandy seabed (75 m), not previously dredged and with a rich benthic community (270 taxa).
- Applied typical dredging disturbance (12 tows, total of five boxes including dredging and reference boxes) with 32-47% of area not crossed by dredge.
- Large invertebrate bycatch
- Effects readily detected above natural variation
- Substantial immediate impacts on both habitat and organisms (1998)
- Changes in seabed topography and lost of complexity
- Still evidence of habitat disturbance in 2003 (sidescan sonar) and tracks collect shells
- Considerable recovery of most non-target benthic species (polychaetes, amphipods, and echinoderms) over two years
- However, no signs of recovery in target species (4 species of bivalves) two years after dredging. Recovery expected to take at least 10 years
- Over two years, no detectable changes in species composition of the benthic community, just a shift in relative abundance
- Recovery of habitat and benthic community still underway
- Important to complete experiment (full sampling in 2008)

Bay of Fundy scallop dredge experiment (1993)

- Concern over using scallop dredge to harvest sea urchins
- Diver observations
- Some immediate impacts on habitat and organisms (urchins and kelp)
- Increase of scavengers
- Recovery on order of six months

Temporal changes in the Digby scallop grounds (1966/67 versus 1997)

- Comparison of data sets collected in 1966/67 (Caddy) and 1997 (Kenchington et al.).
- Area subjected to chronic fishing, both for scallop dredging and otter trawling
- Impacts: significant changes in the composition of the megafaunal community, decline of fragile, sessile, attached and colonial taxa, and increase in robust taxa, grazers and scavengers.
- Truly long-term study (30 y) at the scale of the fishery.

Spatial differences in the Digby scallop grounds (2000)

- Compared structure of hydroid communities on cobble (disturbed) and scallop shells (undisturbed) collected during DFO survey
- 51 taxa examined
- Hydroid assemblages significantly different
- Erect tree-shaped growth forms on shells compared to low-lying runner-like growth forms on cobbles
- Differences related to estimates of fishing effort

Lab studies on soft corals (2002)

- Divers collected colonies attached to cobbles and placed them in tanks with half disturbed and half controlled.
- No significant immediate effect observed.
- Colonies able to retract and survive repeated crushings and to recover from acute injuries.

Deep-water corals (2000-2003)

- Significant bycatch in trawls and longlines.
- Coral damage from fishing gear visible in video footage
- Especially large gorgonians and reef-forming *Lophelia*
- Most evident in the Northeast Channel and Stone Fence
- Little evidence in the Gully and along the Scotian Shelf

**Studies' coverage:** These studies considered otter trawling, scallop dredging and hydraulic clam dredging. Sand and gravel habitats were covered but not mud bottoms. Various sampling tools (acoustic, imaging, grabs) were used over different spatial scales then they were not likely to have missed important direct effects. Indirect effects (e.g. spawning and survival of juvenile demersal fish, biogeochemical exchanges between the seabed and the water column, benthic production, etc.) were not considered.

**Summary of impacts on habitat:** Sandy sea beds were easily disturbed (e.g. furrows, destruction of biological structures, loss of habitat complexity, recovery times variable). Gravel sea beds were more difficult to disturb with immediate impacts being less important but recovery takes longer. Finally, biogenic habitats (corals, sponges) are easily disturbed and very slow to recover.

**Summary of impacts on communities:** Most of the organisms impacted correspond to large epibenthic forms living at the sediment water interface. Recovery times are variable and depend upon mobility, recruitment and growth. Changes in the relative abundance and size of individuals were observed in some cases but there was no evidence of a species being lost. The species sensitivity is related to biological traits. The nineteen species considered as the most sensitive were sponges, hydroids, soft corals, gorgonians, stony corals, polychaetes, sand dollars, brittle stars, sea urchins, sea cucumbers, snow crabs, horse mussels, propeller clams, Arctic surf clams, Greenland cockles, ocean quahogs, brachiopods, tunicates and kelp.

**Summary on gears:** Otter trawls are used on all bottom types. They have a relatively limited contact with the seabed (mainly the doors), the area affected is large but the return period is usually short. They are considered to have major impacts on non-target species. Scallop dredges are used primarily on gravel seabed. The area they affect is smaller but they penetrate the seabed and the return period is longer. They are considered to have major impacts on non-target species. Hydraulic clam dredges are used only on sand bottoms. The area they affect is very small but they penetrate deeper in the seabed and the return period is very long (~10 years). They have major impacts on target species. Based on another study that was not presented in detail at this peer review (Chuenpagdee et al. 2003), the three categories of gears mentioned above seem to be the worst in terms of impacts.

**Comparison with the results from international studies (Working paper 1):** The conclusions of WP2 support (or strongly support) most of the fifteen conclusions of WP1 on impacts on habitats, species and communities. There seem to be only few cases (recent studies that are just getting published) where the agreement is limited to specific conditions. These cases relate to conclusions no 3, 5, 12 and 13. For conclusion no 3 (mobile bottom gear can reduce/remove major habitat features), there is little support on sand and gravel habitats but a strong support for biogenic habitats. For conclusion no 5 (gradient of impacts, with greatest impacts on hard complex bottoms and least impact of sandy bottoms), there is limited support because in the case of otter trawling, immediate impacts are greater on sand bottom (but recovery takes longer on gravel bottoms). For conclusion 12 (impacts…are less important in high-energy/frequent natural disturbance environments…), Digby scallop grounds would represent an exception where there is no support to this conclusion. It is the same for conclusion 13 (…structurally fragile species affected more often and to greater extent than populations of robust species) that would not be supported for horse mussel. Overall, there is an excellent agreement between the general conclusions of WP2 and those from international reviews.

**General conclusions and way forward:** Impacts of mobile bottom gears on benthic habitats and communities is not uniform. It depends on seafloor habitat, the species present, the type of gear (and how it is used), and the history of activities. There is a need to better understand natural variation and not to confuse it with gear impacts. It will also be important to study all spatial scales (hundreds of meters to few centimeters) or we may miss some effects. The temporal scale is also important with long-term impacts being of most concern, especially when the return period of fishing is shorter than the recovery period of the habitat and communities. There is no simple answer that cover all conditions and we must consider each fishery and habitat separately. However, ample information is now available to begin considering gear impacts in fisheries management decisions. Management options include control of fishing effort, gear modification, gear substitution and area closures. More work has to be done on this issue (e.g. manipulative experiments, comparative studies, close heavily fished areas and follow recovery, mapping spatial distribution of fishing effort, mapping spatial distribution of benthic habitat and communities, etc.) but while not all science questions are answered, sufficient scientific information is available for responsible decision making.

## DISCUSSION ON WP2

- How representative are the areas studied relatively to the general areas of Grand Banks, Scotian Shelf, etc.? They are very representative of general benthic communities and diversity we could see on Eastern Scotian Shelf and southern Banks area; considerable work went in to find areas that were very representative.
- These studies represent a lot of information related to Atlantic area. Do we have something on Arctic? The presenter mentions that the general conclusions should stand up for Arctic as we should have similar range of habitats, organisms, structures in Arctic. However, Norway has done some work in the North and it would be useful to do some experimental work in the Arctic just to confirm.
- We might have more low energy environments in Arctic and we may also expect that the profound mixing as seen in east/west coasts would not be as evident up north. However, there are certainly many sites considered as high energy environment (e.g. upwelling areas, shallow waters where ice scour occurs, etc.).
- We can not confirm that we start with a pristine habitat, especially with Grand Banks even if it was not trawled since 13 years.
- Data's coverage may be incomplete (especially many years ago compared to the 90s). There are also questions about the coverage of only offshore fleet versus smaller draggers. There seem to be data from both categories but precisions would be required. More precise data on this issue are expected in the future.
- There is possibly a genetic issue related to fishing impact. There are ongoing studies with hydroids: in some areas there seem to have more asexual reproduction and in other sites it would be mostly sexual reproduction?

## WP3 - DFO Mobile Bottom Fishing Gear Impacts Research in the Newfoundland & Labrador Region

*(K. Gilkinson, E. Dawe, B. Forward, B. Hickey, D. Kulka, and S. Walsh)*
*Presenters: K. Gilkinson and D. Kulka)*

ABSTRACT
(provided by the authors)

Since 1990, the Newfoundland & Labrador (NL) region has been involved in collaborative research with the Maritimes region on the impacts of Canadian mobile bottom fishing gears. There has also been some directed research dealing with specific NL region issues: (1) In recent years, Canadian snow crab (*Chionocetes opilio*) fishers have expressed concern that decreasing crab biomass may be due to crab mortality induced by shrimp trawling. Results of a 2005 study indicated that bottom trawling is associated with an increased incidence of leg loss. However, there is no evidence that shrimp trawling imposes a substantial mortality on snow crab. (2) A study was undertaken to delineate spatial and temporal (20 year period) patterns of commercial trawling in the NL region (and other regions) including patterns of intensity and consistency of trawling effort. This study demonstrated that the distribution of trawling disturbance on Canadian continental shelves is patchy and temporally variable. These findings suggest that over much of the shelf the seabed is either not trawled or only lightly trawled while there are areas of consistent, high trawling effort. The spatial and temporal history of trawling can be used to identify historical and recent trawling activity in areas of vulnerable habitat (e.g. deep-sea corals). (3) The prevailing view is that otter trawl doors inflict more damage per unit area of seabed than other gear components due to their mass and the resulting forces transmitted to the seabed. Due to logistic constraints most field studies of trawl gear impacts have been restricted to examining aggregate impacts of all gear components. In order to examine more closely the physical disturbance and biological damage caused by trawl doors, a simulated trawl door scouring experiment was carried out in an experimental tank at Memorial University of Newfoundland. Various sediment stress sensors, displacement markers and preserved bivalves were placed in a sand testbed and a trawl door model was towed through the sediment. A model was developed to explain the apparent anomaly of bivalve displacement with little associated damage based on sediment mechanics, and size and life position of infaunal bivalves living on this bottom type. The results of this experiment largely corroborated the impacts of experimental trawling on bivalves in the Grand Bank experiment; small near-surface bivalves were not damaged whereas large, semi-infaunal bivalves were destroyed. (4) There has been only one published study investigating the impacts of scallop dredging in NL. In this study, mortality rates (non-yield fishing mortality) of Iceland scallops in a heavily fished population were compared to those of an unfished population. Annual mortality in the Iceland scallop was found to be significantly higher on exploited beds than on unfished grounds. Indirect fishing mortality was gear-dependent with highest mortality rates (31%) associated with the heavy, offshore New Bedford dredge compared to 17% for the inshore Digby dredge. Overall, up to 8 times as many scallops perish as a result of encounters with fishing gear than through natural causes. (5) Mobile bottom fishing gears are destructive to large structure forming epifauna, including deep-sea corals. Given the groundfishery moratorium in the NL region, fishing is now concentrated outside Canada’s EEZ in deep water along the shelf slope which is the prime habitat for deep-sea corals. Through mapping the distribution and diversity of deep-sea corals candidate locations for coral conservation areas can be identified. Beginning in 2001, a long-term NL region deep-sea coral research program was initiated. This is a

collaborative effort between DFO (Science and Oceans) and Memorial University (Departments of Biology, Geography and Earth Sciences). Up to 2005 this program was opportunistic, taking advantage of coral bycatch from the multispecies surveys and Fisheries Observer Programs. This research program was expanded in 2005 when three years of funding was obtained through the International Governance Program (IGP) to study coral trophic relationships, reproductive ecology and their role as fish habitat. (6) The Grand Bank trawling impact experiment (1993-1995) was carried out on a sandy seabed (130 m) on NE Grand Bank. A detailed summary of this experiment is presented in the Maritimes region working paper.

### KEY POINTS FROM WP3

*(based on the presentations made by Gilkinson and Kulka)*

**Historical:** The core of the program is based on field research on impacts of Canadian mobile bottom fish gear conducted by Maritimes and Newfoundland & Labrador DFO regions (15 Years collaboration).

**Sources of information:** This working paper is based on five different studies. These are as follows:

1. Grand Bank trawling impact experiment (previous presentation made by D.C. Gordon).
2. Impacts of shrimp trawling on snow crabs (two phases completed: phase 1 in 2000 and phase 2 from July to November 2001, and preliminary results available from a shrimp trawling field experiment conducted in St. Mary’s Bay in June 2005)
3. Simulated trawl door scouring experiment
4. Impacts of Scallop dredging;
5. Sensitive areas and habitats - geographic distribution and diversity of deep-sea corals
6. Spatial definition of trawl fishing effort in Canadian waters (next presentation by D. Kulka)

<u>Impacts of Shrimp Trawling on Snow Crabs – Phase 1</u>

- Crab fishers maintain that shrimp trawling on their grounds damages crabs and is the cause of missing legs and of an increase of mortality.
- 2000 Snow Crab Management Plan called for research to assess the impact of shrimp trawling on the crab resource.
- Phase 1 was to assess damage to trap-caught crabs on a shrimp fishing ground.
- <u>Methods</u>: fleets of crab pots were set in an area approximately 6 km by 800 m (area to be subsequently trawled) then a shrimp trawler completed 10 tows within the designated fishing area. The crab pots were again set within the fishing zone and recovered crabs were measured and scored for damage.
- <u>Key findings</u>: shrimp trawling did not result in a significant increase in damage to crabs measured as leg loss. However, the experiment was limited in duration and spatial scale. Greater damage may have been recorded if trawling had been carried out at other times of the year, particularly during soft shell periods.

Impacts of Shrimp Trawling on Snow Crabs – Phase 2

- Phase II was to assess damage to crabs not caught but known to have been run over by footgear.
- Methods: retainer bags were designed and tested in a flume tank at the Marine Institute in St. John's (three retainer bags were attached to the shrimp trawl). The field trawling consisted in a series of tows made during three separate trips (July, September, and November). After each tow, a minimum sample of 250 crabs was taken from each retainer bag for measurements and damage assessment. After each tow crabs were taken 10 nm from the trawling area and released.
- Key findings: for each time period, crab populations were similar in terms of general condition, recent and past leg loss, average size and percentage of females present. Frequency of occurrence of recent leg loss was very low (< 4 new leg losses per 100 crabs). In conclusion, phase 2 had basically the same results than phase 1 with experimental shrimp trawling that did not seem to have adversely affected (in terms of damage) the large number of crabs encountered.

However, the debate continued with fishers about the potential damage of this activity then in 2005 DFO initiated further studies on the Interaction between shrimp trawling and the snow crab resource (St.Mary's bay experiment, direct observations on gear-crab interactions and further retainer bag studies).

Field trawling experiment in St. Mary's Bay

- The St.Mary's Bay study was conducted in a shallow-water commercial crab fishery area close to St. John's (commercial stratum 93-183 m). Two trawling corridors were defined: a mid-bay corridor and an outer-bay corridor. Pre and Post trawling surveys were conducted with a Remotely Operated Vehicle (ROV).
- Key findings: Final conclusions are not available at this time but the preliminary results available indicate some impacts on muddy seabed after trawling (bottom with a parallel series of furrows created by the rockhopper discs that were still visible four days after trawling) but no dead crabs were observed in post-trawl ROV surveys.

2J-3K trawling study (retainer bag)

- The preliminary results available indicate that repeated trawling of an area significantly contribute to more new leg loss & carapace damage, and a higher percentage of new leg loss in small crabs (5-50 mm CW).

Simulated Trawl Door Scouring Experiment

- The doors are widely regarded as the most destructive trawl gear component. This study was a companion study to Grand Bank experiment. The objective was to quantify the stresses transmitted to the seabed and the patterns of sediment deformation and displacement, and to identify trawl door-specific damage and displacement of bivalves.
- Methods: The study was conducted in the ice scouring research tank of the Memorial University of Newfoundland (use of gantry, sand test bed, trawl door model, preserved

bivalve specimens from Grand Bank and electronic devices to monitor the changes in the sediments).

- Key findings: Up to 70% of displaced specimens which were originally buried were completely or partially exposed at the test bed surface. 5% of specimens placed in the scouring zone showed evidence of damage (large, shallow burrowing taxa). Infaunal organisms would have experienced maximum sediment stresses at a point ~50 cm from the advancing trawl door. The results corroborated the observed impacts to bivalves in Grand Bank experiment.

Impacts of scallop dredging

- Mortality rates (non-yield fishing mortality) of Iceland scallops (*Chlamys islandica*) in a heavily fished population were compared to those of a population in a recent fishery. There is one published study on Strait of Belle Isle, St. Pierre Bank and Grand Bank.
- Key findings: Annual mortality was higher on exploited beds than on unfished grounds. Indirect fishing mortality was gear-dependent with highest mortality rates associated with the heavy, offshore New Bedford dredge compared to the inshore Digby dredge. Overall, up to 8 X as many scallops perish as a result of encounters with fishing gear than through natural causes.

Sensitive areas and habitats: geographic distribution and diversity of deep-sea corals

- There is a close linkage between this study and the Maritimes research program. Newfoundland began the work in 2001 with opportunistic sampling (DFO vessels). Today, samples (trawl bycatch) originate from various sources (DFO multispecies surveys, Fisheries Observer Program and Northern Shrimp Survey). Possibility of identifying deep-sea coral hot spots compared to traditional trawling areas.
- A new Deep-Sea Coral Research project has been funded in NL. The new areas of research are trophic relationships (isotope studies), coral reproduction/recruitment and Fish-coral associations. These are multidisciplinary projects done in collaboration with Memorial University of Newfoudland.

Spatial definition of trawl fishing effort in Canadian waters (Presenter: D. Kulka)

- This work examined the hypothesis that demersal fishing effort is not persistently and uniformly spread over large spatial areas but is focused on specific areas where fish concentrate and are easier to catch.
- Data for the offshore fleets were made available through fishery observer programs that are in operation in Canada to test this hypothesis. This study spatially defines intensity of demersal fish and shrimp fishing effort (does not include all fisheries like clam, etc.) and estimates the percentage of seabed swept by trawls.
- Trawl effort analysis: Fisheries Observer data adjusted to the total fishery were used to examine the extent and intensity of trawl activity for the Pacific (1994-2000) and Atlantic (1980-2000 for the Scotian Shelf, Grand Banks, NE Nfld Shelf and Labrador Shelf and 1990-2000 for the Gulf of St. Lawrence).
- Methods for mapping: the method allowed the use of a start or end position from fishing logs or observer records (precise information regarding trawl tracks is rarely available).

Potential mapping was done within the scale of the data by setting an area of influence on the scale of the distance trawled. The adjusted data sets were imported to the SPANS Geographic Information System (GIS) for mapping and analysis (useful especially for the analysis of highly unevenly distributed and aggregated point data such as fishing sets). Potential mapping transforms the points (latitude and longitude of the fishing sets) to a surface depicting differential fishing density. This process creates a very large number of areas (crescents or circle fragments) that have a unique value that is assigned to the underlying grid (quadcells). These entities can then be classified into a surface. This method allows the creation of maps that spatially illustrate area trawled at varying intensity.

- Results on area trawled in Pacific: Data available only for 1994-2000. A moderate reduction in extent of effort was seen in 1996 and 1997 but overall, the seven years examined showed fairly similar effort distribution with the effort concentrated in three areas: southwest and north of Vancouver Island, and northeast of the Queen Charlottes (see Appendix 6a).
- Results on area trawled in Atlantic (Gulf of St. Lawrence excluded): In the Atlantic, the effort distribution was more complex and extensive, comprising many fisheries. From 1980-2000, the most consistently intensely fished areas are shown in Appendix 6b. For earlier years (80's), five broad areas were persistently fished for a number of directed fisheries but for later years (mid-1990's), the effort was greatly reduced (from about 15-20% of the area to a low of 5%) mainly due to the collapse of important groundfish stocks.
- Results on area trawled in the Gulf of St. Lawrence: Data for the Gulf are available only for 1990-2000. The reduction in extent of effort is not as dramatic in this area.
- Analysis of centroids of intense activity: The centroids of areas where total area trawled exceeded the extent of the area were also produced in order to identify areas of intense activity. The proportion of intensely trawled area with respect to the number of years appears to be similar across all areas (Atlantic and Pacific) with about 1% of the total area being intensely trawled year after year. There was also spatial consistency in areas fished across years but intensely fished areas shifted sufficiently over time so that exact locations were not intensely re-trawled every year.
- Effort by depth: The fishing effort and the proportion of area fished varied by depth with shallower depths under-represented, and mid-range depths (350-650 m) over-represented. Fishing effort also varied by depth over time with shallower fishing activities in the early 1980's, that went deeper to the early 1990's, with activities that were in the centered mid-range in recent years.
- Next steps: Spatial definition of trawl effort is the first essential stage toward understanding the effects of trawling on the environment. However, trawls are not the only gears that come in contact with the bottom. Geo-referenced data are also available from clam and scallop dredge fisheries that occur in Canadian waters and an analysis of these fisheries is clearly required. Efforts in mapping will also have to be extended into this century (data not available at the present meeting).

## Discussion on WP3

- Is there any correlation between trawling sites in North and hot spots for coral? Most information we have from now on these hot spots come from DFO multi-species surveys. The hot spots should be the ones with high biodiversity. It was suggested to set aside time later in the meeting to discuss more about the type of advice we may want to provide on this particular aspect (areas where a lot of data demonstrate particular diversity, areas with no data but where there might be a need for protection because these are in a pristine stage).

- The maps on the fishing effort in Atlantic and Pacific during the 80's and 90's created considerable discussions. Some argued that these are based on the Observer program coverage and that this program has always been issue-driven in Maritimes (not random) then the data may not be representative of all area fished and of all vessel sizes. The Bay of Fundy and the nose and tail of the Grand Banks are mentioned as examples of areas for which there is possibly incomplete information regarding historical trawl fishing effort. However, it was noted that observer data were adjusted to total landings to estimate areas swept (the working paper and the presentation were clear on this point and on the fact that the areas are minimum estimates) then the group agreed that they are likely quite representatives except for the Bay of Fundy and the NAFO Regulatory area that are underrepresented. For these areas, the next step will be to conduct analyses for this century (from 2000 to date) using fishing log data since it is now reliable (whereas it was not in earlier times). Pacific data seem also to be based only on groundfish fleet and there are other data available on fishing effort.

- All participants considered these maps as really interesting. One mentioned that they may be misleading for policy and management purposes because of the uncertainties about coverage (e.g. maybe poor for some areas/fleets) but again, it was noted by the group that these maps should not be used alone but in the context of the whole work presented that clearly specifies how the maps were derived (fleets, coverage, etc.).

- Centroids of intense activities: one mentioned that where the coverage is low (e.g. inshore 5-10%), even if we extrapolate for total effort, we may underestimate the surface of the area targeted by fishing activities. However, it must be noted that the centroids give locations and they would reflect where the specified fleets > 45 ft fished intensely. There would be areas very close to the coast where effort for vessels < 45 ft would not be captured but we will never know their footprint because they do not have to report fishing position (just catch). Based on the author, there are likely very few trawlers < 45 ft in this area (most of the effort is non-mobile gear and was not part of that study). One possible next step could be to determine how many vessels < 45 ft used non-mobile gear in all areas. In NL, there are few over the period analyses.

# WP4 – Impacts of Mobile Fishing Gear: Perspectives on the Canadian Context and Recommendations for the Way Forward

*(Susanna Fuller, Mark Butler, Dorthea Hangaard)*
*Presenters: M. Butler and D. Hangaard*

OVERVIEW
(provided by the authors)

Declining fish stocks, failure of stocks to recover despite reduction of fishing effort, continued expansion of fisheries into new, previously unfished areas and impacts of these activities on the marine ecosystem are subjects of increasing concern to fisheries scientists and conservation biologists. Fishing impacts on the seafloor and on non-target, bottom dwelling species have been the focus of a large body of research in the past two decades, evidenced by the publication of hundreds of scientific papers and dozens of reviews.

Effects of bottom tending or mobile fishing gear include, but are not limited to, removal of benthic species, destruction of habitat complexity, reduction of species abundance and diversity, and alteration of physical structures on the sea floor (see Thrush and Dayton 2002 for a review). In general, ecosystem impacts of mobile gear have been accepted by the scientific community, with the understanding that impacts will vary with bottom type, community composition, and intensity and frequency of fishing activity. Indeed, comparisons of bottom fishing activities to forest clear cutting indicate similar ecosystem effects (Watling and Norse 1998).

While it is understood that all fishing gears have an impact on the marine system, on target and non-target species, gear with heavy metal components that is towed over the bottom or used to dredge into the benthos will have a greater impact than non-bottom tending gear. This is substantiated by the sheer numbers of studies of mobile gear on the sea floor vs studies examining the effects of fixed gear (ASFA database 2005).

In this document, we focus on gear impacts on the seafloor and on non-target, benthic species in Canadian ecosystems. There has been relatively little research in Canadian waters, considering the present and historical importance of the fishery to both the culture and the economy. Most research has occurred on Canada's east coast with almost no directed research on gear impacts on the west coast of Canada.. We briefly review studies from areas with similar species composition and within the same ecoregion. We examine overall results from a range of study types, as they relate to Canadian waters. We acknowledge that there are numerous types of studies, including experimental trawling (BACI design), comparison of heavily fished areas to areas with low fishing effort, use of historical data to compare present faunal compositions of trawled areas, analysis of trawl contents (see Lokkeborg 2004 for review of types of studies), it is not the purpose of this paper to distinguish between efficacy or scalability of such studies.

An overview of information gathered through traditional ecological knowledge (TEK) is provided. Some of the most poignant observations about the fishery and its impacts on marine resources come from those who make their living from the sea. Indeed, it is due to this concern, that both the Ecology Action Centre and Living Oceans Society, became involved in promoting sustainable fisheries.

We briefly review the existing legal framework through which Canada is obligated to conserver and protect living marine resources. In addition, we outline ongoing efforts in other areas to mitigate damage by mobile gear. Based on existing Canadian science, and relevant science from similar or adjacent marine ecosystems, we present several science based management recommendations that may serve as a way forward in improving Canadian fisheries management (nationally and on the high seas) to ensure sustainable fisheries, protect biodiversity and fish habitat.

### KEY POINTS AND DISCUSSION ON WP4

- The presenter gave a brief historical of the evolution of knowledge of bottom gear impacts since the beginning of the 1900's. The knowledge on this issue has especially increased in the 1970's and 80's, when there has been an increase in research, and since the 1990's, with the improvements in imaging and mapping. However, this peer review meeting seems to represent the first Canadian national review on this issue.
- Bottom trawls and dredges are recognized in various studies as to be among the most destructive gear types in terms of habitat change and bycatch. They affect the seafloor community structure, they reduce the benthic biomass, the biodiversity, and the habitat complexity. They have impacts on productivity, on nutrient cycling, etc.
- Various pictures showing trawled vs untrawled bottom were presented in order to illustrate the decrease in biodiversity in the latter. Changes in physical features caused by trawling were also illustrated based on Traditional Ecological Knowledge (TEK). The head of the Gully, with its hills now flattened off based on a fisher was among the examples that were mentioned.
- Deep sea corals and sponges were clearly identified as especially vulnerable to bottom trawling. Various studies conducted on east and west coast showed the damage to these structures by bottom trawling. Data on sponge and corals bycatch on east and west coast were also presented (trends in sponge bycatch in the Northwest Atlantic – 1979-2000, data from turbot fishery in Davis Strait, Observed Corals and Sponges bycatch in groundfish bottom trawl fishery on west coast) to illustrate the fact that these bycatch are still important year after year.
- The work done in the context of the sponge reef program in British Columbia was presented. The observer data were used (bottom trawling is 100% covered by observers) to establish where the corals and sponges bycatch by groundfish bottom trawls occur. More than 1000 pounds of corals & sponge are landed each year. They looked at all trawl sites (mid-point of sets only) and the bycatch were submitted to density analysis. The comparison of the bycatch maps with the areas that are presently closed showed that there would be important bycatch outside of the closed areas. Living Ocean is recommending area closures not only on the basis of bycatch but also for all other untrawled areas until we know more about habitat.
- Management recommendations like the ones made ICES (reduction of effort, protection of areas and gear modification and substitution) are considered as appropriate measures. The case of Alaska was presented as an example where the establishment of areas closed to bottom trawling, and others (small squares – coral gardens) where all bottom gears are prohibited received a unanimous support from fishing industry. There was little or no trawling in much of this area but there is more than 900,000 km2 protected in US waters. On the latter point, the participants mention that there are

similar examples in Canada (e.g. the Gully and the Scotia/Fundy haddock closed area which is far bigger than any of the US closed areas).

- The participants recognize that we need to pay more attention to the changes in gear technology (e.g. rock hopper gears that make it easier to trawl in newer areas).

**End of day 1**: The chair gives his instructions to the participants. They are invited to read carefully the working papers that will be presented on day 2 (if it has not already been done) and they are also invited to think about an inventory of the things we would need to discuss before starting any detailed discussion of any one issue. Once the presentations of the working papers are completed we will elaborate this inventory and then conduct the relevant discussions on each of its topics before working on the conclusions of the meeting (day 3).

## WP5 - Updates Concerning Unaccounted Fishing Mortalities

*(Alain Fréchet, Claude Savenkoff and Johanne Gauthier)*
*Presenter: A. Fréchet*

ABSTRACT
(provided by the authors)

This contribution covered a number of items:

1. Definition of the various categories of unaccounted fishing mortalities
2. A simulation of potential negative impacts of a change in mesh size
3. Three gear recovery programs in the Gulf of St. Lawrence
4. Survival experiments by gear type
5. By-catch in the shrimp fishery
6. Indirect evidence of unaccounted fishing mortality in ecosystem modelling

These issues were raised in order to increase the awareness of participants to the existence, monitoring and research around these issues in the Quebec region. Of relevance to the impact of the use of mobile bottom fishing gear is the issue of post-selection (or escape) mortality. Recent research in this field has shown that such mortalities can be significant for some groundfish species. A better understanding of post selection mortality could allow the assessment of mortality on target and non target species for the various fishing gears used. Also, such knowledge may improve the accuracy of stock assessments. No field research on this topic is currently being undertaken in Canada.

DISCUSSION ON WP5

- The key point highlighted by this presentation is that all sources of fishing mortality occurring directly as a result of catch or indirectly as a result of contact with or avoidance of the fishing gear should be considered in the assessment of gear impacts. Essentially, these are landed catch, Illegal and misreported landings, discard mortality, escape mortality, ghost fishing mortality (e.g. lost gill nets), habitat degradation mortality, predation mortality and infection mortality. Some of them may represent very important sources of mortality (e.g. misreported or illegal catch may have represented more than 40% of the mortality in the past).
- Bycatch in the Gulf shrimp fishery: the group looks at the bycatch data from observer program. One graph illustrates the percentage of tows catching each species (e.g. 89% of tows catch turbot, 22% catch cod, etc.) but there is no indication of fish size or quantity. It is also noted that the shrimp bycatch are based on 5% coverage (observers data). How do the bycatch change with the season? There seem to be a strong seasonal pattern with more important bycatch in April–May? There is an upcoming project this April (collaboration with Newfoundland fishers) to monitor these bycatch.

- The Nordmore grate is a good example of improvement regarding gear impacts. It excludes everything except very small fish (capelin, cod, redfish, etc.). The fact that there is no more cod trawlers in the Gulf since 1993, and no trawling activity at less than 100 fathoms, are also considered as improvements in terms of impacts.
- The bycatch data presented indicate gradients in space, time and species in bycatch. These are very complex patterns. The group recognizes the fact that it is not possible to draw any precise conclusions from this information and more thorough analysis is required.
- Post-selection mortality: The group also looked briefly at some results of a study on the survival / mortality of fish escaping a cod end of an otter trawl (pollock study). It is mentioned that small fishes injured after escapement may experience higher mortality because the predators may pick them more easily. This represents food for scavengers. Any gear substitution should consider various impacts like having more food for scavengers. If not, we could end up with a gear that is better for the benthic communities, but ends up putting more dead fish back into the water.
- The chair mentions that this presentation was added to the agenda by the steering committee to remind us that bottom gears do not only have impacts on the bottom. The latter represents just one aspect of the effects of mobile gears and it is important to keep the overall picture in mind. Now each issue presented is very complex and would require more quantitative investigations than it was expected for this meeting (this presentation is not an exhaustive one). The group must now focus on the key aspects of this meeting i.e. impact on habitat and benthic communities. However, this presentation illustrated well what should be done on this matter in the future.

## WP6 – Ecosystem Consequences of Fishing on the Bottom

*(D. Duplisea)*
*Presenter: P. Archambault*

ABSTRACT
(provided by the author)

It has been well established that bottom trawling activities reduce the biomass and production of benthic communities through their destructive power. Dragging large pieces of gear over the bottom crushes and kills organisms, preferentially killing the large hard-shelled organism that often compromise a majority of the community biomass and production, and also which can be considered habitat features in themselves. Furthermore, trawling activities mix sediment and increase mortality of benthic bioturbating organisms thus disrupting biogeochemical storage and flux from sediment which can have implications for nutrient regeneration in the water column as well as benthos. Clearly, destructive benthic fishing practices need to be monitored for their ecosystem effects and managed to minimise their impacts. Management of trawl fisheries usually only accounts for the direct mortality on the target species but we discuss an example here of a temporary closed area in the North Sea in 2001 which was designed to protect juvenile cod but may actually have led to a greater system wide decline in benthic production than if the closure had not been imposed. This was caused by the displacement of fleet effort to new areas that were relatively undisturbed during the closure. This example highlights that management actions that do not take into account other potential effects of the action and especially those that do not deal with the difficult problem of fleet capacity and effort, could have counter-intuitive and negative ecosystem consequences.

KEY CONCLUSIONS FROM WP6

These conclusions are based on the presentation made at the meeting. Each of them refers to the conclusion of WP 1 (review of international studies).

- Trawl induced mortality on benthos is usually size dependent such that large structure forming and bioturbating fauna are disproportionately affected by trawling activities **(support #1 & 2)**.
- Bottoms swept by fishing trawls have lower benthic biomass and production owing to trawl inflicted mortality on benthic organisms **(support #8, 9 & 10)**.
- Trawling also affect sediment chemical storage and biogeochemical fluxes owing to mixing caused by trawling gear and mortality of bioturbating organisms **(support #15)**.
- The first passage of a trawl in an untrawled area will have the greatest negative impact on benthos, hence prudence must be used in allowing trawl fisheries in new areas or areas which have not been trawled for a long time **(support #17)**.
- Management of trawl fisheries via closed areas but not dealing with total effort and its spatial distribution can lead to an overall average negative impact on the benthic community **(support #23).**

# WP7 – Effect of the Commercial Fishery on the Île Rouge Iceland Scallop (*chlamys islandica*) Bed in the St. Lawrence Estuary: Assessment of the Impacts on Scallops and the Benthic Community

*(P. Archambault and P. Goudreau)*
*Presenter: P. Archambault*

ABSTRACT
(provided by the author)

Many studies have shown that scallop dredging seriously disturb marine substratum. This study was conducted to characterize the scallop bed and the entire benthic habitat of the sector of the Ile Rouge (Saguenay-St-Lawrence Marine Park) and secondly to quantify the influence of the scallop dredge on the benthic communities and the population of scallops. A photographic survey of the seafloor was used to study the epibenthic communities and surface sediment characteristics. Furthermore, the indices recorded since the beginning of commercial harvesting of the Ile Rouge bed in 1998 were used to assess variations in the scallop population. The commercial sampling data indicate that fishing effort varies from year to year and that fishing pressure shifted during the years 1999, 2000, 2001 and 2002. However, the fishing pressure stayed relatively low after from 2003 to 2005. The modal size of the catches decreased from 80 to 74 mm between 1999 and 2002, but increased to 85, 87 and 84 mm in 2003, 2004 and 2005, respectively. This reason could be linked to the change in fishing strategy. It was observed that in this highly dynamics areas, the influence of scallop harvesting on benthic communities seems to be low. It is important to establish monitoring programs in sensitive areas in order to address different types of disturbances and ecosystem particularities. The robustness of the sampling design was discussed as a key element when implementing a monitoring program. If commercial fishing activities are to take place within a conservation framework, harvesting issues must be assessed as accurately as possible to permit sound management of the resource and conservation of the benthic habitat.

KEY CONCLUSIONS FROM WP7

These conclusions are based on the presentation made at the meeting. Most of them refer to the conclusion numbers of WP1 (review of international studies) as to indicate which conclusions are supported.

- In highly dynamics areas, the influence of scallop harvesting on benthic communities seems to be low. That being said, the short history of exploitation of the bed could also lead to the observed results. However, the idiosyncratic characteristics (highly dynamic area, unknown link with others beds, short time series of data, presence inside a Marine Park, etc.) of the Ile Rouge bed highlight the importance of adopting the precautionary management approach **(support #6 &12)**
- If commercial fishing activities are to take place within a conservation framework such as that established for the Saguenay–St. Lawrence Marine Park, harvesting issues must be assessed as accurately as possible to permit sound management of the resource and conservation of the supporting habitat **(support #23**)

- It is important to establish monitoring programs in sensitive areas in order to address different types of disturbances (mobile fishing gear, management and fishing practices, etc.) and ecosystem particularities. The robustness of the sampling design (e.g. considering natural variation) is also a key element when implementing a monitoring program. Control or reference sites should be preserved in different areas for implementing monitoring programs **(support #23 and FAO conclusion on design)**
- Research on unaccounted fishing mortality is growing worldwide and has vast repercussions on understanding the overall effects of fishing activities as well as prioritizing gear impacts on the ecosystem. A better knowledge of its actual scope influences directly both the quality of stock assessments and sound decisions by fisheries management. However, currently the lack of data from Canadian waters hampers such initiatives.
- Maintain or maximise the patchiness of effort within habitat type are more consistent with the precautionary approach. Patchy distribution of effort could be formalized by area closure.

### DISCUSSION ON WP7

- One of the key points discussed referred to the fact that most of the international studies available did not include control sites (e.g. in FAO study, 70% of the 35 studies used did not include control sites). This may imply confusion of the effects related to fishing or other sources. This study is considered as a stronger one because it implied a control site. It is suggested to add a graph and a paragraph in the paper to illustrate this important aspect.
- Is there any plan to conduct experiments similar to the Maritimes' one (WP 2) and implying pre and post trawling surveys (e.g. photo surveys) on agievn site? Some work was done (master these) and this work refers to one working paper that was supposed to be submitted at this meeting and that had to be withdrawn. We can not confirm if it will be possible to continue this study on impacts of scallop dredging on this site.
- How can we protect these control sites in the context of the ecosystem management? If we could close some areas, we would maintain some heterogeneity and some control areas unaffected. Should we have plenty of small areas or few bigger ones? This requires more discussion (chair): we need to make the difference between "Control site" and "Reference site". Reference site is valuable but may not represent the good approach (we may not want to put any treatment on such site like dredging as experiment). The control site must be one where the only difference is the treatment we apply on it. This site may also be affected by other effects as it is the case in the rest of the ecosystem then it would not be within a close area?

# WP8 – Bottom-Contact Fishing in Atlantic Canada, Spatial and Temporal Overview of Area Fished by Offshore Groundfish Sector

*(B. Chapman)*

KEY POINTS FROM WP8
*(based on the presentation at the meeting)*

**Objective:** provide an overview of information to facilitate a better understanding of spatial and temporal bottom contact by a major fishing sector in Atlantic Canada

**Source of data**: DFO Statistics from 1988-2004 from 0A to and including 5Z (12 miles to 2000 m) were used. Data and analysis was based on annual sampling of the total catch as follows: 1988-1993 (12.5 to 39.8%), 1994-1998 (51.5 to 83.9%) and 1999-2004 (86.8 to 98.1%). The percentage of area fished was overstated as it was assumed that 100% of the bottom within each cell was fished.

**Key findings - Atlantic wide:** The area studied was sectioned into 23,272 cells of 5x5 nautical miles (total 486,350 $NM^2$). 72% of the cells have never been fished in the time series and 4.5 to 9% of the cells were fished in any single year. In 2004, 95% of the cells were not fished and 2/3 of the catch came from 0.34% of the cells (79 cells).

**Key findings – Regional illustration (2J3KLNOP):** The area studied was sectioned into 8,959 cells (total 213,285 $NM^2$). 64% of the cells have never been fished in the time series and 2.5 to 9% of the cells were fished in any single year. In 2004, 92.5% of the cells were not fished and 2/3 of the catch came from 0.47% of the cells (42 cells). Of the 669 cells fished, 50.5% were fished one day only, 36.3% were fished 2-12 days and 13.2% (88 cells) were fished 13-180 days (0.98% of the cells in the region). Of these 88 cells, it was not practical to fish 100% of the area within each cell, especially in slope areas, and the bottom area contacted by doors was < 6% of the area contacted by footgear.

**Conclusions in light of the Canadian context:** Over the past 20 years the offshore groundfish catch has declined by about 90% (340Kt to 35Kt). The efficiency and precision of fishing has improved substantially and fewer seadays and less area are now fished per unit of catch then a major reduction in overall sea days and bottom impacts has occurred. Based on these data, the goals of using the ocean space and resources in an ecologically sustainable manner and of maintaining natural resilience of the ecosystem should not be at apparent risk due to the current level of bottom-contact fishing by the offshore groundfish sector in Atlantic Canada. In terms of bottom-contact fisheries, focus should be on defining, identifying and protecting sensitive areas.

DISCUSSION ON WP8

- These results are considered as consistent with the spatial definition of trawl fishing effort as presented in WP3 (Kulka). Both studies indicate that approximately 2/3 of areas were never fished. However, the group recognizes that a more detailed analysis and comparison of the results from both studies would be necessary. It would also be useful to have detailed maps of these very small areas targeted by fishery.

- What are the driving variables to choose these specific areas for fishing? Essentially, catch rates is the key variable but sometimes other factors may influence the choice of the area fished (e.g. in order to respect management measures and avoid bycatch of a species under moratorium, avoid too many small fish, etc.). It is mentioned that if we fish where fish are, maybe the resilience of the system is compromised, even if we fish in only a few % of the area.
- The approach of giving an equal weight to each cell is questioned. Things like habitat type, benthic communities, depth and productivity must also be taken in consideration.
- Damage to habitat features (e.g. corals): there is no doubt that we damaged corals in the past but most of the damage was likely done many years ago.
- It would help to look at the work done in the context of the ecosystem (e.g. ESSIM) and see if some oceanographic rationale (e.g. upwelling) could explain why these areas are targeted. We suspect that similar situation in Pacific occurs with fishers going always in the same sectors. Maybe corals were there at the beginning but now there is no longer corals in these areas but the fishers continue to go there.
- How many vessels is part of this fleet presently? There are 12 vessels presently but there were probably over 100 in 1998. This decrease is linked with the collapse of groundfish fishery.
- For groundfish and shrimp fisheries the same areas are generally fished over and over again. For scallop fishery and exploratory fishery, the same areas are not fished at the same extent and this difference must be taken into account.

Brief presentation on spatial pattern of British Columbia groundfish trawl fishery (Glen Jamieson) – **Day 2 afternoon session**

The group gave a very brief look at some maps describing majors habitats identified on west coast (type of bottom, near-surface and bottom currents, etc.) and relating those habitats with the spatial distribution of fishing effort and the groundfish CPUE in the bottom trawl fishery off the BC coast from 1996 to 2004. This information gave to the group the opportunity to make some links with the presentations from day 1 on the spatial and temporal patterns of trawling activity in the Canadian Atlantic and Pacific regions. Moreover, it highlighted the fact that it is important to relate what we know about habitats with fishing effort if we want to have the whole picture.

The Chair also presented few maps identifying the preliminary EBSAs (Ecologically and Biologically Significant Areas) identified in the Gulf of St. Lawrence. The intent was to illustrate the scale of the areas at which this group is working before we start the discussions.

## DISCUSSION FOLLOWING ALL PRESENTATIONS

The Chair invited the participants to raise any points that could have been missed during the review of the presentations (first 1.5 days) and that would need to be taken into consideration. It was suggested first to make an inventory of the topics to discuss and to keep the discussions on these for day 3. Once this list is completed, the group will review (and initiate discussions) on the 27 conclusions presented in WP1 and referring to the synthesis of the results from international studies.

Inventory of topics that will require further discussion:

The following list describes the nine key topics identified by the group:

1. The limitations of current knowledge, and our ability to improve our knowledge base:
    - Long-term studies – what "long-term" means and what are the consequences of lacking them?
    - The challenges of getting a good study design at all, and especially in areas where fishing has a long history.
    - There is an initial "unfriendliness" of spatial scales that need to be addressed:
        - Best scales to measure direct impacts on seafloor are cm to 100's of meters;
        - Often the scales of concentrated fishery operations are few 10's to few 100s of $km^{2;}$
        - Most convenient scales of management are usually on several 100's to 1000's of $km^{2.}$
2. How to move forward in areas of inadequate knowledge?
3. The science aspects of how to evaluate the conditions under which there is ecological justification to advise management that actions are needed to reduce impacts:
    - How to establish the degrees of perturbation from which recovery is no longer secure and rapid (in relevant ecological time-frames contexts)?
    - How to address the functional consequences for the ecosystem of various types of impacts (chronic, cumulative, repeated, etc.);
    - Under what conditions is there justification of Precautionary action, and a need for "Interim" or "pre-emptive" measures". [Do we meet those conditions now?]
4. Frontier areas are special compared to areas with a history of past fishing with mobile bottom gears. What special considerations and measures/approaches should apply?
5. What additional challenges are posed by the reality that many frontier areas correspond to Arctic communities, whereas most experience is with temperate and sub-boreal systems?
6. What goals for recovery do we have on a biological basis?
    - Fish habitat needs could be one justification for a biological imperative
    - Recovery relative to objectives of management
    - What has already been lost so our baseline has shifted?

7. What are the other priority questions about ecosystem effects of fishing?
8. What are the primary Research Recommendations
9. Questions beyond the advisory mandate of this meeting: Where should DFO be going and should be the roles for various sectors and stakeholders?

   *Note: Finally, the group did not have the time to discuss this topic in details. Such discussion will eventually have to be done as policy is developed.*

Review of the conclusions from WP1:

The group initiated the discussions on the 27 conclusions of WP1. These discussions occurred on day 2 and 3 (with most of them on day 2) but for a matter of clarity, all the discussions on the conclusions are reported in the following section. The final version of the conclusions that represents the consensus of the participants at the end of the meeting is available in the “Conclusions” section.

The initial numbering of the conclusions (WP1) was affected by the comments then the information below makes the link between the comments of the participants and both the original conclusion number in WP1, and the new conclusion number as it appear in the final version.

*Impacts of Bottom Gears on habitats:*

- Nos 1-2: The group agrees with the conclusions. **Numbers 2 and 3 in the final version.**
- No 3-4: There is a discussion on the possibility of removing the conclusion number 3. Boulders are considered as a bad example. We have no evidence that we “remove” boulders - we do move them, but in general we “can” reduce/remove other major habitat features. The term “habitat” can also mean different things to different people. Scallop dredge (when you collect stuff and dump everything at one site after the set) is another example illustrating that this conclusion may not represent what we want to say on this specific issue. It is also argued that maybe this conclusion is already addressed in conclusions no 1,2 and 4. Finally, it is agreed to merge conclusions 3 and 4 and change the wording in order to reflect this discussion. **Number 4 in the final version.**
- No 5: This conclusion seems to be primarily relevant to towed trawl gears (otter/beam trawls) and does not apply to scallop and clam dredging that have great impacts on sandy bottoms. It does not apply either for frontier areas. Mud and sand are more readily disturbed on a short-term basis but hard bottom may be more affected on the long-term when they are disturbed. It is suggested to change the wording of this conclusion in a way reflecting that the severity of impacts differs between habitats. **Same number in the final version.**
- No 6: Low energy environment may be more affected only because recovery takes longer. Is initial disturbance as great in a low and high energy environment? It is recommended to look at the wording and substitute “site” for “environment”. **Same number in the final version.**
- No 7: Trawls and dredges are the only gears we considered (e.g. we have not looked at seines). Also beam trawls as defined in the reference studies do not seem to be used in Canada (bottom trawl includes beam and otter trawls in the context of ICES

study). There is a hierarchy of gears (heavy beams, light beams, scallop dredges, otter trawls, etc.). No work has been done in Canada to confirm that these types of gears (bottom trawls and dredges) are more damaging than other gears. However, three international studies that considered additional gear types confirmed that they were the most damaging on benthic habitats and communities per unit of effort. The group agrees to maintain this conclusion but we will add a statement telling that "per unit of effort, these gears have the greatest effects of any gears examined in international studies". It is also recommended that <u>as an introduction in the advisory report, there should be a clear mention that this meeting focused on specific suite of gears. All other types of gear will have to be addressed in future/particular studies. They might have different effects.</u> **Same number in the final version.**

*Impacts of Bottom Gears on benthic species and communities:*

- <u>Nos 8-9-10</u>: The group agrees with the conclusions. **Same numbers in the final version.**
- <u>No 11</u>: It is true for trawls but not for dredges. Wording must be adapted to reflect that some types of dredges (i.e. hydraulic clam dredges) can affect burrowing species as greatly as surface living species. **Same number in the final version.**
- <u>No 12-13</u>: The group agrees with the conclusions. **Same numbers in the final version.**
- It is suggested to add one bullet on sublethal effects on individuals (not included in other studies, but consistent with what we saw). **This bullet will be no 14 in the final conclusions**.
- <u>No 14</u>: Scavengers show up in almost all studies but for different lengths of time. It is suggested to be more precise on this conclusion. **Number 15 in the final version.**
- <u>No 15</u>: One study in North Sea (not available when ICES and US academy did their study) has empirical information telling that changes in nutrient can be in either direction. The wording of this conclusion should be adapted accordingly. **Number 16 in the final version.**

*Considerations in the application or adoption of mitigation measures*:

- <u>No 16</u>: The group considers that this conclusion should appear as the first conclusion. This will require a review of the other conclusions to make sure that they are in line with this change. The order of the conclusions in the original list was based on the priorities of international studies, now we must adapt them to take into account Canada's context. On this matter, it is recommended to add a clear statement at the beginning of the advisory report to highlight the context of the present advice (we are using the science basis from international studies but we consider it in the Canada's context). Finally, it is also suggested to make few other changes in the wording of conclusion number 16. The word "Timing" should be added to take into account various aspects like seasonal changes (e.g. hydroids in winter that are reduced to smaller features) or diurnal effects. A precision regarding the frequency with which a site is impacted is also added to the conclusion (trawls could return few days later, whereas clam dredges may not return for a decade). **Number 1 in the final version.**

- No 17: There is an agreement on the monotonic relationship between impacts and fishing effort but a precision is required about the second part of the conclusion ("…the greatest impacts are caused by the first fishing events…"). We have very few information on this particular aspect in Canada but nothing in the available information contradicts this statement. However, some argue that this may not apply to all cases. At the end, there is a consensus to produce a separate conclusion telling that impacts will likely be more important at the first fishing event where there is potential for impacts to be large. **Numbers 17 and 18 in the final version.**
- No18: It is noted that recovery does not mean a return to pristine condition. A precise statement will be added as an introduction to the conclusions to define "Recovery" in the context of this meeting. It is also suggested to add a statement in conclusion number 18 indicating that some changes to habitat features may be permanent and moreover these are not only physical features (damages to some specialized biogenic features may be permanent). **Number 19 in the final version.**
- No 19: There is a discussion about the last sentence of this conclusion (referring to "ecological theory"). At the end, the participants agree that this statement should be maintained. We must use what we know without waiting for site specific studies and knowledge. **Number 20 in the final version.**
- Nos 20-21: They will be removed from the key conclusions. We will rather add some text in the narrative part of the conclusions relating to the tools available to reduce impacts.

*Recommendations for management of mobile bottom gears:*

Note: The title above was changed in the final version of the conclusions to reflect that these management recommendations must be considered as potential tools that may be applied in order to reduce impacts of mobile bottom gears.

- No 22: The participants agree with this conclusion but a statement will be added to reflect the importance of having a good management of the fishing effort (temporally and spatially). **Numbers 21 and 22 in the final version.**
- No 23: It is recommended to add a statement to precise that the effectiveness of closed areas to mobile bottom gears will depend on what happens to the fishing effort that is excluded from the closed areas (the effort may simply be moved in other areas). The effectiveness will also depend on the species and communities of concern (mobility, pattern of recruitment, etc.). **Number 23 in the final version.**
- No 24 The participants agree with this conclusion. **Same number in the final version.**
- Nos 25-27: These conclusions will be removed from the key conclusions. It is suggested to cover the relevant aspects of these in the narrative section of the conclusion.

Before adjourning the second day of the meeting, the chair proposed to produce an update of the conclusions integrating today's discussions and then make the text available to the group soon in the evening. The participants were invited to read this text before day 3 in order to be ready for the final review of the conclusions on day 3.

**End of day 2.**

DAY 3, MARCH 24, 2006

DISCUSSION OF THE TOPICS INCLUDED IN THE INVENTORY LIST ELABORATED ON DAY 2

The chair proposed to start with discussions of topics from the inventory list. In the mean time, paper copies of the conclusions from day 2 were made available to the participants who did not have the opportunity to get a copy on the evening of day 2. This approach allowed time for participants to read the conclusions before initiating the final discussion on this matter.

Some items of the inventory list were discussed in the morning and others in the afternoon of day 3. The group also had to interrupt the discussions on the inventory list and complete the discussions on the key conclusions initiated on day 2. This approach allowed the production of an update text on the inventory list before submitting it to the participants for a final review.

For a matter of clarity (as it was done for the conclusions of the meeting), all the relevant discussions related to the inventory list are described in the section below whatever is the precise period of day 3 when they were discussed. The final text resuming the discussions on this list of topics was integrated in the final conclusions from the meeting that are available in the “Conclusions” section.

<u>The limitations of current knowledge, and how to move forward in areas of inadequate knowledge:</u>

*What do we mean by **long-term studies**?*

- In the literature, 3 years studies seem to be considered as long term studies. With the northern cod closure 12-14 years ago, there was a drastic reduction in trawling but is that long enough to look at the area as, not pristine, but close to it? It is noted that trawling has been replaced there by shrimp trawling in many parts of 2J3KL. 2GH maybe seen as an exception as it has not been trawled in most portions of it since the 70s (there is still some shrimp and turbot fishery in small areas of 2GH)? We do not know enough on natural variability to discuss about any difference between areas then we must stay very general in our conclusions. Based on the information from a few international studies, documenting background natural variation might require 2-3 decades (greater than the time since the groundfish closures).
- Most of the organisms we work with have live spans of 30 years or so (there are exceptions, it may be shorter or longer - for coral reefs, it could be centuries). Maybe we should consider long term studies as 15-25 years (at least 10 years). This would fit better with the scale for ecosystem objectives. We have to consider impacts and responses on various scales of time: Immediate (1-3 years); intermediate (3-10 years) and long-term (more than 10 years).

*Challenges of good **study design**:*

- Benthos should be considered as a particular component of the ecosystem. You can probably take out seals, birds, and fish and the system still functions but if you remove the benthos, then you may expect important changes in the system. We have extensive databases about fish, but we are very deficient in benthic databases. It will be a long time before we can produce maps and time series about the benthos compared to the maps we already have on fish.

- The group agreed that it will be important to use standard qualifications for advice and decision making when background variation is not quantified or when we have to interpret the results from studies where there are inadequate controls. These will apply to benthos as much as any other part of the ecosystem.
- Closed areas are considered as very important for scientific study. They may not represent true control sites but there is consensus about highlighting their value in our advisory report.

*Unfriendliness of **spatial scales**:*

- Most of the management plans are on the scale of NAFO areas but science studies are on much smaller spatial scales (the best scales to measure direct impacts on seafloor are cm to 100's of meters). We need to establish bridges between these various scales (laboratory work, surveys and models, management measures, etc.). A reference is made to a workshop in New Zealand where "diagonal" reasoning and bridging from experiments to surveys to management measures was made. The group recognizes that we can now manage to the scale of the things we want to protect. It is perfectly feasible to bring management and fishing operations down to scales of 10's of km, and even less if necessary (e.g. scallop and clam dredging does move to even smaller spatial scales).

<u>The science aspects of how to evaluate the conditions under which there is **ecological justification** to advise that management actions are needed to **reduce impacts**</u>:

- Is there any difference with benthos compared to how we think of target fisheries i.e. recovery to a level/state it was years ago when there was a sustainable fishery (not to a pristine state)? The basic logic of PA reference points (productivity of impacted components) could apply but the uncertainty about nearly every property of benthos will be higher than for target species of fisheries. This means that less perturbation due to human activities will pose any given level of risk than compared to target species of fisheries. Life history of some parts of benthos impacted negatively by fishing will be more like managing redfish/rockfish than herring.
- Cumulative effects of chronic impacts relative to ecosystem functioning is of particular concern and ecosystem resilience really amplifies the concern to be risk averse. Resilience could be a risk reduction tool and impacts on specific site-restricted benthic components could be included in the application of that tool.
- The aggregation of fishery operations and our ability to manage its spatial distribution may help to work at the scale of the properties that give the system its functional properties. Particular tools could also be used to protect the areas where we know that there are now important benthic communities or features (e.g. sponges).

<u>What special considerations and measures/approaches should apply to **frontier areas**</u>?

- There was a discussion about what should be considered as a "frontier area". We are starting to fish in new areas (which have not been fished before or has not been fished in recent history). Should we consider these as frontier areas? Some argue that it should not be the case. They are more like exploration to new depths made by fishers and they do not necessarily correspond to sensitive areas. Others argue that they may potentially be moving to sensitive areas and that we should stop the expansion of the footprint of the fishery until we know more on these areas. The problem is that we don't know what is there.

- Information available suggests that fishing operations currently occur (at least occasionally) at substantial depths (1500-2000 m) in Atlantic and Pacific, and in the North. It is suggested that such depth should be considered as a limit to define frontier areas. Depth is certainly an important factor but the participants recognize that we should not try to quantify a precise depth at this meeting in order to define frontier areas. Unfished areas can be found at a variety of depths, and in the North, and a careful examination of all the available sources of information is required in order to delineate the boundaries appropriate for all three oceans. However, we must take into consideration that these deep areas likely include habitats that are readily impacted by mobile fishing gears and where uncertainty about ecosystem processes and resilience are high.

- When a new technology is used, new species may be fished even within an area that was already fished (for another species). This also represents a change that should be taken into consideration. Traditionally, Canadian policy that was developed for new fisheries/species included initial low level of effort when we were at the information gathering stage. Now what we are saying is that the rationale behind that policy could apply for an existing fishery that wants to expand its geographic area or depth, or want to use a new technology in a given area.

- Managers will have to develop specific protocol / guidelines on how they want to manage the issue of frontier areas. The concepts underlying the new emerging fisheries policy should be a starting point for existing fisheries moving into new areas. The information collection components will have to be stressed and the habitat provisions will need a careful review and may need to be strengthened. A science based approach behind environmental assessment may be applicable to fisheries expanding their areas (make prediction about the effect of the activity, gather the information during the entry level fishing, evaluation of the information, etc.).

<u>What additional challenges are posed by the reality that many frontier areas correspond to **Arctic** communities, whereas most experience is with temperate and sub-boreal systems</u>?

- Most of the information we have seen from now was from temperate and sub-boreal systems. We should mention formally in the report something about Arctic regions. We don't have a lot of information about arctic. Is there something different in Arctic to say that our conclusions would not apply to it? One says that ice cover (present approximately for half of the year) and less energy in the summer (maybe less wave/wind effect in areas sheltered within the Arctic archipelago) make the Artic a generally low energy environment. However, it is mentioned that some areas in Arctic may be impacted by strong summer wind and waves (e.g. the areas along the Yukon North Slope, the Beaufort Sea, and the east coast of Baffin that may have similar wind/wave effects than the Labrador coast) and then may represent very active waters. It may be difficult to generalize but the group agrees that the energy level of the sea floor of areas being fished is a particularly important thing to establish at the earliest stages of any expansion.

What goals for **recovery** do we have on a biological basis?

- The Chair reminds to the group the proposed text in the introduction of the conclusions' section that was produced at the end of day 2. The Recovery to which we refer is not the pristine state. It is rather the return to a state from which the current fishing events perturbed it.
- Some physical features will take a very long time to recover (e.g. corals could be 100s of years), other will not (e.g. boulder removed) and some others might be at the scale of a couple of years or even of a few days or weeks (e.g. polychaetes, hydrozoids, etc.). The group agrees on the fact that when recovery is mentioned, it is assuming that recovery is possible. Moreover, there is a consensus on the fact that we do not need to recover everything. The corals are used as an example where the debate about recovery is still ongoing. Some participants argue that we should not curtail areas to be fished any more just to protect/recover corals in those small areas. However, it is mentioned that even if we should not necessarily try to recover all the corals where we have been trawling for years, we must look for opportunities where it can be recovered.
- There is ample evidence that habitat impacts are occurring, and based on international studies, that there are ecological consequences of those impacts. Little effort has been allocated in Canada to quantify those impacts and priority should be given to improve our knowledge of the functional significance of habitat features impacted by fishing and other human activities.

What are the primary **Research** Recommendations?

The group resumed its discussion on the items of the inventory list that had not been discussed until now. The following primary research recommendations were identified by the participants:

- Continue the mapping of the distribution of current and past fishing effort. Highlight frontier areas at level of quantitative or qualitative detail possible.
- Continue the mapping of habitats, particularly sensitive ones – Highlight frontier areas, and use all sources of information from high technology to experiential knowledge.
- Research on impacts of these mobile bottom gears and other gears in the short-term, and long-term studies of the changes post impact.
- Monitoring of the natural variability in benthic community components (this is not unique to this meeting)
- Research on the functional significance of different types of habitats and habitat features.
- Analyses of data from on-going sources (e.g. Observers, etc.).

What are the other **priority questions** about **ecosystem effects** of fishing?

- The development of the science basis for advice on sustainable bycatch levels is required. This could address particularly fragile / sensitive / less resilient features of benthos (e.g. sponges, corals, etc.). There has never been any formal science advice provided (by DFO Science) on management and consequences of bycatch except maybe for few advice that were provided in a very specific context of a given species at risk.
- It is required to develop the science basis for advising on what is a healthy ecosystem generally, and in particular what contributions "habitat" and "ecosystem services" makes to it. Our policy is to manage to it.
- More work is needed on the definition of recovery of the ecosystem if we want to develop the ability to advice on it, and monitor/achieve it.
- Operational habitat objectives should be set and used in management as soon as possible. They must include functions of habitat not just their beauty, and must address how to achieve it, once it is decided that we want to. Habitat objectives should be part of the LOMA (Large Ocean Management Area) process and habitat function and structure need to be highlighted in that process. As part of the LOMA, the EBSA must be considered as one of the possible tools that can be used for features that may require particular attention. However, we need to address operational objectives for habitat in ALL areas, not just for EBSAs.
- There is a discussion about the way to identify the need to make an adequate risk management of the impacts of mobile bottom gears on the ecosystem. There are some concerns about an advice saying that each time we want to do something we must make a very active risk management. Others think that if we are too general, it could imply that some activities that may have important impacts will not be managed adequately. Risk assessment is used to manage risks of other human activities then it may also be used to manage risk of fisheries on ecosystem benthic communities. The decision to explicitly manage the risks associated with bottom gears is a policy decision but all the participants agree on the need to put at least a general statement telling that the usefulness of RA tools should be explored.

**Publication process**: all WP presented should be upgraded in Research Documents.

**Adjournment of the meeting at 4:00 pm.**

# CONCLUSIONS

*NOTE: The participants did not necessarily make a thorough review of the precise wording of each statement of the conclusions but this information represents the key points on which they agreed at the end of the meeting. This information will be used in the elaboration of the science advisory report.*

Points to be made in the introduction:

ALL gears have impacts. This meeting considered ONLY mobile bottom-impacting gears, specifically otter trawls (defined broadly), scallop dredges, and hydraulic clam dredges. Effects of others should be reviewed and similar advice provided.

Where "recovery" is mentioned below, it is not intended to refer to return to a pristine state. Rather, it refers to return to the state from which the current fishing events perturbed it. The larger issue of other possible objectives for recovery is discussed in a following narrative section.

Basis of advice begins with international experience adapted WHERE WE HAVE CANADIAN information to use that fully. Where we don't we do use international (see the strategy described in the Terms of reference – Appendix 2).

Overall conclusion

1. Mobile bottom-contact fishing gears do have impacts on benthic habitats and communities. The effects are not uniform, however, they depend on:
    a. the features of the seafloor habitats, including the natural disturbance regime;
    b. the species present;
    c. the type of gear used, the methods and timing of deployment, and the frequency with which a site is impacted by these gears;
    d. the history of human activities, especially past fishing, in the area of concern.

The form of many of these dependencies is present in the following additional conclusions.

Impacts of Bottom Gears on physical features of the seafloor:

2. Mobile bottom gears can damage or reduce structural biota.
3. Mobile bottom gears can damage or reduce habitat complexity.
4. Mobile bottom gears can alter seafloor structure and large habitat features; with positive or negative consequences depending on the features affected and the nature of the alteration.
5. The impacts of bottom trawl gears are initially greater on sandy and muddy bottoms than on hard, complex bottoms; but the duration of impacts is usually greater on hard complex bottoms than on sandy bottoms and probably longer that on muddy bottoms (for site of comparable "energy"). Dredges are used in only specific habitats (for example – hydraulic dredges in sandy sites) and this generalisation is less relevant.

6. For a given type of habitat, dredges and trawl gears have greatest impacts on low energy sites and least (often negligible) impact on high-energy sites.
7. In the international studies which considered additional gear types, dredges and bottom trawls were considered to be the most damaging to benthic habitats and communities (per unit of effort).

Impacts of Bottom Gears on benthic species and communities:

8. Mobile bottom gears can change the relative abundance of benthic species and hence of benthic communities
9. Mobile bottom gears can decrease the abundance of long-lived species with low turnover rates.
10. Mobile bottom gears can increase the abundance of short-lived species with high turnover rates.
11. Bottom trawl gears currently used in Canada affect populations of surface-living species more often and to greater extents than populations of burrowing species; However hydraulic clam dredges and possibly some other types of dredges can affect burrowing species as greatly as surface-living species.
12. For a given habitat type, impacts of mobile bottom gears are less in high-energy / frequent natural disturbance sites than in low energy sites where natural disturbances are less frequent.
13. Mobile bottom gears affect populations of structurally fragile species more often and to greater extents than populations of "robust" species.
14. Mobile bottom gears may have sublethal effects on individuals. These effects may increase their vulnerability to other sources of mortality or lower their fitness.
15. The abundance of epibenthic scavengers may increase temporarily in areas where a bottom-impacting gear has passed, and these increases may persist for days to possibly weeks. When areas are impacted repeated over several years, the increased presence of scavengers in the community become persistent.
16. Rates of sedimentation are increased in areas where mobile bottom gears have been used. Rates of nutrient cycling may be changed, but the change can be in either direction, depending on the nature of the habitat and disturbance.

Considerations in the application or adoption of measures to reduce impacts:

17. Taking account of the factors in 1), the impact of mobile bottom gears has a monotonic relationship with fish effort,
18. Taking account of the factors in 1) for habitats and communities where there is potential for impacts to be large, the greatest impacts are caused by the first few fishing events.
19. Recovery time from disturbance by mobile bottom gears can take from days to centuries, and for physical features and some specialized biogenic features never, and depends on the factors listed Conclusion 1.
20. Application of measures to reduce impacts of mobile bottom gears requires case specific analyses and planning; there are no universally appropriate fixes. However, the effects of

mobile bottom gears on seafloor habitats and communities are consistent enough with well-established ecological theory, and across studies, that cautious extrapolation of information across sites is legitimate.

Tools that are available for reduction of impacts of mobile bottom gears:

21. The impact of mobile bottom gears on seafloor habitats and species can be reduced through major reduction in effort in fisheries using those gears
    - The effectiveness of this measure depends on how the remaining effort is distributed spatially and temporally, compared to its distribution prior to the reduction.
22. The impact of mobile bottom gears on seafloor habitats and species can be reduced through spatial management in effort in fisheries using those gears
    - The effectiveness of this measure depends on the how the remaining effort is distributed spatially and temporally, compared to its distribution prior to the reduction, and the timeframe over which it is applied.
23. The impact of mobile bottom gears on seafloor habitats, species and communities can be reduced through implementation of areas where use of those gears is not permitted.
    - This tool is highly effective for reducing impacts on physical features of the habitats,
    - Its effectiveness for reducing impacts on species and communities of concern depends on their biological properties, especially mobility and pattern of recruitment.
    - In larger contexts its effectiveness will depend on what happens to the fishing effort that is excluded by the area that is closed.
24. The impact of mobile bottom gears on seafloor habitats and species can be reduced through substitution of another gear or modification of the bottom-impacting gears to reduce contact with the benthos and seafloor.
    - The effectiveness of this measure depends on the nature of the modification or substituted gear, and the relative effectiveness of the new or modified gear to catch the target species.

Risk assessment tools can be an effective aid in choosing and designing implementation plans for measures to reduce the impact of mobile bottom gears.

These are NOT all recommended measures right away. Each one requires taking account of conclusion 20 AND the current situation. In the Canadian context the “current situation” involves major changes to many fisheries, particularly trawl fisheries, relative to their levels of effort and types of gear prior to the collapse of many East Coast groundfish.

Operational ecosystem objective setting in the 5 DFO LOMAs should give priority to setting biologically based habitat objectives, and using them effectively in management.

As quickly as operational objectives become available from the LOMAs, they should be reviewed for applicability in other areas [fisheries occur or may be expanding as well].

Attention should be given to identifying habitats of particular ecological significant, as through the EBSA and LOMA processes, and ensuring habitat protection efforts give priority to those areas. However, the process needs to address operational objectives for habitat in ALL areas, not just for EBSAs.

Long-term studies are important to assessing benthic impacts of fishing (or any other human activity)

- Impacts and responses are discussed on three general time frames – Immediate and short term (1-3 years), intermediate (3-10 years), long-term (10+ years)
- Based on information from a few international studies of benthic species and communities, documenting background natural variation would be expected to need 2-3 decades, which is greater than the time since the groundfish closures. Part of 2GH has not been trawled for groundfish over that long a period, although shrimp trawling has occurred in some places.
- Even multi-decadal studies are inadequate for measuring the response to biogenic & geomorphic features after gear impact. Responses are expected to be multi-centuries, or not at all for some physical features.
- "Best practices" in science advice provide clear user-warnings and qualifications on advice for decision-making when background variation is not well quantified, so impacts of the managed activity are difficult to partition from other changes, or may not show up in short term monitoring. These practises apply to benthos as much as any other part of ecosystem. Moreover they become particularly important for benthos because
    - o there is evidence from Canadian and international studies that benthos play a particularly crucial role in ecosystem functioning
    - o Benthic communities may be particularly vulnerable to invasive species impacts, so that it is particularly challenging to establish baselines against which to measure impacts of fishing and other activities.

The nature of studying impacts of fishing benthos through both experiments and monitoring mean it is often very difficult to meet high scientific standards for good experimental study design. This is especially the case in benthos because

- There are so many areas where fishing has a long history.
- Benthic systems are "Noisy" with lots of background variance to address
- The study designs often must confound treatment (fishing or non-fishing with site-specific characteristics

Again "best practices" in science advice provide clear user-warnings and qualifications on advice for decision-making to use caution in interpreting results from studies where there are inadequate controls.

**Controls – areas closed to fishing have special value for scientific study – even there we need to acknowledge what there are and are not controls for.

These are even MORE important in benthos impact studies because science lacks even the descriptive background of distribution and abundance in space and time that exists (although with high variance) for fish communities from trawl surveys.

There is an initial "unfriendliness of spatial scales that need to be addressed

- Best scales to measure direct impacts on seafloor are cm to 100's of meters

    - Often the scales of concentrated fishery operations are few 10's to few 100s of of km$^2$
    - Most convenient scales of management usually on several 100's to 1000's of km$^2$

- As management takes account of habitat impacts of fishing, it is feasible to move management down to spatial scales of 10's of km, and fishing operations can response on those scales as well. Scallop and clam dredging does move to even smaller spatial scales. Management tools including VMS and observers also facilitate the feasibility of managing impacts on that spatial scales that are appropriate for protection of habitat.
- These concerns have been considered in other international science meetings (e.g. New Zealand) where valuable lessons were provided about how to move conceptually and through analytical extrapolations up in space and time from local experiments to surveys to management scales

SCIENCE aspects of how to evaluate the conditions under which there is ecological justification to advise that management actions to reduce impacts are needed, and establish the degrees of perturbation from which recovery is no longer secure on relevant ecological time-frames. The need to consider this comes in substantial part because the overall trend is that fishing leads to reductions in biomass, productivity & diversity (see numbered conclusions), although there are numerous case-specific exceptions to each of those generalizations.

The basic logic behind the establishment of PA reference points (based on protecting the productivity of impacted components from serious harm) applies to benthos as well, but the risks will be expected to be larger for three reasons

- Uncertainty about nearly every property of benthos will be higher than for target species of fisheries. In the context of practices in applying the PA in fisheries, that means that whenever policy and management have adopted a specified level of risk tolerance, the degree of perturbation of benthos due to human activities which will exceed that tolerance will be smaller than the degree of perturbation that is acceptable to target species of fisheries.
- The life history of some parts of benthos impacted negatively by fishing (conclusion 9) will be more like managing long-lived, slow-growing target species (rockfish, redfish) than short-lived, resilient species. This again means a lower level of perturbation is acceptable for a specified level of risk aversion in management.
- The potential for cumulative effects of chronic fishing impacts on the benthos poses risks to alter negatively key properties of ecosystem functioning and/or ecosystem resilience amplify the need to be risk averse in managing these impacts.

With regard to risks posed, the aggregation of fishery operations and ability to manage its spatial pattern facilitates localizing the impacts at spatial scales smaller that the scales of ecosystem dynamics that give the system its functional properties and resilience. Management can use this feature of fisheries as a core part of risk reduction strategies. However, in doing so the potential impacts of mobile bottom fisheries on significant site-restricted benthic features needs to considered.

The decision on whether the risks to benthic habitats and communities from mobile bottom gears should be actively managed in a particular situation is a policy decision, informed by the PA process (above). If that decision is made, then a suite of risk assessment tools appropriate to the expected levels of risk and biological objectives need to be available. In some parts of the world, some of the risk assessment tools used in assessing the impacts of other human activities on marine ecosystem benthic components are already being used to assess the impacts of fisheries on benthos. Those tools should be explored for applicability in Canadian context.

“Frontier Areas” require special considerations in managing the risks posed by mobile bottom gears.

Unfished areas can be found at a variety of depths and in the North and information sources from recent fisheries should be reviewed carefully to delineate the boundaries appropriate for all three oceans.

Information has been presented that fishing currently does occur at least occasionally at substantial depths in the Atlantic and Pacific and up to North Atlantic Fisheries Organization (NAFO) Division OA in the North. These get into habitats with many features identified in the conclusions list (from 2-16) that are readily impacted by mobile fishing gears, and areas where uncertainty about ecosystem processes and resilience are high. These need to be considered in managing risks of these fisheries

The concepts underlying the New Emerging Fisheries Policy should be a starting point for existing fisheries moving into new areas.

- The information collection components need to be stressed.
- The habitat provisions need careful review and may need to be strengthened.
- The science based approach behind them is appropriate to evaluating impacts of fisheries on benthic communities and habitats.
    - Make prediction from existing knowledge about potential effects
    - Gather the information during the entry-level fishing
    - Evaluation of the information
- All these issues are acknowledged to add costs to industry, and create need for greater science capacity to apply quality assurance to information collection, hypotheses testing, and evaluation of information collected.

The reality that many frontier areas are in the Arctic whereas most experience is with temperate and sub-boreal systems, poses a few additional challenges.

- This affects the uncertainty and risk profiles and adds even greater importance to information collection provisions.
- We need to make full use of what information and general ecological knowledge that we do have in making predictions,
- The energy level and substrate of seafloor of areas being fished is a particularly important thing to established at the earliest stages of expansion

With regard to biological goals for recovery:

- Ample evidence that habitat impacts are occurring,
- Little effort in Canada to quantify the ecological consequences of habitat impacts but from international studies there is ecological evidence that there are ecosystem consequences of impacts when they occur on spatial scales relevant to ecological processes.

Priority should be given to improving our knowledge of the functional significance of habitat features impacted by fishing – AND other human activities

What are the primary Research Recommendations?

1. Continue to map distribution of current and past fishing effort.  Highlight frontier areas at level of quantitative or qualitative detail possible
2. **Continue mapping habitats, particularly sensitive ones – Highlight frontier areas, and use all sources of information from high tech to experiential knowledge.
3. Research on impacts of these and other gears in the short term, and long-term studies of changes post impact.
4. Monitoring natural variability in benthic community components  **NOT unique to THIS meeting
5. Research on the functional significance of different types of habitats and habitat features.
6. ANALYZE data from on-going sources (observers etc).

What are other priority questions about ecosystem effects of fishing and follow-up to this meeting?

1. Operational habitat objectives set and used in mgmt ASAP – must include functions of habitat not just their beauty, and must address how to achieve it, once it is decided that we want to.
2. Develop the science basis for advice on sustainable bycatch levels.  Address particularly fragile / sensitive features of benthos
3. Develop the science basis for advising on what IS a healthy ecosystem generally, and in particular what contributions “habitat” and “ecosystem services” makes to it.

## APPENDIX 1: List of participants

National peer review meeting on impacts of trawl gears and scallop dredges on benthic habitats, populations and communities, March 22-24, 2006.

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# APPENDIX 2: Terms of Reference

National Peer Review and Advisory Meeting to provide a DFO framework for evaluating the impact of fishing gears on benthic habitats and communities.

Background and Approach:

1. The main Working Paper for the meeting will be based on the US National Academy of Science report from 2002 and the ICES advice to the EU DG Fish and OSPAR (2000) on this topic (urls are, respectively, http://www.nap.edu/books/0309083400/html/.html and http://www.ices.dk/pubs/crr/crr241/CRR241.PDF. Both of these publications represent major reviews by large teams of experts, were themselves subjected to expert peer review, and considered highly credible treatments of the issue. The Working Paper will consist of a CONCISE summary / amalgamation of the *conclusions and advice* of two the major, independent expert reviews. It will also be informed by an additional recent recent review by FAO (Fisheries Technical Paper #472 – Impacts of Trawling and Scallop Dredging on Benthic Habitats and Communities) and the recently published Proceedings of the 2002 Symposium in Tampa (Benthic Habitats and Effects of Fishing; P.W. Barnes and J.P. Thomas, eds. American Fisheries Society Symposium 41; 2005)

2. Each Region has been invited to prepare a Working Paper on recent research done in the Region on trawl impacts on seafloor habitats, and/or what is known at present about the nature and distribution of benthic habits in the Region. This would NOT have to be original research viewed for the first time; rather the primary intent are concise summaries of what has been done in the Region, placed in the context of the overviews listed in 1). Some Regions have concluded that insufficient local information has been collected to warrant a Working Paper or that their regional information will be covered in another presentation.

3. The meeting will follow the standard CSAS NAP process, with DFO experts as regions choose to send them and a broad range of invited external participants. The invited experts will be selected for objectivity and credibility among peers and balanced across the diverse perspectives. The meeting will conduct a peer review of

> a) The first Working Paper with regard to the question to "Is it a fair amalgamation/summary of the advice from the separate advisory documents".
>
> b) The working papers from 2), with the nature of the review depending on how much information in the WP is new results and how much is results that have already been peer reviewed, and the extent to which the regional material provides additional background information for the context of this meeting.

4. Based on the information from 3a & b, the meeting will discuss and provide advice on the question: "Are there features of the Canadian benthic communities & habitats that are sufficiently different from the conditions considered in the National Academy and ICES reviews that conclusions of those two comprehensive, costly expert reviews would not be a reasonable science basis for management of activities (particularly fisheries) affecting Canadian areas. The default is we accept the existing expert advice unless there is sound reason not to.

Products:

1. A Science Advisory Document presenting the science basis for management of fishing gears and other activities affecting Canadian benthic habitats
2. One or more Research Documents, based on the WP in 1) and any other WPs prepared as part of 2)
3. A Proceedings Document

## APPENDIX 3: Meeting agenda

Impact of Trawl Gears and Scallop Dredges on Benthic Habitats and Communities, March 22-24, 2006, Queen Elizabeth Hotel, Montreal.

<u>Wednesday 22 March</u>

| | |
|---|---|
| 09:00-09:15 | Welcome and Introductions |
| 09:15-09:30 | Review of meeting objectives and agenda |
| 09:30-10:15 | WP 1 - Overview of other reviews (J. Rice) |
| 10:15-10:30 | Break |
| 10:30-12:00 | WP 1 - continued |
| 12:00-13:00 | Lunch |
| 13:00-14:30 | WP 2 - Review of Maritimes Research (D. C. Gordon) |
| 14:30-15:00 | WP 3 - DFO Mobile Bottom Fishing Impacts Research in the Newfoundland & Labrador Region (Two presentations: K. Gilkinson and D. Kulka) |
| 15:00-15:15 | Break |
| 15:15-15:45 | WP 4 - Review of trawl impacts (Two presentations: Butler and Hangaard) |
| 15:45-16:30 | General Discussion and make-up time from earlier working papers |

<u>Thursday, March 23</u>

| | |
|---|---|
| 09:00-09:40 | WP 5 - Updates of Unaccounted Fishing Mortalities (A. Frechet) |
| 09:40-10:15 | WP 6 - Ecosystem Consequences of Fishing on the bottom (P. Archambault) |
| 10:15-10:30 | Break |
| 10:30-11:15 | WP 7 - Effects of the commercial fishery on the Ile Rouge Iceland scallop bed (P. Archambault). |
| 11:15-12:00 | WP 8 - Bottom-Contact Fishing in Atlantic Canada, Spatial and Temporal Overview of Area Fished by Offshore Groundfish Sector (B. Chapman). |
| 12:00-13:00 | Lunch |
| 13:00-13:30 | Spatial pattern of British Columbia groundfish trawl fishery (G. Jamieson) |
| 13:30-15:00 | General discussion of Regional working papers and presentations |
| 15:00-15:15 | Break |
| 15:15-17:00 | Overall discussion of evidence and components of advice |

<u>Friday March 24</u>

| | |
|---|---|
| 09:00-12:00 | Open discussion and review of draft conclusions (opportunistic break) |
| 12:00-13:00 | Lunch |
| 13:00-16:00 | Adoption of conclusions and recommendations; Next steps. |
| 16:00 | Adjourn |

## APPENDIX 4: List of the working papers submitted at the meeting

WP1 - Impacts of Mobile Bottom Gears on Seafloor Habitats, Species, and Communities: A Review and Synthesis of Selected International Reviews (J. Rice).

WP2 - A Review of Maritimes Region Research on the Effects of Mobile Fishing Gear on Benthic Habitat and Communities (D.C. Gordon Jr. et al.).

WP3 - DFO Mobile Bottom Fishing Gear Impacts Research in the Newfoundland & Labrador Region (K. Gilkinson et al.).

WP4 – Impacts of Mobile Fishing Gear: Perspectives on the Canadian Context and Recommendations for the Way Forward (S. Fuller, M. Butler and D. Hangaard).

WP5 – Updates Concerning Unaccounted Fishing Mortalities (A. Fréchet, C. Savenkoff and J. Gauthier).

WP6 – Ecosystem consequences of fishing on the bottom (D. Duplisea)

WP7 – Effect of the commercial fishery on the Ile Rouge Iceland scallop (*Chlamys islandica*) bed in the St. Lawrence estuary: assessment of the impacts on scallops and the benthic community (P. Archambault and P. Goudreau).

WP8 - Spatial and temporal overview of area fished by offshore groundfish sector (B. Chapman)

## APPENDIX 5: Working paper 1 submitted at the peer review meeting

Impacts of Mobile Bottom Gears on
Seafloor Habitats, Species, and Communities:
A Review and Synthesis of Selected International Reviews

Dr. Jake Rice
CSAS – DFO Science Branch – Ottawa

Working Paper for National Review and Advisory Meeting on
A Science Basis for Policy and Management Plans for Addressing Impacts of Otter Trawls
and Bivalve Dredges on Benthic Habitats and Communities
(March 22-24, 2006)

# DRAFT

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## I. Introduction

DFO policy and management sectors have requested scientific information and advice to support development of policies and management measures to ensure impacts of mobile bottom gears on benthic communities and habitats are sustainable. Current policies and practices do take account of these impacts, but the science advice for a consistent and practical approach to this issue has not been consolidated in Canada. This Working Paper is a contribution to filling that gap.

In the early part of the 2000s, groups of science experts associated with three different non-partisan agencies or organisations (International Council for Exploration of the Seas – HQ in Copenhagen [ICES]; the US National Academy of Sciences - HQ in Washington DC [NAS]; and the US National Marine Fisheries Service – HQ Silver Springs, MD [NMFS] together with the New England and Middle Atlantic Fisheries Management Councils reviewed the scientific information on this issue. These reviews produced summary conclusions and management recommendations, following from their reviews of the scientific information available.

In 2005 the UN Food and Agriculture Organisation - HQ in Rome [FAO], and the American Fisheries Society – HQ Bethesda, Maryland [AFS]) have both published major documents on this topic as well. The FAO overview was prepared by a single contracted author rather than a team of experts, although it went through the standard FAO process of extensive internal review and external review by selected experts. As it is standard practice with ICES reviews which are to be used as background for other Expert Meetings, it summarizes findings and draws conclusions, but does not make specific management recommendations. The AFS "review" was actually the papers from a Symposium, wherein individual authors provided specific conclusions and sometimes recommendations from their work. Standard journal peer review was applied to all papers, but the conclusions and recommendations cannot be taken as a consensus of the Symposium participants. Despite these differences in approach, compared to the three reviews from 2001 and 2002, these two publications are included to make sure that the results summarized here reflect any more recent findings. For the rest of the this paper all five publications are referred to as "reviews", but it should be kept in mind that the AFS publication was not a "review" in the sense of the other four.

This Working Paper first extracts the conclusions and recommendations from each of these five sources. The strategy was to quote conclusions and recommendations directly wherever possible, to reflect accurately the intended meaning of the original source. In the quotations strings of examples and references were deleted for sake of conciseness, but can be found, of course, in the original documents. Where the original source qualifies conclusions and recommendations relative to specific places (for examples in the ICES review, often to the North Sea and Irish Sea) commentary is provided on whether the qualifications are thought to restrict the relevance of the conclusion or recommendation to Canadian contexts. Otherwise the extracted material from each source is presented at face value as the views of the group of experts whose work is being cited.

Following the five sections presents the extracted information from each source separately. A final section provides a cross-comparison and synthesis of the material from all five Here, discrepancies among the sources, when present, are accompanied by some interpretation of the likely causes and implications of the differences. The synthesis and tabulation of the results of the four separate reviews provides the basis for a final set of conclusions which reflect the consolidated views of the different groups of science experts who have reviewed the issue of impacts of mobile bottom gears on benthic populations, communities and habitats.  Combined with a series of Working Papers being prepared on the specific information about Canadian benthic habitats, communities, and studies of gear impacts, it should be possible to provide the necessary scientific foundations for Canadian policies and management practices.

II: ICES Advisory Committee on the Marine Environment (ACME)– 2000

Mandate of Review

The European Commission DG of Fisheries communicated to ICES that "ICES is requested to consider the report "The effects of different types of fisheries on the North Sea and Irish Sea benthic ecosystems" (Lindeboom and de Groot, eds) and to formulate management advice as to how effects of the gears discussed in the report on benthic ecosystems could be measurably reduced, without unduly reducing the possibilities of catching commercially important species.  ICES is invited to consider all possibilities, like establishing closed areas for bottom gears, reducing the weight of bottom gears, etc."

Context and Structure of their Review

The Lindeboom and de Groot report, referred to as IMPACT II, was the product of a three year research programme, funded by DG Research.  The research reported in IMPACT II was conducted by over 40 scientists working in 13 research centres around the North Sea and Irish Sea.  The 404 page IMPACT II report was structured to begin with a series of research reports of the 9 component projects, which used a variety of research designs including designed experimental manipulations, comparative historical analyses, opportunistic comparisons of areas known to have different trawling histories, and literature reviews.  These research reports were followed by a final section presenting 13 generalizations and conclusions, and 10 management and research recommendations (many quite broad, such as "Fisheries management should not only be based on management of fish stocks with commercial value, but also on ecosystem management").

The Regional Fisheries Management Agencies of the northeast Atlantic and DG Fish were prepared to adapt management plans to take account of the findings and recommendations of IMPACT II.  However, they wanted an independent peer review of the report, to ensure that the conclusions and recommendations were supported adequately by the research findings.  ICES was requested to conduct this peer review, and provide management advice as per the request quoted above.

The peer review of IMPACT II was conducted by the ICES Working Group on Ecosystem Effects of Fishing (WGECO), in December 1999.  The WGECO meeting attracted 26 experts from 14 countries, covering the disciplines of benthic ecology, ecosystem dynamics, gear design and operation, fisheries population dynamics and management, and fish ecology.  At least five scientists involved in IMPACT II research projects participated in the review, including both editors of the overall report.  The report of WGECO was considered by ACME in its 2000 meeting.  ACME, comprising one nominated expert from each of the 18 member countries of ICES plus an elected Chair, provided a second-level independent review of the WGECO review, conclusions, and recommendations, and formulated the management advice on behalf of ICES.  Chairs of several Working Groups reporting to ACME, including the chair of WGECO, participated in the meeting as resource experts, but the advice was formulated by the ACME members.

The WGECO review first considered all studies in IMPACT II with regard to research design, appropriateness of analytical methods, and the strength of evidence which the studies provided for the conclusions drawn from each one. It then considered each overall conclusion and recommendation with regard to first its support from the IMPACT II component studies and then in the context of the wider scientific literature on impacts of trawl gears. From the results of that review WGECO prepared a cross-tabulation of the possible effects trawl gears could have on benthic populations, communities and habitats by the strength of evidence from IMPACT II and from other literature, and by the relative seriousness of the effect and corresponding need for mitigation. "Relative seriousness" was judged on three criteria:

- Temporal scale – permanent or enduring effects are of most concern;
- Spatial scale – the larger the area affected, the greater the concern;
- Direction of change – declines in abundances or features are of greater concern than increases.

In several cases more than one effect was given the same priority, reflecting ICES view that it was inappropriate to weight seriousness on one of the three criteria as necessarily of greater or lesser importance than other criteria, and that nuanced discriminations among effects of generally comparable seriousness would be artificial and possibly misleading.

Finally, WGECO considered the possible mitigation measures and provided judgments on the effectiveness of each type of mitigation measure for each type potential effect.

From this scientific basis ACME built a series of management recommendations for reducing the impact of trawl fisheries on the benthos of the North Sea and Irish Sea. ACME stressed that application of most measures would require some scoping of specific problems before an effective package of measures could be developed for each case. It stressed that "**the advised Priority Management measures should not be viewed as universally applicable remedies, to be applied without further thought. They should be developed as well-planned mitigation programmes to address well-specified problems**". [bold in original]. It also advised some "Specific Immediate Actions" that should be actioned as quickly as problems could be adequately scoped. ACME also noted that the advice had been developed specifically for the types of otter trawls and beam trawls used in the North Sea and Irish Sea. However, detailed configurations of both of these gears were quite variable around the northeast Atlantic, and ACME warned that many of the advised measures would probably require some adaptation for other mobile gears used in other areas. However, in the advice that followed the caution, many of the advised measures were noted as likely to be generally applicable to a wide range of mobile gears and fisheries.

<u>Findings and Recommendations:</u>

The ICES advice on *possible* effects of trawl gears on seafloor habitats and communities is readily conveyed by repeating table 5.3.1.1 from their Advisory Report. This table has been modified only by reconfiguring columns reporting whether the scientific evidence for the effect came from the North Sea and Irish Sea or from other areas, and from experimental studies or from long-term monitoring. The information on the source of evidence has not been influential in application of the advice since it was provided by ICES, and is not crucial to likely use in Canadian waters.

*Table 1 –Summary of the information on evidence for the various possible effects of bottom trawling on species (macrobenthos and fish closely associated ecologically or spatially with the benthos) and habitats. Cell entries reflect ICES decisions on the weight of evidence. For many reasons related to study design , implementation, and analysis, or to true differences among specific situations, individual studies may differ in their conclusions regarding various effects of bottom trawling. In the table X means an effect can be present, but is rarely large. XX means that an effect is usually present, and can be large. "None" means no evidence is present from the type of study being considered. "Unclear" means that few studies have provided any information about whether the type of environment affects the likelihood or severity of effect.*

| **Type of Effect** | **Strength of Evidence** | **Type of Evidence** | **Duration Of Effect** | **Environment Affected** | |
|---|---|---|---|---|---|
| | N=North or Irish Sea<br>G=Global | L=Long-term monitoring<br>E=Experimental | | High Energy | Low Energy |
| 1. Removal of major habitat features - HP 1 | N-Weak/mod<br>G-Strong | L-XX<br>E-None | Permanent | XX | XX |
| 2. Reduction of structural biota – HP 1 | N-Weak/mod<br>G- Strong | L- XX<br>E-XX | Years to decades | X | XX |
| 3. Reduction of habitat complexity – HP 2 | N – Weak<br>G – Weak | L-None<br>E-XX | Days to several months | Negligible | XX |
| 4. Changes in seafloor structure – HP 3 | N-Strong<br>G –Strong | L-None<br>E-XX | Days to several months | Negligible | XX |
| 5. Reduction in geographic range –SP1 | N-Mod*<br>G-Strong* | L-XX<br>E-none | Years to decades | XX | XX |
| 6. Decrease in species with low turnover rates – SP 1 | N-Weak/mod<br>G-Mod/strong | L-XX<br>E-XX | Years to decades | X | XX |
| 7. Fragmentation of species ranges - SP 1 | N-None<br>G-Weak | L-XX<br>E-none | Years to decades | XX | XX |
| 8. Changes in relative abundance of species – SP 2 | N-Strong*<br>G-Strong* | L-XX<br>E-XX | Days to many years | XX | XX |
| 9. Fragile species more affected- SP 3 | N-Weak<br>G-Weak | L-None<br>E-XX | Unclear | X | XX |
| 10. Surface-living species more affected than burrowing species– SP 3 | N-Weak<br>G-Weak | L-None<br>E-XX | Weeks to a few years | Unclear | Unclear |
| 11. Sub-lethal effects on individuals – SP 4 | N-Mod/strong<br>G-Mod/strong | L-None<br>E-XX | Weeks to a few years | X | XX |
| 12. Increase in species with high turnover rates – SP 5 | N-Moderate<br>G-Moderate | L-XX<br>E-None | Months to a few years | X | XX |
| 13. Increase in scavenger populations – SP 5 | N-Weak<br>G-Moderate | L-XX<br>E-X | Days to months | XX | XX |

* Evidence for changes in population abundances and/or ranges is moderate or strong. However, because environmental conditions have changes over the period of fishing, and many stocks are exploited by several fisheries, it is usually difficult to unambiguously partition the contribution of a single factor, such as bottom trawling, to the quantified change.

The overall conclusions from the table are that:
"**ICES concludes that there is evidence for the occurrence of all the effects in [the table], and the evidence is strong for the two higher priority habitat effects, and all the higher priority effects on species effects except the fragmentation of populations**".[bold in the Advisory Document] The ICES evaluation of impacts of trawl gears on benthic habitats and communities gave special attention to two considerations. First, it noted that effects are potentially more severe in low-energy environments with consolidated sediments (muds, gravel, boulders) than in high energy environments and habitats with unconsolidated sediments that are re-suspended frequently by natural events. Second, the impacts of bottom trawling on populations, communities and habitats may alter their ability to recover when fishing ceases. ICES noted that habitats are expected to undergo natural changes over time, so the concept of returning to a "pre-perturbation" state is not appropriate. Nonetheless fishing affects natural ecosystem processes in ways that differ from natural forcing factors, so the absence of a permanent natural equilibrium is not an excuse to ignore effects of fishing on seafloor habitats.

ICES also considered the effects of bottom trawling on food-web and ecosystem properties. It concluded that any effects would be indirect consequences of the direct effects listed above. It noted that there is much less scientific consensus on both the theory predicting the indirect effects, and on which data would constitute empirical evidence for or against the presence of these effects. It advised that because any ecosystem-scale effects would be indirect consequences of the direct effects, so any measures which reduced the direct effects would move the indirect effects in the correct direction. Hence the indirect effects increase the justification to address the direct effects of fishing, but do not suggest that completely different suites of corrective measures would be necessary.

In developing its advice on mitigative measures for the effects of bottom trawling, ICES began with several considerations which it labelled as "common sense". These included:

14. Recovery from a perturbation cause by trawling could take from weeks to centuries, and if recovery is desired, trawling must be reduced, and sometimes prevented, in the affected area for the duration of the recovery period. Thereafter, for the recovered conditions to persist, the reduced (or terminated) rate of trawling must be continued;
15. There is a generally monotonic relationship between intensity of trawling and degree of change in the benthos, with the greatest effects following the initial trawling events. The shape of the asymptotic curves depend on history of natural disturbances, type of gear, and characteristics of the species and habitats affected;
16. All technical measures intended to mitigate trawl impacts are specific to the species and habitats to which they are applied, and the scale and duration of their use. None are generic for all species and habitats;
17. Different technical measures may interact synergistically, so suites of measures should be considered for simultaneous application;
18. Economic incentives can be important for successful implementation of potentially beneficial mitigation measures;
19. Application of all mitigation measures requires case-specific analysis and planning.

These factors, and particularly the last one, all need to be taken into consideration, when drawing inferences from the tabulation of measures to potentially reduce effects of trawling by the specific effects of concern. (Table 5.4.1 in the Advisory Document). Two general types measures were identified; those whose expected benefits are proportional to the extent of their implementation across a fleet, and those whose effects are inherently spatial, and therefore proportion to the area to which they are applied. Because of the inherent proportionality of effects of several of the tabulated mitigation measures, ICES made arbitrary assumptions of a scale of implementation in each case. ICES stressed that these assumptions were to allow comparative illustration of the potential effectiveness of different measures for various impacts of trawling, and did not endorse the assumed level of implementation, or any other one. Rather, ICES stressed again the need to address each specific case according to the information available on the particular circumstances.

*Table 2. ICES judgements of the effectiveness of various possible mitigation measures in addressing the priority habitat and species impacts of mobile bottom gears. Adapted from ICES (2000).*

| | Proportional to implementation in the fleet | | | | | | Proportional to area of implementation | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Effect (see Table 1)** | Reduce effort[1] | Gear substitution[2] | Change gear usage[3] | Make gear lighter[4] | Make gear more selective[5] | Bycatch quota[6] | Spatial closure | Real time closures | Improve habitat | Species augmentation |
| **Mitigating habitat impacts** | | | | | | | | | | |
| Physical (HP 1) | - | C | - | - | - | - | C | - | C | - |
| Biogenic (HP 1) | - | C | - | - | - | - | C | - | E | M |
| Complex (HP 2) | E | C | - | M | - | - | C | - | M | - |
| Structure (HP 3) | E | C | - | M | - | - | C | - | - | - |
| **Mitigating species & community impacts** | | | | | | | | | | |
| Range (SP 1) | E | E | M | M | M | M | M | - | M | M |
| Low Turnover (SP 1) | E | E | M | M | M | M | M | - | M | M |
| Fragment (SP 1) | M | E | M | M | M | M | - | - | M | - |
| Relative (SP 2) | M/E | E | - | E | E | - | M/E | M | - | - |
| Fragile (SP 3) | E | C | - | M/E | - | M | M/E | M | M | - |
| Surface (SP -3 ) | E | C | M | M/E | - | - | M/E | M | - | - |
| Sub-lethal (SP 4) | E | C | M | M/E | E | - | M/E | M | - | - |
| Small species inc. (SP 5) | M/E | E | - | M/E | M | - | E | - | - | - |
| Scavengers Inc. (SP 5) | E | C | M | M/E | E | E | M | M | - | - |

Key - -= no expected effect; M=moderate protection; E = effective protection; C = complete protection

[1] Assuming a 50% reduction in effort.

[2] Assuming full substitution of present demersal gears in enough areas to reduce seafloor impacts.

[3] Assuming are made in ways that reduce discard mortality

[4] Assuming modifications to gear reduce their impact on the seafloor

[5] Assuming modifications such as excluder devices which increase species selectivity and/or survivorship of fish not retained in gear

[6] Assuming that bycatch quotas are set at an appropriate level to provide protection of valuable non-target populations.

Based on this table of effects, and the priorities assigned to the various effects of bottom trawling, ICES identified six priority management measures, and presented them in ranked order, with the most important measure first. These measures were:

20. Major reduction in fishing effort. ICES noted that almost all effects of fishing on benthic populations, communities, and habitats would be reduced by major reductions in fishing effort, particularly fishing with bottom gears. Benefits would be greater for species effects of trawling than for habitat effects of trawling. Reductions in fishing effort would interact synergistically with many of the other potential mitigation measures, and would be necessary for lasting benefits to be obtained from several of the other mitigation measures. ICES did discuss what would constitute a "major reduction", and concluded that it would be case-specific, but usually at least 30% below recent historical levels.
21. Closed Areas. ICES noted that closed areas can fully and effectively protect habitat features from harm, if the areas are sited correctly and implementation is effective. Sedentary species are expected to benefit much more from permanent closures than highly mobile species. The nature of the closure would depend on the objectives intended to be achieved, but for most habitat-related objectives, the closures would have to be year-round and permanent. Closing areas where fishing occurs would be expected to displace the effort to other areas, and careful planning is needed to ensure that the displaced effort does not cause as many new problems as the closure was intended to address.
22. Gear substitution. Species-related benefits will depend completely on the differential mortality caused by the bottom gear and the gear substituted for it. Habitat-related benefits can be large, but only if the substituted gear has much less impact on the seafloor, and the new gear is used by a substantial portion of the fleet.
23. Gear modification. Effects will be case-specific but can be large, both for species and habitat effects of trawling. To be effective in mitigating effects of bottom trawling, the modified gear has to be used by a substantial portion of the fleet, and therefore cannot reduce the catching efficiency of the gear substantially (or else must be accompanied by substantial financial incentives). Gear modifications which substantially reduce catching efficiency are likely to lead to greatly increased fishing effort with the modified gear, possibly dissipating any potential benefits of the lesser impact per unit of fishing effort.
24. Habitat rehabilitation. ICES considered this method to be appropriate only in specific and local cases, where the habitat needs were well understood. However, for any benefits of habitat rehabilitation to persist, additional measures will be needed to protect the habitat from damage by the fishing methods which caused the habitat degradation to begin with.
25. Governance changes. ICES noted that the management of fishing in the northeast Atlantic was poorly integrated with management of other human activities in the same area, and agencies responsible for managing fisheries had limited interaction with agencies responsible for nature conservation. The situation is different in Canada – and now in Europe as well – as the ecosystem approach to fisheries has been endorsed by the appropriate departments of governments on both sides of the Atlantic.

Finally, ICES recommended four immediate actions for the northeast Atlantic:

26. Prevent expansion of areas impacted by bottom trawls;

27. Prevent expansion of the number of bottom trawlers;
28. Strengthen the interactions of fisheries management agencies with agencies and groups working in marine conservation;
29. Improve ability to detect and measure impacts of fishing through improvements to instrumentation and monitoring.

These recommendations were made in the context of ICES repeated admonitions that all remedial actions should be matched to the specific circumstances of individual applications. Hence they should not be interpreted as globally appropriate immediate actions. Nonetheless, each warrants careful consideration for application in Canadian contexts as well, although the history of fishing effort, particularly bottom trawling, has been very different between the northeast Atlantic and the Canadian Atlantic and Pacific coasts over the past 15 years.

III. National Research Council – Effects of Trawling and Dredging in Seafloor Habitats

Mandate of Review:

“This first study will 1) summarize and evaluate existing knowledge on the effects of bottom trawling on the structure of seafloor habitats and the abundance, productivity, and diversity of the bottom-dwelling species in relation to gear type and trawling method, frequency of trawling, bottom type, species, and other important characteristics; 2) summarize and evaluate knowledge about changes in seafloor habitats with trawling and cessation of trawling; 3) summarize and evaluate research on the indirect effects of bottom trawling on non-seafloor species; 4) recommend how existing information could be used more effectively in managing trawl fisheries; and 5) recommend research needed to improve understanding of the effects of bottom trawling on seafloor habitats.”

Context and Structure of Report:

In the 1996 reauthorization of the legislation under which federal management of fisheries in the US is conducted (The Magnusson-Stevens Fishery Conservation and Management Act, aka The Sustainable Fisheries Act) several provisions were added or strengthened which gave greater focus to protection of “essential fish habitat”. Implementation of the provisions to “minimize to the extent practicable adverse effects on such habitats caused by fishing” proved problematic. Consequently, the National Oceanographic and Atmospheric Administration (NOAA) contracted the Ocean Studies Board of NRC to conduct several reviews of information on how fishing affects marine communities and habitats, and provide recommendations for management measures to minimize any detrimental effects. The first of those studies addressed the effects of bottom trawling on marine habitats, and is the focus of the rest of this section of this report. (The second study, currently [Jan 06] underway, considers how fishing affects trophic relationships in the sea.) The review was restricted to otter trawling and dredging, which represent the major mobile bottom fishing gears in use in US waters

The Ocean Studies Board appointed a panel of twelve experts; eight based at universities, three in marine research laboratories, and one consultant, of which two academics were from outside the US. The Panel was supported by three project officers from the OSB. The Panel reviewed the scientific literature, including their own research, conducted three open sessions where interested parties could present information, and their draft report was reviewed by six independent experts. The consensus report was released in 2002.

Report chapters address characteristics of fishing gear, effects of trawling and dredging, habitat mapping and distribution of fishing effort in the US, approaches to assessment of risk to seafloor habitats, management options, and findings and recommendations. For the purposes of the DFO review the chapters on effects of trawling and dredging and on findings and recommendations are most relevant.

Report Findings and Recommendations:

The report notes that "the acute, gear-specific effects of trawling and dredging on various types of habitat are well documents". However, to assess the risks that these types of fishing pose to seafloor habitats and communities also requires information on the spatial distribution of fishing effort and the distribution of habitats and benthic communities. Incomplete knowledge of the latter factors meant that general recommendations regarding trawl impacts and mitigation measures could be made, but few recommendations were possible regarding how specific fisheries should be managed in particular places.

Based on a literature review reported in their Chapter 3 the Panel concluded that the main potential effects of trawling and dredging included:

1. "Trawling and dredging reduce habitat complexity" – particularly the loss of erect and sessile epifaunas, smoothing of the seabed and reduction of bottom roughness.
2. "If the interval between trawls is shorter than the recovery time, the original benthic structure and species populations might not have the opportunity to recover."
3. "Repeated trawling and dredging result in discernable changes in benthic communities" – the changes include shifts to communities of taxa with smaller body sizes and shorter life spans. Very heavily trawled areas tend to have species richness reduced.
4. "Bottom trawling tends to reduce the productivity of an area." Although there is a tendency to change towards species with higher productivity *per unit of biomass*, the reduction in standing biomass of benthic organisms in heavily trawled areas results in an overall reduction in productivity.
5. "The effects of mobile bottom gears are cumulative and depend on trawling frequency."
6. "Fauna that live in low natural disturbance regimes are generally more vulnerable to fishing gear disturbance." Exceptions were found in the literature, but in general ecological disturbance theory applies to fishing effects as well as natural disturbances.
7. "Fishing gears can be ranked according to effects on benthic organisms. … This ranking is consistent with the degree of bottom contact and sediment penetration of the different gears."
8. "Benthic fauna can be ranked according to vulnerability. … vulnerability to mobile gear is predicated on the morphology and behaviour of the benthic species. Soft-bodied, erect, sessile organisms are more vulnerable … than are hard-bodies, prostrate organisms."

Note that not all the numbered quotes above were listed as leading subheadings of paragraphs, so the number of generalizations extracted here from the Research Summary is greater than in the NRC report. The numbering of the generalisations is for use later in this document, and is not used in the NRC Report.

Several algebraic models presenting curvilinear but monotonic relationships between fishing and harm to benthic communities and habitats were presented in the report. All were conceptual, and none were parameterized.

Consequences of the change in habitat structure for the fish community were listed as potentially increased predation risk for juvenile fish which used habitat complexity for cover due to both decreased prey abundance and increased exposure, and potential changes in species composition of the fish community as habitat suitability for various species changes. The report notes that these effects have rarely been quantified in the field, but this is due to difficulties in conducting long-term studies of adequate statistical power, not the absence of the effects.
Several other indirect of bottom trawling on fish and benthic communities and their habitats are reported, including:

9. Changes to nutrient cycling – could be either an increase or decrease, and pulses of re-suspended nutrients could occur outside the natural seasonal cycle of nutrient availability to which biological communities have adapted.
10. Changes to community structure and trophic linkages – the report does not differentiate clearly the degree to which such changes are a result of the direct mortality caused by encountering the fishing gear (whether retained as landed catch or not) or are an indirect result of species abundances responding to changes to the seafloor habitats. To the extent that the community changes are consequences of direct mortality by fishing, the changes are a general effect of fishing, and not bottom trawling and dredging per se.
11. Changes to ecosystem processes – Bottom trawling and dredging can selectively remove "ecosystem engineers"; species that are particularly important for filtering the water column, providing three-dimensional habitat structure, and stabilizing substrates.
12. Increased susceptibility to other stressors – By simplifying habitat structure and forcing species to occupy suboptimal habitats, these species are exposed to other potential sources of mortality and stress, such as predation, hypoxia, and pollution.

Finally, with regard to recovery, the NRC Report notes the recovery from perturbation by trawling or dredging depends on a number of factors, including:

13. type and spatial extent (relative and absolute) of habitat alteration;
14. intensity and frequency of disturbance compared to 'normal' disturbance regimes
15. habitat characteristics (sediment type, natural hydrodynamic regime)
16. species and life histories of the biotic community

Some communities, such as biogenic structures (e.g. corals) and bottom-rooted plants and macro-algae may suffer major impacts and display very slow recoveries, whereas communities in mobile sandy sediments could withstand two or three trawl impacts per year with no marked changes.

The results in Chapter 3 are summarized in Chapter 7 (Findings and Recommendations) as:

"Stable communities of low-mobility, long-lived species are more vulnerable to acute and chronic physical disturbance than are communities of short-lived species in changeable environments"

"Habitat complexity is reduced by towed bottom gear that removed or damages biological and physical structures."

"The extent of the initial effect and the rate of recovery depend on the stability of the habitat. The more stable biogenic, gravel, and mud habitats experience the greatest changes and have the slowest recovery rates."

"Less consolidated coarse sediments in areas of high natural disturbance show fewer initial effects, …, recovery is also faster."

These generalizations were the basis for a series of recommendations for management and research.

17. "Fisheries managers should evaluate the effects of trawling based on the known responses of specific habitat types and species to disturbance by different fishing gears and intensity of fishing effort, even when region-specific studies are unavailable."

    This recommendation acknowledges that whenever possible site specific information should be the basis for management actions. However, there is sufficient consistency between current ecological theory and the documented effects of fishing gears that predictions from general trends observed in similar areas would provide a sound basis for management.

18. "The National Marine Fisheries Service and its partner agencies should integrate existing data on seabed characteristics, fishing effort, and catch statistics to provide geographic databases for major fishing grounds."

    This recommendation acknowledges that substantial relevant data exist of fishing effort and seafloor habitats, but the data are often scattered and not readily accessed together. Bringing these databases together in a common geo-referenced framework will facilitate effective management on local and regional scales. Nothing in the concepts underlying the recommendation restricts its applicability to the US NMFS.

19. "Management of the effects of trawling and dredging should be tailored to the specific requirements of the habitat and the fishery through a balanced combination of the following management tools:

    - fishing effort reductions; …
    - modification of gear design or restrictions on gear type; …
    - establishment of areas closed to fishing."

This recommendation acknowledges that no single management tool is universally the best for minimizing impacts of trawls and dredges on seafloor habitats and communities, but combinations of the three tools listed above should be sufficient to provide the necessary protection to benthic habitats.

20. "The Regional Fishery Management Councils should use comparative risk assessment to identify and evaluate risks to seafloor habitats and to rank management actions within the context of current statutes and regulations."

    This recommendation acknowledges that risk-based management approaches are appropriate for among choosing management options. Further, it notes that even when data are inadequate to support full quantification of risks, suitable tools exist to apply risk-based approaches. Nothing in the concepts underlying the recommendation restricts its applicability to US Regional Fisheries Management Councils and US statutes and regulations.

21. "Guidelines for designating essential fish habitat (EFH) and habitat areas of particular concern (HAPC) should be established based on standardized ecological criteria."

    This recommendation stresses the importance of basing descriptions of the habitat requirements of aquatic organisms on knowledge of the species' biology and not just data availability. It is relevant to requirements under SARA to protect critical habitat of Endangered and Threatened species, and to application of DFO habitat policies, but it is not unique to managing fisheries using mobile gears.

22. "A national habitat classification system should be developed to support EFH and HAPC designations."

    As with the preceding recommendation, this recommendation has relevance to general aquatic habitat management and application of an ecosystem approach to managing human activities in aquatic ecosystems. However, it is not unique to managing fisheries using mobile gears.

The report concludes with a number of recommendations for further research on gear impacts, habitat evaluation, and management mitigation. All of these recommendations address deficiencies in the global state of knowledge of impacts of mobile gears on benthic habitats and communities. Information needs are similar in Canadian marine jurisdictions, and it would be valuable to consider these recommendations in prioritizing marine ecosystem research in Canada as well.

IV. National Marine Fisheries Service Workshop (Northeast Fisheries Science Center Reference Document 02-01).

<u>Mandate of the Review.</u>

The purpose of the review was "to assist the New England Fisheries Management Council (NEFMC), the Mid-Atlantic Fisheries Management Council (MAFMC) and NMFS with 1) evaluating the existing scientific research on the effects of fishing gear on benthic habitats; 2) determining the degree of impact from various gear types on benthic habitats in the Northeast; 3) specifying the type of evidence that is available to support the conclusions made about the impacts; 4) ranking the relative importance of gear impacts on various habitat types; and 5) providing recommendations on measures to minimize those adverse impacts".

Context and Structure of the Review

In the charge to the workshop by opening speakers from NMFS and the two management councils, it was made clear that "habitat" was to be interpreted in the context of "essential fish habitat" under the Magnusson-Stevens Act (1996). As such it only considered benthic species and communities in the narrow context of prey for commercially exploited fish stocks. Hence although the workshop conclusions regarding impacts of mobile fishing gears on physical habitat features can be contrasted directly with the conclusions of the other reviews, the basis for comparing this study to the others with regard to impacts on biological properties of the benthos is very different. The review contains many observations on impacts of gears on benthic communities, but unlike impacts on physical habitat the review rarely specifies whether the observation is a consensus conclusion or a point made in discussion. Assuming that report was reviewed by participants, so views highly divergent from the views of the majority were labelled as such, these observations are reported and tabulated here.

In that context, the workshop was given five explicit objectives (from Appendix C in that report):

1) Peer review background documents prepared by the workshop Steering Committee

2) Evaluate the applicability of national and international fishing gear effects research to the Northeast.

3) Evaluate the strength of evidence regarding the effects of different types of gear and fishing practices on marine habitats in the Northeast.

4) Identify and evaluate types of management measures that could reduce the impacts of fishing gear on marine habitats in the Northeast.

5) Provide advice and recommendations to the New England and Mid-Atlantic Fisheries Management Councils for minimizing adverse effects of fishing gear on marine habitats in the Northeast.

For the workshop, 23 experts were invited, including 5 academics, two fishing masters, and two members of conservation advocacy groups. They were given 19 specific questions by the Steering Committee, which also provided background working papers as starting points for discussion. Some discussions were held in subgroups, but all conclusions were produced in plenary sessions. It was not possible for all participants to reach consensus on a number of the conclusions, and those cases are clearly identified in the report. The workshop considered several fishing gears, including several static gears. Only the results on otter trawls and scallop dredges are reported here, as those are the gears most similar to the ones being reviewed in the other documents.

Report Findings and Recommendations

For each gear type considered, the report summarizes the impacts in a table with the same structure for all gears. The table collapses all impacts on benthic populations, species and communities into the single row "changes in benthic prey", which cannot be compared the other reviews attention to different types of benthic species, such as emergent and buried, long-lived vs short-lived, etc. Occasionally some specific type of organisms might be mentioned in the context of a particular type of impact. However, the format of the meeting and report did not make it possible to determine if such statements were consensus conclusions of the meeting or were just offered by a participant, nor if the absence of such statements in sections on other gears or for other types of organisms meant that the effects were not expected for those other types of gears or species. Hence, this Report is not contrasted with the others in the context of impacts of gears on populations, species, and communities. On the other hand, the report consistently addresses the degree to which impacts may differ in high-energy and low energy environments, and among sand, mud, gravel, and hard-bottom habitats. These differences are brought out strongly in the review of the impacts of each gear type.

The most concise presentation of the conclusions from this review are tables 4 and 5 from that report on scallop dredges and otter trawls, respectively. These are copied directly as tables 3 and 4 of this report:

*Table 3 Impacts of scallop dredges on benthic habitat*

| Type of Impact | Degree of Impact | Duration | Type of Evidence | Comments |
|---|---|---|---|---|
| MUD | | | | |
| Removal of Major Physical Features | N/A | | | |
| Impacts to Biological Structure | N/A | | | |
| Impacts of Physical Structure | N/A | | | |
| Changes to Benthic Prey | N/A | | | |
| SAND | | | | |
| 1. Removal of Major Physical Features | Unknown | | | |
| 2. Impacts to Biological Structure | XXX(L)<br>X | (H)Months-Years | PR,GL,PJ | |
| 3. Impacts of Physical Structure | XXX(H,L) | Days-Months | PR,GL,PJ | Cut shell provides additional structure |
| 4. Changes to Benthic Prey | Unknown | | | Disposal of shucked scallop viscera may alter local food sources – impacts unknown |
| GRAVEL | | | | |
| 5. Removal of Major Physical Features | Unknown | | | |
| 6. Impacts to Biological Structure | XXX (H)<br>N/A(L) | Several Years (H) | PR,GL,PJ | (L)=deepwater banks, gravel ridges in GOM; fishery is not prosecuted here. |
| 7. Impacts of Physical Structure | XXX (H)<br>N/A(L) | Months – Years (H) | PR,GL,PJ | (L)=deepwater banks, gravel ridges in GOM; fishery is not prosecuted here; Cut shell provides additional structure. |
| 8. Changes to Benthic Prey | XXX (H)<br>N/A(L) | Months – Years (H)b | PR,GL,PJ | (L)=deepwater banks, gravel ridges in GOM; fishery is not prosecuted here |
| KEY: X=Effect can be present, but is rarely large; XX = Effect is present and moderate; XXX= Effect is often present and can be large; (H) = High energy environment; (L) = Low energy environment; PR=Peer reviewed literature; GL= Grey literature; PJ = Professional Judgment. [Other notes included re definitions]. | | | | |

The report included the findings of a number of published studies that were considered applicable to other similar habitats. However, these may not be consensus conclusions of the workshop, or else the effect may not have been linked to the dredges:

9. "disruption of amphipod tube mats and decline in dominant megafauna species in sand"
10. "increased epifauna on cobble/shell bottom in a closed area"
11. "disturbance of storm-created coarse sand ripples"
12. "increased abundance of emergent sponges inside a sandy area closed to dredging"
13. "redistributed gravel, pebbles, and boulders, flattened sand and mud bedforms, and resuspended fine sediments"
14. "reduced epifaunal community, smoother bottom, and disturbed and overturned boulders in a gravel area"
15. "reduced densities, biomass, and species diversity of megabenthic organisms in disturbed gravel habitats"

From their discussions other points that were included in the Report include

16. "higher percentage cover of emergent colonial epifauna in undisturbed gravel habitats"
17. "The panellists also agreed that the first pass of a dredge over an undisturbed area is expected to have more significant effects than subsequent passes."
18. "Structure-forming biota that are present in sandy habitats are just as vulnerable to scallop dredging as in gravel habitats, but the biological impacts of dredging on emergent epifauna are less significant in high energy sand environments …"
19. The possibility of nutrients and contaminants being resuspended was discussed, but it was noted most studies were done in inshore coastal and estuarine habitats, and could not be the basis for generalisations.
20. With regards to Management options, the report includes statements that effort reduction, gear modification and area management could all contribute to reducing impacts of scallop dredges on benthic habitats, with spatial management getting particularly strong support.

*Table 4 – Impacts of Otter Trawls on Bentic Habitat*

| Type of Impact | Degree of Impact | Duration | Type of Evidence | Comments |
|---|---|---|---|---|
| MUD | | | | |
| 21. Removal of Major Physical Features | XXX (H)<br>N/A (L) | Permanent | PJ | (H) in Mud refers to clay in all cases |
| 22. Impacts to Biological Structure | Unknown (H)<br>XX* (L) | Months - Years | PJ | (L) opinions ranged from X-XXX |
| 23. Impacts of Physical Structure | XXX* (H)<br>XX* (L) | Months - Years | PR,GI,PJ | (L) opinions ranged from XX-XXX and unknown |
| 24. Changes to Benthic Prey | Unknown | | | |
| SAND | | | | |
| 25. Removal of Major Physical Features | N/A | N/A | N/A | |
| 26. Impacts to Biological Structure | XX* (H,L) | Months - Years | PR,GI,PJ | (H) opinions ranged from X – XXX<br>(L) opinions ranged from XX – XXX |
| 27. Impacts of Physical Structure | X* (H)<br>XX* (L) | Days - Months | PR,GI,PbJ | (H,L) opinions ranged from X - XXX |
| 28. Changes to Benthic Prey | XX* (H,L) | Months - Years | PR,GI,PJ | (H) opinions were XX or unknown<br>(L) ranged from X-XXX and unknown |
| GRAVEL | | | | |
| 29. Removal of Major Physical Features | XXX (H,L) | Permanent | PR,GI,PJ | |
| 30. Impacts to Biological Structure | XXX (H,L) | Months - Years | PR,GI,PJ | |
| 31. Impacts of Physical Structure | XXX (H,L) | Months-Years | PR,GI,PJ | Rocks altered or relocated |
| 32. Changes to Benthic Prey | Unknown | | | |
| KEY: X=Effect can be present, but is rarely large; XX = Effect is present and moderate; XXX= Effect is often present and can be large; (H) = High energy environment; (L) = Low energy environment; PR=Peer reviewed literature; GL= Grey literature; PJ = Professional Judgment. [Other notes included re definitions].<br>* This does not represent a consensus among the panel. | | | | |

The report discussed several indirect effects of otter trawling that are reported as "potential effects". However, these may not be consensus conclusions of the workshop, or else the effect may not have been linked to the otter trawls. These effects include

33. "1) altered trophic function of benthic communities primarily caused by a reduction or change in large biota, a reduction or change in predators,, or a reduction or change in epiphytes, and 2) altered demersal communities, primarily caused by loss of structure-forming biota and an alteration of physical features."

34. "The most significant potential effects of otter trawls … included changes to bottom structure and long-term changes in benthic trophic function or ecosystem function. …

these changes may result either from a reduction of organisms or the replacement or organisms."

35. There was discussion of effects on scavengers and sediment dispersion, but no clear conclusions.

36. The panel did agree that "the effects of otter trawls are believed to vary by the specific configuration used, by the intensity of the trawling activity, and by the type of habitat in which the gear is used".

37. With regard to Management the panel listed effort reductions, area restrictions, and gear improvements as all appropriate. Strongest support was given to area closures as offering the most permanent protection to habitat features, but the three measures could be used together for best overall effects

V. Impacts of trawling and scallop dredging on benthic habitats and communities" – FAO Technical Paper 472.

The scientific basis for both the ICES and the National Academy advice was research completed in the 1990s or very early in this decade. There have been two major overviews published in 2005, which bring the scientific basis for managing trawl fisheries in the context of impacts on seafloor species and habitats up to date. Neither report includes formal management advice, but the scientific content can be considered for consistency with the ICES and National Academy advice.

The first document is "Impacts of trawling and scallop dredging on benthic habitats and communities" – FAO Technical Paper 472, released in September 2005. It reviewed more than 35 studies of trawl and dredge impacts published since 1990. The review focused particularly on critical evaluation of the methodologies used in impact studies, finding many shortcomings in published works. Although there are many kinds of design problems in trawl impact studies, the review concludes that the net tendency is for studies to often overestimate short-term effects of trawling by including natural variation in the treatment effect but to underestimate long-term effects through the limited time span of many studies.

Despite these common tendencies, the FAO report does contain a number of conclusions regarding physical and biological effects of trawl gears and scallop dredges. (As with previous sections, the numbering of conclusions is internal to this report, for comparative purposes across sections. In the quoted text, lists of examples or references have been deleted to save space, and these deletions are marked with three dots.)

Conclusions regarding physical effects include:

1. Particularly for beam trawls and scallop dredges “the most conspicuous physical impact is flattening of bottom features such as ripples and irregular topography”;
2. “features such as bioturbation mounds and polychaete tubes are shown to be eliminated in the tracks of beam trawls and scallop dredges”;
3. “The physical impacts on the sea bed caused by otter trawling are likely to be different from those caused by beam trawling and scallop dredging. As the latter two gear types penetrate into the sediment …”;
4. “The ecological impacts of eliminating natural bottom features on the benthic community are not clear and have not been adequately addressed in the studies on trawling disturbance published to date.”;
5. “Furrows and berms created by the trawl doors are the most conspicuous physical impacts from otter trawls. The trawl doors …. create an irregular bottom topography rather than flattening natural features.”
6. For otter trawls “The area disturbed by the trawl doors comprises only a small proportion of the total area swept by the trawl. … Because no or only faint marks are created by the other parts of an otter trawl, the physical impacts on the sea bed are likely to be marginal in most otter trawl fisheries. An exception may be intensively trawled fishing grounds in sheltered areas or in deep water, where trawl marks may last a long time.”
7. “The longevity of these effects [of all three gear types] is determined by sediment type and natural disturbances, …, and has been shown to last from a few hours to more than a year.”
8. “Data are too scarce to allow a clear relationship between persistence of trawl marks and bottom type/natural disturbance to be made.”
9. Importantly this report concluded that “the tools and methods used to determine physical impacts … are rough and crude ways of describing seabed characteristics.” A study using “very high-resolution acoustics were able to determine small-scale structural changes in the upper 4.5 cm of the sediment, at a scale of resolution that is relevant to the benthic biota. This is the scale at which the physical impacts of trawling should be investigated.”

Conclusions regarding biological impacts include:

10. “Several studies … state that trawling is the most disruptive and widespread anthropogenic disturbance on benthic habitats and may substantially alter benthic communities” By considering the deficiencies in many studies “this review ... has shown that the evidence for such statements is not well documented or convincing.”
11. However, with regard to studies that have concluded that there are few documented benthic impacts of fishing, at least on the scale of commercial fisheries “it is difficult to conduct studies that give clear and unambiguous results, and such statements should be avoided. … The chance of detecting potential changes caused by trawling can be low because the power of the statistical tests in some studies has been shown to be very low.”

12. Of the few otter trawl studies considered scientifically sound in this report "The comprehensive experiment conducted on the Grand Banks showed a 24 percent decrease in total biomass of megabenthic species", but this may "represent an overestimate of the real effect of the disturbance. … This decline seemed to recover within a year, and very few community indices or taxa showed any long-term effect from trawling."
13. With regard to shrimp trawling "The four experiments on shrimp trawling provide no clear evidence of disturbance effects on benthic soft-body communities, with the exception of a decrease in the abundance of echinoderms."
14. "Studies on the impacts of trawling on hard bottoms are few, but the three studies reviewed here all showed effects on large, erect sessile invertebrates. … tall sessile invertebrates such as sponges are damaged to a large extent when hit by the ground gear and, depending on the proportion of the fishing ground that is touched by this part of the trawl, habitats dominated by large sessile fauna may be severely affected by trawling."
15. For scallop dredges, with two exceptions "effects on community structures were demonstrated in all the studies … The most common effects demonstrated were a decrease in the number of species and reduced abundance for certain species."
16. The few studies of "Recovery of the benthic community after [scallop] dredging disturbance … showed that few effects lasted beyond eight months after dredging".

In the final overall conclusions this report notes:

17. "Although current knowledge of the linkage between benthic habitat complexity and the dynamics of fish populations is rudimentary …some effects on the fish community have been demonstrated, e.g. higher juvenile survivorship in more complex habitats … and changes in the abundance of different fish general following alteration in the abundance of eipbenthic fauna."
18. "Several studies have demonstrated that anthropogenic impacts have a negative effect on longer-lived benthic species, but a positive effect on small opportunistic species."
19. "the knowledge of how towed fishing gears affect different habitat types is still rather rudimentary. The main reasons … is [sic] that such studies are very complicated and demanding to conduct and that benthic communities show large natural variability that is not well understood."

VI. Benthic Habitats and the Effects of Fishing" edited by Barnes and Thomas (2005).

The other major recent publication is the Proceedings of an American Fisheries Society Symposium entitled "Benthic Habitats and the Effects of Fishing" edited by Barnes and Thomas (2005). Although the Symposium was held late in 2002, the editoring process for the publication resulted in many of the 59 full papers and 99 abstracts contain more recent information. As a scientific symposium, the format did not allow challenge and debate of the content of most presentation, and no management advice or consensus conclusions was produced. Several of the book sections were on overarching policy issues, technologies for measuring impact, and social issues, which are outside the purview of this meeting. However, for many of the papers in the sections on Linking Fisheries ... to Benthic Habitat

Character and Dynamics, Effects of Fishing: Assessment and Recovery, Comparison of Effects of Fishing with Effects of Natural events and Non-Fishing Anthropogenic Impacts on Benthic Habitats, Extrapolation of Local and Chronic Effects of Fishing …, and Minimizing the Adverse Effects of Fishing on Benthic Habitats: Alternative Fishing Techniques and Policies, the factual information in many of the presentations is relevant to the deliberations at this meeting. The key conclusions of selected papers are presented below, and as in the other sections, numbered for comparative uses in the Synthesis and Discussion section.

1. Linking Fisheries to Benthic Habitats at Multiple Scales: … (Anderson et al.). Quantification of habitat preferences of haddock become more specific as the spatial resolution of the data analyzed becomes finer. From the range of habitats available on various banks, haddock consistently were at higher densities in more rugged areas.
2. Combining Scientific and Fishers' Knowledge to Identify Possible Groundfish Essential Fish Habitats (Bergmann at al.). Fishers and scientific surveys provided generally compatible indications of preferred habitats for groundfish, and cod, haddock and whiting seem to be fairly general in their habitat usage.
3. Delineating Juvenile Red Snapper Habitat … (Patterson et al.). Habitat characterisation required fairly fine-scale (less the tens of km, and possible less than km) data, and snapper consistently reach highest densities in areas with small-scale (cm to m) spatial complexity.
4. Living Substrate in Alaska: Distribution, Abundance and Species Associations (Malecha et al.). Bycatch data from research surveys allowed the spatial distribution of sponges, sea anemones, etc to be characterised, and areas with high densities of such "living habitat" features also tended to have high densities of several commercially important fish and invertebrates.
5. Effects of Fishing on Gravel Habitats: Assessment and Recovery … (Collie et al.) A comparative study of lightly and heavily trawled areas on Georges Bank found that the lightly trawled area had significantly higher numerical abundance and biomass of benthic megafauna. The undisturbed area also had more fragile species that live in the complex habitats presented by the epifauna. When a heavily trawled area was closed to bottom gears, over 5 years there was a 4-fold increase in abundance, an 18-fold increase in biomass, and a 4-fold increase in productivity. There was also a change in species composition with increases in crabs, molluscs, polychaetes, and echinoderms, and larger animals came to dominate the fauna in the closed area.
6. Effects of Area Closures on Georges Bank (Link et al.). After a 5 year closure of portions of Georges Bank, there were few differences in nekton or benthic species composition and richness between paired areas inside and outside the closure. However, larger individuals of many species of fish were found inside the closed areas. Additionally, habitat type strongly influenced the distribution, abundance, biomass, size, and feeding ecology of many species. The areas of higher habitat complexity and lower natural disturbance ("low energy environment") had higher values of many of the biotic variables, and showed greater differences in benthic faunas between areas opened and closed to fishing.
7. Effects of Fisheries on Deepwater Gorgon Corals (Mortensen) – Using underwater video, signs of fishing impacts were found on three species of deepwater corals in waters off Nova Scotia, in an ares fished intensively by otter trawls, gill nets, and long lines. Damage included broken, tilted, and scattered skeletons of corals, with less

brittle corals showing less damage. 4% of the coral colonies examined were damaged, and damage was present in nearly 30% of the transects.

8. Susceptibility of the Soft Coral … to Hydraulic Clam Dredges .. (Gilkinson et al.) – Using underwater video, in an experimental study no statistically significant effects of dredging were observed on soft corals normally attached to shells and gravel. However, the study had a low power to detect differences, and coral-bearing shells may have been displaced out of the path of the dredge by dredge-generated turbulence. Larger effects might occur in areas of greater shell and coral density.

9. Effects of Experimental Otter Trawling on Feeding of Demersal Fish .. (Kenchington et al.) – In an area closed to fishing for more than a decade, intensive experimental trawling was conducted in selected study area. Following the first trawl event the density of species such as cod, haddock and winter flounder increased markedly. The diets of cod haddock and several flatfish showed significant changes after trawling, with an increase in amount of prey consumed, an increase in diversity of taxa eaten, and increased in consumption of some particular prey species, including horse mussels and polycheates.

10. Summary of the Grand Banks Otter Trawl Experiment … : Effects on Benthic Habitat and Macrobenthic Communities (Gordon et al.) – A 3-year trawl experiment on a relatively high-energy sandy-bottom ecosystem found short term (< 1 year) effects on habitat structure, and an average of a 24% reduction in mean epibentic biomass immediately after trawling. The species showing greatest effects were snow crabs, several echinoderms, and soft corals. Immediate effects on infauna were small and limited to a few species of polychaetes. The biological community appears to recover in < 1 year, and no effects were recorded 3 years after the experimental trawling.

11. Effects of Chronic Bottom Trawling on the Size Structure of Soft-bottom Benthic Invertebrates (McConnaughey et al.). Comparing adjacent heavily trawled and untrawled high-energy, sandy-bottom areas, three years after trawling ceased, for 15 of 16 benthic taxa examined mean sizes of individuals were smaller in the heavily trawled area than in the untrawled area. For the remaining species, the larger size was due to a rarity of small crab, not an increase in abundance of large crab.

12. Effects of Commercial Otter Trawling on Benthic Communities in the … Bering Sea (Brown et al.) An area closed to fishing for 10 years was contrasted with an adjacent recently reopened area in a shallow, high-energy sandy area. The fished area had lower macrofauna density, biomass, and richness than the unfished area. Sessile taxa were more common in the closed area and scavengers were more common in the open area. Fragile taxa were rare but appeared unaffected by fishing.

13. Effects of Bottom Trawling on Soft-bodies Epibentic Communities in the Gulf of Alaska (Stone et al.). Benthic communities on adjacent low or moderate energy areas open to fishing and closed to fishing for 11-12 years were compared using video methods. In the areas open to fishing species richness tended to be lower, and biogenetic structures, low mobility taxa, and prey taxa for commercially harvested species were less abundant.

14. Biological traits of the North Sea Benthos: Does Fishing Affect Benthic Ecosystem Function? (Bremner et al.) – Trends in 18 biological traits representing morphology, life history, feeding and habitat use of benthic species were examined over a 30 period of increasing fishing pressure. Opportunistic species dominated the communities, and increased with initial increases in fishing effort, thereafter maintaining relative stability. Traits expected to be associated with vulnerability to

fishing decreased proportionately to increasing fishing effort. Species with high regeneration potential and asexual reproduction also declined. Traits related to feeding and habitat usage remained relatively stable.

15. The Impact of Trawling on Benthic Nutrient Dynamics …: Implications of Laboratory Experiments (Percival et al.) – Nutrient concentrations and fluxes under simulated trawling at moderate and high rates were compared to control rates. Trawl impacts affected all the nutrient measurements and flux rates, and elevated levels of ammonium and phosphate persistent more than 48 hours. This suggests regular trawling may have altered benthic nutrient fluxes widely, with impacts on coastal nutrient dynamics and productivity.

16. Potential Impacts of Deep-Sea Trawling on the Benthic Ecosystem along the Northern European Coastal Margin (Gage et al.) – In a review of scattered information, it is reported that trawl scour marks on soft sediments persist longer then in shallower areas. Many other implications of results from elsewhere were extrapolated to deep-sea continental marginal areas.

17. Immediate Effects of Experimental Otter Trawling on a Sub-Arctic Benthic Assemblage inside … a Fishery Protection Zone .. (Kutti et al.) – Experimental trawling seemed to affect the community mainly through resuspension of surface sediments and relocation of shallow burrowing infauna species. 1 day post-trawling there was an increase in the biomass and abundance of the majority of the infauna bivalve taxa. No dramatic changes in composition of the fauna due to trawling was found.

18. Preliminary Results on the Effects of Otter Trawling on Hyperbenthic Communities. (Koulouri et al.). Although the analyses of results were incomplete, an experimental investigation of the effect of otter trawl ground-ropes showed significant perturbation of small benthos living at the sediment-water interface. Effects persisted at least a week post-trawling, and reflected a likely in-migration of small organisms to feed on an increased food supply. Several groups of hyperbenthos did not show changes in abundance after trawling.

19. Trawl Fishing Disturbance and Recolonization Dynamics (Pranovi et al.) – Medium-term (~9 months) recolonization of an area experimentally trawled a single time was studied with a number of ecological indices. Scavengers increased for ~ 7-30 days, then decreased, depending on the substrate type. Complete recovery required approximately 9 months in both sand and mud habitats. The benthic communities in heavily trawled areas resembled the community in the experimental area soon after the trawl treatment.

20. Short-term Effects of the Cessation of Shrimp Trawling (Sheridan and Doerr) – In a shallow, high-energy sandy environment, after a 7-month experimental closure to shrimp trawling, there were no differences in sediment rates or characteristics compared to an adjacent area which was open to fishing. Densities and biomasses of most small epibenthic and infauna invertebrates did not different between the areas.

21. Comparison of Effects of Fishing and Effects of Natural Events and Non-Fishing Anthropogenic Impacts … (Lindeboom) A review article presents few new data. However, it highlighted the very complex interactions among natural changes and various human activities. It concluded that effects of fishing on benthos are several orders of magnitude greater than effects of sand and aggregate extraction, or oil and gas development.

22. Spatial and Temporal Scales of Disturbance to the Seafloor … (Thrush et al.) – This paper included few new data, but developed a heuristic model applying ecological theory of disturbance rates and magnitudes to fishing effects. It concluded that many effects of fishing may be difficult to reverse if the rates of disturbance by fishing were much more frequent than rates of natural disturbance. Recovery potential also depends importantly on the spatial extent of fishing relative to the mobility of species affected by fishing.

23. Muddy Thinking: Ecosystem-based Management of Marine Benthos: (Frid et al.) This paper developed a conceptual framework for managing human activities that affect the benthos. It stressed the value of performance metrics and decision rules, and concluded that few currently used metrics of ecosystem status, particularly community metrics, provide a robust foundation for evaluating performance of management or for guiding decision-making.

24. Spatial and Temporal Distributions of Bottom Trawling off Alaska … (Rose and Jorgensen) This paper highlighted the difficulties of providing accurate estimates of total area exposed to trawl gears during a fishing season. It concluded that spatial overlap of repeated trawl events is high in the fisheries studied, and given the spatial scale of reporting commercial effort, most analysis methods will over-estimate the total area exposed to trawling and underestimate the frequency with which the most preferred grounds are fished.

25. Impacts of Fishing Activities …: Approaches to Assessing and Managing Risk (Fogarty) – This paper is primarily about reference points and multi-criterion management strategies. In the context of the current meeting it does highlight that recovery of depleted populations may be intimately tied to recovery of altered habitats. It also noted that the management tactics available to address habitat impacts are combinations of effort controls, changes in gear configuration or usage, and spatial management strategies which restrict use of bottom gears in selected areas.

26. An alternative Paradigm for the Conservation of Fish Habitat … (DeAlteris) – This is another largely conceptual paper about management strategies. It proposed to have degree of protection of areas from bottom gears depend on vulnerability of the substrate (with sand substrates less vulnerable than muddy ones) and rarity of the habitat type.

27. Habitat and Fish Populations in the Deep-Sea *Oculina* Coral Ecosystem … (Koenig et al) - These structurally complex and fragile habitats support particularly high densities of many fish. They have been protected from trawling since 1984, but there is evidence that the protection has been far from completely effective. Less than 10% of the *Ocalina* stands examined with video appeared to be undamaged, with the source of the damage inferred indirectly to be most likely fishing.

28. The Impact of Demersal Trawling on …The Darwin Mounds (Wheeler) – Several parts of this field of deep-water (<1,000 m) small coral-topped mounds was shown by acoustic and video methods to be extensively impacted by trawling, despite their depth and the comparative recency of deep-water trawl fisheries in the Northeast Atlantic. There is evidence of heavy trawl activity in some areas, where dead coral and coral rubble are common, and trawl marks are clearly visible.

29. Fishing Impacts of Irish Deepwater Coral Reefs (Grehan et al.) – In an area of large, complex, and fragile coral reefs in the deep-sea off Ireland video methods showed no evidence of trawl damage, but gill nets and long-lines were entangled in coral

branching in some areas. These areas are not thought to have been trawled, but expanding deep-water fisheries were considered a threat, and they were recently identified as a priority habitat conservation area. This situation is considered a test of the effectiveness of EU marine habitat conservation policies and practices.

## VII. Synthesis and Overall Conclusions

There are many similarities in the conclusions of the five review sources with regard to impacts of bottom trawling and effectiveness of mitigation measures. Only the ICES advisory report has comprehensive management advice, although both the National Academy and the NMFS reviews do have management recommendations as well as research recommendations.

The conclusions and management recommendations of the five studies are tabulated in Table 5 (using the numberings in the preceding sections and not from the original reports). The table begins with the ICES list, both because it was the first of the reviews to be published, and because it had the most explicit mandate to provide management advice. The other reviews are tabulated chronologically, so the phrasings of the conclusions and recommendations (column 1) are shortened paraphrases of the wording used in the first report where the conclusion or recommendation occurs.

Many judgement calls were needed in preparing this tabulation, as different reports often came at the same issue from different perspectives so the wordings used were different. However, where it was judged that the same basic conclusion was being drawn, they are tabulated as the same. In a few cases a particular conclusion was not drawn explicitly, but for some other conclusion to have been drawn the corresponding conclusion would have to have been drawn as well. In these cases the corresponding number is in parenthesis (). Moreover, in only a few cases were findings or conclusions of one report contradictory with the findings or conclusions of another report. These cases are noted in **bold** type.

*Table 5 – Synthesis and tabulation of the conclusions and recommendations in each of the four reviews. Numbers refer to the numbered conclusions or papers from the previous sections of this Working Paper. Symbols used are explained in the preceding paragraphs.*

| **Types of Effects of Mobile Bottom Gears** | **ICES** | **NAS**[1] | **NMFS**[1] | **FAO**[2] | **AFS**[3] |
|---|---|---|---|---|---|
| Removal of major habitat featu[2]res | 1 | 1, 18 | 21,28 | | 10 |
| Reduction of structural biota | 2 | 1,11,18 | 2,6,22,26 30,31 | 2 | 10,13,(28),(29) |
| Reduction of habitat complexity | 3 (weak) | 1,(11),18 | 3,7,23,27 | 1 | 10,13 |
| Changes in seafloor structure | 4 | | 11,13,14 | 5 | 10,17 |
| Reduction in geographic range | 5 | | | | |
| Decrease in species with low turnover rates | 6 | 3,(6), 17 | | 14, 18, **13** | 12,14 |
| Fragmentation of species ranges | 7 (weak) | | | | |
| Changes in relative abundance of species | 8 | 3,(6),8,10, 17 | 8,914,15,1 6 28,33,34 | **10,** 12, **13**, 14, 15, 17 | 5,6,9,11,12,13, 14,18, **19, 20,** |
| Fragile species more affected | 9 (weak) | 3,8, 19 | | 14 | 5,7,**8,12** |
| Surface-living species more affected than burrowing species | 10 (weak) | 1,8,17 | 9,10,12,16 | 14 | 5, 10,12,13,**17** |
| Sub-lethal effects on individuals | 11 | | | | |
| Increase in species with high turnover rates | 12 | 3,(6),17 | | 18 | 5,14,(17) |
| Increase in scavenger populations | 13 | | **35** | | 5, (9), 12,18,19 |
| Decrease in productivity &/or changed nutrient cycling & sedimentation | | 4,9 | **19?** | | 5,15,**20** |
| Impacts greater in low disturbance (energy) regimes than high ones | (All of Table) | 6,19,20 | 2-8,21-28 | | 6 |
| Increased susceptibility to other stressors | | 12 | | | |
| **Mitigation and Management Issues** | | | | | |
| Recovery can take weeks to centuries, and measures to facilitate recovery must continue in the long term | 14 | 2,13-16 | 2-8,21-28 | 13, 16 (< 1 yr) | 10 (<1-3 years) 18 (~1 wk), 19 (~9 mo), |
| Monotonic relationship between effort and impact, with greatest impacts from the first few exposures | 15a | 5 | 17,36 | 8 | 14,21,22 |
| Shape of the relationship depends on history of area, gear, and features of species and habitats affected | 15b | 5,7,8, 13-16,20 | 18,37 | 6,7 | 6,16,21,22, 24,(26) |
| Effectiveness of all technical measures will be case-specific | 16 | | (17)(36) | (20)(22) | (22) |
| Technical measures can act synergistically, so suites of measures should be considered | 17 | | | | |
| Economic incentives can be important to successful implementation | 18 | | | | |

[1] Effects numbers 1, 4, 5, 24, and 32 are reported as "unknown" and hence not tabulated
[2]

| Types of Effects of Mobile Bottom Gears | ICES | NAS[1] | NMFS[1] | FAO[2] | AFS[3] |
|---|---|---|---|---|---|
| Application of all mitigation measures requires case-specific planning and analysis | 19 | (20), 21 | | | (22) |
| **Management Recommendations** | | | | | |
| Major reductions in fishing effort needed | 20, (27) | 23 | 20,36 | | 25 |
| Implement Closed areas | 21, (26) | 23 | 20,36 | | 25,(27) |
| Gear substitution | 22 | 23 | 20,36 | | 25 |
| Gear modification | 23 | 23 | 20,36 | | 24 |
| Habitat rehabilitation | 24 | | | | |
| Governance changes | 25, (28) | | | | |
| Apply comparative risk assessment | | 24 | | | |

[1]22 and 26 are research recommendations; 25 is not trawl impact issue
[2]3,4,9,11,and 19 are research recommendations or recommendations about methodologies for stbudies.
[3]1-4 are about fish use of different types of habitats; 11 is about sizes of organisms, which could be related directly to fishing, and 22 is about the management performance of various benthic indicators.

Based on this table, a number of conclusions about impacts and mitigation measures receive consistent support. These are listed in an order reflecting their relative breadths and strengths of support.

*Impacts of Bottom Gears on habitats:*

1. Mobile bottom gears can damage/reduce structural biota - All reviews, strong evidence or support.
2. Mobile bottom gears can damage/reduce habitat complexity - All reviews panel, variable evidence or support .
3. Mobile bottom gears can reduce/remove major habitat features (boulders etc) – Some reviews, strong evidence or support
4. Mobile bottom gears can alter seafloor structure – Some reviews, conflicting evidence for benefits or harm.

Other emergent conclusions on habitat impacts included;

5. There is a gradient of impacts, with greatest impacts on hard, complex bottoms and least impact on sandy bottoms – All reviews, strong support (with qualifications).
6. There is a gradient of impacts, with greatest impacts on low energy environments and least (often negligible) impact on high-energy environments – All reviews, strong support.
7. Trawls and mobile dredges are the most damaging of the gears considered – Three of the reviews considered other gears, all drew this conclusion, often with qualifications.

*Impacts of Bottom Gears on benthic species and communities:*

8. Mobile bottom gears can change the relative abundance of species – All reviews, strong evidence or support.
9. Mobile bottom gears can decrease the abundance of long-lived species with low turnover rates – All reviews, moderate to strong evidence or support.
10. Mobile bottom gears can increase the abundance of short-lived species with high turnover rates – All reviews, moderate to occasionally strong evidence or support.
11. Mobile bottom gears affect populations of surface-living species more often and to greater extents than populations of burrowing species – All reviews, weak to occasionally strong evidence or support.
12. Impacts of mobile bottom gears are less in high-energy / frequent natural disturbance environments than in low energy environments where natural disturbances are uncommon - 4 reviews (one did not address the factor)– strong evidence or support.
13. Mobile bottom gears affect populations of structurally fragile species more often and to greater extents than populations of “robust” species – All studies, variable evidence and support.
14. Abundance of scavengers increases temporarily in areas where bottom trawls have been used – 3 reviews, variable support or evidence, all argue for only transient effect.
15. Rates of nutrient cycling and/or sedimentation are increased in areas where bottom trawls have been used – 2 reviews , mixed views on magnitude of effects and conditions under which they occur.

Scattered and inconsistent support was found for other conclusions on biological effects of mobile bottom gears. For example, no group found moderate or strong evidence for considerations 5, 7, and 9 of ICES.

*Considerations in the application or adoption of mitigation measures*:

16. The impact of mobile fishing gears on benthic habitats and communities is not uniform. It depends on:
    a. the features of the seafloor habitats, including the natural disturbance regime - All reviews and NMFS panel, strong evidence or support;
    b. the species present - All reviews, strong evidence or support; Not mentioned by NMFS panel
    c. the type of gear used and methods of deployment; - All reviews and NMFS panel, moderate to strong evidence support; and
    d. the history of human activities (particularly past fishing) in the area of concern - All reviews, strong evidence or support.
17. Given the above considerations, the impact of mobile bottom gears has a monotonic relationship with fish effort, and the greatest impacts are caused by the first few fishing events – (All reviews, moderate to strong evidence or support)
18. Recovery time from trawl-induced disturbance can take from days to centuries, and depends on the same factors as listed in conclusion VI-13. (All reviews, strong evidence or support).

19. Application of mitigation measures requires case specific analyses and planning; there are no universally appropriate fixes - Three reviews, moderate to strong evidence or support. The issue of implementing mitigation was not addressed in the FAO review. It is also stressed in the US National Academy of Sciences review and discussed in the ICES review that extensive local data are not necessary for such case-specific planning. The effects of mobile bottom gears on seafloor habitats and communities are consistent enough with well-established ecological theory, and across studies, that cautious extrapolation of information across sites is legitimate.
20. Conclusions regarding the potential synergy of technical mitigation measures, and the value of economic incentives in facilitating implementation and compliance were only discussed in the ICES review and the NMFS panel report. However, nothing in the other reviews directly contradicts these conclusions.
21. The same is the case for the ICES admonition that in cases where benthic communities or habitats have recovered due to application of some mitigation measures, the benefits of the recovery can be quickly dissipated unless either the measures are continued in the long term or the fishery is otherwise managed in ways the prevent a resumption of the detrimental impacts.

*Recommendations for management of mobile bottom gears:*

The FAO review did not include management recommendations, so there are only three reviews to tabulate in this case. Moreover, only the ICES review and the NMFS Panel ranked their management recommendations in order of importance. The ICES ranking was labelled as specific to the North Sea and Irish Sea, the areas for which science advice was requested. However, the considerations which led to their ordering are generally applicable, and consistent with the lines of reasoning in the National Academy of Sciences review as well. The ranking of the NMFS panel was also labelled as specific to the US Northeast, and noting that there had already been an effort reduction of more than 50% in the area. Also, although recommendations contained in papers published in the AFS Symposium are tabulated here, it should be noted that the recommendations are those of individual authors, not the Symposium participants as a whole, and no attempt was made to consolidate possibly redundant recommendations of different authors nor to be comprehensive in matching to coverage of recommendations to the full range of fisheries impacts on benthic populations, communities, and habitats.

22. The impact of mobile bottom gears on seafloor habitats and species can be reduced through major reduction in effort in fisheries using those gears – All reviews, strong support.
23. The impact of mobile bottom gears on seafloor habitats and species can be reduced through implementation of areas where use of those gears is not permitted – All reviews; strong support for habitat features, especially by NMFS, support for species and communities qualified in all cases to depend on the characteristics of the species of concern.
24. The impact of mobile bottom gears on seafloor habitats and species can be reduced through substitution of another gear or modification of the trawl gears to reduce contact with the benthos and seafloor – All studies, moderate to strong support.
25. Only the ICES review considered habitat rehabilitation, to which it gave qualified support under specific circumstances.

26. Only the ICES review discussed the need for governance changes as a part of the strategy to reduce the detrimental effects of fishing activities in general, as well as the impacts of mobile bottom gears. However, much of the argumentation in the National Academy of Sciences review, and many of the papers on social sciences in the American Fisheries Society Symposium publication are consistent with this recommendation from ICES.
27. Only the National Academy of Sciences review considered risk assessment tools explicitly, and recommended use of comparative risk assessment methods in planning mitigation measures. Nothing in the other reviews would contradict this recommendation.

Finally, at different points all the reviews highlight that benthic habitats are themselves dynamic, and undergo changes for many reasons other than impacts of fishing gears. This does not mean that the impacts of fishing gears are unimportant, or that mitigation is unnecessary. However the natural variability of benthic systems does mean that studies to link fishing to impacts on benthos cannot be expected to provide simple and unambiguous results within great care in design and execution, and sometimes even very good studies will produce results open to multiple interpretations.

These overall conclusions on impacts and mitigation measures, and recommendations for management action form a coherent and consistent whole. They are relevant to the general circumstances likely to be encountered in temperate, sub-boreal, and boreal seas on coastal shelves and slopes, and probably areas within Canadian jurisdiction beyond the continental shelves. They allow use of all relevant information that can be made available on a case by case basis, but also guide approaches to management in areas where this is little site-specific information. Augmented by the specific Canadian information in the other Working Papers to be tabled at the March meeting, they provide a scientifically sound and practical basis for developing Canadian policies and management programmes.

**Major Literature Sources Used:**


ICES 2000a. Report of the Advisory Committee on the Marine Environment 2000. ICES Cooperative Research Report #241.

ICES 2000b. Report of the Working Group on Ecosystem Effects of Fishing Activities. ICES CM 2000/ACME:02.

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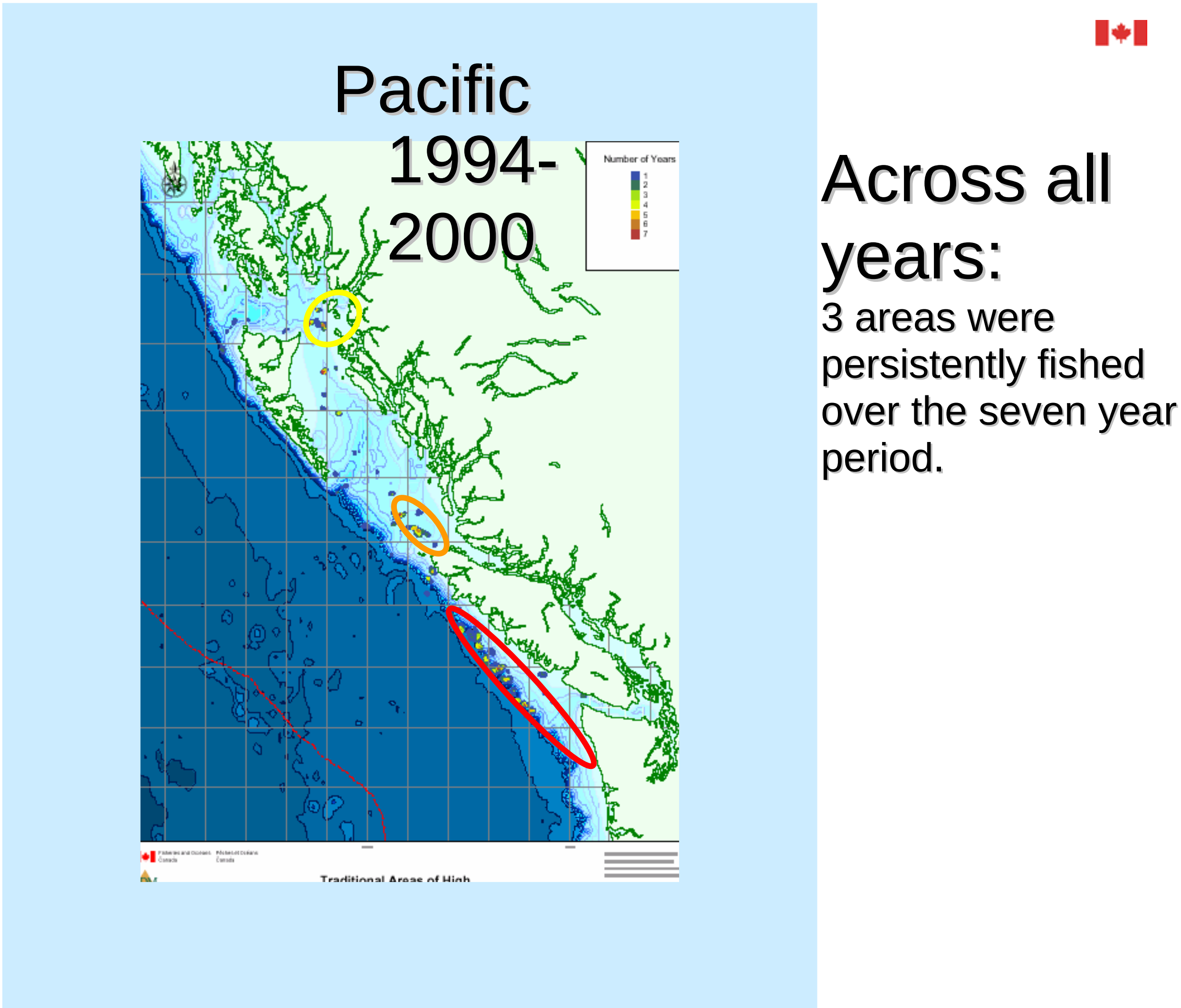
National Marine Fisheries Service Workshop. 2002. Workshop on the effects of Fishing Gear on Marine Habitats off the Northeastern United States October 23-25, 2001. Northeast Fisheries Science Center Reference Document 02-01.

Barnes, P.W. and J.P Thomas (eds) 2005. Benthic Habitats and Effects of Fishing. American Fisheries Society Sumposium #41. American Fisheries Society, Bethesda, MD.

Lokkeborg, S. 2005. Impacts of trawling and scallop dredging on benthic habitats and communities" – FAO Technical Paper 472.

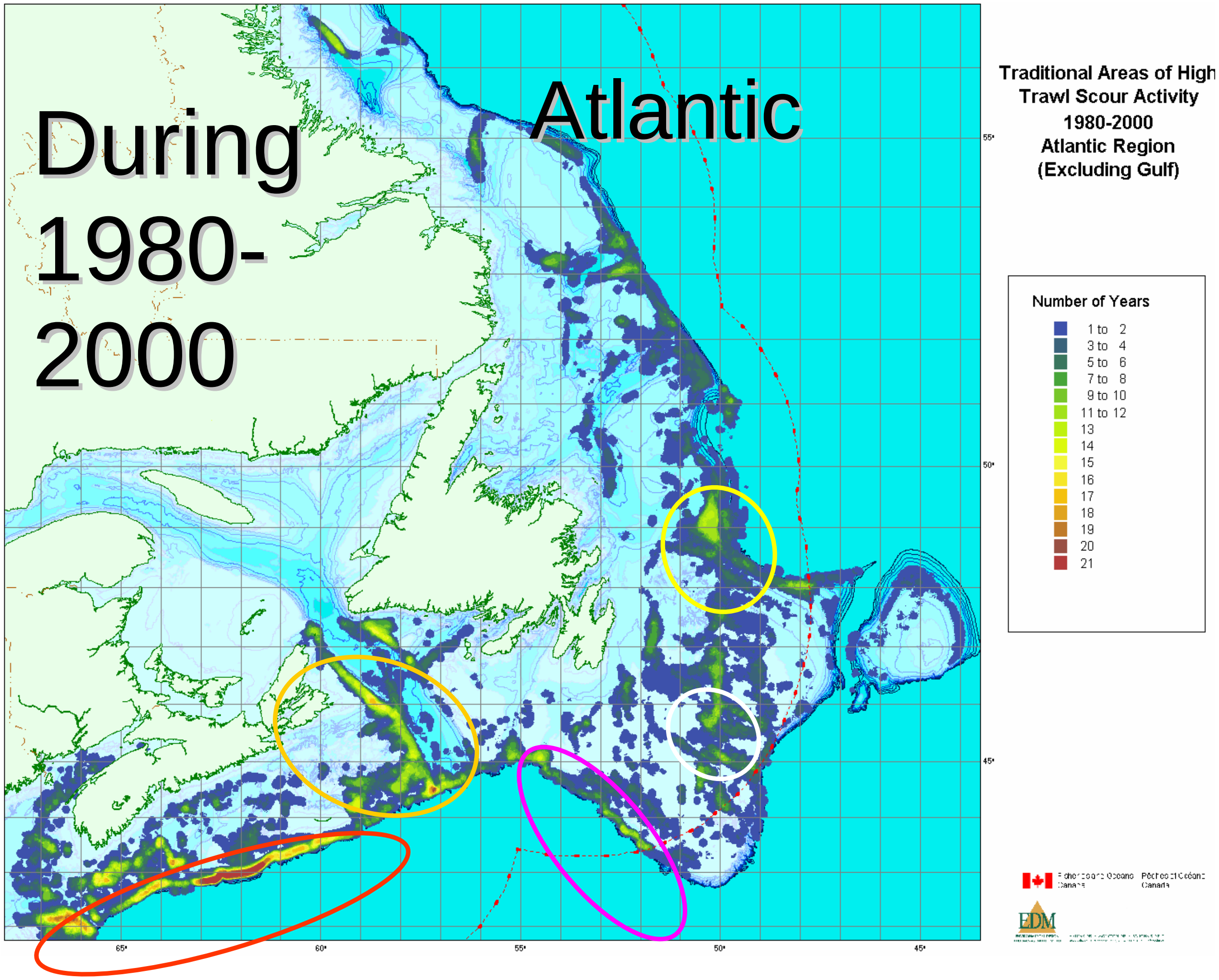
**APPENDIX 6a: Effort distribution in Pacific (1994-2000)**

*(Based on working paper no 3, D. Kulka)*



## APPENDIX 6b: Effort distribution in Atlantic (1980-2000)

*(Based on working paper no 3, D. Kulka)*




Gulf Excluded

**From 1980-2000, the most consistently intensely fished areas are shown in red to yellow.**