INTERIM GUIDE TO THE APPLICATION OF SECTION 35 OF THE *FISHERIES ACT* TO MARINE SALMONID CAGE AQUACULTURE

Fisheries and Oceans Canada

February 15, 2002

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This guide will be reviewed and updated on a regular basis to reflect recent research findings, changes in aquaculture technologies and practices, and new legislative and policy initiatives.

Comments or feedback on the content and format are welcome and will be incorporated into future versions, as appropriate. Please send any comments to:

Office of Sustainable Aquaculture
Fisheries and Oceans Canada
200 Kent Street
Ottawa, Ontario
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Table of Contents

1.0 INTRODUCTION

The federal Minister of Fisheries and Oceans Canada (DFO) is responsible for the administration and enforcement of Section 35 of the *Fisheries Act*. When reviewing project proposals, regional Habitat Management staff determines what effects the project may have on fish habitat. This is done in accordance with the *Policy for the Management of Fish Habitat* (DFO, 1986) and with Subsection 35(1) of the *Fisheries Act* which states that "no person shall carry on any work or undertaking that results in the harmful alteration, disruption or destruction (HADD) of fish habitat" except when authorized by the Minister, DFO, as contemplated in subsection 35(2) or through regulations under the *Fisheries Act*.

This document was developed in response to the rapid growth of the aquaculture industry to provide a practical and nationally consistent approach to the application of Section 35 to salmonid cage aquaculture developments. The determination by DFO Habitat Management assessors of whether a project has the potential to result in a HADD of fish habitat related to organic deposition is aided by the document, *Decision Framework for the Determination and Authorizations of Harmful Alteration, Disruption or Destruction of Fish Habitat* (DFO, 1998(a)). In the case of aquaculture, additional direction is required to assist assessors in determining whether an aquaculture project could cause a HADD of fish habitat.

The guide describes a strategy that incorporates:

- Performance-Based Standards (PBS) (Appendix 1) which are physical or chemical indicators that approximate and rank the quality of fish habitat in an area. The PBS approach advocated in this guide has been proven the most cost-effective method (Wildish, et al. 2001) in terms of speed and simplicity of use for monitoring benthic effects while providing sufficient information to assess the potential fish habitat effects relative to the section 35 requirements of the *Fisheries Act*. As scientific knowledge expands, these standards may be refined;

- risk assessment which combines knowledge of the existing pre-project site conditions and the operation itself to determine the appropriate instrument to ensure that mitigation and monitoring requirements are respected; and

- adaptive management which uses monitoring results to accommodate uncertainty with respect to the effectiveness of measures to prevent a HADD and ecosystem complexity to permit early intervention through additional mitigation or avoidance to control a potential HADD from developing.

The guide was developed from an in-depth examination of the issues by the National Habitat Management Working Group on Aquaculture (NHMWGA) and it captures many of the main concerns expressed in those discussions. In addition, it incorporates the experience of aquaculture monitoring in New Brunswick, British Columbia, and the work of DFO scientists.

It is an interim strategy which, over the longer term, may be replaced or complimented by other approaches such as: regulations under section 36 or 43 of the *Fisheries Act*, integrated management, ecosystem-based objectives, marine environmental quality (MEQ) criteria, class screenings, and siting guidelines, as the science associated with these develops. Therefore, DFO should review the guide after it has been in use for 24 months. The review should determine, among other things, the ongoing need for the document or specific sections of it.

There are several options available to DFO to ensure the mitigation, monitoring, and reporting requirements are met. They provide varying levels of assurance that these needs can be met. These options are discussed in Appendix 2.

This document is not intended to provide technical details of benthic monitoring. General guidance on this may be found in Wildish et al (1999). Specific details must be developed on a regional, ecosystem, or even a case-by-case basis.

2.0 THE STRATEGY

2.1 Application of the Strategy

The strategy focuses on the potential negative benthic effects of the project on fish habitat. Therefore, it will apply to all new projects, proposed expansions, and relocations of salmonid cage culture regardless of the size of the operation.

Cod grow-out sites, are not included in this strategy. It is believed that the risks associated with cod grow-out as presently conducted in Newfoundland and Quebec are substantially less than with more traditional types of operations such as salmonid cage aquaculture. This assumption is based on the type of feed used, the length of time the fish are held in cages, and the fact that the stock is captured wild instead of using hatchery stock. Cod grow-out may be included in subsequent versions of this strategy if research indicates the need.

2.2 Anticipated Benefits

This strategy is expected to have several benefits:

- It should encourage proponents to seek out sites where the effects of aquaculture on fish habitat will be minimised.
- It will enable the acquisition of data to enhance the knowledge of the effects of aquaculture operations on fish habitat. This will, in turn, allow for more comprehensive and permanent solutions such as scientifically defensible siting guidelines, class screenings, and possibly regulations. It will also aid in the development of new tools that will more accurately predict impacts and effects.
- It will address the proponent's section 35 responsibilities with respect to the near-field effects on habitats.

2.3 Assumptions

This strategy was developed around a number of assumptions.

The *Habitat Conservation and Protection Guidelines* (DFO, 1998) will be followed as appropriate with respect to assessing other options, such as project relocation and redesign, (3.0 and 3.1).

To make effective decisions on the likelihood of a HADD, it is necessary that the *Guide to Information Requirements for Environmental Assessment of Marine Finfis Zquaculture Projects* be followed to permit an accurate assessment of the risks to fish habitat as the result of the project as it includes requirements for baseline information.

3.0 PROJECT ASSESSMENT

This section describes the process to identify the appropriate instrument to ensure that the principle of no net loss of the productive capacity of fish habitat is respected. The instrument identification will be based on benthic baseline conditions combined with risk assessment and an adaptive management approach to ensure that the principle of no net loss of the productive capacity of fish habitat is respected.

3.1 Determining Benthic Baseline Conditions

The initial step is to determine the pre-development benthic baseline site conditions, using a variety of physical or chemical proxies that rank the quality of fish habitat in an area. The results of this analysis should characterize the benthos within the scope of the project as oxic, hypoxic, or anoxic. Appendix 1 provides a more detailed explanation of determining benthic baseline conditions.

3.2 Risk Assessment

Risk assessment integrates the results of the baseline conditions with the information on the project and its operation. This information is obtained from the proponent through the *Guide to Information Requirements for Environmental Assessment of Marine Finfish Aquaculture Projects* (DFO, 2001) which the proponent will complete. As decisions at this point are very much on a case-by-case basis, additional information, such as local knowledge and expertise within DFO should be used as the assessor determines necessary.

Decisions at this point should be guided by the hierarchy of conservation and protection preferences of project relocation, redesign, mitigation, and compensation as outlined in the *Habitat Conservation and Protection Guidelines* (DFO, 1998(b)).

The result of this analysis will enable DFO to conclude that:

- a HADD is not anticipated to result from this project;
- there is uncertainty with respect to the effectiveness of measures to prevent a HADD; or
- a HADD will result from this project.

This initial risk assessment then determines the appropriate instrument (Table 1) to ensure that the mitigation and monitoring requirements are respected.

Table 1: Risk assessment categories with proposed instrument

Assessed risk of a HADD	Proposee instrument
HADD not anticipated to result	Letter of Advice
Uncertainty with respect to the effectiveness of measures to prevent a HADD	HADD Avoidance, Mitigation, and Monitoring Agreement
HADD will result	Subsection 35(2) Authorization (or reject as proposed)

4.0 PROPOSED INSTRUMENTS

4.1 Letter of Advice

In the case of salmonid aquaculture proposals where a HADD of fish habitat is not anticipated to result from organic enrichment, the preferred instrument would be a Letter of Advice (LOA) (see Appendix 4, templates 1A and B; Appendix 5, chart 1).

The LOA should clearly outline the proposed work or undertaking and the manner of carrying it out which led DFO to conclude that the project is not anticipated to result in a HADD. The LOA could also recommend regular monitoring and, based on evaluation of the monitoring report, additional mitigation measures, or changes in the operation's location or production levels. Site remediation may also have to be considered.

In all cases, the LOA should state that the document is not a subsection 35(2) Authorization. It should also reserve DFO's rights to take any appropriate actions under the *Fisheries Act*.

4.1.1 Monitoring Results and LOAs

If subsequent monitoring during the operational phase indicates that a HADD could be a concern in the future in spite of the original assessment, the proponent may apply for a subsection 35(2) Authorization as outlined in this document and Appendix 5, Chart 3. It is important to note that this is not a retroactive Authorization. Whether the proponent carried out the work or undertaking in the manner described in the LOA will be a factor considered in the decision to issue or not issue a s.35(2) Authorization. DFO is not obligated to issue an Authorization and will be guided by the *Decision Framework for the Determination and Authorization of Harmful Alteration, Disruption or Destruction of Fish Habitat* (DFO, 1998(a)).

4.2 HADD Avoidance, Mitigation, and Monitoring Agreement

In the case of salmonid aquaculture proposals, where there is uncertainty with respect to the effectiveness of measures to prevent a HADD, the preferred option is a HADD Avoidance, Mitigation, and Monitoring Agreement developed between the proponent and DFO (see Appendix 4, template 2; Appendix 5, chart 2).

Aquaculture projects should be assessed and regulated in the same manner as projects in other industry sectors. However, there is often uncertainty about the effectiveness of measures to prevent a HADD. Marine ecosystems are complex and dynamic. Our understanding of them and our ability to predict how they might react to management actions especially on a larger scale is relatively limited. In addition, our experience with aquaculture perturbation in the far-field and cumulative effects is inadequate in many instances. It is necessary to address this uncertainty in a manner that will ensure that there is no net loss of the productive capacity of fish habitat.

To compound this uncertainty, it is necessary to address the effects of the operational phase of the project. Unlike many other industry sectors where the operation is a consideration, aquaculture inputs of organics can vary greatly and irregularly depending on such variables as the season, fish size and type, chemical use and market conditions.

In these situations, a Letter of Advice is not adequate to address concerns, and a more responsive instrument, a HADD Avoidance, Mitigation, and Monitoring Agreement will be used as an adaptive management approach to deal with this uncertainty. The use of such agreements is a formal, systematic, and rigorous approach to learning from the outcomes of management actions, accommodating change, and improving management.

The Agreement should outline mitigation, monitoring and reporting, agreed upon by DFO-Habitat Management and the proponent and the possible need for remediation measures. Monitoring requirements should be detailed in the Agreement and based on performance-based standards. The Agreement should also indicate the need for regular monitoring reports to be submitted to DFO along with the supporting data and state that the document is not a subsection 35(2) Authorization. It should provide for a security of costs should the proponent fail to comply with the terms and conditions. The Agreement should also contain a statement that reserves DFO's rights to take appropriate actions under the *Fisheries Act*.

If a proponent does not wish to enter into an agreement, the Authorization option may be considered if the proponent files an application in the form set out in Schedule VI to the *Fisheries (General) Regulations*.

Assessors are advised to consult with DFO Legal Services when drafting agreements.

4.2.1 Monitoring Results and Agreements

Based on the results of the operational phase monitoring reports, additional mitigation measures or remediation may be required. Additional recommendations arising from the evaluation of these monitoring reports might include further mitigation, site remediation, or changes in the operation's location and/or production.

If the results of the monitoring confirm that the site is operating within the conditions of the Agreement, the Agreement may be continued and the monitoring cycle repeated at the agreed-upon interval. If the results indicate a change from baseline conditions that has not resulted in a HADD where enforcement action would be warranted, but a HADD could be a concern in the future, two options may be considered:

- The Agreement may be modified to reflect changes required in mitigation and the cycle of monitoring. This contingency would be stated in the original Agreement.

- The proponent may apply for a subsection 35(2) Authorization as outlined in this document and Appendix 5, Chart 3 if a HADD is likely to occur. This is not a retroactive Authorization. Whether the proponent has respected the terms and conditions of the Agreement will be a factor considered in the decision to issue or not issue a s.35(2) Authorization. DFO is not obligated to issue an Authorization and will be guided by the *Decision Framework for the Determination and Authorization of Harmful Alteration, Disruption or Destruction of Fish Habitat* (DFO, 1998(a)).

4.3 Subsection 35(2) Authorization

In the case of salmonid aquaculture proposals, when the risk assessment predicts that a HADD will, or is likely to, result from organic enrichment, the only option is to determine if a subsection 35(2) Authorization can be issued (see Appendix 4, template 3; Appendix 5, chart 3).

DFO is not obligated to issue an Authorization and will be guided by the *Decision Framework for the Determination and Authorization of Harmful Alteration, Disruption or Destruction of Fish Habitat* (DFO, 1998(a)) especially in situations where adverse effects to fish habitat are judged to be unacceptable. Examples of unacceptable HADDs are outlined in Appendix 6. In addition, an Authorization will not be considered until the options outlined in the *Habitat Conservation and Protection Guidelines* (DFO, 1998(b)) have been adequately considered.
If a decision is made to issue the Authorization, the Authorization could include the following conditions:

- the specific mitigation measures to be undertaken by the proponent;

- the specific limits of organic enrichment and the compensation required to offset the loss of habitat that will result as per the *Policy for the Management of Fish Habitat* (DFO, 1986). Compensation options, other than those on-site may have to be considered. The proponent is responsible to undertake compensation;

- the specific monitoring required and monitoring cycle; and

- the need to provide security for costs should the proponent fail to comply with the terms and conditions of the Authorizations (e.g. letter of credit).

To provide some measure of security to the proponent, the Authorization validation period should not exceed the period of time of the NWPA approval, if such approval is required for the proposed work or undertaking. If an NWPA approval is not required, the Authorization period should not exceed 5 years, but may be of shorter duration.

4.3.1 Monitoring Results and Authorizations

Monitoring is vital to determine if mitigation is working and to ensure the terms of the Authorization are being respected. If the results of the operational phase monitoring confirm that the site is operating within the conditions of the Authorization, the Authorization will continue and the monitoring cycle will be repeated at the interval determined in the Authorization. If the monitoring results indicate that the operation has exceeded the conditions of its Authorization, then appropriate enforcement action will be considered.

4.4 Changes to Monitoring Cycle or Production Levels

In cases of LOAs and HADD Avoidance, Mitigation, and Monitoring Agreements, where monitoring has repeatedly indicated no change of concern from baseline conditions, increasing the time between monitoring cycles could be considered. Alternatively, an increase in the production levels could be considered. These changes would be at the discretion of the assessor on a case-by-case basis. They are based on DFO's assessment of productive capacity.

APPENDIX 1: DETERMINING BENTHIC BASELINE CONDITIONS

In determining benthic baseline conditions it is necessary to use a variety of physical and chemical proxies or indicators that approximate and rank the quality of fish habitat in a particular area. Indicators include parameters such as percent volatile organic solids in sediment, production of sulfides, and sediment redox potential. These are used to assess the quality (i.e. performance) of benthic receiving environments, rather than assessing what has been released into the environment and predicting the effects.

This information is then used in conjunction with information supplied on the operation of the site itself to determine the actual risk of a HADD occurring. It is based on the anticipated change in the benthic community at or near the site as defined by the presence of characteristic microfauna and/or geochemical measures of redox (Eh) or sulfides (S^{--}). Janowicz and Ross (2001) and Ross (2000) describe how these are used to monitor the effects of aquaculture on fish habitat in New Brunswick. From this assessment it is possible to determine which of the three instruments described in the strategy should be used. A guide to information requirements is currently being developed to ensure that this baseline data is collected (DFO, 2001) to conduct both fish habitat and CEAA assessments.

Realistic performance-based standards (PBS) provide regulators with a fair, accurate, and objective method of ensuring compliance with regulatory requirements. They also provide site operators with the opportunity to better understand the environmental conditions near their site and the potential consequences these could have on their operations.

The PBS advocated in this guide have been determined by Wildish et al. (2001) to be the most cost-effective method, in terms of speed and simplicity of use, for monitoring benthic effects while providing sufficient information to address issues related to fish habitat. The PBS determined for New Brunswick are provided in Appendix 3 as an example of the standards in use in the Maritimes Region.

Areas that naturally receive a heavy load of organic matter will quite often have anoxic sediments, but these will invariably be covered with at least a veneer of oxidized sediment. The infaunal benthic community will be effected, but epifaunal organisms do not experience unnatural habitat. This natural condition indicates that this system is already at or near its loading capacity for organic input. Therefore the incremental effects of loading from fish culture will be extreme and the potential for negative feedback on the culture operation is high.

PBS Related Monitoring

PBS are used to understand the changes in the benthic conditions at a site as operations are underway. Based on the results of this monitoring, additional remediation may be required. The key to effectively conserving and protecting fish habitat from the effects of aquaculture operations is through the application of an adaptive management approach, closely monitor effects, and mitigate those effects of concern and the specifics would be included in the Agreement or Authorization

The effects that result from the operation of aquaculture sites clearly depend on the pre-development conditions in the area where the site is located and how the site is operated. There is a substantial body of knowledge that allows operators to manage husbandry and operational variables to mitigate a significant proportion of effects. Measures, such as fallowing, can be used to accelerate the restoration process. There are several mechanical measures available that have unproven results. These measures should not be considered as substitutes for good site location and may be considered for existing sites only where permitted.

Validating PBS

This technique must be validated for different geographic regions and ecosystems in areas where aquaculture is practised.

Adopting other PBS

Where individual provinces have developed PBS strategies for monitoring these may be considered for use by DFO provided the data obtained meets DFO's requirements and DFO has unrestricted access to, and use of, all the data.

APPENDIX 2: PROPOSED INSTRUMENTS

DFO-Habitat Management can use several instruments to pursue its section 35 requirements. These are discussed based on their relative ease-of-use; their appropriateness in a given situation; and the anticipated risks associated with the project.

Subsection 35(2) Authorization

Under subsection 35(1) of the *Fisheries Act*, any harmful alteration, disruption or destruction (HADD) of fish habitat is prohibited unless authorized under subsection 35(2). The Authorization can provide the means and conditions with which the proponent can cause a HADD. These conditions could include methods of operation, mitigation measures, monitoring and reporting requirements, and the requirement to undertake remediation and compensation if required. The proponent would be in contravention of subsection 35(1) if these conditions are not met.

Subsection 36 and 43 Regulations

Regulations can be enacted under the *Fisheries Act* for carrying out the purposes and provisions of the Act. Sections 36 and 43 provide the authority to make regulations for certain purposes. Under such regulations, DFO-Habitat Management could prescribe conditions to be followed for various fish and fish habitat related issues associated with the aquaculture operations.

Requests for Information

Sections 37 and 61 of the *Fisheries Act* have provisions that oblige individuals to provide DFO, in certain situations, with information, data, and/or reports when requested to do so.

A request for information under section 37 of the *Fisheries Act* may be made when a work or undertaking results or is likely to result in a HADD. This authority is exercised by the Minister to determine if the HADD would constitute an offence under the Act and what measures could, if any, prevent that result or mitigate the effects.

Section 61 of the *Fisheries Act* also creates the obligation to provide information requested by a fisheries officer if regulations, or the terms and conditions of a lease or licence issued under the Act, requires keeping this information on record.

APPENDIX 3: EXAMPLE OF THE USE OF PBS

The following are the redox and sulfide Performance-Based Standards (PBS) used in Maritimes Region to define benthic conditions under salmonid cages. This table is provided as an example only. Specific relationships between redox, sulfides, and biological resources must be developed to meet specific (e.g. site regional, geographic) conditions.

sediment condition	EMG* rating	redox (mV)	sulfides (*uM*)
Oxic 1	A	>+100	<300
Oxic 2	B	0 to 100	300 to 1300
Hypoxic	B-	0 to -100	1300 to 6000
Anoxic	C	<-100	>6000

* EMG: Environmental Management Guideline (NBDAFA, 2000)

The following is from the EMG for salmonid aquaculture in New Brunswick. It describes unacceptable habitat concerns that would trigger some level of enforcement action. The EMG also describes additional requirements such as remediation, mitigation, etc. that would apply at other levels of impact.

> "For the purposes of salmonid aquaculture, unacceptable habitat concerns occur when the sediment becomes anoxic. This is defined by the absence of macrofauna, a change from aerobic to anaerobic microflora, or by geochemical measurements of sulfide in excess of 6000*uM* and a negative redox potential (Eh). Hypoxic conditions, as defined either by the presence/absence of macrofauna, microflora or by geochemical measurements of sulfide and redox potential, would be of concern to DFO. In cases where hypoxic conditions are demonstrated, remediation measures would be indicated to mitigate the situation and to prevent further progression to anoxia." (NBDAFA, 2000, p17)

APPENDIX 4: TEMPLATES FOR PROPOSED INSTRUMENTS

Template	Proposed instrument	Associated risk of a HADD	See chart
1A	Letter of Advice	HADD not anticipated to result	1
1B	Letter of Advice	HADD not anticipated to result with proposed modifications to the project	1
2	HADD Avoidance, Mitigation, and Monitoring Agreement	uncertainty with respect to effectiveness of measures to prevent a HADD	2
3	ss 35(2) *Fisheries Act* Authorization	HADD will result	3

Template 1A Letter of Advice (HADD not anticipated to result)

Fisheries and Oceans
Pêches et Océans

DATE

NAME
ADDRESS

SUBJECT:

Dear :

Fisheries and Oceans Canada (DFO) has received your proposal to [describe the aquaculture operation]. To expedite future correspondence or inquiries, please refer to your file number when you contact us.

FILE # : FILE NAME

It is our understanding that your proposal consists of:

- List proposed works or undertaking (e.g. size and number of cages, species cultured, stocking densities)
- List related activities (e.g. maintenance activities, harvesting, feeding)

as outlined in the following plans:

- List relevant documents, engineering diagrams, letters, faxes, conversations etc.

If these plans have changed since the time of your submission, the advice provided in this letter may not be applicable to your circumstances and you should consult with us to determine if further review is required.

DFO believes that your proposal, as set out above, does not require an Authorization at this time. This position does not constitute an Authorization to harmfully alter, disrupt or destroy fish habitat. DFO may revisit this position at any time if a harmful alteration, disruption or destruction of fish habitat occurs as a result of your proposal. Subsection 35(1) of the *Fisheries Act* states:

> *"No person shall carry on any work or undertaking that results in the harmful alteration, disruption or destruction of fish habitat."*

To ensure that this operation does not result in a harmful alteration, disruption or destruction of fish habitat, DFO recommends that you undertake regular monitoring as described in the attached document and report the results to: [provide contact name and mailing address].

Please note that this Letter of Advice does not release you from the responsibility for obtaining any other approvals that may be required under federal, provincial or municipal legislation.

If you have any questions concerning the measures listed, or should there be any changes to the proposed work, please contact me directly at ( ) .

Fish Habitat Biologist
Fish Habitat Management

Copy:

Template 1B Letter of Advice with Mitigation
(HADD not anticipated to result)

Fisheries and Oceans / Pêches et Océans

DATE

NAME
ADDRESS

SUBJECT:

Dear :

Fisheries and Oceans Canada (DFO) has received your proposal to [describe the aquaculture operation]. To expedite future correspondence or inquiries, please refer to your file number when you contact us.

FILE # : FILE NAME

It is our understanding that your proposal consists of:

- List proposed works or undertaking (e.g. size and number of cages, species cultured, stocking densities)
- List related activities (e.g. maintenance activities, harvesting, feeding)

as outlined in the following plans:

- List relevant documents, engineering diagrams, letters, faxes, conversations etc.

If these plans have changed since the time of your submission, the advice provided in this letter may not be applicable to your circumstances and you should consult with us to determine if further review is required.

Your proposal, as described above, is not adequate to avoid a harmful alteration, disruption or destruction (HADD) of fish habitat. However, if the following changes to the project are made and implemented, it is our opinion that a HADD will not occur.

1. Measure 1
2. Measure 2
3. Measure 3

With the additional measures outlined above, DFO believes that your proposal does not require an Authorization at this time. This position does not constitute an Authorization to harmfully alter, disrupt or destroy fish habitat. DFO may revisit this position at any time if a harmful alteration, disruption or destruction of fish habitat occurs as a result of your proposal. Subsection 35(1) of the *Fisheries Act* states:

> *"No person shall carry on any work or undertaking that results in the harmful alteration, disruption or destruction of fish habitat."*

To ensure that this operation does not result in a harmful alteration, disruption or destruction of fish habitat, DFO recommends that you undertake regular monitoring as described in the attached document and report the results to: [provide contact name and mailing address].

Please note that this Letter of Advice does not release you from the responsibility for obtaining any other approvals that may be required under federal, provincial or municipal legislation.

If you have any questions concerning the measures listed, or should there be any changes to the proposed work, please contact me directly at ( ) .

Fish Habitat Biologist
Fish Habitat Management

Copy:

Template 2 HADD Avoidance, Mitigation, and Monitoring Agreement

**HADD HABITAT AVOIDANCE, MITIGATION,
and MONITORING AGREEMENT**

BETWEEN: HER MAJESTY IN RIGHT OF CANADA as represented by THE DEPARTMENT OF FISHERIES AND OCEANS, CANADA ("DFO")

AND PROPONENT NAME, proponent's designation (e.g. a corporation incorporated pursuant to the laws of (Province) ("PROPONENT")

HEREINAFTER REFERRED TO AS THE PARTIES

Whereas the proponent made representations to DFO to the effect that the proposed aquaculture facility is not likely to result into a harmful alteration, disruption or destruction of fish habitat (HADD);

Whereas DFO is uncertain of the effectiveness of measures to prevent a HADD;

Whereas the Parties wish to enter into an agreement setting out the terms pursuant to which an aquaculture site in [proposed location] can be established;

Now therefore, in consideration of the sum of one dollar ($1.00), the receipt and sufficiency of which is hereby acknowledged, the Parties agree as follows:

- The Proponent can establish an aquaculture facility at [lease number and location] once:
  a) the approval for that site has been issued by DFO pursuant to the *Navigable Waters Protection Act*;
  b) the baseline studies, conducted by the Proponent, covering the area underneath the aquaculture structures have been completed to DFO's satisfaction, which will be acquiesced to in writing by DFO; and
  c) the peripheral areas to the aquaculture facility that are requiring additional baseline studies have been identified by the Proponent to DFO's satisfaction, which will be acquiesced to in writing by DFO.

  The aquaculture operation and the site location are more fully described in Schedule A to this Agreement.

The following points should be considered in developing individual agreements:

- the conduct, completion, and reporting of baseline studies;
- the development of environmental management and monitoring requirements;
- outline options if monitoring indicates a change from baseline conditions that is of concern;
- letter of credit to ensure monitoring and mitigation;
- provisions for contingency site if required;
- provision to modify/amend contract;
- any other points that may be required on an individual basis.

- Nothing in this Agreement shall be construed or interpreted as limiting DFO's powers to enforce its legislation.

- This Agreement is not an authorisation pursuant to subsection 35(1) of the *Fisheries Act* nor does it constitute a permission, advice or approval of any form regarding the alteration, disruption or destruction of fish habitat.

- This Agreement shall come into force on the date on which it has been executed by both Parties and shall remain in force for a period of five years.

- Any notice, report, request or order under this Agreement shall be in writing and shall be addressed to the appropriate Party as follows:
- For DFO: [Name and mailing address of Regional Director General]
- For Proponent: [Name and mailing address of the proponent's designate]

- Neither Party may assign this Agreement without the prior written consent of both Parties.

- The laws in effect in the Province of [province or territory where the aquaculture site is located] shall apply to the interpretation and administration of this Agreement.

- The terms and conditions herein, together with Schedules A and [other schedules added], form the entire Agreement of the Parties with respect to this aquaculture site.

DFO has executed this Agreement by its duly authorised representative, and [proponent] has affixed its corporate seal under the hands of its duly authorised officer.

______________________	______________________
Witness (Signature)	The Department of Fisheries and Oceans, Canada ("DFO")
______________________	______________________
(print name)	Date
______________________	______________________
Witness (Signature)	[Proponent]
______________________	______________________
(print name)	Date

Schedule A
Site Description

[Give a description of the operation and the location of the proposed site]. Site coordinates are as listed below.

- **Give the geographic coordinates of the site**
- **Specify the datum used.**
- **Give the area of the proposed site.**

Template 3 Authorization

ss 35(2) *Fisheries Act* Authorization

[number]
Authorization No.

AUTHORIZATION FOR WORKS OR UNDERTAKINGS EFFECTING FISH HABITAT

Authorization issued to (herein referred to as the proponent):

Name:
Address:

Telephone No.: ( ) -
Facsimile No.: ( ) -

Location of Project

- [description of location]
- [geographic location]

Valid Authorization Period

The valid authorization period for the harmful alteration, disruption or destruction associated with the operation of the finfish net cages is five years from the date of issuance.

Description of Works or Undertakings

– Describe the works or undertakings proposed. (e.g. size and number of cages, species cultured, stocking densities, maintenance activities, harvesting, feeding)

– Describe the specific HADD(s) being authorized, including specific limits of organic enrichment.

Authorization

The holder of this Authorization is hereby authorized under the authority of subsection 35(2) of the *Fisheries Act*, R.S.C., 1985, c. F. 14, to carry out the work or undertaking described herein.

This Authorization relates only to those works and undertakings described in this authorization. Any changes, modifications, alterations to the aquaculture facilities (e.g. residences, net washing facilities, food storage barges, etc.) including structures that are required to service the facility, are not covered by this authorization and should be subject to another application for authorization under the *Fisheries Act.*

Conditions of Authorization

1. **All debris and waste materials generated by the proponent shall be disposed of in accordance with applicable legislation, guidelines, and best management practices.**

2. Mitigation Measures

   [Specify all mitigation measures required.]

If, while complying with the conditions of the current authorization, a HADD of fish habitat occurs other than the one currently authorized, as indicated by monitoring, the proponent shall apply forthwith for a new Authorization.

3. Monitoring of the Site

   - Outline the monitoring requirements for the proposed operation. This may include:
     - Defining the need for baseline data to be gathered before initiation of the operation;
     - Stipulating that existing provincial or regional monitoring programs or codes of practice be adhered to;
     - Prescribing the scope and detail of monitoring information to be provided and the frequency at which monitoring reports should be filed with DFO;
     - Prescribing sampling methodologies and the technologies to be used.

   - Outlining the monitoring cycle, a description of the content of result reports, and designate an individual to receive monitoring results.
     - DFO should reserve the right to modify the monitoring conditions based on results

- Appendices may be used to outline detailed procedures and requirements
- Where possible, reference should be made to existing monitoring programs
- Monitoring may be required for areas adjacent to the proposed operation if those areas are deemed to essential fish habitat that may be effected by the proposed operation.

Conditions that relate to Compensation

4. [Describe specific compensation measures to be undertaken by the proponent.]

5. The proponent shall supply a letter of credit in a form acceptable to DFO, in the amount of [estimated cost of five (5) years of monitoring and compensation works] to be held as security to ensure the implementation of the mitigation measures and monitoring requirements set out in this Authorisation.

General Conditions

1. This Authorization is valid only with respect to fish habitat and for no other purposes. It does not purport to release the applicant from any obligation to obtain permission from or to comply with the requirements of any other regulatory agencies.

2. Failure to comply with any condition of this Authorization may result in appropriate enforcement action pursuant to the *Fisheries Act*.

3. This Authorization should be held on site and work crews should be made familiar with the conditions attached.

Date of issuance: ______________________

Approved by: ______________________

Title:

The proponent acknowledges that DFO has consulted with it regarding the terms of this Authorization, and confirms that it has reviewed and understands the terms of this Authorization, and it will comply with them.

Executed by an authorized signatory of the proponent on the_________day of ______, 200__ in the presence of:	)	[Proponent's name]
	)	Per:
______________________________	)	______________________________
Witness (signature)	)	Authorized signatory
______________________________	)	______________________________
(print name)	)	Name:
	)	______________________________
	)	Title:

APPENDIX 5: FLOWCHARTS

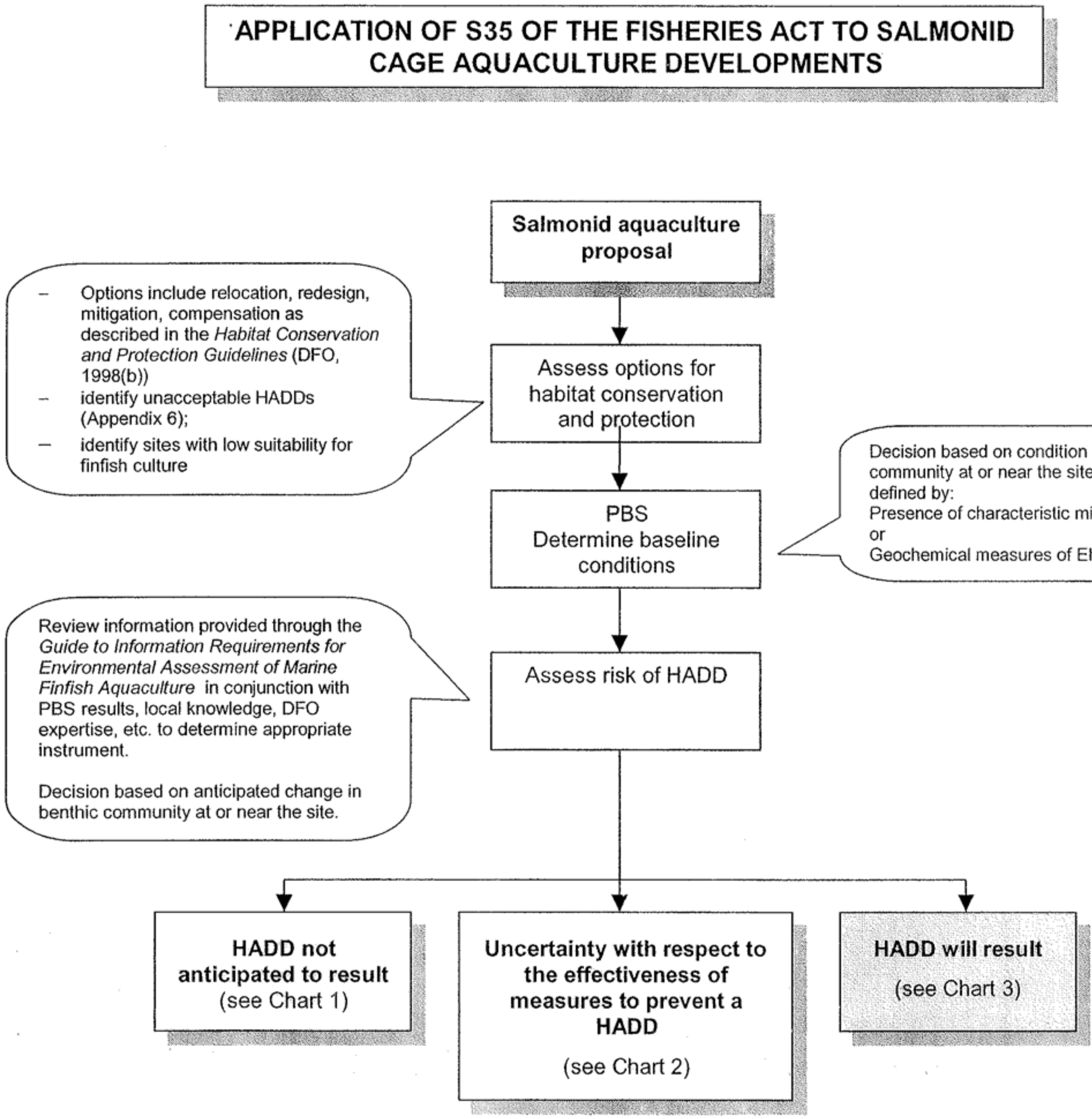


CHART 1

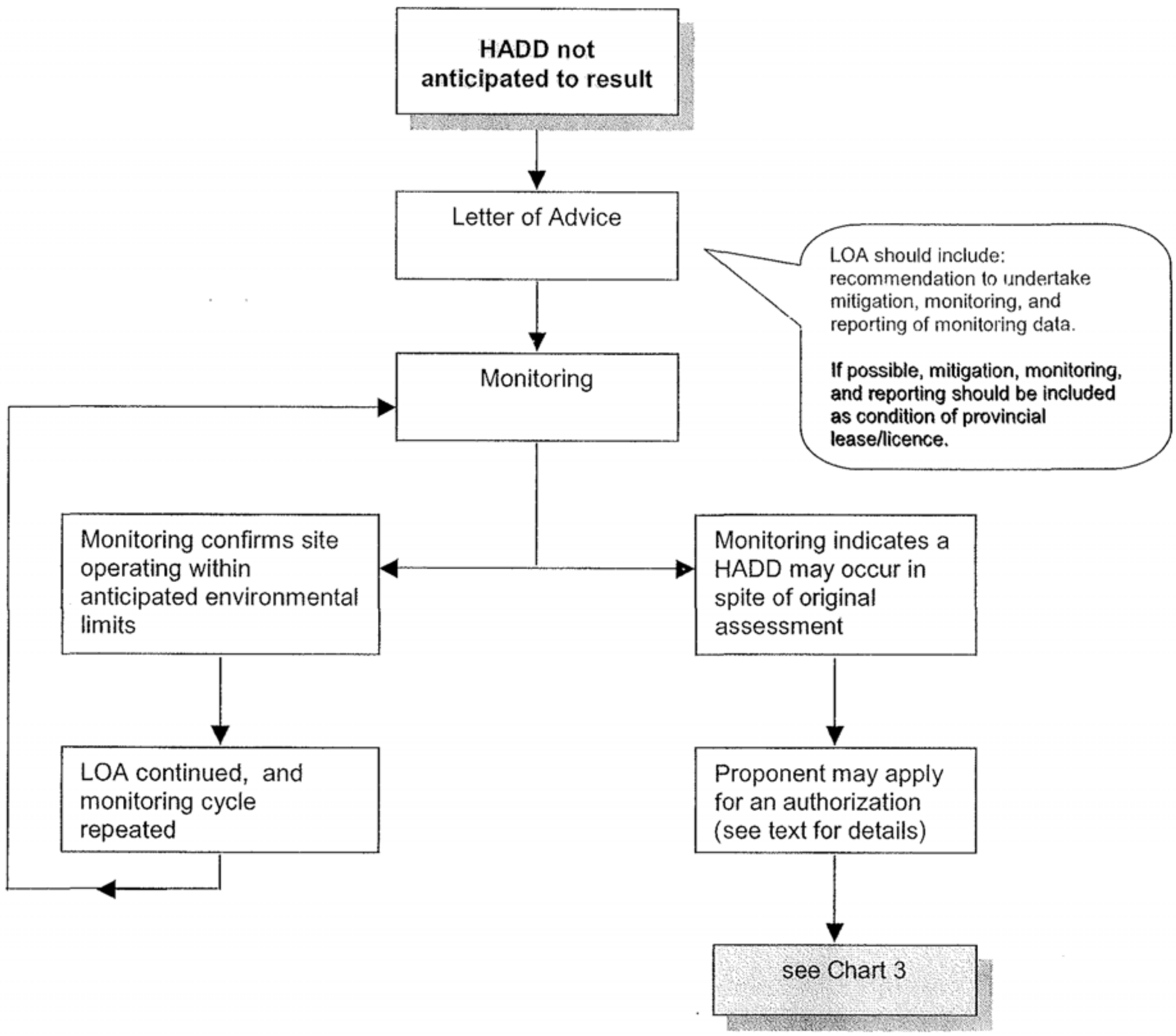

HADD not anticipated to result
Letter of Advice
LOA should include: recommendation to undertake mitigation, monitoring, and reporting of monitoring data.
If possible, mitigation, monitoring, and reporting should be included as condition of provincial lease/licence.
Monitoring
Monitoring confirms site operating within anticipated environmental limits
Monitoring indicates a HADD may occur in spite of original assessment
LOA continued, and monitoring cycle repeated
Proponent may apply for an authorization (see text for details)
see Chart 3

CHART 2

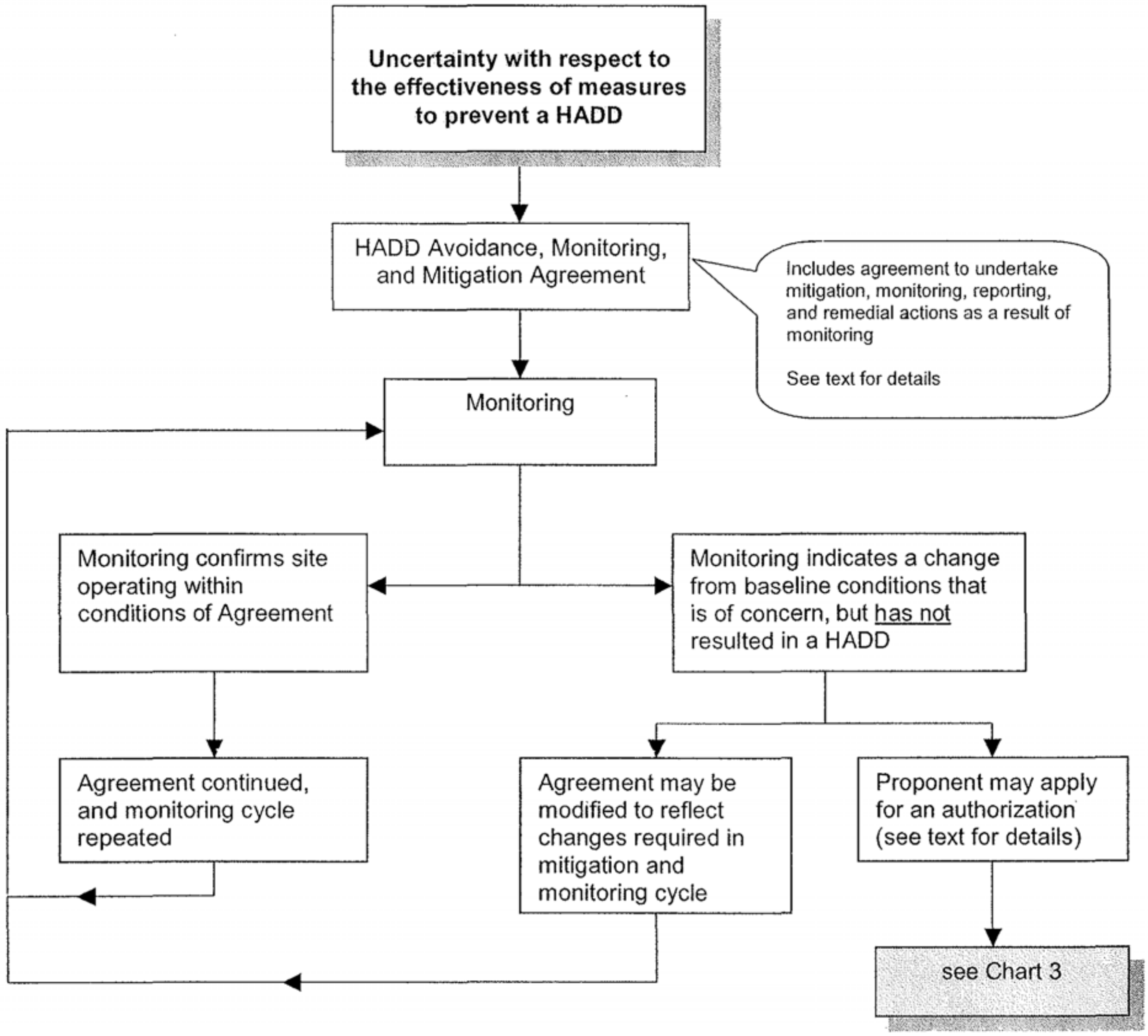
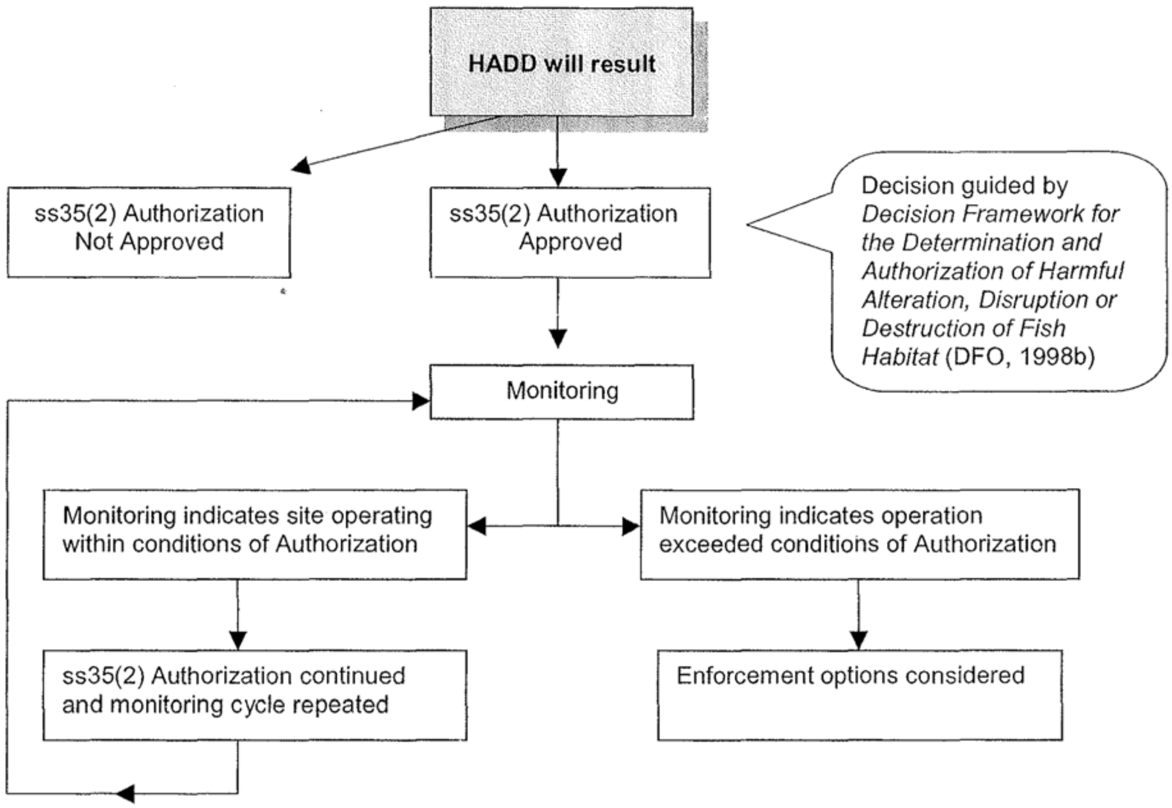

Uncertainty with respect to the effectiveness of measures to prevent a HADD
HADD Avoidance, Monitoring, and Mitigation Agreement
Includes agreement to undertake mitigation, monitoring, reporting, and remedial actions as a result of monitoring
See text for details
Monitoring
Monitoring confirms site operating within conditions of Agreement
Monitoring indicates a change from baseline conditions that is of concern, but has not resulted in a HADD
Agreement continued, and monitoring cycle repeated
Agreement may be modified to reflect changes required in mitigation and monitoring cycle
Proponent may apply for an authorization (see text for details)
see Chart 3

CHART 3


HADD will result
ss35(2) Authorization Not Approved
ss35(2) Authorization Approved
Decision guided by *Decision Framework for the Determination and Authorization of Harmful Alteration, Disruption or Destruction of Fish Habitat* (DFO, 1998b)
Monitoring
Monitoring indicates site operating within conditions of Authorization
Monitoring indicates operation exceeded conditions of Authorization
ss35(2) Authorization continued and monitoring cycle repeated
Enforcement options considered

APPENDIX 6: IDENTIFYING UNACCEPTABLE HADDS

One of the first tasks as outlined in the *Guide to the Application of S35 of the Fisheries Act to Salmonid Cage Culture Aquaculture Developments* is to identify unacceptable HADDs or "showstoppers" for which DFO would not issue a subsection 35(2) *Fisheries Act* authorization. These can be defined as specific overriding concerns related to both ecosystem and site-specific variables that, if one or more were present, would prevent an aquaculture operation from proceeding in that specific area as proposed.

DFO is not obligated to issue an Authorization in situations where adverse effects to fish habitat are judged to be unacceptable (DFO, 1998(a)). The discussions of the National Habitat Management Working Group on Aquaculture (NHMWGA, 2001) and the work done be DFO scientists have led to the development of the following list of areas that should be considered when determining unacceptable HADDs:

- The presence of **critical habitat** such as spawning areas, restricted migration routes, etc. at the site, or sufficiently close to the site that the effects cannot be mitigated adequately.

- **Prior history** of the site such as failure of an operation due to environmental causes, etc., where the situation remains essentially unchanged.

- Potential significant contribution of the proposed development to **cumulative effects on fish habitat**.

- **Low suitability** of the proposed site for aquaculture as determined by baseline benthic conditions which could have negative effects on the culture operation and possible implications for the fish habitat as a result.

Note: Considering it is not possible to develop an exhaustive list of showstoppers, proponents are reminded that it is important to contact DFO early in the process to determine if they have a situation where adverse effects to fish habitat are unacceptable.

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GLOSSARY

Anoxic sediment. Benthic conditions characterized by very high sediment accumulation, depositional with a high silt/clay ration, O_2 absent at sediment/water interface, anaerobic respiration and gas bubbles are released from sediments, high sulfide accumulation, extensive bacterial mat cover, sediment colour is black.

Benthos. The aggregate of animals and plants living on or at the bottom of a body of water. Within this context, benthos also includes the characteristics of the physical and chemical environment on the sea or lake bed. (*Guide to Information Requirements for Environmental Assessment of Marine Finfish Aquaculture Projects*)

Compensation. The replacement of natural habitat, increase in the productivity of existing habitat, or maintenance of fish production by artificial means in circumstances dictated by social and economic conditions, where mitigation techniques and other measures are not adequate to maintain habitats for Canada's fisheries resources. (*Policy for the Management of Fish Habitat*)

Critical habitat. Environmentally sensitive habitat. Areas that require an added degree of caution owing to features and characteristics that support protected species and/or unique habitats (e.g., rearing or spawning habitat, migration corridors, protected areas or proposed protected areas, location of salmon streams, sensitive migratory bird habitat, etc.). (*Guide to Information Requirements for Environmental Assessment of Marine Finfish Aquaculture Projects*)

Epifauna. Benthic fauna living on the substrate (as a hard sea floor) or on other organisms (Merriam-Webster Dictionary)

Fish. Includes parts of fish, shellfish, crustaceans, marine animals and any parts of shellfish, crustaceans or marine animals, and the eggs, sperm, spawn, larvae, spat and juvenile stages of fish, shellfish, crustaceans and marine animals. (*Fisheries Act*, sec. 2).

Fish habitat. Spawning grounds and nursery, rearing, food supply and migration areas on which fish depend directly or indirectly in order to carry out their life processes (*Fisheries Act*, sec. 34)

Hypoxic sediment. Benthic conditions with high sediment accumulation, high silt/clay ratio, high diversity of infauna, O_2 penetration to a few millimetres, anaerobic respiration is greater than anaerobic respiration, unreleased gas bubbles, moderate sulfide accumulation, bacterial mats may occur in patches, sediment colour is brown to black.

Infauna. Benthic fauna living in the substrate and especially in a soft sea bottom (Merriam-Webster Dictionary)

Mitigation. Actions taken during the planning, design, construction and operation of works and undertakings to alleviate potential adverse effects on the productive capacity of fish habitats. (*Policy for the Management of Fish Habitat*)

No net loss. A working principle by which the department strives to balance unavoidable habitat losses with habitat replacement on a project-by-project basis so that further reductions to Canada's fisheries resources due to habitat loss or damage may be prevented. (*Policy for the Management of Fish Habitat*)

Oxic sediment. Benthic conditions with little sediment accumulation, erosional to variable seafloor, high diversity of epifauna and infauna, O2 penetration to several millimetres or several centimetres, aerobic respiration is equals or is greater than anaerobic respiration, no or little sulfide accumulation, sediment is light brown to dark grey in colour.

Productive capacity. The maximum natural capability of habitats to produce healthy fish, safe for human consumption, or to support or produce aquatic organisms upon which fish depend. (*Policy for the Management of Fish Habitat*)

Redox potential. A measure of oxidation and reduction reactions in water, measured as the loss or gain of electrons. Elements that donate electrons are oxidants while those that accept electrons are reductants (or de-oxidizers). In neutral, fully oxygenated water in equilibrium with air, redox potentials slightly greater than 500 mv are obtained. Redox measurements in natural waters should not be quantitatively interpreted or compared. Qualitative or relative comparisons, however, can be helpful in defining the degree of change within a system. Within an oxygenated water column, oxidative reactions predominate. As oxygen concentrations approach zero and anoxic conditions appear, as happens near the sediment-water interface, the redox potential drops significantly. Within the sediments, it is common for reducing conditions to prevail and the redox potential to approach zero or even a negative value. (*Guide to Information Requirements for Environmental Assessment of Marine Finfish Aquaculture Projects*)

Remediation (restoration of habitats). The treatment or clean-up of fish habitat that has been altered, disrupted or degraded for the purpose of increasing its capability to sustain a productive fisheries resource. (*Policy for the Management of Fish Habitat*)

Salmonid. Of the family Salmonidae.

Vol. 326: 1–9, 2006

MARINE ECOLOGY PROGRESS SERIES
Mar Ecol Prog Ser

Published November 17

OPEN ACCESS

FEATURE ARTICLE

Impact of fish farms on maerl beds in strongly tidal areas

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ABSTRACT: In Scotland, Atlantic salmon *Salmo salar* cages are being moved out of areas with slow water movements, to disperse wastes and reduce impacts on benthic communities. This first study of the effects of fish farms on maerl beds (red algal coralline gravels of high conservation importance) demonstrated major impacts on the benthos, even in strongly tidal areas. SCUBA surveys of 3 fish farms located over maerl revealed a build-up of waste organic matter and 10 to 100-fold higher abundances of scavenging fauna (e.g. *Necora puber, Pagurus bernhardus*) than on 6 reference maerl beds. Visible waste was noted up to 100 m from cage edges, and all 3 farms caused significant reductions in live maerl cover, upon which this habitat depends. Near-cage infaunal samples showed significant reductions in biodiversity, with small Crustacea (ostracods, isopods, tanaids and cumaceans) being particularly impoverished in the vicinity of cages, and significant increases in the abundance of species tolerant of organic enrichment (e.g. *Capitella* spp. complex, *Ophryotrocha hartmanni*). Relocation of fish farms to areas with strong currents is unlikely to prevent detrimental effects to the structure and organisation of the benthos, and 'fallowing' (whereby sites are left unstocked for a period of time to allow benthic recovery) is inadvisable where slow-growing biogenic habitats such as maerl are concerned, as this may expand the area impacted.

KEY WORDS: Salmon farming · Maerl · Organic enrichment · Benthos · Scotland

This first study on the effects of offshore salmon farms on strongly tidal maerl beds (above) reveals that strong currents do not prevent major degradation of benthic habitats (inset). Changes in management policy are therefore required to prevent detrimental effects to seabed ecology, and rotation of farmed sites (fallowing) is inadvisable where slow-growing biogenic habitats are concerned.

Photos: Jason Hall-Spencer

INTRODUCTION

Marine fish farming is the fastest growing food production sector in the world and its impacts require careful management to prevent unnecessary damage to coastal ecosystems (FAO 2002). As the industry expands and evolves, environmental regulatory agen-

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cies strive to modify and develop their strategies to encourage environmentally and socio-economically sustainable development. Scotland is now the largest aquaculture producer in the European Union, with products worth around £500 million (Sterling) per annum (RCEP 2004). As in Chile, British Columbia and Norway, Scotland's fjords provide the sheltered cool waters and high water exchange that are well suited for farming salmon. Almost all fjords in Scotland now have mariculture developments and the national production of *Salmo salar* L. increased from 5000 t yr^{-1} in the 1980s to 145 000 t yr^{-1} in 2002. This has provided jobs and infrastructure in remote rural areas, but concerns have been raised over the environmental effects of such development (Fernandes et al. 2001, RCEP 2004).

This study concentrated on the effects of organic deposition on the benthos in locations with fast water movements. Such effects are well documented for fish farms situated in areas with slow water movements in muddy fjord habitats (Pearson & Black 2001), and conform to the model of species succession in relation to organic enrichment proposed by Pearson & Rosenberg (1978), but the effects of fish farms are poorly known in areas with fast currents (Lee et al. 2006). In sheltered conditions, around 5% of protein-rich salmon pellets (ca. 55% fishmeal) are uneaten and pass through fish cages, along with fish faeces. Some waste feed may be eaten by wild fish, but much of it builds up below cages in areas with low current speeds, resulting in alterations to infaunal community structure, such as increased abundance of opportunistic scavengers and lowered species diversity (Pearson & Black 2001). Our study was initiated in light of a shift in management policy encouraging the movement of cages away from sites with low current speeds to areas with stronger currents in order to disperse wastes and, hopefully, lessen the potential impacts upon the seabed below and adjacent to cages (Fernandes et al. 2001, Henderson et al. 2001). Predictive deposition models used for licencing farm operations have been developed and validated for use on muddy substrata, but not in high energy sites (Henderson et al. 2001, Cromey et al. 2002), which support a different set of benthic biotopes.

In Scotland, highly dispersive sites can be suitable for maerl habitats which comprise loose-lying coralline red algae (Corallinales, Rhodophyta) that can build-up over millennia to create carbonate-rich gravel deposits that form isolated habitats of high benthic biodiversity (Hall-Spencer 1998, Grall & Hall-Spencer 2003, Grall et al. 2006). Maerl growth requires light for photosynthesis and usually occurs in areas with clear water and strong currents. Laboratory experiments show that smothering by fine sediment and lowered oxygen concentrations are particularly damaging to maerl-forming algae (Wilson et al. 2004). The conservation importance of maerl beds is increasingly recognised, not only because of their longevity and high biodiversity, but also due to potential benefits for commercial fisheries. Maerl beds can harbour high densities of broodstock bivalves and act as nursery areas for the juvenile stages of commercial species such as cod *Gadus morhua* L., crabs *Cancer pagurus* L. and scallops *Aequipecten opercularis* (L.), which are attracted to the complex 3-dimensional unconsolidated structure (Kamenos et al. 2004).

The movement of fish farming operations to more open conditions is relatively new, with few studies of their effects on benthic habitats in strong current regimes (Lee et al. 2006). The present study aimed to establish the effects of salmon farms upon maerl habitats, focusing on the impacts of organic deposition upon the associated epifaunal and infaunal communities. Salmon farms and reference sites were surveyed in 3 widely separated localities to determine if (1) strong currents prevented a build up of organic waste on the seabed, (2) farm waste had significant effects on live maerl cover and (3) farm waste had significant effects on benthic community structure.

MATERIALS AND METHODS

Scottish Environmental Protection Agency (SEPA) records showed that in 2003 there were 346 salmon farms operating in Scotland, of which 16 were situated above maerl beds. To obtain a wide geographic spread, we chose 3 farms that were 200 to 350 km apart and located over shallow sublittoral maerl beds in Shetland (North Sandwick, Yell; 60.640° N, 0.990° W; –14 m chart datum [CD]), Orkney (Puldrite Bay, Wide Firth; 59.045° N, 3.005° W; –14 m CD) and South Uist (North Bay, Loch Sheilavaig; 57.346° N, 7.237° W; –10 m CD). Fish farming began at the Shetland farm in May 1991, the Orkney farm in 1993 and the South Uist farm in 1999. For each site, SEPA provided annual monitoring reports and hydrographic data sets. Diving surveys were carried out between 24 May and 29 June 2003 when these farms were permitted to stock 995 t, 980 t and 311 t of salmon, respectively, with the highest feeding rate (698 kg pellets pen^{-1} d^{-1}) at the Shetland farm. Circular plastic-ringed cages were in use in Shetland (where adult salmon were fed large pellets from a feed barge) and in Orkney (where smolts were hand fed with smaller feed pellets). In South Uist, adult salmon were held in rectangular metal cages and were fed large pellets from automatic hoppers fitted to each cage. At each farm, we laid out 4 weighted transect lines on the sea bed at right angles from cage edges to locate 4 sets of stations at 0, 25 and 50 m, and 2 sets of stations at 75 and 100 m from the cages. Near each farm, pairs of shallow sublittoral (−10 to −14 m CD) reference maerl beds were surveyed at sites 500 to 1000 m distant from any known anthropogenic sources of organic enrichment (60.649° N, 0.983° W and 60.649° N, 0.982° W in Shetland; 59.049° N, 2.993303° W and 59.047° N, 2.991° W in Orkney; 57.346° N, 7.24739° W and 57.346° N, 7.247° W in South Uist). Station positions were recorded using GPS (Garmin E-trex).

Effects on the epibenthos. At 6 reference sites and at 25 m intervals along 4 perpendicular weighted transect lines, divers recorded surface conditions of the sea bed around each farm. Live and dead maerl cover was recorded in three 0.25 m^2 quadrats (divided into 10 × 10 cm squares) dropped haphazardly onto the seabed at each station, giving 6 to 12 replicate quadrats per sampling distance from each farm. At each sampling station, feed pellets, *Beggiatoa* mats (sulphur-reducing bacterial colonies indicative of anoxic sediment conditions) and fish farm litter (e.g. ropes, plastic mesh, old mooring gear) were noted and the abundances of conspicuous scavengers (e.g. crabs and whelks) were estimated using the semiquantitative 'SACFOR' scale, where S = Superabundant, A = Abundant, C = Common, F = Frequent, O = Occasional and R = Rare (see Hiscock 1998 and Table 1 for details). Maerl samples were collected from quadrats at 0 and 50 m from the cages and at reference sites. These were examined microscopically (first using ×40 dissection light microscopy, then ×2200 scanning electron microscopy) to determine their identity and their condition (by examining their phycobilin pigmentation and the structure of the surface layer of cells). Taxonomic identification followed Irvine & Chamberlain (1994) and was achieved using a JSM 5600 LV Scanning Electron Microscope.

Effects on the infauna. In Shetland and Orkney, divers took 5 samples from reference sites and 5 from each of the transect line sampling stations around cages, using cylindrical capped cores (0.01 m^2) inserted to a sediment depth of 20 cm. On surfacing, core samples were double bagged and preserved using 15 to 20% borax-buffered formalin for later laboratory sieving (1 mm mesh). The 1 mm fraction was elutriated with fresh water to float off lighter fauna. This elutriate was then examined using a dissecting microscope, for identifying and counting the species present. The heavy elements remaining were then scanned under low magnification and fauna removed, identified and counted.

Data analysis. Differences in live maerl cover and infaunal diversity of core samples (Shannon-Wiener H') were tested using univariate analyses. Preliminary analysis using ANOVA indicated a strong interaction between farms and sampling distance from farms (using reference sites as a category). Therefore, to avoid inflating Type I errors by using multiple testing, and to account for the distance of the reference sites from the cages, a separate slopes General Linear Model (GLM) was adopted in Statistica 6.0 (www.statsoft.com) for both analyses. The Type III least squares hypothesis decomposition was used to account for the unbalanced nature of the designs. The distance of samples from cage edges was used as the covariate and sites as the main effect to analyse the slopes of the relationships with distance. Proportional live maerl cover data were subjected to arcsin transformation, and Bartlett's test for non-homogeneity of variances was applied prior to both GLMs. Neither data set required transformation to homogenise variances.

Multivariate analyses were carried out using PRIMER-E 5.0 (Clarke & Warwick 2001) on 4th-root transformed abundance data for Shetland and Orkney core samples to produce a Bray-Curtis sample similarity matrix. Overall assemblage similarity between sample locations (pairs of reference sample sets for each site were considered to be in the same category) was compared using an *a priori* 2-way crossed analysis of similarity (ANOSIM). A second similarity matrix was then calculated for each site to analyse the overall percentage contribution of different taxa to the dissimilarity between samples taken near to (0 m and 25 m), and far from the cages (100 m and reference sites) across both sites using the similarity percentages (SIMPER) routine in PRIMER-E. Finally, ranked species abundance plots (K-dominance plots) were constructed for each site to analyse changes in assemblage structure (see Lambshead et al. 1983).

Table 1. Abundance of scavengers (ind. m^{-2}) from *in situ* estimates (C = 1–9 m^{-2}, F = 0.1–0.9 m^{-2}, O = 0.01–0.09 m^{-2}, R = 0.001–0.009 m^{-2}, – = not seen). Ref = Reference

Taxa	Shetland		Orkney		South Uist	
	Ref site	Near cage	Ref site	Near cage	Ref site	Near cage
Cancer pagurus	O	F[a]	R	R	O	R
Carcinus maenas	R	–	–	O[a]	R	F[a]
Liocarcinus spp.	O	F[a]	O	F[a]	O	F[a]
Necora puber	R	O[a]	R	O[a]	R	O[a]
Paguridae	O	F[a]	O	F[a]	O	F[a]
Asterias rubens	R	R	R	O[a]	O	C[a]
Buccinum undatum	R	O[a]	O	–	R	O[a]

[a]10 to 100 times higher abundance near cages

RESULTS

Divers noted strong currents at all fish farms and all control sites. Current meter data from annual environmental monitoring reports showed peak near-seabed values of ca. 0.5 m s^{-1} for Shetland, 0.7 m s^{-1} for Orkney and 0.4 m s^{-1} for South Uist. Currents were consistently strongest at the Orkney fish farm, with regular periods of sluggish water-flow at all 3 farms. The most detailed hydrographic data were available for the Shetland farm, where current speeds recorded for a 15 d survey period had means of 0.11, 0.12 and 0.12 m s^{-1} and maxima of 0.21, 0.21 and 0.47 m s^{-1} for heights of 3.2 m, 7.7 m and 10.7 m above the sea bed, respectively.

Effects on the epibenthos

There was consistently less live maerl around all 3 farms than the 50 to 60% cover that typified reference sites (Fig. 1), with a consistently significant response of maerl cover to distance from the cages (R^2 (adjusted) = 0.63; F_5 = 37.43, $p < 0.001$). The Shetland farm had the highest cover of live maerl close to the cages; here the sea bed was sculpted into a series of megaripples indicating live maerl transportation into the area during rough weather (see Hall-Spencer & Atkinson 1999). Maerl around the Orkney and South Uist fish farms was not megarippled (indicating less mobility); most of it was dead and clogged with black sulphurous silt next to the cages, indicating anoxic conditions. Maerl thalli collected for identification were all *Phymatolithon calcareum* (Pallas) Adey et McKibbin; many specimens collected near cages had a mottled appearance, due to loss of pigmentation and erosion of the epithallus. Most (ca. 90%) of the live maerl collected 50 m from the salmon cages, and all of the live maerl collected at the reference sites had a healthy, uniformly pigmented appearance and intact epithallial cells.

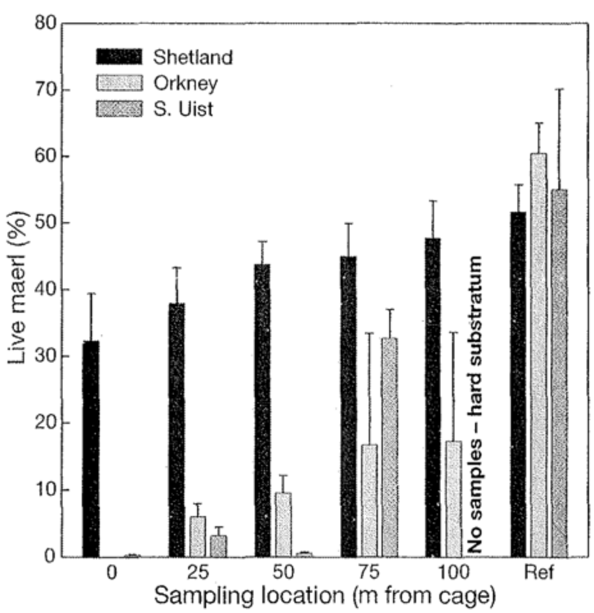

Fig. 1. Mean percentage + SE of live maerl in replicate 0.25 m^2 quadrats taken at reference sites (n = 6) and on perpendicular transects at 0 m (n = 12), 25 m (n = 12), 50 m (n = 12), 75 m (n = 6) and 100 m (n = 6) from 3 salmon farms in May/June 2003. NB: hard substratum but no maerl was found at 100 m from the South Uist farm

All reference sites (2 in Shetland, 2 in Orkney and 2 in South Uist) showed no signs of organic waste, with abundant epiphytic growths of foliose red algae, small sponges, hydroids and bryozoans. Large bivalve siphons, e.g. *Tapes rhomboides* (Pennant), *Dosinia exoleta* (L.), and tentacles of the holothurian *Neopentadactyla mixta* (Ostergren) indicated high infaunal biomass. Vagile fauna was abundant, particularly small gastropods, cryptic Crustacea (e.g. amphipods, squat lobsters, small crabs) and juvenile ophiuroids. At the fish farms, uneaten feed and fish faeces had accumulated in troughs between sediment waves, in pits dug by bioturbators (e.g. *Cancer pagurus*), and within the interlocking matrix of maerl thalli. Fig. 2 illustrates the 'footprints' of visible wastes derived from *in situ* observations at the 3 sites. Physical impacts included crushed maerl under mooring chains, shading and smothering by nets together with ropes and mussel shells (*Mytilus edulis* L.) on the sea bed that had fallen from the fish farms. Near-cage sites had few attached epiphytes and epifauna, no visible bivalve siphons, an absence of large suspension feeders (e.g. *N. mixta*) and a lowered diversity and abundance of cryptic fauna such as small crustaceans and gastropods. The South Uist site was the most visibly impacted, with *Beggiatoa* mats and decomposing crabs *Carcinus maenas* (L.) and *Necora puber* (L.), sea urchins *Echinus esculentus* L. and tunicates *Ciona intestinalis* (L.). Feed pellets were seen on the sea bed near all cages, to a distance of 100 m from the cages in Orkney, where currents were strongest and the smallest pellets were in use. Whelks, crabs and starfish were seen feeding on farm waste around each farm, and most of these taxa were over 10 times more abundant near farms than at reference sites (Table 1).

Effects on the infauna

Sponges and bryozoans were present in small numbers in core samples but were excluded from analyses due to the difficulties of enumerating colonial organisms. Species from a diverse range of other phyla were

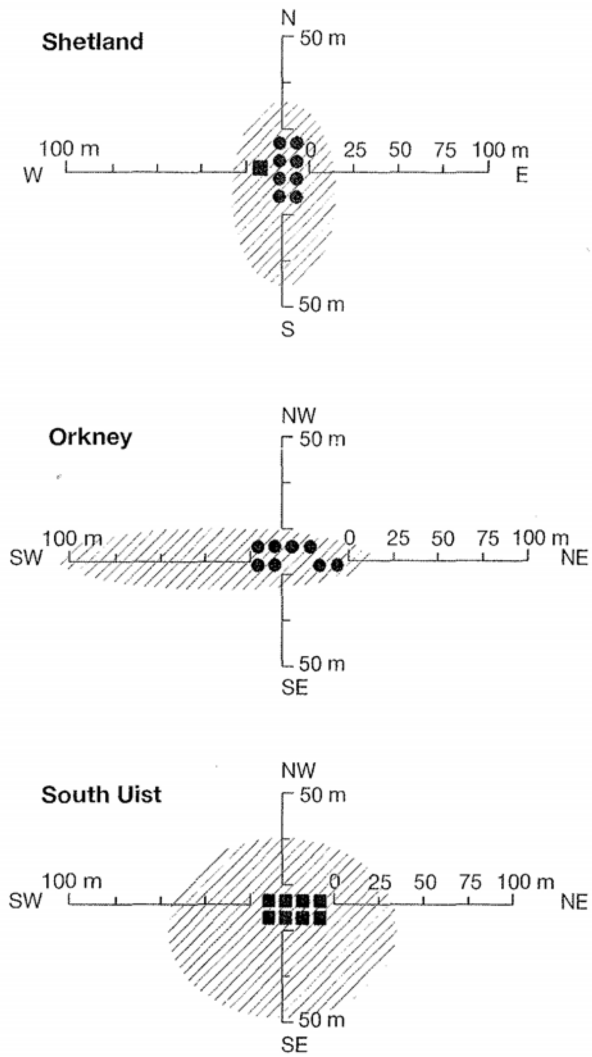

Fig. 2. Schematic diagram showing layout of 3 salmon farms surveyed, with shaded areas indicating visible organic enrichment (feed pellets, fish faeces and/or *Beggiatoa* mats) recorded by divers around salmon farms on maerl beds in May/June 2003

identified and counted (viz. Cnidaria, Nemertea, Priapulida, Chaetognatha, Sipuncula, Annelida, Chelicerata, Crustacea, Mollusca, Phoronida, Echinodermata, Chordata). Each of these phyla had a greater number of species in reference cores than in cores collected along fish farm transects. For example, the numbers of species for the 4 most diverse phyla collected in ten 0.01 m^2 cores at reference sites versus numbers in ten 0.01 m^2 cores from close to the cages were 72:56 for Annelida, 40:28 for Crustacea, 21:12 for Mollusca and 12:5 for Echinodermata. Macrofaunal diversity increased consistently with distance away from the cages (R^2 (adjusted) = 0.31, F_3 = 21.88, $p < 0.001$). Diversity (H') averaged 4.59 ± 0.39 at reference sites, 3.87 ± 0.79 at 100 m from the cages, 3.83 ± 0.75 at 75 m, 3.6 ± 0.95 at 50 m, 3.31 ± 0.99 at 25 m and 2.31 ± 1.07 at 0 m.

There was a clear, consistent effect of distance from the cages on the assemblages at each site (ANOSIM R = 0.598, p <0.001). A gradient of assemblage difference between pairs of samples according to distance from the cages was evident (Tables 2 & 3), with consistent differences between reference sites and those nearer to the cages. SIMPER analysis showed that a few opportunistic species, e.g. the polychaetes *Capitella* spp. complex and *Ophryotrocha hartmanni* Claparède et Mecznikow, were rare at reference sites but were significantly more abundant close to cages (Fig. 3). Conversely, many maerl-dwelling taxa that were abundant at reference sites had marked reductions in population density close to the farm cages. Fig. 4 shows the reduction in ostracods and cumaceans near to farm cage sites. The following isopods, tanaids and cumaceans were plentiful at reference sites, but were clearly impoverished at farm cage sites: Gnathidae sp. indet., *Eurydice* juvenile sp. indet., *Cymodoce* sp., *Janira maculosa* Leach, *Microcharon harrisi* Spooner, *Munna* sp., *Paramunna bilobata* G.O. Sars, *Eurycope* sp., *Idotea granulose* Rathke, *Leptognathia breviremis* Liljeborg, *L. paramanca* Lang, *Pseudoparatanais batei* G.O. Sars, *Tanaopsis graciloides* Liljeborg, *Typhlotanais microcheles* G.O. Sars, *Vaunthompsonia cristata* Bate, *Cumella pygmaea* G.O. Sars, *Nannastacus brevicaudatus* Calman, *N. unguiculatus* Bate.

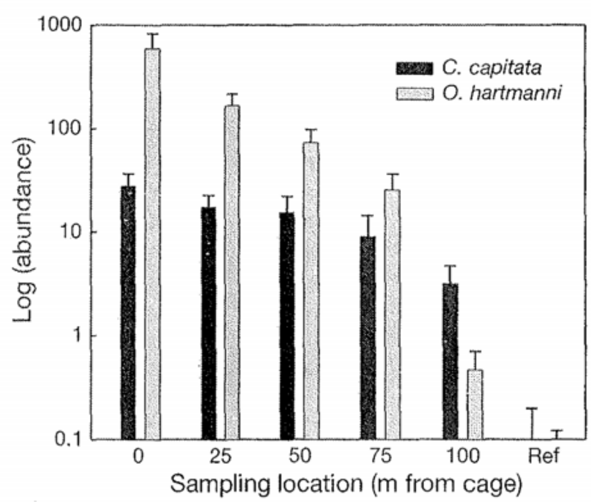

Fig. 3. *Capitella* spp. complex and *Ophryotrocha hartmanni*. Mean number + SE recorded in replicate 0.01 m^2 core samples taken on reference maerl beds and on transects at 0 to 100 m from salmon cages in Shetland and Orkney, Scotland, June 2003 (n = 40 at 0, 25 and 50 m; n = 20 at 75 and 100 m and reference sites). NB: log scale and very high abundances near cages

Table 2. SIMPER analysis comparing infaunal assemblages near cages (0 and 25 m) with distant sites (100 m and reference sites); data for Shetland and Orkney combined. NB: arbitrary cutoff at 30% cumulative dissimilarity; average Bray-Curtis dissimilarity between samples in the 2 groups = 7859

Species	Phylum	Increasing/decreasing near cage	Mean abundance Near cage	Mean abundance Far from cage	Cumulative % dissimilarity
Ophryotrocha hartmanni	Annelida	+	281.93	0.23	2.75
Socarnes erythrophthalmus	Crustacea	+	47.02	30.23	4.58
Capitella spp. complex	Annelida	+	20.05	1.40	6.24
Chone filicaudata	Annelida	–	24.33	45.31	7.76
Phyllodoce mucosa	Annelida	+	18.69	1.23	9.26
Amphipholis squamata	Echinodermata	–	5.44	18.77	10.74
Enchytraeidae sp.1	Annelida	–	6.71	19.37	12.20
Ostracoda spp.	Crustacea	–	5.85	19.40	13.63
Ceradocus semiserratus	Crustacea	–	9.47	13.2	15.02
Parametaphoxus fultoni	Crustacea	–	3.80	14.86	16.35
Leptocheirus pectinatus	Crustacea	–	3.24	42.63	17.56
Urothoe elegans	Crustacea	–	2.69	4.80	18.69
Mediomastus fragilis	Annelida	–	2.27	3.31	19.82
Tubificidae sp.1	Annelida	+	3.47	2.06	20.95
Exogone hebes	Annelida	+	3.29	1.97	22.05
Tubificidae sp.2	Annelida	–	1.87	3.03	23.10
Gyptis propinqua	Annelida	–	1.13	3.80	24.06
Cumella pygmaea	Crustacea	–	0.69	4.23	25.00
Ophiothrix fragilis	Echinodermata	–	0.38	6.91	25.93
Paramunna bilobata	Crustacea	–	1.56	3.94	26.86
Prionospio banyulensis	Annelida	–	0.75	2.26	27.76
Liljeborgia kinahani	Crustacea	–	0.56	2.94	28.62
Spaerosyllis taylori	Annelida	–	1.02	3.51	29.48
Nannastacus unguiculatus	Crustacea	–	0.13	4.63	30.32

These dramatic community changes are illustrated by *K*-dominance curves for infaunal data from Shetland and Orkney combined (Fig. 5). Samples closest to the cages were dominated by very high numbers of 1 or 2 species and were less diverse. With increasing distance from the cages, the assemblages became less dominated by a few species and more similar to reference sites, where large numbers of species occurred at low densities.

Table 3. Significance levels of differences in pairwise combinations of distances using 2-way crossed ANOSIM for infaunal data from Shetland and Orkney combined. ***p < 0.001, **p < 0.01, *p < 0.05, ns not significantly different

	Distance from cages (m) 0	25	50	75	100
25	ns				
50	ns	ns			
75	***	*	ns		
100	***	***	**	*	
Reference	***	***	***	***	***

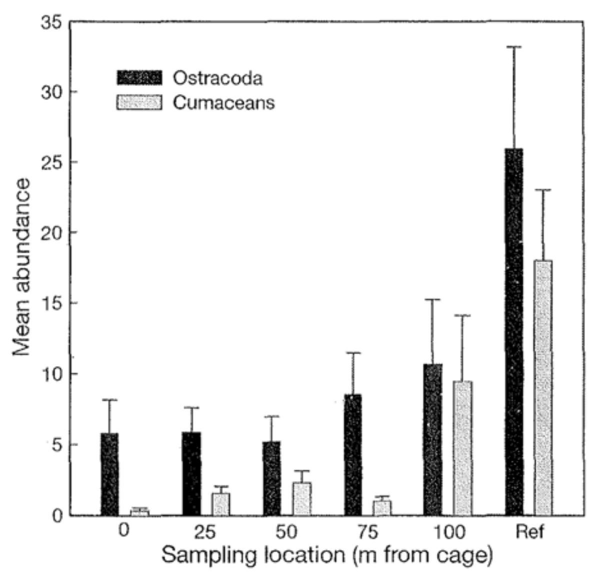

Fig. 4. Mean number + SE of ostracods and cumaceans found in 0.01 m^2 core samples taken on reference maerl beds and on transects at 0 to 100 m from salmon cages in Shetland and Orkney, Scotland, June 2003 (n = 40 at 0, 25 and 50 m; n = 20 at 75 and 100 m and reference sites). Note their paucity near cages. Ref = reference

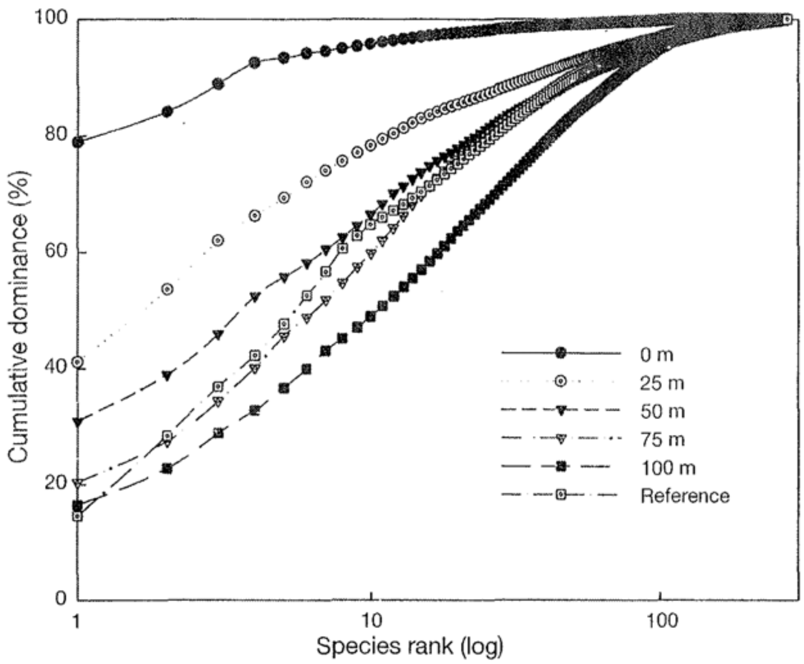

Fig. 5. *K*-dominance curves showing changes in community structure with distance from salmon farms in Shetland and Orkney, Scotland; data from 1 mm sieved 0.01 m^2 core samples taken at reference sites and along transects around farm cages in June 2003 (n = 80 at 0, 25 and 50 m; n = 40 at 75 and 100 m and reference sites)

DISCUSSION

The need for this study arose from the increasing numbers of sea cage fish farms located over strongly tidal maerl beds, a habitat for which no previous environmental impact assessments had been made. The work involved close collaboration between industry, regulatory authorities and independent scientific advisors, following best practice recommendations given by Fernandes et al. (2001). The initial expectation, based on current measurements, was that even at high feeding rates (up to 698 kg pen^{-1} day^{-1}) most of the particulate wastes from the fish farms would be dispersed and that there would be minimal effects on the benthos. *In situ* observations revealed that during periods of slow water flow, fish farm particulates settled in seabed depressions and became trapped within a complex interlocking matrix of maerl thalli, rather than being resuspended and dispersed widely as can occur on smooth sediments (Cromey et al. 2002). Surveys of 3 maerl beds over a wide geographic area (500 km) clearly demonstrated that, despite the action of strong currents, salmon farms could lead to a build-up of organic wastes in the vicinity of cages and significantly alter seabed benthos. The farmed sites, which had been in use for 4 to 12 yr, had each caused long-term environmental damage, because slow-growing photosynthetic maerl thalli had been killed, inhibiting regeneration and growth of the habitat. These findings have important implications for the sustainable management of marine fish farming operations worldwide, as advances in sea-cage technology allow the positioning of cages at more exposed locations. Management procedures have been based largely on studies of fish farms located in sheltered conditions with open-ocean mariculture operations being considered advantageous, because they use locations in which enrichment effects can be mitigated by increased current activity and dilution (Henderson et al. 2001). Our study adds to that of Lee et al. (2006) in showing significant eutrophic effects in high energy habitats despite dilution due to exposed conditions.

The European Council Directive 92/43 (1992) provides legislative protection to maerl, which is now a key habitat within a number of UK Special Areas of Conservation and subject to a UK Habitat Action Plan that aims to maintain the extent, variety and quality of maerl beds and associated seaweed and animal communities (Wilson et al. 2004). The Nature Conservation (Scotland) Act (Anonymous 2004) places an onus upon environmental managers to conserve and promote biodiversity. Habitats such as maerl should therefore be taken into account in the development of regulation for fish farm authorisations. *Phymatolithon calcareum* was present at all 9 of the strongly tidal sites we surveyed and is the most widely distributed maerl-forming species in the British Isles (Irvine & Chamberlain, 1994). The fjordic coastline of North and West Scotland is well suited to maerl growth, with 376 records, compared with a combined total of around 16 sites in England and Wales combined (National Biodiversity Network, www.searchnbn.net). That maerl was predominantly dead or in poor condition close to cages, but increased in live cover with distance from the farms, is analogous to the detrimental effects of fish farms on slow-growing seagrass meadows (Dimech et al. 2002) and ties in with laboratory evidence showing that maerl is particularly sensitive to siltation and lowered oxygen tension (Wilson et al. 2004). This is particularly problematic since maerl grows only ca. 1 mm yr^{-1}, forming seabed deposits that take 1000s of years to accumulate (Grall & Hall-Spencer 2003). Thus whilst the practice of periodic abandonment of cage sites to allow recovery (fallowing) has been recommended as a management tool for sustainable fish farming (Fernandes et al. 2001), this remains controversial due to long recovery times (Pereira et al. 2004) and is not advantageous where slow-growing biogenic habitats are concerned. At sites where maerl beds have already been inadvertently degraded by fish farming operations, it makes environmental sense not to move farm location and impact areas elsewhere, as maerl recovery rates are so slow.

Our 6 strongly tidal reference sites had no visible signs of organic pollution and were highly biodiverse. The polychaete and crustacean components of the fauna were particularly rich, similar to those reported in French maerl deposits (Grall et al. 2006). In contrast, the 3 fish farm sites all had visible signs of organic enrichment (feed pellets, fish faeces and/or *Beggiatoa* mats) and significantly lower biodiversity. Similar reductions in the diversity of maerl beds have been linked to anthropogenic eutrophication and organic enrichment in the Bay of Brest (Grall & Glémarec 1997). Shifts in trophic status and community structure are typical effects of organic enrichment in marine sediments (Pearson & Rosenberg 1978), and were noted at all 3 fish farm sites, with most scavenging macrofauna (e.g. whelks and starfish) being 10 to 100 times as abundant close to the cages than at reference sites. Core sampling showed that some species were super-abundant in sediment collected near to the cages, e.g. the organic disturbance indicators *Capitella* spp. complex, the hypoxia- and sulphur-resistant *Tubificoides benedini* and the opportunistic scavenger *Ophryotrocha hartmanni*.

Donnan & Moore (2003) recommended a moratorium, based on the precautionary principle, on fish farm licences above unexploited maerl beds, as maerl was thought to be easily damaged by fine particulate matter. The laboratory studies of Wilson et al. (2004) coupled with the present field study confirm that maerl habitats are highly susceptible to the effects of fish farm deposition, with significant effects recorded to at least 100 m from 3 farmed sites. This knowledge can now be incorporated into management procedures for sustainable fish farm development and has planning implications for other strongly tide-swept habitat types. The fallowing system whereby cage positions are rotated to allow the deposit-feeders of muddy fjord habitats time to process organic waste (Fernandes et al. 2001) is not suited to maerl habitats because of the likely longevity of the damage caused. High organic loading results in the long-term loss of living maerl, upon which generation of the habitat depends, and many species at shallow high-energy sites (e.g. maerl, sponges, hydroids, soft corals and bryozoans) are intolerant of smothering by organic particulates. The findings outlined here are likely to apply to sea cage fish farms in other fjordic settings, such as those in Chile, Canada, Tasmania and Norway where sensitive seabed habitats occur in strongly tidal areas. In the light of this study it would seem advantageous to limit potential environmental degradation (1) by careful consideration of alternatives to locating new fish farms on long-lived biogenic habitats, perhaps choosing less structurally complex sedimentary habitats in preference, and (2) if maerl habitats are to be licenced for salmon farming, then cage positions should be fixed within leased areas, as opposed to the fallowing system of site rotation which may extend damage to vulnerable habitats.

Acknowledgements. We are grateful to C. Howson, T. Mercer and A. Shaw for planning and execution of SCUBA fieldwork and to P. Garwood for infaunal identifications. J.H.S. had a Royal Society University Research Fellowship and the project was funded by Scottish Natural Heritage, the Scottish Environmental Protection Agency, Marine Harvest (Scotland) Ltd. and the Esmée Fairbairn Foundation.

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Editorial responsibility: Otto Kinne (Editor-in-Chief), Oldendorf/Luhe, Germany

Submitted: July 28, 2006; Accepted: October 4, 2006
Proofs received from author(s): November 2, 2006