IMPACTS OF TRAWL GEARS AND SCALLOP DREDGES ON BENTHIC HABITATS, POPULATIONS AND COMMUNITIES

Figure 1: Department of Fisheries and Oceans' (DFO) six administrative regions.

Context:

Both domestically and internationally, DFO is moving towards an ecosystem approach to management of human activities in the sea. This includes considering the effects of human activities on ecosystem components in addition to adjust the intended targets of each activity. For fisheries this means considering how fisheries may affect the seafloor and the benthic species and communities living on the seafloor, among other effects. Canada's position has been that all activities should be managed to ensure that all impacts are sustainable, including those on benthic populations, communities, and habitats. In addition, ecologically significant or vulnerable species and habitats should be given enhanced protection, with the nature of that protection matched to the type of activities, the ecological scale of the habitat feature or the benthic community, and the characteristics that make the feature or community significant or vulnerable. In this context, there is debate, particularly in the media and in international policy fora, about the severity and ubiquity of detrimental impacts of bottom trawling and mobile dredges on the seafloor and benthic communities.

In the fall of 2005, Policy, Oceans and Habitat Management, and Fisheries and Aquaculture Management Sectors of DFO joined in a request for science advice on the potential impacts of mobile bottom-contacting gears on benthic habitats and communities. Experts prepared an overview working paper that reviewed and consolidated the results of five major international reviews or symposia, and several additional working papers that considered results of regional studies of these impacts in Canada. These papers were subjected to peer review at a national advisory meeting in March 2006. This peer review included participants from the fishing industry and conservation organizations as well as experts from the university community. Those working papers and the resultant dialogue provided the basis for the following scientific advice.

SUMMARY

- Mobile bottom-contact fishing gears do have impacts on benthic populations, communities, and habitats. The effects are not uniform, but depend on at least:
  - the specific features of the seafloor habitats, including the natural disturbance regime;
  - the species present;
  - the type of gear used, the methods and timing of deployment of the gear, and the frequency with which a site is impacted by specific gears; and
  - the history of human activities, especially past fishing, in the area of concern.
- The nature of many of the dependencies referenced above are described in the advice
- Application of measures to reduce impacts of mobile bottom-contacting gears requires case specific analyses and planning; there are no universally appropriate fixes. However, the documented effects of mobile bottom-contacting gears on seafloor populations, communities, and habitats are consistent enough with well-established ecological theory, and across studies, that cautious extrapolation of information across sites is legitimate. Case-specific research programmes are not required to develop options for case-specific applications of these generalisations.
- Circumstances are discussed under which general spatial management, closed areas, gear modifications, and effort reductions could provide some mitigation of the effects of mobile bottom-contacting gears on benthic habitats, populations, and communities.
- "Frontier areas" (areas without histories of fishing by bottom-contacting gears) require special considerations in managing the risks posed by mobile bottom-contacting gears. Several of these special considerations are discussed.
- In the application of precaution for managing the ecosystem effects of any human activity, the capacity of ecosystem components to recover from perturbations is an important consideration. Several considerations in this context are discussed, as are related issues of more general risk management relative to fisheries using bottom-contacting mobile gears.
- A number of gaps in knowledge and necessary scientific studies are discussed.

INTRODUCTION

This report considers only the effects of selected mobile bottom-contacting gears used in Canada, specifically otter trawls, scallop dredges, and hydraulic clam dredges, and only their effects on seafloor habitats and on populations and communities of benthic species. Most of the Canadian studies considered only direct effects of these gears, although the reviews considered some indirect effects due to trophodynamic relationships and habitat alterations. All three of these types of fishing gears are in fact classes of gears, and particularly for otter trawls, the trawls used in Canada can differ substantially in their size, how they are rigged, and how they are fished. These differences, in turn, may affect how the gears interact with benthic communities and habitats. Although many generalisations are presented below, the specifics of each fishing gear should be considered when evaluating potential impacts on a case by case basis. Moreover, all fishing gears have impacts on components of aquatic ecosystems other than just the target species of the fishery. Effects of other fishing gears, such as nets, traps, and lines should be reviewed in the future, and similar advice on their impacts on various components of aquatic ecosystems should be provided. This would allow a more fully informed consideration of options for managing fisheries, when taking individual and cumulative ecosystem effects of fisheries into account.

Discussion of the impacts of any human activity on the ecosystem, including fishing, cannot avoid addressing the issue of "impact" relative to what benchmark state. Other initiatives within DFO are proceeding towards the setting of ecosystem objectives for marine and some other aquatic ecosystems. Once operational objectives have been specified for an area, an important context for evaluating "impact" of a fishing gear will be relative to the state of the ecosystem consistent with corresponding objectives. However, such objectives are not available at this time for benthic populations, communities, and habitats. Therefore in this Science Advisory Report, impacts are discussed relative to the current state of those habitats and communities. Hence "perturbation" is to be interpreted as the degree to which a current fishery changes a benthic population, community or habitat from the state it was in prior to the fishing events comprising the "current" fishery. When "recovery" is mentioned, it refers to the return of a benthic population, community, or habitat to the state from which the current fishing events perturbed it. It is not intended to refer to the return of the community to a pristine state, prior to any fishing whatsoever. This approach is taken to be clear and objective about what is considered an "impact" in this Science Advisory Report. It should therefore not be interpreted as assuming that ecosystem objectives should necessarily be to maintain the current state of benthic populations, communities, and habitats. The larger issue of other possible objectives for managing human impacts on benthic populations, communities and habitats is discussed in the "Other Considerations" part of this Science Advisory Report. Even there, the discussion is intended to highlight links between this advice and the separate process underway to set operational ecosystem objectives for marine areas, and not to prejudge what those objectives should be.

ANALYSIS

The body of this advice is made up of a series of conclusions about:

- Effects of mobile bottom gears on structural features of benthic habitats, on benthic populations, and on structural and functional properties of benthic communities;
- Management tools available for altering, or reducing, effects that are considered undesirable; and
- Considerations relevant to advising or deciding when and which management tools to apply.

Where Canadian research results are available, they are given prominent weight in the framing of individual conclusions, but the international research results are taken into account fully. For topics for which Canadian studies are not available, the scientific basis for the present advice is drawn from the conclusions of international experience. This was considered justified, because where both domestic and international studies were available on a given topic, the meeting specifically considered if there was any evidence that the Canadian situation was sufficiently unique that conclusions arising from the international reviews would not apply to the Canadian context. Where such comparative evaluations could be made, Canadian findings were consistently complementary to the international results. Consequently, when only international results were available on a topic, they are considered to be an appropriate basis for the best science advice possible with current information. Such cases are usually identified as being based exclusively on international studies, whereas generalisations where sources are not specified are supported by both domestic and international studies.

CONCLUSIONS

The overall conclusions of the review are presented in point form below.

1. Mobile bottom-contact fishing gears do have impacts on benthic populations, communities, and habitats. The effects are not uniform, however, but depend on at least:
    a. the specific 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 of the gear, and the frequency with which a site is impacted by specific gears; and
    d. the history of human activities, especially past fishing, in the area of concern.

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

Impacts of Bottom-Impacting Gears on Physical Features of the Seafloor

2. Mobile bottom-contacting gears can damage or reduce structural biota.
3. Mobile bottom-contacting gears can damage or reduce habitat complexity.
4. Mobile bottom-contacting 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. However, the duration of impacts is usually greater on hard complex bottoms than on sandy bottoms and probably longer than on muddy bottoms.

    This set of comparative generalisations is for sites of comparable “energy”, and may not hold, for example, when comparing potential impacts of a gear on a hard bottom in a high energy area (i.e. with frequent wave or current disturbance) to impacts of the same gear on a low energy sandy bottom (i.e. with extremely infrequent natural disturbances). Dredges are used only in specific habitats; for example, hydraulic dredges are used only in sandy sites. Hence this set of generalisations is less relevant to dredges than to bottom trawls.
6. For a given type of habitat, mobile bottom-contacting 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 (such as gill nets, seines, and long-lines), dredges and bottom trawls were considered to be the most damaging to benthic populations, communities, and habitats per unit of effort. Several of the international studies stressed that consideration of gear impacts needed to take into account both the expected impact per unit of effort and the amount of effort required to harvest a given amount of the target species.

Impacts of Bottom-Impacting Gears on Benthic Populations and Communities

8. Mobile bottom-contacting gears can change the relative abundance of benthic species and hence can alter the composition of benthic communities.
9. Mobile bottom-contacting gears can decrease the abundance of long-lived species with low turnover rates.
10. Mobile bottom-contacting 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 they affect surface-living species.
12. For a given habitat type, impacts of mobile bottom-contacting gears are less in high-energy sites or sites with frequent natural disturbances than in low energy sites where natural disturbances are infrequent.
13. Mobile bottom-contacting gears affect populations of structurally fragile species more often and to greater extents than populations of "robust" species.
14. Mobile bottom-contacting gears may have sublethal effects (i.e. injury, exposure) on individuals of benthic populations. These effects may increase the vulnerability of these individuals to other sources of mortality or lower their fitness.
15. The abundance of scavengers that feed on the surface of the seafloor may increase temporarily in areas where a mobile bottom-impacting gear has passed, and these increases may persist for days to possibly weeks. When areas are impacted repeatedly over several years, the increased presence of scavengers in the community can become a persistent feature of the community.
16. Rates of sedimentation are increased temporarily in areas where mobile bottom-contacting 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 Conclusion 1, the impact of mobile bottom-contacting gears has a monotonic relationship with fish effort.
18. Taking account of the factors in Conclusion 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 perturbation by mobile bottom-contacting gears can take from days to centuries, and for physical features and some specialized biogenic features recovery may not be possible. Recovery time also depends on the factors listed in Conclusion 1.
20. Application of measures to reduce impacts of mobile bottom-contacting gears requires case specific analyses and planning; there are no universally appropriate fixes. However, the documented effects of mobile bottom-contacting gears on seafloor populations, communities, and habitats are consistent enough with well-established ecological theory,

and across studies, that cautious extrapolation of information across sites is legitimate. Case-specific research programmes are not required to develop options for case-specific applications of these generalisations.

Management Tools Available for the Reduction of Impacts of Mobile Bottom-Contacting Gears

21. The impact of mobile bottom-contacting 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-contacting gears on seafloor populations, communities, and habitats can be reduced through spatial management of effort in fisheries using those gears taking into account the spatial distribution of benthic habitat and communities.
    - The effectiveness of this measure depends on how the effort is redistributed spatially and temporally, compared to its distribution prior to implementation of the spatial management regime, and the timeframe over which it is applied.
23. The impact of mobile bottom-contacting gears on seafloor populations, communities, and habitats 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 within the closed areas;
    - Its effectiveness for reducing impacts on populations and communities of concern depends on their biological properties, especially their mobility and spatial pattern of recruitment. It is especially effective in protecting long-lived sedentary species such as large deep-water corals and sponges; and
    - 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-contacting gears on seafloor populations, communities, and habitats can be reduced through substitution of another type of 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.

OTHER CONSIDERATIONS

Considerations in Application of the Conclusions

Risks and Expanding Fisheries

The management tools available to reduce impacts of mobile bottom-contacting gears on benthic populations, communities, and habitats (Conclusions 21-24) are *not* all recommended measures for immediate implementation. Decision-making about the implementation of each one requires taking account of Conclusions 1 and 20 and the current situation (including both management regime and operational practices) in each fishery. In the Canadian context the "current situation" includes major changes that have already been made in many fisheries over the past decade or more, particularly in trawl fisheries for East Coast groundfish. Current fishing effort is much less than effort prior to the collapse of many groundfish stocks, and the types and modes of deployment of the trawls gear have changed substantially.

The decision on whether the risks to benthic populations, communities, and habitats from mobile bottom-contacting gears should be actively managed in a particular situation is a policy decision, informed by science and the precautionary approach as described below. If there is concern that the risks may be high enough to possibly warrant active management of a fishery to reduce its benthic impacts, then a suite of risk assessment tools appropriate to the expected levels of risk and biological objectives need to be available. In some international settings, 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. There should be further discussion of the possible applicability of those tools in Canadian contexts.

The term "Frontier Areas" is being used to apply to areas where there is little or no history of use of mobile bottom-contacting gears. Such unfished areas can be found at a variety of depths at mid-latitudes and in many areas of the Canadian North. Spatial information sources from historical and recent fisheries should be reviewed carefully to delineate the boundaries of potential frontier areas appropriate for all three oceans. Information was presented at this meeting that fishing currently does occur at least occasionally at substantial depths in the Atlantic and Pacific including as far north as NAFO subarea 0A on the Atlantic Coast. Such fisheries would be expected to encounter habitats with many features identified in the Conclusions 2 through 16 as features readily impacted by mobile fishing gears. Most scientific studies on bottom gear impact and ecosystem processes have not included deep-water and polar areas, and as a result there is greater scientific uncertainty about ecosystem processes and resilience to perturbation. These considerations need to be taken into account in managing risks of fisheries using mobile bottom-contacting gears in these areas.

In Canada many frontier areas are found in Arctic ecosystems, whereas most experience with assessing the impacts of fishing gears has been acquired in temperate and sub-boreal ecosystems. The need to transfer knowledge to Arctic ecosystems poses additional challenges. Key ones include:

- Working in poorly studied Arctic (and deep-water) ecosystems increases the scientific uncertainty and broadens the risk profiles. This underscores an even greater than usual importance to information collection provisions in such fisheries.
- Science needs to make full use of what information and general ecological knowledge is available in the step of making predictions, so that their testing can be as informative as possible about risks and consequences of fishing.
- The energy level and substrate makeup of seafloor of areas to be fished are particularly important properties to establish at the earliest stages of expansion of a fishery.

It follows from the discussion of frontier areas that they require special considerations in managing the risks posed by mobile bottom-contacting gears. Meeting participants who were familiar with the New Emerging Fisheries Policy of DFO proposed that it should be a starting point for managing existing fisheries that are moving into new areas, because it has many concepts in common with those in this advisory report. It was proposed, though, that the concepts in that Policy should be adapted to apply to the situations where fisheries are expanding into frontier areas. For example:

- The information collection components in the Policy should be developed and adapted to address the information needs implied by the Conclusions above.
- The habitat protection provisions in the Policy are quite general. They need careful review and may need to be strengthened.
- The science based approach behind many aspects of the Policy is appropriate to evaluating impacts of fisheries on benthic populations, communities, and habitats. Specifically, the following stepwise approach should be considered.
    - Make prediction(s) from existing knowledge about potential effects of the fishery;
    - Gather information relevant to the prediction(s) during the entry-level fishing; and
    - Evaluate the information and use the results in adaptive management.
- All these issues are acknowledged to add costs to industry, and to create a need for greater science capacity to apply quality assurance to information collection, hypotheses testing, and evaluation of the information collected. These costs need to be considered as an intrinsic part of programmes and policies intended to increase fishing opportunities.

Many participants were unfamiliar with the New Emerging Fisheries Policy, so no specific recommendation was appropriate. However, with further study and appropriate consultation, the similarities of many issues in the two areas may provide an efficient avenue for progress on management regimes for fisheries in “frontier” areas.

Although the discussion above of expansion of fishing into frontier areas was conducted in the context of mobile bottom-contacting gears, the ecological considerations regarding impacts in such areas are not specific to only those gears. It is likely that the same considerations would apply to any type of fishery expanding into frontier areas as well.

Ecosystem Objectives, Precaution, and Managing Impacts of Mobile Bottom-Contacting Gears

As noted in the Introduction, the setting of operational ecosystem objective is a vital step in conservation of benthic components of aquatic ecosystems. Correspondingly the five DFO current Large Ocean Management Areas (LOMAs) should give priority to setting biologically-based habitat objectives, and using the objectives effectively in developing management plans. Attention should be given to identifying habitats of particular ecological significance, according to the DFO criteria for identifying ecologically or biologically significant areas (“EBSA”’s), and ensuring habitat conservation efforts give priority to those areas. However, the process needs to address operational objectives for habitat in *all* benthic areas, not just for EBSAs. Moreover, results of the advances made by the LOMA initiatives should be disseminated rapidly to other areas where fishing occurs or into which fishing is likely to expand. As quickly as operational ecosystem objectives for benthic habitats become available from the LOMAs, they should be reviewed for wider applicability in Canadian waters.

Setting of operational ecosystem objectives is only a part of conservation and sustainable use of benthic populations, communities, and habitats. All human activities being managed should be reviewed relative to their compatibility with the operational ecosystem objectives, including the various fisheries operating in each LOMA. To be practical, these reviews need to be focused on priority benthic concerns and oriented towards informing management plans.

Moreover, priority should also be given to the implementation of management plans to achieve these objectives once they are set. There are several scientific tasks associated with such objectives-based management of human activities relative to benthic ecosystems. Many are associated with simply providing the science support needed to apply the many conclusions listed above in real-world contexts. However, there are also important *scientific* (as well as policy) considerations in setting priorities for management actions.

Science Sector has an important role in priority setting in management. As a generalisation with numerous case-specific exceptions, repeated human disturbances, including fishing with mobile bottom-contacting gears, lead to reductions in biomass, productivity and diversity of benthic ecosystem components, as explained in Conclusions 1-20. Sustainable use of fisheries resources is expected to be associated with sustainable levels of perturbation of ecosystem components, but at some point loss of biomass, productivity, or diversity becomes a serious ecological concern. Consequently, one priority for Science consideration is establishing the conditions under which there is ecological justification for Science to advise that management actions to reduce impacts are biologically necessary. A second related one is to establish the degrees of perturbation from which recovery of various benthic community properties is no longer secure on relevant ecological time-frames. Both tasks will usually have to be conducted with high scientific uncertainty about these benthic systems and fishing effects on them, and with worst-case scenarios possibly including serious or irreversible harm. Consequently they are conditions where the application of precaution is likely to apply.

Within DFO (and many other jurisdictions) the framework for establishment of precautionary reference points for fisheries management is based on protecting the productivity of impacted components from serious harm. The basic logic behind this approach applies directly to benthos as well. However, the risks that have to be managed within a precautionary framework will be expected to be larger for fishery impacts on benthic species, communities, and habitats than in managing the impacts of fisheries on target species for three reasons:

- Uncertainties about most properties of benthos will typically be higher than the uncertainties associated with the target species of fisheries. This uncertainty will have direct consequences for decision-making in the context of applying precaution in fisheries. Within a precautionary framework, policy and management are expected to adopt a pre-specified level of risk tolerance, which will determine the degree of perturbation that is acceptable. Within such frameworks, all other things being equal, the greater the uncertainty about an ecological feature, process, or impact, the smaller the ecological perturbation that will exceed the pre-set risk tolerance. Thus, in the specific case of impacts of mobile, bottom-contacting fishing gears on benthos, when there is greater uncertainty about benthos than about the target species of a fishery, the acceptable amount of perturbation due to fishing (i.e. the amount of perturbation that will exceed any pre-set tolerance) will be smaller than the degree of perturbation that is acceptable to the target species of fisheries.

- As noted in Conclusion 9 the life histories of some parts of benthic communities likely to be impacted negatively by fishing are similar to life histories of long-lived, slow-growing target species. Hence managing benthic impacts of fishing in areas where such communities are found will require approaches more like managing fisheries of species such as Pacific rockfish or Atlantic redfish, than like managing fisheries of shorter-lived and more resilient target species. This again means that the whole risk management framework should be designed to allow a fairly low level of perturbation before there is a noteworthy risk of serious harm, regardless of what degree of uncertainty exists.

- In marine areas, where fisheries repeatedly impact the same area at least several times a decade, and in some cases multiple times each year, there is potential for cumulative effects of these repeated fishing impacts on the benthos. The location and extent of these repeated impacts need to be considered in managing the risks of fishing impacts on key properties of ecosystem functioning and/or ecosystem resilience. The potential for such cumulative impacts needs to be taken into account in determining the degree of risk aversion necessary to manage the impacts of fishing on benthic populations, communities and habitats.

It is important to stress, however that the typical aggregation of fishery operations spatially and the ability to manage its spatial pattern actively poses opportunities as well as risks. The spatial pattern of typical fisheries facilitates localizing the impacts of mobile bottom-contacting gears at spatial scales much smaller than the ecological scales at which ecosystem relationships give the system its dynamic functional properties and resilience. Management can use this feature of fisheries as a core part of risk reduction strategies, so overall ecosystem processes can be protected, even though some local sites may be impacted substantially. However, in doing so the potential impacts of mobile bottom-contacting gears on significant site-restricted benthic features needs to considered, so the fisheries do not become localised in areas with particularly ecologically or biologically significant features.

In the application of precaution for managing the ecosystem effects of any human activity, the capacity of ecosystem components to recover from perturbations is an important consideration. With regard to possible biological goals for recovery of benthic populations, communities, and habitats, several points were noted:

- There is ample evidence that habitat impacts from mobile bottom-contacting gears are occurring in Canada.
- In the areas of Canada where most research on benthic impacts has been conducted and where fisheries with mobile bottom-contacting have long histories of operation, the research results indicate that the known direct impacts are spatially local and temporally reversible on scales of months to years. Therefore the known impacts on ecological or biological functions by recent fisheries using mobile, bottom-impacting gears are at local scales and not at scale of whole ecosystems.
- Little effort is being invested in Canada to quantifying the indirect ecological consequences of habitat impacts. However, from international studies there is ecological evidence that where impacts occur on spatial scales large enough to alter ecological processes at the ecosystem scale, these impacts have ecosystem consequences.
- Consequently priority should be given to improving our knowledge of the functional significance of habitat features that are impacted by fishing (and all other human activities) to clarify the degree to which both short-term and cumulative impacts are occurring on ecosystem-relevant scales as well as local scales.

Other Science Considerations

The science task of placing the impacts of mobile bottom-contact gears (and all other ecosystem effects of fishing) into ecosystem scale contexts that are particularly relevant to management is not simple. Long-term scientific studies are important to assess such benthic impacts of fishing (or any other human activity). There are several important considerations regarding scientifically sound long-term studies:

- Impacts of fishing gears and ecosystem responses are commonly discussed on three general time frames – Immediate or short term (1-3 years), intermediate (3-10 years), and long-term (10+ years);

- Based on information from a few international studies of benthic populations and communities, documenting the magnitude and pattern of natural variation in benthic communities that provides the background for evaluating any ecosystem effects of fishing would be expected to require 2-3 decades. This is a longer period than the time since the Atlantic groundfish closures in the early 1990's, so even areas not trawled since the groundfish closures have not had an ecologically "long" time to recover from perturbations due to fisheries.

- Even multi-decadal studies are inadequate for measuring the response of biogenic and geomorphic features such as corals after impacts from fishing gears. Recovery of these areas is expected to require multi-centuries, and may not occur at all for some physical features.

- "Best practices" in science advice highlight that it is necessary to provide clear user-warnings and qualifications on scientific advice for decision-making when background variation is not well quantified. This should be particularly the case for advice on impacts of managed activities that are difficult to partition from changes due to other causes, or impacts that may not show up in short-term monitoring. These conditions are likely to apply to evaluating impacts of fishing on benthos as much or more than impacts on other parts of an ecosystem. Moreover it is particularly important for such "best practices" in science advice to be applied with regard to potential benthic impacts because:
    - It is well documented by Canadian and international studies that the benthos plays a particularly crucial role in ecosystem functioning. This is yet another justification to consider the application of precaution when formulating such advice.
    - Benthic communities may be particularly vulnerable to invasive species impacts, although this point remains a conjecture at this time. However, the additional risk makes it particularly challenging to establish baselines against which to measure scientifically the impacts of fishing and other activities.

With such challenges associated with conducting long-term studies for assessing the impacts of fishing on benthic populations, communities and habitats, it is attractive to conduct experimental studies and use on-going monitoring to help fill key knowledge gaps. Unfortunately, it is often very difficult to meet high scientific standards for good experimental study design because of the nature of studying the impacts of fishing in benthic populations, communities, and habitats. This is especially the case in studies of benthos because:

- There are so many areas where fishing has a long history, or where the history is unknown, so non-disturbed comparative sites are difficult to locate with certainty.

- Benthic systems are "noisy" with lots of background variance to address in monitoring and experimental designs, so detecting signals due to human activities in the background noise will be difficult.

- The study designs often must confound site-specific characteristic with the scientific treatments, as an individual site can only be fished or not fished, but not both.

Again "best practices" in science advice require the provision of clear user-warnings and qualifications on advice for decision-making to use caution in interpreting results from studies where there are imperfect scientific designs. All the above points highlight that – areas closed to fishing in the long term have special value for scientific study. However, even these cannot be considered true "controls" in the sense of good experimental design for evaluating impacts of mobile bottom-contacting gears on benthic populations, communities, and habitats, because they will be different from sites where fishing is allowed in *all* the ways that fishing affects marine ecosystems, and not just in the possible benthic impacts. Nonetheless, monitoring or research at such sites are particularly important in trying to develop the best science understanding and advice possible for benthic impacts of fishing gears. This importance arises because for the benthos, Science usually lacks even the descriptive background information on distribution and abundance of species in space and time that often exists (although with high variance) for fish communities because of the history of scientific trawl surveys.

A final consideration with regard to designing monitoring programmes, experiments, and other types of studies to assess the effects of mobile bottom-contacting gears on benthic populations, communities, and habitats that there is an initial "unfriendliness of spatial scales" that needs to be addressed in designing any evaluation programmes.

- The best scales to measure direct impacts of mobile bottom-contacting gears on properties of the seafloor are centimetres to a few 100's of meters;
- The key functional properties of the coupled benthic-demersal and the pelagic ecosystems can be determined at spatial scales from occasionally a few km^2 to often 1,000's of km^2;
- Often the scales of concentrated fishery operations are a few 10's to a few 100's of km^2; and
- The most convenient scales of management have traditionally been on several 100's to 1000's of km^2.

The scale of incompatibilities in management has proven tractable in many cases. As management takes account of habitat impacts of fishing, it is feasible to move management down to spatial scales of 10's of km; spatial scales at which fishing operations can respond readily. Scallop and clam dredging can be managed and operated at even smaller spatial scales possibly allowing the management of impacts at the same scale at which they can be measured. Management tools including Vessel Monitoring System (VMS) and observers may facilitate managing impacts of most mobile bottom-contacting on spatial scales that are both readily measured and are appropriate for protection of local features of benthic habitats, and individual populations that may need enhanced protection. Where management is achieving conservation and sustainable use on such spatial scales, with current knowledge it is highly likely that key ecosystem processes arising from the benthic coupling with the demersal and pelagic systems are also being protected. However, there is still substantial scientific uncertainty about this issue, and it should be revisited as additional relevant information is acquired.

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