Environmental impact assessment and monitoring in aquaculture

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Review of environmental impact assessment and monitoring in salmon aquaculture

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ABSTRACT

This report compiles and reviews environmental impact assessment (EIA) and environmental monitoring procedures and practices in salmon cage aquaculture in Canada, Chile, Ireland, New Zealand, Norway, the United Kingdom and the United States of America.

The regulatory process for pre-development EIA in each of the 7 countries is described. For existing farms, environmental monitoring regulations and practices are described and differences of approach noted. Weaknesses are highlighted and some suggestions for improvement are given.

All the countries studied have a regulatory system in place for a systematic study of the environmental costs and benefits of a proposed new salmon farm (EIA). The EIA system highlights potentially negative environmental impacts but socio-economic costs and benefits are generally not part of the EIA process. However, in some countries, e.g. Scotland, a brief socio-economic analysis is often included. A more rigorous and explicit approach to assessing socio-economic costs and benefits would be very helpful in allowing decision-makers to balance these against any environmental costs.

All countries have regulations regarding the monitoring of existing salmon farms to ensure compliance with a variety of environmental standards. In most countries there is a perception that regulation does offer protection to the environment. However, in most cases farmers regard the regulatory process as relatively slow and bureaucratic. This is particularly the case in the United States of America where responders to a questionnaire indicated that development was stifled by the complex regulatory regime. In Chile, while regulations and standards exist, there is a perception that regulatory authorities have insufficient resources to adequately monitor performance and police compliance.

In all countries, but particularly in North America, greater dialogue between all stakeholders in a non-litigious arena would be highly beneficial, as there appears to be considerable mistrust between the industry, the regulators and NGOs. Interchange of scientists and regulators between salmon growing countries and the willingness to learn from regulatory developments in other countries, must be strongly supported. All countries need to put greater effort into determining impacts at the waterbody rather than site scale. This requires modelling approaches backed up by long time-series measurements for validation and calibration.

Improvements in technologies for preventing escapes and in regulation should follow the Norwegian example where escapes of farmed fish must be reported on a statutory basis, particularly in Atlantic areas. Sea lice are a threat to wild populations so compulsory delousing should be implemented in all jurisdictions (following Norway) and a robust framework of basin-scale cooperation between farmers and wild fish interests regarding synchronous stocking and treatment should be encouraged to minimize medicine use. There is a clear need for environmental data collected at farms to be placed in the public domain to increase confidence in the regulatory process.

CONTENTS

Acronyms and abbreviations

AAA	Authorised Area for Aquaculture (Chile)
ADRIS	Association of Directors and River Inspectors of Scotland
AEE	Assessment of Environmental Effects (New Zealand)
ALL	Aquatic Lands Lease (United States of America)
AM	Annual Monitoring (United States of America)
AMA	Aquaculture Management Area (New Zealand)
ANZECC	Australian and New Zealand Environmental Conservation Council
APL	Clean Production Agreement (Chile)
ASERC	Aquaculture site Environmental Review Committee (Canada)
AZE	Allowable Zone of Effects (United Kingdom)
BA	Biological Assessments (United States of America)
BC	British Columbia (Canada)
BCSFA	British Columbia Salmon Farmers Association (Canada)
BEP	Best Environmental Practice (United Kingdom)
BIM	Irish Sea Fisheries Board (Ireland)
BS	Baseline Monitoring
CAAP	Concentrated Aquatic Animal Production (United States of America)
CAR	Water Environment (Controlled Activities) (Scotland) regulations 2005
CBD	Convention on Biological Diversity
CEAA	Canadian Environmental Assessment Act (Canada)
CEQ	Council on Environmental Quality (United States of America)
CITES	Convention on the International Trade on Endangered Species
CLAMS	Co-ordinated Local Aquaculture Management System (Ireland)
CoGP	Code Of Good Practice (United Kingdom)
CONAMA	National Commission for the Environment (Chile)
CoPA	Control of Pollution Act (United Kingdom)
COREMA	Regional Commission for the Environment (Chile)
CPBA	Code of Environment Best Practice for Salmon Farms (Chile)
CPS	Preliminary Characterisation of Site (Chile)
CWA	Clean Water Act (United States of America)
DCMNR	Department of Communication, Marine and Natural Resources (Ireland)
DEP	Department of Environmental Protection (United States of America)
DFO	Department of Fisheries and Oceans (Canada)
DIA	Environmental Impact Declaration (Chile)
DMR	Department of Marine Resources (United States of America)
DENV	Department of the Environment (Canada)
EA	environmental assessment (Canada)
EC	European Commission
EC	Environmental Condition (Norway)
ECLAC	Economic Commission for Latin America and the Caribbean, (Chile)
ECOPACT	Environmental Code of Practice for Irish Aquaculture Companies and Traders (Ireland)
EEM	Environmental Effects Management (Canada)
EI	Environmental Information (Chile)
EIA	environmental impact assessment

EIS	Environmental Impact Statement (United States of America)
ELG	Effluent Elimination Guidelines (United States of America)
EMP	Environmental Management Program for the Marine Finfish Cage Aquaculture Industry in New Brunswick (Canada)
EPA	Environmental Protection Agency (United States of America)
EQS	Environmental Quality Standard
ES	Environmental Statement, resulting from an EIA
ESA	Endangered Species Act (United States of America)
ESPOO	United Nations Economic Commission for Europe: Convention on Environmental Impact Assessment in a Transboundary Context
FAO	Food and Agriculture Organization of the United Nations
FAWCR	Finfish Aquaculture Waste Control Regulation (Canada)
FLE	Framework Law on the Environment (Chile)
FONSI	Finding of no significant impact
FRS	Fisheries Research Services (United Kingdom)
GPS	Global Positioning System
HAB	Harmful Algal Bloom
HAS	Habitats of special significance
HPA	Hydraulic Project Approval (United States of America)
ICZM	Integrated Coastal Zone Management
ID	Identification
IMR	Institute of Marine Research (Norway)
INTESAL	Salmon Technological Institute (Chile)
ISO14001	International Organization for Standardisation standard primarily concerned with environmental management systems
ISO14004	International Organization for Standardisation standard primarily concerned with environmental management systems
ISO9001	International Organization for Standardisation standard primarily concerned with quality management systems
LA	Local Authority
MAL	Ministry of Agriculture and Land (Canada)
MARPOL	International Convention for the Prevention of Pollution from Ships, 1973, as modified by the Protocol of 1978 relating thereto
MDEP	Maine Department of Environmental Protection
MePDES	Maine Pollutant Discharge Elimination System (United States of America)
MEQO	Marine Environmental Quality Objectives (Canada)
MOE	Ministry of the Environment (Canada)
MOM	Modelling-On-growing fish farms-Monitoring
MSc	Master of Science Degree (United Kingdom)
MWLA	Ministry of Water, Land and Air (Canada)
N/A	Not Applicable
NBDAFA	New Brunswick Department of Agriculture, Fisheries and Aquaculture (Canada)
NBDELG	New Brunswick Department of the Environment and Local Government
NBDENV	New Brunswick Department of the Environment (Canada)
NCPA	Norwegian Pollution Control Authority
NEPA	National Environmental Policy Act (United States of America)
NGO	Non-Governmental Organization
NIVA	Norwegian Institute for Water Research
NOAA	National Oceanic and Atmospheric Administration (United States of America)

NPDES	National Pollutant Discharge Elimination System (United States of America)
NS9410	Norwegian Environmental Monitoring Standard
NS9423	Norwegian Environmental Monitoring Standard
NYTEK	Technical Requirements for Fish Farming Installations (Norway)
OECD	Organisation for Economic Co-operation and Development
OSPAR	Convention on the Protection of the Marine Environment of the North East Atlantic (United Kingdom)
PBS	Performance Based Standards (Canada)
PSD	Preliminary Site Description (Chile)
QA/QC	Quality Assurance/Quality Control
RAMA	Environmental Regulation for Aquaculture (Chile)
RAMSAR	The Ramsar Convention on Wetlands
RMA	Resource Management Act (New Zealand)
ROV	Remotely Operated Vehicle
RPD	Redox Potential Discontinuity depth
SAC	Special Area of Conservation
SAIC	Science Applications International Corporation (United States of America)
SALEIA	This case study on EIA and environmental monitoring in marine based salmon aquaculture in Canada, Chile, Ireland, New Zealand, Norway, the United Kingdom and the United States of America.
SBM	Single Bay Management (Ireland)
SCS	Site Characterisation Survey (United States of America)
SCUBA	Self Contained Underwater Breathing Apparatus
SEERAD	Scottish Executive Environment and Rural Affairs Department (United Kingdom)
SEIA	Environment Impact Assessment System (Chile)
SEPA	Scottish Environmental Protection Agency (United Kingdom)
SEPA	State Environmental Policy Act (United States of America)
SGS	Sediment Grain Size
SIGES	Integral Management System (Chile)
SMA	Shoreline Management Act (United States of America)
SNH	Scottish Natural Heritage (United Kingdom)
SOP	Standard Operating Practices for the Environmental Monitoring of the Marine Finfish Cage Aquaculture Industry in New Brunswick (Canada)
SPA	Special Protected Areas
SubPesca	Under Secretariat for Fisheries (Chile)
TOC	Total Organic Carbon
TBT	Tri-butyl Tin
UK	United Kingdom
UKAS	United Kingdom Accreditation Service
UNECE	United Nations Economic Commission for Europe
USA	United States of America
USACE	United States Army Corps of Engineers (United States of America)
USFWS	United States Fish and Wildlife Service (United States of America)
UWWT	Urban Waste Water Treatment EC Directive (United Kingdom)
VHS	Video recoding
WDFW	Washington Department of Fish and Wildlife (United States of America)
WDNR	Washington Department of Natural resources (United States of America)
WDOE	Washington Department of Ecology (United States of America)
WFGA	Washington Fish Growers Association (United States of America)

Introduction

APPROACH

The information presented in this report comes from a variety of sources including the peer-reviewed literature, the grey literature and the Internet – many important documents are now available only on the web. The amount and sources of information available varied between the study countries; the predominant sources of information for New Zealand were web based and very comprehensive, as was the United Kingdom of Great Britain and Northern Ireland. In the case of some countries, such as Canada and the United States some information was sourced from the Internet, but much of the detail was gained from questionnaire respondents. Throughout this report footnotes detail the specific information source and Web links. In addition, a questionnaire (Appendix 1) based on the terms of reference was circulated widely in each country to a range of stakeholder representatives, but the number of responses was disappointingly low (Appendix 2) – to those who responded we are extremely grateful. Information sourced from returned questionnaires is not directly referenced to individual responses to maintain anonymity.

INTERPRETATION OF EIA AND ENVIRONMENTAL MONITORING IN THIS REPORT

Formally, Environmental Impact Assessment (EIA) is the term used to describe the analysis of environmental costs and benefits that is required in many legislatures prior to granting a licence for some new development or extension of a pre-existing development that is perceived to have at least some negative environmental consequences. EIA is a short-term, one-off study used by coastal planners to inform sustainable development and coastal zone management. EIA assesses the likelihood of impacts and their significance and provides recommendations for mitigating the impacts.

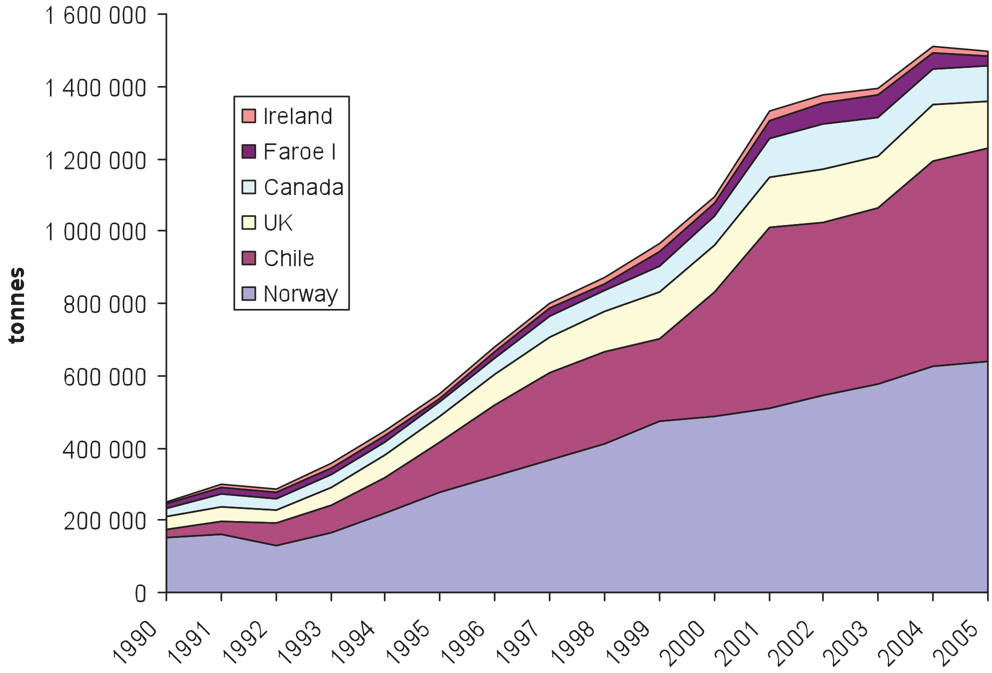
Quite separately, environmental monitoring of salmon farming is a process for determining the actual impacts of an operational farm. In all countries studied, environmental monitoring is established in law, occasionally supplemented by voluntary agreements. It may be carried out by independent bodies, governmental organizations or the farmer. In this report we have interpreted the terms of reference as referring to both practices and consider both in terms of informing the pre-development analysis and the post-development monitoring as required in each of the 7 different countries under study.

BACKGROUND

Globally the aquaculture industry is expanding rapidly, with the production of farmed salmon growing apace. With the continuing overexploitation of the worlds wild fisheries there will be increased pressure on industry to meet this shortfall and increase production. It is predicted that aquaculture production will exceed capture fisheries production by around 2030 (Brugère and Ridler, 2004).

The culture of salmonids is a significant industry in several mid-latitude countries and global production continues to increase at a fast rate reaching 1.3 million tonnes in 2005. Norway and Chile are the largest producers with 41 and 38 percent of total production respectively. The United Kingdom of Great Britain and Northern Ireland and Canada have only 8.5 percent and 6.4 percent, while the United States accounts for 0.6 percent and New Zealand 0.1 percent. (Figure.1)

FIGURE 1
Salmon farming annual production since 1990; countries comprising 97 percent of total world production



Source: FAO, 2007

As salmon culture expands there is growing awareness and intolerance of the negative environmental impacts that may result. Farming activities which may impact on the environment generally fall into two categories; those that have a detrimental effect on the ecosystem, the flora and fauna around the farm and those that impact on wild fish populations. These impacts are summarised in Table 1 below.

The level of impact varies according to production scale and farming techniques as well as the hydrodynamic, chemical and physical characteristics of the site and region and its environmental sensitivity; nutrient discharges will have less impact in a highly flushed site than in an enclosed fjord.

Salmon farming brings societal benefits to coastal areas where traditional employment opportunities are declining, by creating new jobs and businesses. Globally it provides opportunities to reduce the dependence on capture fisheries and to meet the demand

TABLE 1
Salmonid aquaculture activities and their environmental impacts

Farming activity	Source of impact	Potential environmental impact	Environmental risk
Discharge of particulate and dissolved nutrients	Waste feed Faecal matter Excretory products	Organic enrichment of sediments	Sediments underlying cages become anoxic and changes in benthic assemblage
		Nutrient enrichment of water column	Eutrophication
Discharge of chemicals	Medicines Anti-foulants	Eco-toxicity	Loss of sensitive species
Interactions with wild fish populations	Escapes	Genetic dilution of wild stock	Decrease in genetic diversity, fitness
	Disease and parasite transference	Diseased wild stock	Decrease in health, increase in mortality

Source: adapted from Scottish Executive, 2002.

for year round stable supplies of quality seafood (Fernandes *et al.*, 2000). However there are concerns relating to the sustainability of this industry. In 2002 the European Commission recognised the need to address this "through the integrated management of land, water and living resources promoting conservation and sustainable use of marine resources in an equitable way" European Commission, (2002[1]).

To ensure the industry is developing sustainably with minimal environmental impacts, the process of Environmental Impact Assessment (EIA) can be influential in determining which new sites, and extensions to production on existing sites, are approved. The subsequent environmental monitoring of operational sites will determine aquaculture industry management strategies. The objectives of environmental monitoring are that the farms activities do not adversely affect ecosystem function and productivity, do not lead to the deterioration of rare or sensitive habitats, take only a proportionate share of the resource with respect to other users and so are sustainable in the long term.

The EIA system was first formally established in the United States of America in 1969 and has since spread worldwide. Within Europe it has been subject to two European Commission Directives in 1985 and 1997, (85/337 and 97/11EC[2]). Subject to these Directives, salmon farming in marine waters comes under Article 4 (2) Annex II where the requirement for an EIA is determined on a case by case basis or by thresholds and criteria set by each Member State. With its origins in land planning laws, there are difficulties in applying the EIA process to the marine environment; often in planning regulatory systems there is no authority below the low water mark and therefore no clear framework to aid decision-making. In contrast, environmental monitoring is tailored for the specific impacts of actual farming activities. It is used by regulatory bodies and industry to ensure farming practices comply with licensing consent stipulations.

EIA is a systematic process that assesses the impact of a planned (or existing) development on the environment. It is an aid to decision-making, the formulation of development actions and an instrument for sustainable development, (Glasson *et al.*, 1999). It combines a pro-active approach to environmental management by industry and administrative authorities, with aquaculture developments being designed to reduce or eliminate adverse environmental impacts and meet environmental standards prior to granting development consent. The pre-development EIA process should be information driven, with decisions made on the basis of sound baseline data, culminating with the production of an Environmental Statement (ES) by the developer, the content of which should include a range of elements (e.g. Box 1) that approaches a holistic analysis.

In addition to domestic national legislation and polices directed at marine environmental regulation there are international and regional obligations:

- international conventions and agreements – The United Nations Convention on the Law of the Sea, MARPOL for the control of discharges form shipping, CITES, RAMSAR, CBD and OSPAR;
- Regional European Directives- EIA Directives, the Habitats and Birds Directives, the Water Framework Directive.

This report considers the EIA approach and environmental monitoring in relation to salmon farming, implemented by seven countries: Canada, Chile, Ireland, New Zealand, Norway, the United Kingdom of Great Britain and Northern Ireland, the United States of America.

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1 www.govdocs.aquake.org/cgi/reprint/2004/1017/10170080.pdf

2 www.europa.eu/environment/eia/full-legal-text/9711.htm

BOX 1*

Contents of an Environmental Statement

1. A description of the project, including in particular:
   - a description of the physical characteristics of the whole project and the land-use requirements during the construction and operational phases;
   - a description of the main characteristics of the production processes, for instance, nature and quantity of the materials used;
   - an estimate, by type and quantity, of expected residues and emissions (water, air and soil pollution, noise, vibration, light, heat, radiation, etc.) resulting from the operation of the proposed project.
2. An outline of the main alternatives considered by the developer and an indication of the main reasons for this choice, taking into account the environmental effects.
3. A description of the aspects of the environment likely to be significantly affected by the proposed project, including, in particular, population, fauna, flora, soil, water, air, climatic factors, material assets, including the architectural and archaeological heritage, landscape and the inter-relationship between the above factors.
4. A description of the likely significant effects of the proposed project on the environment resulting from:
   - the existence of the project;
   - the use of natural resources;
   - the emission of pollutants, the creation of nuisances and the elimination of waste.

   and the description by the developer of the forecasting methods used to assess the effects on the environment.
5. A description of the measures envisaged to prevent, reduce and where possible offset any significant adverse effects on the environment.
6. A non-technical summary of the information provided under the above headings.
7. An indication of any difficulties (technical deficiencies or lack of know-how) encountered by the developer in compiling the required information.

From Annex IV, "Information referred to in article 5 (1) of the amended (1997) EIA Directive"

* www.europa.eu/environment/eia/full-legal-text/9711.htm

The regulatory requirements and voluntary practices for EIA and environmental monitoring of salmon farms

In this section we briefly summarise the key features of the EIA process for salmon marine cage aquaculture in each of the 7 countries chosen. Where possible, references are given to original source regulations or other documentation but these are not reproduced in detail here.

CANADA

Aquaculture operations in Canada are regulated both at federal and provincial level. The Department of Fisheries and Oceans (DFO) is the lead federal department responsible for the management of aquaculture[3]. It is the DFO's responsibility to review aquaculture license applications in order to identify and help mitigate any impacts on marine environmental and wild fish stocks. The main federal legislative tool guiding the environmental assessment process within Canada is the Canadian Environmental Assessment Act (CEAA). The act came into force in 1995. The act details the responsibilities of the federal government in relation to the environmental assessment of projects, including aquaculture projects. Approval for aquaculture projects can only be given once an environmental assessment has been carried out under the CEAA. The assessment is carried out to ascertain the potential impacts of the proposed aquaculture operation. The Canadian Environmental Assessment Agency[4] was established under the CEAA in order to administer and promote the federal environmental assessment process. Both Environment Canada and DFO have responsibilities under the Fisheries Act. Environment Canada is responsible for promoting pollution prevention and sustainable management practices, as well as ensuring that water quality is maintained, while the DFO, through the Act, prohibits the harmful alteration, disruption or destruction of fish habitat. Both agencies also have responsibilities under the Species at Risk act in order to ensure that species at risk are not harmed or killed as a result of aquaculture activities.

All proposed aquaculture facilities are also reviewed and require approval under both the Navigable Waters Protection Act[5] (through Transport Canada department) and the Fisheries Act to assess any impacts on wild fish stocks and fish habitats.

During the Environmental Assessment (EA) the DFO or provincial governments may consult with other federal or provincial departments and agencies as is deemed necessary (such as Environment Canada, the Department of Indian Affairs and Northern Development, Integrated Land Management Bureau).

There are four types of EA carried out under CEAA:

- screening (including class screening)
- comprehensive study
- mediation
- review panel

[3] www.dfo-mpo.gc.ca/aquaculture
[4] www.ceaa-acee.gc.ca/index_e.htm
[5] www.dfo-mpo.gc.ca/aquaculture).

The majority of marine aquaculture projects will undergo a 'screening' EA. This type of EA is aimed at detailing the environmental effects of an aquaculture project. As a result of the EA there may be a recommendation to minimize or mitigate such impacts or modify the aquaculture project proposed. The outcome of the EA may also recommend further assessment, either through mediation or the review panel process[6].

Under the Fisheries and the Species at Risk Acts, substantial consideration is given to ensuring that fish habitats and any species at risk are not threatened by aquaculture activities or impacts. Atlantic salmon escapes can have significant ecological consequences on the west coast of Canada, where this species is not indigenous. In British Columbia there are substantial regulations covering the prevention of escapes.

Provincial government is responsible for issuing operating licenses, ensuring compliance with regulations (both provincial and federal) and carrying out onsite inspections. In British Columbia (BC) the Ministry of Agriculture and Land (MAL) is responsible for assessing aquaculture applications and issues licenses under the provincial Fisheries Act. Together with the Ministry for the Environment, MAL are responsible for the compliance and enforcement of aquaculture regulations in BC. The impact of fish waste products is regulated through environmental standards set by the Ministry of Water, Land and Air protection. The Finfish Aquaculture Waste Control Regulation, or FAWCR, (BC regulation 321/2004[7]) is part of the Environmental Management Act (BC) and provides the legal authorization for finfish farms to discharge waste. This regulation requires farmers to monitor the marine environment to determine any detrimental effects on the benthic environment. This regulation is administered through the Environmental Protection Division of the Ministry of Environment.

In New Brunswick, the Department of Agriculture, Fisheries and Aquaculture (NBDAFA) is responsible for reviewing and approving marine aquaculture sites and for the control of the spread of disease, parasites, toxins and other contaminants. The New Brunswick Department of the Environment (NBDENV), under the Clean Environment Act, are responsible for administering an Approval to Operate certificate, which sets out the conditions with which the site must comply. This includes environmental monitoring requirements and waste managements plans. An Environmental Management Program for the Marine Finfish Cage Aquaculture Industry in New Brunswick (EMP) was developed by NBDENV in 2006 and is enforced through the Aquaculture Approvals programme under the Water Quality Regulation (part of Clean Environment Act) and the Fish Habitat Protection provisions of the Fisheries Act (NBDENV 2006a). The EMP provides guidance on long-term environmental sustainability within the industry. The programme has several components, including the Environmental Management Framework and a Mitigation and Remediation programme. The EMP also details a set of Operational Best Management Practices to be used by the finfish industry. These practices have been devised to minimise the organic and inorganic loading from finfish aquaculture activities. Guidance is provided on a number of issues, including waste management, equipment cleaning and disinfection, feed handling and storage and feeding practices.

Voluntary systems

The British Columbia Salmon Farmers Association (BCSFA) Code of Practice[8] was revised in 2005. The code is aimed at improving sustainable environmental stewardship and maximising product quality assurance. The code has five principles, including a commitment to minimise impacts on the environment and to ensure a healthy environment for culturing salmon stock. A number of industry companies in British

[6] www.dfo-mpo.gc.ca/aquaculture/ref/AAPceaafin_e.pdf
[7] www.al.gov.bc.ca/fisheries
[8] www.salmonfarmers.org/attachments/codeofpractice1.pdf

Columbia are also involved in application of ISO 14004 Environmental Management Systems[9].

The New Brunswick Salmon Growers Association devised an Environmental Policy and Code of Practice[10] in 2004. This policy provides a commitment to sustainable development and operation of the salmon industry as well as setting out a number of guiding principles that can be applied to all aspects of the industry.

CHILE

The General Fisheries and Aquaculture Law (Law 18.892, 1989) is the primary legislative tool applied to the establishment and authorization of aquaculture facilities in Chile[11] (Leon, 2006). The Ministry of Economy, Promotion and Reconstruction has jurisdiction over the prevention of the introduction and spread of high risk diseases and ensures that aquaculture development is in accordance with the carrying capacity for the area. This law defines concessions and authorizations depending on where the project site is – coastal area, beach, water column and sea bed lots. A number of regulations apply to the planning and authorization of aquaculture facilities, these were summarised by Leon (2006) as follows:

- Regulation for Aquaculture Concessions and Permits (SD 290/93);
- Regulation of the Environmental Impact Assessment System (SD 95/2001);
- Environmental Regulation for Aquaculture, RAMA (SD 320/01);
- Regulation for Protective, Control and Eradication Measures of High Risk Diseases of Hydrobiologic Species (SD 319/2001);
- Regulation for the Control of Water Pollution (SD 1/1992);
- Navigation Law (SD 2222/1978).

SubPesca (Under Secretariat for Fisheries) has the authority to grant aquaculture concessions and authorizations, while SerNaPesca (National Service for Fisheries) is responsible for maintaining a national register of aquaculture facilities. The Ministry of National Defence has the responsibility for granting concessions on State owned property. Potential operators must submit an application for the proposed aquaculture project to SerNaPesca, who are charged with verifying the information and ensuring that all requirements under Regulation for Aquaculture Concessions and Permits have been met. The application and associated reports are then submitted to SubPesca, who certify that all permit requirements have been met. The applicant may then submit the project to the Environmental Impact Assessment System.

In collaboration with SubPesca, the Ministry of National Defence is responsible for establishing areas which are suitable for aquaculture development. To date, two areas have been decreed as Authorised Areas for the establishment of Aquaculture (AAA, Law 18.892), <Norte Chico> and <Sur> (Leon 2006). These areas are deemed to be suitable for aquaculture and there is seen to be reduced conflict with other potential resource uses such as small-scale community fisheries, protected areas (parks and reserves), important navigational areas and natural shellfish beds.

The Framework Law on the Environment (FLE), No. 19.300 (1994) states that aquaculture activities are subject to an EIA process. The main coordinating agency for FLE is CONAMA (National Commission for the Environment). This body represents 13 State ministerial departments and is represented at the regional level by COREMA (Regional Commission for the Environment). CONAMA is responsible for coordinating governmental environmental policies and preparing appropriate environmental regulations (OECD, 2005). Project applications must be registered with either CONAMA or COREMA, depending on whether the environmental impact pertains to one or more regions. The General Law on Fishing and Aquaculture and the

[9] www.iso14000-iso14001-environmental-management.com/index.htm
[10] www.nbsga.com/articles/2004-CodesandPolicyJune2004CompleteDocument(1).pdf
[11] www.fao.org/fi/website/FIRetrieveAction.do?dom=legalframework&xml=nalo_chile.xml

Regulations for Aquaculture Concessions and Permits provides the legal framework for the granting of aquaculture permits and concessions and sets out the environmental requirements.

Aquaculture activities on private and State owned land are subject to the EIA process and environmental permits are granted though that process. The Environmental Regulation on Aquaculture[12], RAMA (SD 320/2001), was introduced in 2001 to provide regulatory authority for assessing environmental impacts and associated mitigation measures within the aquaculture industry (Leon, 2006). The focus of this regulation is placed on avoiding and assessing sediment anoxia (Niklitschek *et al.*, 2005). This regulation requires the mandatory preparation of the Preliminary Characterisation of Site, or PSD (OECD, 2005), for all water column and sea bed lot projects, which must be submitted to SubPesca. The aim of the study is to provide information on the biological, physical and chemical parameters of the proposed project site. The Regulation on the EIA System (SEIA, 1997) provides the regulatory framework to aquaculture operations through the sectoral environmental permits. An aquaculture facility may be required to submit an Environmental Impact Declaration (DIA). However, where a project is deemed to have the potential for additional major impacts, (Box 2), an Environmental Impact Study (EIA) may be required.

The EIA is aimed at providing adequate field information to identify and predict potential impacts and enable formation of any mitigation measures. The DIA are used for projects where there is less potential impact on the environment. The public have the opportunity to be involved in an EIA, but this is not necessary for a DIA. CONAMA and COREMA publish a list of all Declarations and Studies presented, on a monthly basis. All relevant agencies involved in the EIA process must approve the final technical report, which is compiled by the Commission. The technical report contains a number of items, including but not limited to:

- reference to the technical reports drafted by the other participating agencies;
- summary of the observations made by the community;
- summary of the environmental impact assessment, of the main environmental impacts and of the proposed mitigation, repair and compensation measures;
- conclusions on the appropriateness of the proposed mitigation, repair and compensation measures with regard to the effects for which an Environmental Impact Study is required;
- indication of the sectoral environmental permits, related to the project or activity.

BOX 2

Additional factors requiring a full Environmental Impact Study for an aquaculture project in Chile

- risk to human health, caused by the quantity of effluents or waste matter;
- significant adverse effects on renewable natural resources, including soil, water and air;
- resettlement of human communities, or significant alteration of the life system and customs of local communities;
- location close to human communities, protected areas or resources which may be affected;
- significant alteration, to the scenic or tourism value of an area;
- alteration of monuments, sites of anthropological, archaeological or historical interest and areas of cultural significance.

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[12] www.subpesca.cl/docs_ingles/RAMA_english.pdf

Voluntary systems

Several codes of practice and industry agreements have been drawn up by the salmon farm industry in support of improving environmental quality of culture sites. SalmonChile (previously Chilean Salmon and Trout Producers Association) has developed a number of these agreements, including:

- Clean Production Agreement (APL)
- Sustainable Production Agreement
- Integral Management System (SIGES)

Fundación Chile has developed the Code of Environmental Best Practices for salmon farms (CPBA) (Niklitschek *et al*., 2005; OECD, 2005; Leon, 2006). In 1995, SalmonChile set up a technical branch, Salmon Technological Institute (INTESAL). This organization has been concerned with a number of technological issues within the salmon industry, including research and promotion of technologies aimed at improved efficiency and reducing environmental impact (Niklitschek *et al.*, 2005). Exporting companies in Chile are reported to be progressing toward the implementation of environmental and quality standards, such as ISO 14001 and ISO 9001.

IRELAND

Under the Irish regulations for implementing the EC Directives 85/33/EEC and 97/11/EC in relation to EIA, for some salmon farm activities an EIA is mandatory, for others it is at the discretion of the Minister of the Marine, Head of the Department of Communications, Marine and Natural Resources, the principal regulatory authority for the industry. According to the EC Directive, "intensive fish farming" falls under Annex II Class 1 (f), which means that each member State may accord specific criteria for the application of EIA on a case by case basis.

Ireland has approached EIA requirements for aquaculture activities by applying different requirements to fish breeding installations than to fish rearing installations. An EIA is mandatory for all marine salmonid breeding installations for which a licence is sought, as opposed to a salmon farm were an EIA may be requested by the Minister for the Marine if the salmon farm is deemed likely to have a significant effect on the environment.

Similar to Norway, Irish EIA is closely associated with planning laws. The first legislative instruments addressing EIA were implemented in 1989, when statutory procedures were laid down and the content of an ES were specified. The requirements for EIA of salmon farming installations were reviewed in 1999, resulting in a more rigorous approach. The current system requires that a marine salmon development applies for two licences; a foreshore licence issued under a planning law, the Foreshore Act 1933 and an aquaculture licence issued under the Fisheries Amendment Act (1997). This means that an EIA may be requested by local authorities under the former legal instrument, as well as the Minister for the Marine under the latter[13]. Where an EIA is required the farmer can only apply for the foreshore and aquaculture licences once approval has been gained.

The foreshore licence specifies the dimensions and number of fish cages allowed at each site and is generally issued for ten years. The aquaculture licence clearly defines the type of aquaculture allowed at the site for a specified period of time, which will not exceed 20 years, the norm being ten years. These two licenses are linked in that the granting of one is contingent on the other. A 'trial licence' may also be applied for under the Fisheries Amendment Act (1997). This licence permits aquaculture activities that have an investigative or experimental nature and will not be for more than one year. Trial licences are not renewable.

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[13] dcmnr.gov.ie/Marine/Environmental+Assessment/Environmental+Assessment.htm

BOX 3
Irish Aquaculture Licence Conditions

- Only salmon may be cultivated under the terms of the licence.
- The position of the cages shall not prevent the passage of migratory fish and all necessary precautions will be taken to prevent the escape of farmed fish.
- Records shall be kept of all chemicals and antibiotics discharged, quantity and date of use.
- Any disease, abnormal loss or mortality of fish will be notified to the Department of the Marine and Natural Resources within 24 hours.
- The Department of the Marine and Natural Resources shall be notified within 24 hours of any escapes of farmed fish.
- Prior approval must be sought from the Department of the Marine and Natural Resources for any cages towed into or away from the licensed area.

Aquaculture Licence Special Conditions (assigned on a case by case basis):
- annual production levels;
- annual smolt input;
- maximum stocking density – 15 kgm^{-3} and not to exceed 20 kgm^{-3} at any one time;
- a minimum fallowing period, typically 60 continuous days;
environmental monitoring.

McMahon, 2000.

The aquaculture licence has several general and special conditions attached, relating to escapes, fish disease, stocking density and environmental monitoring (Box 3).

The environmental monitoring requirements stipulated in the licence include:
- sea lice monitoring
- water column monitoring
- sea bed monitoring

Voluntary systems

Voluntary initiatives have been established since 1992. The first management initiative was a Single Bay Management Plan (SBM), which set out agreed husbandry practices. The SBM has recently been developed further into Co-ordinated Local Aquaculture Management System[14] (CLAMS). This is overseen by the Irish Sea Fisheries Board and includes all resource users in developing and implementing a locally relevant management system that can evolve with changing needs.

In conjunction with the CLAMS process an initiative for environmental management has been developed by the Irish Seas Fisheries Board and the Irish aquaculture industry; the Environmental Code of Practice for Irish Aquaculture Companies and Traders[15], (ECOPACT). ECOPACT is designed to encourage widespread adoption of environmental management systems by the industry.

NEW ZEALAND

In New Zealand EIA (or as it is referred to there, ‘Assessment of Environmental Effects’, (AEE)), is integrated into the statutory planning framework of the Resource Management Act (RMA, 1991). Prior to this there was no statute relating to EIA, but with the implementation of the RMA all resource consents require an EIA/AEE, irrespective of the size of the development. The content of an EIA/AEE has been outlined[16].

[14] www.bim.ie/templates/text_content.asp?node_id=244
[15] www.bim.ie/templates/text_content.asp?node_id=700
[16] www.es.govt.nz/Departments/Consents/assessment%20of%20effects.aspx.

The aquaculture industry has come under the jurisdiction of the RMA with the Aquaculture Reform Act[17] (2004), which took effect on 1 January 2005. This act has simplified the legislative process in relation to managing the aquaculture industry, replacing the two-permit system with a single consent application, a coastal permit and restricting salmon farms to designated Aquaculture Management Areas (AMAs). The coastal permit sets the limits of the scale of the salmon farm, productivity and location. Inherent in the coastal permit is the assessment of environmental effects, which feeds directly into the environmental monitoring requirements of each AMA. The responsibility of administering coastal permits for salmon farms lies with the regional councils, who also monitor the environmental impacts of the farm.

Each regional council in New Zealand has produced a Regional Coastal Plan and this stipulates whether there is an AMA in that region and, if so, the conditions that the salmon farm must conform to, dependent on the sensitivities of the receiving environment. The coastal plan determines whether the salmon farm needs 'resource consents' to operate. Resource consents allow the salmon farmer to discharge pollutants into the waterbody. If the coastal plan does not require this of the farmer, a certificate of compliance must be issued to the farm to allow it to operate lawfully.

Currently there are three areas in New Zealand where salmon farms operate, each coming under the jurisdiction of a different Regional Council (Southland, Canterbury and Marlborough). Each regional council has a different environmental monitoring strategy, but in all areas the onus is on the farmer to avoid, mitigate or remedy any adverse environmental effects. The areas highlighted in the Southland Regional Coastal Plan[18] where salmon farming can create adverse effects are listed in Box 4.

Incorporated into each AMA is a refuge area which the farm can utilize if an event should occur requiring the temporary relocation of the farm to maintain the health of the farmed stock, e.g. harmful algal bloom (HAB). The coastal plan also regulates on the effects that may occur when the farm has to move and includes the transmission of exotic species. It is considered that the physical difficulties and restrictions applied to farms whilst occupying a refuge site are incentive enough to ensure a return to the original location as soon as it is appropriate without additional regulations needed.

BOX 4

Regional Coastal Plan for Southland, recognized areas of adverse effect of salmon farming

Each farm in an AMA will be monitored to assess environmental effects and effects on other coastal resource users. The areas recognised where salmon farming can have adverse effects are:

- exclusive occupation of large areas;
- interference with navigation;
- reduced amenity value;
- visual impacts;
- build up of benthic sediments;
- discharge of contaminants;
- interference with heritage values;
- water quality impacts;
- loss of natural character;
- loss of habitats of significant indigenous fauna and significant indigenous vegetation.

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17 www.mfe.govt.nz/rma/index.php

18 www.es.govt.nz/Departments/Planning/index.aspx#CoastalPlan

Voluntary Codes of Practice

New Zealand is currently developing a National Environmental Code of Practice[19], encompassing all aspects of aquaculture. This will replace the current practice where farms develop a voluntary code in association with other stakeholders.

NORWAY

Norwegian salmon farming is strictly controlled by a number of laws and regulations[20]. The Ministry of Fisheries and Coastal Affairs is the principal regulatory authority responsible for the industry, with three other Ministries also having a degree of authority; the Ministry of Environment, the Ministry of Agriculture (disease control and regulations) and the Ministry of Local Government and Labour. The Aquaculture and Coastal Management Department of the Directorate of Fisheries has overall responsibility for management of the Aquaculture Act[21]. In relation to EIA the responsibility for Norwegian environmental policy lies with the Ministry of the Environment, with this Ministry developing legislation and guidelines. In relation to EIA of salmon farms, the Directorate of Fisheries is the competent authority but the Norwegian Pollution Control Authority (NCPA) - a Directorate under the Ministry of the Environment – and the County Governor's Department of Environmental Affairs have particular responsibilities.

The Norwegian Government adopted the first generation of legislation on EIA in 1990, as part of the Planning and Building Act and the EIA system continues to be closely integrated with land use planning processes. In 1999 the management of the EIA system was revised and responsibility was devolved to local authorities. The current EIA provisions implement the EC Directive 97/11/EC on EIA and the requirements of the UN ECE Convention on Environmental Impact Assessment in a Transboundary Context, (the Espoo Convention)[22].

An EIA may be required for a movable/floating marine salmon farm with a volume of 48 000 m^3 or more, or a permanent marine farm site with a volume of 36 000 m^3 or more, according to criteria listed in Section IV of the Norwegian Regulations[23]. If the competent authority decides that an EIA is required no permit will be granted until the requirements have been fully satisfied. Once approved the Directorate of Fisheries may order additional monitoring, to that already required under statutory monitoring, before the farm begins operating, during operation and after the site is abandoned.

The regulatory framework was established in 1973, through the Act of Fish Farming, revised in 1981, 1985 and 2006. All regulations applicable to salmon farming are transposed into a common regulation (The Operation and Diseases Regulations ([2004]). These regulations are implemented through a licensing system, issued by the Ministry of Fisheries and Coastal Affairs and through a monitoring programme drawn up by the Pollution Control Authorities. The licensing system sets limits on the size of fish farms and the numbers of licences issued and requires the licensee to provide a comprehensive annual report detailing the operational activities of the farm. The licence requires the farmer to keep records regarding the operational activities of the farm.

In 1997 Norway implemented the National Action Plan for sea lice on salmon farms, ratified by law and enforced by the Norwegian health authorities. This gives local authorities the jurisdiction to gather monthly reports, make unannounced checks on farms and demand delousing if lice levels exceed the targets in the plan (Boxaspen, 2006).

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19 www.nzmic.co.nz/Assets/Content/Publications/sector%20strategy%20final%20low%20resolution.pdf
20 lovdata.no/info/lawdata.html
21 www.fiskeridir.o/fiskeridir/english/about_the_directorate/about_the_departments_1/the_aquaculture_and_coastal_management_department)
22 www.unece.org/env/eia
23 www.regjeringen.no/nb/dokumentarkiv/Regjeringen-Bondevik-I/231606/232935/260617/t-1306_environmental_impact_assessment.html?id=260622

BOX 5

Norwegian Standard – NS9415 – design, dimensions construction installation and operational requirements.

This standard contains requirements for the physical design of the installation and the associated documentation. This includes calculation and design rules, as well as installation, operating and maintenance requirements.

There are requirements for the physical design of all the main components in an installation, functionality after assembly and how the installation shall be operated to prevent escape.

All components of new installations must be certified by an accredited body and existing installations must be issued with a capability certificate.

The standard stipulates what parameters shall be used to determine the natural conditions at a given locality and the procedure for classification of localities.

In addition to regulating the operational activities of the farms, Norway adopted a new regulation in 2003, implemented from January 2006, with a certification scheme, which sets an industry standard for cage construction and mooring systems (NS9415, see Box 5). Referred to as the Nytek regulations[24], all new farms must hold a certificate for each site.

The monitoring programme is based on an environmental management system called Modelling-Ongrowing fish farms-Monitoring (MOM). It integrates elements of EIA, monitoring of impacts and achieving Environmental Quality Standards (EQS) into one system (Ervik *et al*., 1997; Maroni, 2000; Hansen *et al.*, 2001). There are two monitoring investigations (B and C) of increasing complexity and monitoring frequency depending on the degree of environmental impact and three zones to which impact assessment criteria are applied, (local, intermediate and regional). Monitoring investigation B is applied to the local zone and monitoring investigation C is applied to the intermediate and regional zones (Hansen *et al.*, 2001). The frequency of applying the B investigation is directly related to the degree of exploitation of the site, whereas the frequency of employing C investigation is at the discretion of the local authority. EQS's are set for the parameters of both investigations and the monitoring is described in Norwegian Standard NS9410.

Currently Norway is reviewing the regulation and monitoring procedures in relation to aquaculture, primarily in response to escapes. Included in this review is the recommendation that a separate environmental monitoring program is implemented, as part of an environmental action plan developed by the Ministry of Fisheries and Coastal Affairs[25].

Voluntary systems

There are no voluntary self monitoring systems or codes of practice in Norway.

UNITED KINGDOM

The Aquaculture industry in the United Kingdom is primarily located in Scotland, along the West coast and in Orkney and Shetland. Scotland produces 90 percent of the United Kingdom finfish market, 95 percent of which is Atlantic salmon; therefore, this report focuses on the regulation and monitoring framework in Scotland.

In the United Kingdom of Great Britain and Northern Ireland, EC Directive 85/337 (the EIA Directive) is implemented through over 40 different secondary regulations, in response to this Scotland (which has a separate legal system from the rest of the

[24] www.tekmar.no/tema/ns9415.asp
[25] www.fiskeridir.no/fiskerdir/english/news/vision_no_escapees

United Kingdom of Great Britain and Northern Ireland) developed three Statutory Instruments (secondary legislation):

- Part 2 of the Environmental Assessment (Scotland) Regulations 1988 (Statutory Instrument (SI) 1221);
- Town and Country Planning (General Development Procedure) (Scotland) Order 1992 (SI 224);
- Environment Assessment (Scotland) Amendment Regulations 1994 (SI 20212).

In respect to salmon farming, the regulations were reviewed in 1999 pending the transfer of responsibility for authorization of marine aquaculture from the Crown Estate to local authorities in 2006. This review resulted in the implementation of the main legislative act now applying to marine fish farming:

- Statutory Instrument no 367: The Environmental Impact Assessment (Fish Farming in Marine Waters) Regulations 1999

The main actors with responsibility for regulating salmon farming in Scotland are outlined in Box 6.

The 1999 regulations specify criteria that determine whether a proposed new aquaculture development or modification to an existing development requires an EIA. These are:

- all proposals in 'sensitive areas' as defined in the Regulations;
- all new proposals with a designed biomass ≥100 tonnes or cage surface area ≥1 000m^2;
- any modifications with a designed biomass ≥100 tonnes or cage surface area ≥ 1 000m^2.

The new legislation[26] (Environmental Assessment (Scotland) 2005 Act), regarding EIA came into force in Scotland in February 2006. This Act transfers authority to Scottish local authorities who now have the responsibility for formally determining whether an EIA is required which previously rested with the Crown Estate. In the Scottish Islands of Shetland and Orkney, local councils have had that authority since 1974, under the County Council Act (1974).

BOX 6

Key Regulatory Bodies of Scottish Aquaculture

The Crown Estate – the owner of the sea bed and currently regulates the aquaculture industry through the issuing of sea bed leases. EIA is a requirement of the lease under Environmental Impact Assessment (Fish farming in marine waters) Regulations 1999.

Scottish Environmental Protection Agency (SEPA) – a government agency responsible for safeguarding the cleanliness of Scotland's tidal waters and protecting aquatic fauna and flora. SEPA regulates the aquaculture industry through the issuing of discharge consents under the Water Environment (Controlled Activities) (Scotland) Regulations (2005).

Scottish Natural Heritage (SNH) – responsible for conserving the Scottish environment and it is consulted on the environmental impacts of aquaculture by the Crown Estate on EIA and SEPA on discharge consents.

Local Authorities – advises Crown Estate on lease conditions – shortly to replace the Crown Estate as the statutory planning authority for aquaculture.

Scottish Government Environment and Rural Affairs Department (SEERAD) – has responsibility for the protection of fish, fisheries and the wider marine environment. All fish farms must register with it for the control of fish diseases.

[26] www.opsi.gov.uk/legislation/scotland/acts2005/20050015.htm

A review of current practice and decision-making process that applies to salmon farming is currently underway[27].

All proposed developments must apply for a lease to develop operations on the sea bed to the Crown Estate, apply the Local Authority (LA) for Planning Permission and to SEPA for 'Consent to Discharge'. The LA are responsible for screening, scoping and evaluating formal EIA, taking advice from a wide range of statutory and non-statutory bodies, and SEPA regulate and monitor the benthic and water column environmental impacts of the farms activities.

The SEPA 'Consent to Discharge' sets conditions and restrictions on the salmon farm to achieve a balance between site productivity and environmental impact. The main legislative instrument, the Control of Pollution Act (1974), upon which 'Consents' were set, was replaced by the Water Environment (Controlled Activities) (Scotland) Regulations 2005 on 1 April 2006. These regulations, referred to as the 'CAR' regulations, contain a pre-application discussion process between the farmer and SEPA that establishes the information that will be required to be included in an Environmental Statement (ES)[28]. 'Consent' conditions are drawn up on a site-by-site basis and include cage position and quantity, species farmed and biomass limits based on the carrying capacity of the receiving environment. 'Consent to discharge' are time limited and usually remain in place for a minimum of four years.

The main legislative instrument relating to salmon farming has been reviewed and this has led to the Aquaculture and Fisheries (Scotland) Bill (2006) being approved. On its implementation this Bill will make sea lice management and monitoring a statutory process and address the environmental impact of escaped fish[29].

There is no formal zoning system for fish farming in Scotland but the government has produced Locational Guidelines[30] that delineate coastal areas[31] according to their suitability for development on the basis of nutrient modelling and sensitive habitat assessment:

- Category 1 where the development of new or the expansion of existing marine fish farms will only be acceptable in exceptional circumstances. These are only likely to arise where it can be demonstrated conclusively, by the applicant, that the development will not have a significant adverse effect on the environmental qualities of the area.
- Category 2 where the prospects for further substantial developments are likely to be limited although there may be potential for modifications of existing operations or limited expansion of existing sites, particularly where proposals will result in an overall reduction in environmental effect, so enhancing the qualities of the area and hydrological conditions.
- Category 3 where there appear to be better prospects of satisfying environmental requirements, although the detailed circumstances will always need to be examined carefully.

Voluntary systems

The recently published Code of Good Practice for Scottish Aquaculture[32] is the main self-regulatory instrument and contains monitoring practices for sea lice control and environmental monitoring policies. The large majority of farms in Scotland are signatories to this code, which includes annual, independently accredited audits.

27 www.sarf.org.uk/SARF024.htm
28 www.sepa.org.uk/pdf/wfd/regimes/car_practical_guide.pdf.
29 www.scottish.parliament.uk/business/bills/67aquaFish/index.htm
30 www.govdocs.aquake.org/cgi/reprint/2004/524/5240210.pdf
31 www.marlab.ac.uk/Delivery/Information_Resources/information_resources_view_document.aspx?contentid=1416
32 www.scottishsalmon.co.uk/aboutus/codes.asp

UNITED STATES OF AMERICA

The National Environmental Policy Act (NEPA, 1969) was the first legislative instrument to require an EIA/EIS process (in the United States of America an Environmental Impact Assessment is referred to as an EIS – Environmental Impact Statement). It operates at a federal level and is the basic national charter for protecting the environment, establishing policy and goals and provides a means for implementing policy[33]. The Council on Environmental Quality (CEQ) was created with the specific remit to interpret the Act and prepare guidelines on requirements for EIS. In 1977 the CEQ was given enforceable regulatory status in regard to NEPA and EIA/EIS. A "Lead Agency" is designated to co-ordinate the EIS process for any proposal or development. The "Lead Agency" is usually the local government and has the responsibility to make a "Determination of Significance". This process determines whether a full EIS is required or not, or whether a "finding of no significant impact" (FONSI) is required by a development. In relation to salmon farming a permit system regulates the industry. All new salmon farm developments are subject to the EIS system. The whole system is governed and referred to as the State Environmental Policy Act (SEPA). Specific requirements for the EIS system may vary from State to State.

New salmon farm developments are subject to a maximum of 14 permits, depending on the State, the most important being those issued under State Environmental Policy Act (SEPA), National Environmental Policy Act (NEPA) (note that compliance with the permit process does not imply automatic compliance with NEPA, (Glasson *et al.*, 1999). Biological Assessments (BA) are also required for United States Army Corps of Engineers (USACE), Section 10 permits (assures protection of public interest, including navigation, water safety and water quality) (Amos and Appleby, 1999). USACE distribute the BA's to other agencies that have jurisdiction over permitting, such as the National Oceanic and Atmospheric Administration, (NOAA) and the United States Fish and Wildlife Service (USFWS). National Marine Fisheries Service administers the Endangered Species Act (ESA) for anadromous salmonids. ESA may require commercial salmon farmers to obtain permits to take fish for their use due to the impact on listed species (Amos and Appleby, 1999).

The Clean Water Act (CWA, 1977) is the primary legislation dealing with the protection of surface water quality, through application of a number of regulatory and non-regulatory tools. These tools[34] are employed to achieve the broader goal of restoring and maintaining the chemical, physical and biological integrity of the nation's waters such that they support "protection and propagation of fish, shellfish, wildlife and recreation in and on the water". The United States of America Environmental Protection Agency (EPA) is the primary federal administrative agency for both acts. The CWA is enacted through a permit process and this has become the main method for evaluating environmental impacts.

The CWA prohibits the discharge of pollutants from a point source except when authorized through a National Pollutant Discharge Elimination System (NPDES) permit[35]. The primary aim of the NPDES is to protect and improve water quality by regulating point source discharges. For the purposes of the NPDES, the EPA define finfish farms in the Concentrated Aquatic Animal Production (CAAP) Point Source category, and thus subject to the NPDES permit system. Routine environmental monitoring of salmon farm sites is conducted under the NPDES permit system and is administered at State level.

In 2004 the EPA established Effluent Limitation Guidelines (ELGs) and New Source Performance Standards for the CAAP Point Source category. Any net pen facility producing 100 000 lbs (~45 tonnes) or more of fish per year is deemed to be subject to

[33] www.epa.gov/epahome/laws.htm
[34] www.epa.gov/watertrain/cwa
[35] cfpub.epa.gov/npdes/

the ELG's. All such facilities are required to develop and maintain a best management practice plan detailing how the ELG requirements will be achieved (EPA, Aquatic Animal production Industry Effluent Guidelines 2004[36]). The CAAP regulatory and permitting programme is usually administered at State level, on approval from the EPA.

Two States are involved in salmon net-pen culture – Washington and Maine. Much of the regulatory authority for aquaculture and environmental assessments is devolved to the State agencies and in some cases local county authorities.

Regulatory authorities involved in management of salmon aquaculture in Washington State were summarized by Amos and Appleby (1999) (Box 7). The EIS process works under a programmatic EIS system that was established in Washington in 1991 (J. Rensel, personal communication). In Washington State the Department of Ecology has responsibility for monitoring and compliance of salmon culture operation. An

BOX 7

Agencies and regulations involved in management of aquaculture in Washington State

Washington Department of Fish and Wildlife (WDFW) - management and regulatory authority over all free-ranging fish in the State. WDFW authority over commercial fish culture in State waters is restricted to disease control and protection of wildlife in general.

- The Finfish Import and Transfer Permit (WAC 220–77–030) assures that diseases, pests and predators are not introduced or transferred.
- Hydraulic Project Approval (RCW 75.20.100, WAC 220–120), or HPA, assures that all construction projects ensure protection of wildlife and habitats.

Washington Department of Ecology (WDOE) - regulatory authority over discharges of pollutants into State waters for the protection, preservation and enhancement of the environment.

- The National Pollution Discharge Elimination System Permit (40 Regulation CFR, Part 122.21), or NPDES, assures compliance with State and federal water quality laws.
- The Water Discharge Permit (RCW 90.48) assures that discharges and wastes do not adversely affect water quality and standards. Under the Clean Water Act and the Water Pollution Control Act, WDOE can take regulatory action against net-pen operators who allow Atlantic salmon to escape.

Washington Department of Natural Resources (WDNR) - regulatory authority over State-owned aquatic lands, extending over lands covered and exposed by the tide.

- The Aquatic Lands Lease (RCW 79.90–79.96), or ALL, assures the specification of all uses of the land and the proposed facilities.

Local county authorities - act as lead agencies for applying the environmental policies of the State and the management of their respective county shorelines.

- The State Environmental Policy Act (RCW 43.21C, WAC 197–11), or SEPA, assures consideration of social and environmental impacts of proposed actions.
- The Shoreline Management Act (RCW 90.58), or SMA, assures appropriate and orderly development of State shorelines, management of their uses and preservation of their natural character.

WDFW, WDOE and WDNR jointly provide guidance to state and local agencies on siting farms in order to avoid adverse impacts on the environment.

[36] www.epa.gov/guide/aquaculture/

NPDES permit is required for all farms producing in excess of 20,000 lbs of salmon per year. "Recommended Interim Guidelines for the Management of Salmon Net-pen Culture in Puget Sound", as prepared by the SAIC (Science Applications International Corporation), have been adopted as the basic requirements for environmental site study and routine monitoring of environmental performance (Weston, 1986).

In the State of Maine, Aquaculture Lease Regulations[37] are administered by the Department of Marine Resources (DMR). For discharge applications, DMR works in conjunction with the Department of Environmental Protection, DEP (State of Maine), to ensure that requirements, at State and federal level, are adhered to. Developers for new salmon net pen sites must apply for a standard aquaculture lease[38] permit. This application details the requirements for the Environmental Baseline Field Survey (part 4 of Application Information requirements). The application is designed to facilitate the processing of aquaculture applications and is used jointly by DMR, DEP and USACE. Salmon net pen facilities require a permit under the Maine Pollutant Discharge Elimination System[39] (MePDES), which is administered at State government. This permit details the requirements for routine monitoring of salmon farm environmental performance.

Voluntary systems

Two main codes of practice for the aquaculture industry exist in the United States of America. The Code of Conduct for Responsible Aquaculture Development in the United States Exclusive Economic Zone[40] was devised by the NOAA Fisheries Service in collaboration with a number of stakeholders in 2000. The code provides a set of principles and standards that are applicable to all production systems and helps promote consistency across the industry. Among its main objectives are the promotion of marine stewardship and the establishment of standards to manage environmental issues associated with the industry.

The Saltwater Salmon Net-pen Operations Code of Conduct[41] was devised by the Washington Fish Growers Association (WFGA) in 2002. The code encompasses a number of general principles, including the protection and conservation of marine ecosystems and to take all reasonable measures to minimize impacts on the environment.

CONCLUSIONS

All of the countries examined have legislation in place to ensure that consideration of the environmental consequences of a proposed new salmon farm is mandatory. There are relatively minor variations between countries in the type of information that must be evaluated within an Environmental Statement (or other similar document that contains the product of the EIA process). In all cases assessments of benthic impact, eutrophication and damage to important habitat must be considered. Considerations of sea lice transmission to wild populations, disease transmission between farms and the consequences of escapes are now seen as extremely important. Genetic interactions with con-specifics is not likely in Pacific or Southern Hemisphere countries where Atlantic salmon are non-native and do not in general successfully breed, but transfer of parasites is an issue, particularly in British Columbia.

All the countries included in this study regulate the operation of salmon farming through a system of licences or permits to which various levels of environmental monitoring are appended. Supplemental to this is a series of voluntary codes of practice, summarised in Table 2 below. The most complex regulatory system is that found in the United States of America, with farmers requiring up to 14 different

[37] www.maine.gov/dmr/aquaculture/Chapter02.pdf
[38] www.maine.gov/dmr/aquaculture/documents/StandardFinfishApplication07.pdf
[39] www.maine.gov/dep/blwq/docstand/aquaculture/MEG130000.pdf
[40] www.nmfs.noaa.gov/trade/AQ/AQCode.pdf
[41] www.wfga.net/conduct.asp

permits, issued from different regulatory authorities. The simplest approach is found in New Zealand, with farmers applying for a single licence, the responsibility devolved down to the Regional Council. New Zealand and Chile are the only countries to define areas were salmon farming is permitted and where it is prohibited, although Norway has a relatively strong system of Coastal Zone Management and Scotland, together with several other countries, has defined areas where development of salmon farming (or its expansion if already existing) is precluded.

In the United Kingdom, some have argued that the current dual process, where the planning and environmental pollution aspects are separated, makes the process of applying for a new fish farm unnecessarily cumbersome and expensive. Others have argued that the planning and pollution functions have distinct ends and so have to remain separate and farmers often pursue both processes in parallel, even though the planning application would be unsuccessful if the pollution consent was not granted. In general, although a "one-stop-shop" may reduce bureaucracy for the farms, having a clear separation of different functions should ensure that no important aspect of a proposed development is missed. However, too much sectoral regulation, as appears to be the case in the United States of America and also in some other countries, may preclude changes in the industry that may have net environmental, as well as socio-economic, benefits.

TABLE 2

Summary of the voluntary codes of practice followed in the study countries

Country	Voluntary Agreements/Codes of Practice	Devised by	Web-link Source
Norway	None		
United Kingdom -Scotland	Code of Good Practice for Scottish Aquaculture (2006)	Scottish Finfish Aquaculture Working Group	www.scottishsalmon.co.uk/aboutus/codes.asp
Ireland	Single Bay Management (SBM) (1992)	Overseen by Irish Sea Fisheries board (BIM)	www.bim.ie/templates/text_content.asp?node_id=244
	Co-ordinated Local Aquaculture Management System (CLAMS) (1998)		
	Environmental Code of Practice for Irish Aquaculture Companies and Traders (ECOPACT) (2003)		www.bim.ie/templates/text_content.asp?node_id=700
United States of America	Code of Conduct for Responsible Aquaculture Development in the United States Exclusive Economic Zone (2000)	NOAA Fisheries Service	www.nmfs.noaa.gov/trade/AQ/AQCode.pdf
	Saltwater Salmon Net-pen Operations Code of Conduct (2002)	Washington Fish Growers Association (WFGA)	www.wfga.net/conduct.php
Canada	British Columbia Salmon Farmers Association Code of Practice (2005)	British Columbia Salmon Farmers Association (BCSFA)	www.salmonfarmers.org
	Environmental Policy and Code of Practice (2004)	New Brunswick Salmon Growers Association	www.nbsga.com/articles/2004-CodesandPolicyJune2004CompleteDocument(1).pdf
Chile	Clean Production Agreement Sustainable Production Agreement Integral Management System	SalmonChile	www.salmonchile.cl/frontend/seccion.asp?contid=&secid=6&secoldid=6&subsecid=141&pag=1
	Code of Best Practices for Salmon Farms (CPBA)	Fundación Chile	
New Zealand	National Environmental Code of Practice, (2007/2008).	New Zealand Aquaculture Council	www.Salmon.org.nz/Sector_Strategy_final_low_resolution.pdf

EIA and Environmental Monitoring in Practice

In this section we examine the practical application of EIA and environmental monitoring for marine salmon farming in terms of data collection, sampling analysis, standards, quality assurance etc. For each country a brief summary of the methods used in generic terms is given.

CANADA

Responsibility for environmental assessment and monitoring are based at the provincial level. Salmon aquaculture operations are found in four provinces – British Columbia, New Brunswick, Nova Scotia and Newfoundland. In New Brunswick, 95 percent of the salmon sites occur in the Bay of Fundy, constituting 90 percent Atlantic Canadian salmon production. This report therefore concentrates on British Columbia in the west and New Brunswick in the east.

In New Brunswick, the Department of the Environment (NBDENV) has primary responsibility for environmental monitoring and compliance. Monitoring is usually carried out by third party service providers and consultants.

Within the EMP, the Environmental Management Framework has a number of components with the ultimate aim of providing maximum protection to the environment (NBDENV 2006a). This includes the marine environmental quality objectives (MEQO), as applied to the marine finfish aquaculture industry. Oxic site condition, as determined by sediment sulphide concentration, is used as the MEQO for finfish aquaculture site classification. This applies to the benthic conditions in the area of the cage structures and lease area. Classification is based on the mean sediment sulphide concentration determined during the annual monitoring programme (between August and October), as detailed in Table 3. An Environmental Effects Management Framework (EEM) component has been devised in support of a Performance Based Standards (PBS) approach to compliance and regulation of marine environmental quality. The process relies on a tiered monitoring and management system based on compliance with the MEQO, with monitoring efforts and management requirements increasing as the level of impact increases. Details are provided in Table 3. The

TABLE 3
Classification of marine finfish aquaculture sites by sediment sulphide concentrations, as applied in New Brunswick

Site Classification		Sediment sulphide concentration	Responsive management decision framework	
Oxic	Oxic A	0 – 750 µM	Tier 1 monitoring**	Adhere to Operational Best Management Practices*
	Oxic B	750 – 1500 µM		
Hypoxic	Hypoxic A	1500 – 3000 µM	Tier 1 monitoring**	Adhere to Operational Best Management Practices, including appropriate Adjustments to the practices*
	Hypoxic B	3000 – 4500 µM	Tier 1, 2 monitoring**	Adhere to Operational Best Management practices, including appropriate Additional measures*
	Hypoxic C	4500 – 6000 µM	Tier 1,2,3 monitoring**	Adhere to Further enhanced Operational Best Management Practices*
Anoxic	Anoxic	> 6000 µM	Tier 1,2,3 monitoring**	Response measures to be decided in consultation with ASERC.

* Refer to Environmental Management Program for the Marine Finfish Cage Aquaculture Industry in New Brunswick (NBDENV, 2006a).
**See SOP (NBDENV, 2006b)

EMP gives full details on the Operational Best Management Practices to be adopted according to the level of compliance with the MEQO (NBDENV, 2006a).

"Standard Operating Practices for Environmental Monitoring of the Marine Finfish Cage Aquaculture Industry in New Brunswick" (SOP) have been devised and describes how monitoring should be carried out according to the monitoring tier (NBDENV, 2006b). The number of transects and sediment samples required is determined by the number of fish on site at the time of monitoring and the water depth at the site, as follows:

Sites of less than 30.5 m depth:

- One transect and three sediment samples per 100 000 fish;
- Minimum of 2 transects and 6 sediment samples for 1 – 200 000 fish.

Sites in a depth greater than 30.5 m:

- No transects to be laid but 3 sediment samples per 100 000 fish;
- Minimum of 6 sediment samples for 1 – 200 000 fish.

Guidance is also provided on the positioning of transects and sediment samples in relation to the cage array and individual cages, according to monitoring tier (see SOP, NBDENV, 2006b). Annual monitoring consists of video surveys along the transects (as stipulated by the monitoring tier) and the required sediment samples (as described above). Details of the components of each component are described in Table 4, however, the SOP should be consulted for full details (NBDENV, 2006b).

In British Columbia, provisions for environmental monitoring are contained in the Ministry for Environments Finfish Aquaculture Waste Control Regulation 2004 (FAWCR). In collaboration with the Ministry of Water, Land and Air (MWLA), Protocols for Marine Environmental Monitoring have been developed to facilitate application of FAWCR[42] Available details on the sampling protocols are given in Table 5. Baseline monitoring is performed at potential production sites prior to the commencement of construction and stocking. Operational monitoring protocols are applied to sites already in production.

Baseline Monitoring must be carried out in accordance with Schedule A (Baseline Inventory) of FAWCR[43].

Operators in BC are required to carry out routine monitoring at all sampling stations within 30 days of peak finfish biomass for each production cycle. In cases where the cage array has been relocated within the production cycle, the vacated site must be

TABLE 4

Components of the annual monitoring program conducted in New Brunswick, as detailed in the *Standard Operating Practices for the Environmental Monitoring of the Marine Finfish Cage Aquaculture Industry in New Brunswick*, (NBDENV, 2006b)

Monitoring component		Methodology	Determinand
Video survey		To be carried out along transects where appropriate Collection of all diver collected cores to be recorded Sea floor observation at each end of transects1	Seafloor observations as follows; Approximate sediment thickness; sediment colour; sediment consistency; surface consolidation; gas bubbles; % Beggiatoa coverage; presence of feed and faeces; macrofauna/flora; presence of detritus and fouling organisms.
Sediment samples	< 30.5 m depth	Cores to be collected by diver Minimum disturbance to cores is desirable. Clear cores 30 cm x 5 cm. Cores to be pushed into a depth of 10 cm	**Redox** Redox potential to be determined within the top 2 cm for each core or grab sample1 **Sulphide** A 5 ml subsample from the top 2 cm (after redox analysis) for sulphide determination1
	> 30.5 m depth	Gravity corer for silt and clay sediments Heavy grab for other sediments Three cores or grabs per sample location	

* Full details provided in SOP. SOP also gives details of any deviations from the details provided (i.e. differences between monitoring tiers). References to full technical documents are available from NBDENV.

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42 www.env.gov.bc.ca/epd/epdpa/industrial_waste/agriculture/pdfs/reg_protocols.pdf

43 www.qp.gov.bc.ca/statreg/reg/E/EnvMgmt/256_2002.htm#schA

TABLE 5
Sampling methodology employed in British Columbia, Canada, as detailed by Protocols for Marine Environmental Monitoring (MWLA)

Determinand	Sampling equipment	Sampling location	Spatial scale	Replicates
Baseline monitoring				
Class abundance and richness of megafauna	transect	Across entire site Reference stations*	Length /width of site At least 100 m long	Enough to identify biophysical characteristics to 50 m resolution two at each station (One transect should run perpendicular to the shore)
Class abundance and richness of macrofauna	quadrat	Across entire site Reference stations	1 x 1 m (nine 33 x 33 cm sections) as above	Enough to represent each substratum Five at each station
S^{2-}, E_h, TVS or TOC, SGS, Cu or Zn,	Petit-Ponar, Ponar, Smith-MacIntyre, van Veen grab	All stations	Any size	Three grabs per sediment type for each probable footprint. Minimum five grabs if only one sediment type present
Species richness and abundance of infauna and epifauna	Smith-MacIntyre, van Veen grab	All stations	0.1 m^2	Three grabs per sediment type for each probable footprint. Minimum five grabs if only one sediment type present
Operational monitoring				
S=, E_h,	Petit-Ponar, Ponar, Smith-MacIntyre, van Veen grab	All stations – perimeter of cage array, 30 m from 0 m station, perimeter of tenure and reference stations. Transect should be parallel to prevailing current	Any size	Three grabs at all stations. If mean S^{2-} value is above 1300 µM additional two grabs should be obtained from that station for S^{2-} and Eh.
TVS or TOC, Cu or Zn,	See as for S^{2-}	Only stations at perimeter of cage array and reference station	Any size	Three grabs at each station located at perimeter of cage array and at each reference station
SGS	See as for S^{2-}	Only stations at perimeter of cage array and reference station	Any size	One grab at each station located at perimeter of cage array and at each reference station
Family richness and abundance of infauna and epifauna	Smith-MacIntyre, van Veen grab	All stations	0.1 m^2	five grabs at each station. Three at each reference station

* Reference stations for Baseline Monitoring – should be 0.5 - 2.0 km from facility and must be 0.5 km apart. The mean depth at the reference station should be within 20 percent of the mean depth of the tenure. Characteristic and influences at the reference stations should be similar to that of the tenure

monitored within 30 days of the relocation. If free sulphide concentration is found to exceed specified levels the operator must repeat sulphide monitoring and undertake sediment biological sampling. Monitoring and additional sulphide monitoring should be carried out in accordance with Schedule B (Operational Monitoring) of FAWCR[44].

The protocols for marine monitoring used to facilitate FAWCR used in BC also provide guidance on statistical procedures to be used in interpretation of baseline and operational monitoring data (MWLA, 2002)[45].

In New Brunswick environmental monitoring field measurements are carried out be consultants or third party service providers. In British Columbia professional biologists carry out field surveys. These professionals may be consultants or industry staff. The Ministry of the Environment (MOE), British Columbia, carries out annual benthic audits are certain sites.

Ecological standards

Concentration of free sulphides in pore water is used as an environmental standard in British Columbia, through FAWCR.

44 www.qp.gov.bc.ca/statreg/reg/E/EnvMgmt/256_2002.htm#schB

45 www.env.gov.bc.ca/epd/epdpa/industrial_waste/agriculture/pdfs/reg_protocols.pdf

Marine Environmental Quality Objectives (MEQO) have been set in New Brunswick for sulphide concentrations in soft sediments as follows (see above for more detail):

- Oxic A – 0 – 750 µM
- Oxic B – 750 – 1 500 µM
- Hypoxic A – 1 500 – 3 000 µM
- Hypoxic B – 3 000 – 4 500 µM
- Hypoxic C – 4 500 – 6 000 µM
- Anoxic 0 > 6 000 µM

Quality assurance

British Columbia, through FAWCR, has environmental standards based on the concentration of free sulphide. An approved training course on the determination of free sulphide is provided to relevant personnel from consultants, industry and regulatory agencies, as a means of providing some Quality Assurance/Quality Control (QA/QC). There are fewer QA provisions for other parameters other than those provided by the commercial labs used to carry out analytical work (i.e. accreditation schemes). The Ministry of the Environment (MOE) carries out annual benthic audits are certain production sites.

In New Brunswick the Environmental Monitoring Program has an auditing component, which is carried out by DENV. A minimum of 20 percent of finfish aquaculture sites are audited annually as part of the auditing programme. This process is to ensure that the regulatory agencies are receiving accurate and reliable information on the environmental conditions at culture sites and ensures that procedures in the SOP are being adhered to (NBDENV, 2006a).

Modelling approaches used

In British Columbia, DEPOMOD (Cromey *et al*,. 2002a; 2002b) is used to predict the aerial extent of the 5 g/C/m²/day contour as an indication of the area of maximum impact from culturing operations. DEPOMOD is also used in cases where farms are being re-sited to avoid conflict with valued marine resources. In New Brunswick, DFO may use DEPOMOD in current and depositional modelling studies.

CHILE

Through RAMA, The Environmental Regulation on Aquaculture (2001), all farms entered into the Environmental Impact Assessment System (SEIA) are required to carry out a Preliminary Site Description (PSD). The methodologies to be applied during the PSD are provided for in Resolution 404/2003[46]. In addition, an Environmental Information report is required from all farm sites at a specific time, as part of the routine monitoring. This report should provide information on the environmental condition of the farm site, (water quality and sediment parameters within the sedimentation area) at the time of annual maximum biomass.

The regulation focuses on maintenance of aerobic conditions in the sediment and states that authorization for an aquaculture site will only be approved where the PSD indicates that the sediment will remain aerobic in the future (RAMA, Article 17). The owner/operator of the site must ensure that aerobic conditions are maintained at the sea floor surface (RAMA article 17). The methodologies used in the PSD are detailed in Table 6.

The system is based on the categorisation of the farm and this determines the parameters to be measured in the PSD and Environmental Report. The five categories are described in Box 8. The parameters required, according to the farm category, are detailed in Box 9.

[46] www.subpesca.cl/docs_ingles/Resolution_N404_english.pd

TABLE 6
Methodologies to be applied to Preliminary Site Descriptions and Environmental Information in Chile, as directed by Resolution 404/2003

Determinand		Sampling equipment		Sampling Stations		Replicas/ timings	Notes
Current		Acoustic Doppler current profiler		To be measured 1 m from the seafloor in the middle of the farm site.		Readings every 5 mins for at least 4 days	
				Water column divided into ten layers, speed and current to be measured in each		Readings every 5 mins for an entire tidal cycle (at least)	
Bathymetry	Cat 1 & 2	Lead line		Depth to be measured at each vertex of a 25 m x 25 m grid over the site			Bathymetric profile to be drawn with 10 m isobaths. To be presented along with a site plan.
	Cat 3,4 & 5	Continuous echo sounder		Entire area of site should be measured			
Visual registry	**PSD**	Diver operated digital recording, or be ROV		Two transects, running from furthest vertexes of site and passing through mid point		Minimum of ten minute recording for each transect	VHS format. Should describe sediment, presence of micro-organisms, presence of gas bubbles
	EI			Visual register of sedimentation area. 2, 100 m perpendicular transects. Should be under cage array with maximum biomass.			
Sediment granulometry		Sediment samples obtained using a grab with 0.1 m² bite	130 g, top 3 cm	**PSD**. The licensed operating area should be divided into quadrants of 1 hectare (100 m x 100 m). Each vertex is deemed to be a sampling station **EI.** At least three stations within area of sedimentation, with maximum biomass levels should be sampled. In addition to this two reference stations should be sampled.		No replicates required for **PSD** Resolution 404/2003 states 3 replicas at each sampling and reference station for the EI	Detailed methodology provided in resolution 404/2003
Organic matter content			100 g, top 3 cm				
Benthic macrofauna			1.0 mm sieve				ID to family or species level. Each species or family to be weighed.
Redox and pH		From grab or corer	Top 3 cm				pH probe temperature compensated
Dissolved oxygen	**PSD**	In situ, ex situ (from water sampler)		Centre of site	To be determined every 5 m, from 10 m to 1 m above seafloor	To be carried out once for **PSD**, then every two months during production.	Concentration and saturation to be determined
	EI			Beneath two cages			

PSD – Preliminary Site Description, **EI** – annual Environmental Information

The resolution states that sampling stations (as described in Table 6) should only be determined for areas of soft sediment (RAMA, 2001). Where hard substrate is present a visual register should be carried out (see Table 6). Sites where there are both soft sediment and hard substrate should use both sampling methodologies where appropriate.

In addition, RAMA requires that each farm operation must formulate a contingency plan. This should provide details of what action will be taken in the event of circumstances arising that may cause environmental damage. The plan should consider a number of possibilities, including large-scale mortality or escapes and accidental loss of food and other material[47].

Site evaluations and annual monitoring is carried out by consultants hired by the farmers.

Environmental quality standards

The primary environmental quality objective is based on the maintenance of aerobic sediment conditions. When anaerobic conditions are detected there is a mandatory mitigation strategy where production levels must be decreased by 30 percent until aerobic conditions are restored.

[47] www.subpesca.cl/docs_ingles/RAMA_english.pdf

BOX 8

Farm categorisation as described in Resolution 404/2003 of RAMA

Category 1
- Extensive suspended production systems with annual production equal or less than 300 tonnes. Located over soft sediment in 60 m or less.

Category 2
- Suspended production systems with annual production between 301-750 tonnes. Located over soft sediment in 60 m or less.
- Intensive production systems with annual production equal or less than 50 tonnes. Located over soft sediment in 60 m or less.

Category 3
- Extensive production systems with annual production greater than 750 tonnes. Located over soft sediment in 60 m or less.
- Intensive production systems with annual production greater than 50 tonnes. Located over soft sediment in 60 m or less.

Category 4
- Intensive production systems located in hard or semi hard substrate in 60 m or less.

Category 5
- Production systems located in depths greater than 60 m.

BOX 9

Environmental determinands required for the PSD, according to category

Category 1
- Bathymetry
- Organic matter in sediment

Category 2
- Bathymetry
- Organic matter in sediment
- Sediment granulometry
- Benthic macrofauna

Category 3
- Bathymetry
- Organic matter in sediment
- Sediment granulometry
- Benthic macrofauna
- Redox and pH in sediment
- Eulerian current
- Dissolved oxygen profile of water column

Category 4
- Bathymetry
- Eulerian current
- Visual register

Category 5
- Bathymetry
- Eulerian current
- Dissolved oxygen profile of water column

Quality Assurance

Certification programs are currently under consideration. Implementation of appropriate schemes is planned for the end of 2007.

Modelling approaches

There may be cases where SubPesca would request the use of modelling approaches. They would be used to help determine the area of maximum sedimentation[48]. A more comprehensive inclusion of modelling approaches is expected in 2007.

IRELAND

Monitoring of the aquaculture industry is carried out by the self-monitoring and confirmation approach, where environmental reports are produced by farm operators and a proportion of sites are independently assessed by scientists from the Marine Institute, for verification purposes.

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48 www.subpesca.cl/docs_ingles/Resolution_N404_english.pdf

Monitoring of the environment around finfish operations is carried out by a number of methods:

- Water column monitoring is carried out on a monthly basis from December to March in each year. Sampling is conducted at stations located among cage structures and at control stations away from the cages. Measurements of temperature and salinity are made and samples are taken for ammonia, nitrate, nitrite and phosphate.
- Benthic sampling is carried out within 30 days of peak biomass at most sites. Sampling is carried out according to three levels of investigation:
  Level 1 – a visual assessment of transects through the site;
  Level 2 – a visual inspection of transects through each site with accompanying Redox (reduction-oxidation potential) measurements;
  Level 3 – a full faunal analysis of sediments throughout the sites.

All sites are assessed against sedimentary conditions at control locations away from the farm. This Programme is applied to assess compliance with the conditions stipulated in individual license conditions.

Techniques for water, sediment and biota sampling, sample storage and transport requirements and analytical protocols are designed to be consistent with international aquaculture monitoring programmes. The parameters measured and sampling methodology for the regulatory programme are currently being reviewed. The criteria which are currently applied are summarised in Table 7.

Sea lice monitoring

The Marine Institute is charged with carrying out regular inspection of sea lice levels on finfish farms around the country in accordance with protocols set out under the National Sea Lice Monitoring Plan (Box 10). All fish farms undergo lice inspections 14 times per year. One lice inspection takes place each month at each site where fish are present, with two inspections taking place each month during the spring period of March to May. Only one inspection is carried out in the December/January period. The results of the sea lice surveys are reported to stakeholders (DCMNR, BIM, Irish Salmon Growers Association, individual farms and Regional Fisheries Boards) on a monthly basis and are published annually by the Marine Institute with detailed monitoring results by farm (Status of Irish Aquaculture, 2004[49]).

Water column

Water column monitoring is also carried out by the Marine Institute, however the majority of the monitoring is in relation to shellfish aquaculture. There are a series of EQS's set for salmonid water quality and these are detailed in Table 7. The water column parameters to be measured and the frequency of sampling is stipulated in each individual aquaculture licence, dependant on the particular sensitivity of the receiving environment. Three water column parameters are monitored at all salmon farms: dissolved oxygen, chlorophyll a and dissolved inorganic nutrients (nitrate, nitrite, phosphate), on a monthly basis.

Benthic impact

The benthic monitoring programme adopted by Ireland is based largely on the programme implemented by the United Kingdom of Great Britain and Northern Ireland based Scottish Environmental Protection Agency. There are three levels of monitoring programme targeted at the benthic impacts of salmon farms:

- Level 1: Video/photographic and visual observations/recordings taken at sample stations directly underneath the cages, at the edge of the cages, at 10 m, 20 m, 50 m and 100 m downstream at peak biomass period.

[49] www.bim.ie/templates/reports.asp?node_id=268

TABLE 7
Irish environmental monitoring methodology

Area of Impact		Sampling Location	Determinand	Methods employed	EQS	Frequency
Sea Lice*		Presence of ovigerous sea lice on farmed fish in cages	Number of lice per fish	Visual quantitative count. 30 fish sampled form 2 cages, one selected at random, one inspected each time	2 ovigerous lice per fish, (June-February). 0.3-0.5 ovigerous lice per fish (March-May)	14 times a year. Fortnightly during March, April and May.
		Presence of mobile lice in cage	Number of mobile lice in cage	Visual quantitative count	When numbers are high even if there are no ovigerous females present.	
Water Column		Sampling stations along a transect agreed by the Marine Institute in accordance with Single Bay Management and CLAMS plans. All stations are logged using Differential Geographic Positioning System with an accuracy of +/-0.5m	Temperature Ammonia Nitrite mg/l Nitrate Phosphate Salinity	Samples are collected from water directly beside the cages at the surface, mid-depth and 1m above the sea bed.		Monthly during December to March each year. Report submitted to DCMNR by 30 April each year
Benthic	Level 1	Numerous stations directly under the cages, at the edge of the cages, along two transects at right angles to each other at +/-10m, +/-20m, +/-50m and +/-100m and a control site at least 500m distant from the cages.	Presence of bacterial mats, feed pellets, litter, gas bubbles, anoxic areas, fauna, macro-algae, sediment colour and texture	Video and/or underwater photography. Observational survey by divers.	Yes	Annually, during peak biomass or within 30 days after end of harvesting a year class. Report submitted to the DCMNR by end November each year.
	Level 2		Level 1+ redox	In addition to the above a minimum of 3 redox measurements are taken at each station using a platinum electrode.	Yes	
	Level 3		Level 2 + macro-fauna	Biological samples taken by grab or core, sieved through 1mm sieve. Specimens identified to species level, number of species and abundance recorded.	Yes	

* www.marine.ie/NR/rdonlyres/0210E4CE-F4AA-47F2-8D51-EFEA10A4C4EB/0/MonitoringProtocol3.pdf

BOX 10

Irish Sea Lice Management Plan

In 1991, in response to concerns about the possible impacts of sea lice from salmon farms on wild populations of sea trout, a sea lice monitoring programme was initiated by the Department of the Marine. In 1992/1993 the programme was expanded and culminated in the publishing in May 2000 of the "Offshore Finfish Farms - Sea Lice Monitoring and Control Protocol" (Department of the Marine and Natural Resources, 2000).

The purpose of the National Sea Lice Monitoring Plan is to:

- provide an objective measurement of infestation levels on farms;
- investigate the nature of the infestations;
- provide management information to drive the implementation of the control and management strategy; and
- facilitate further development and refinement of control and management strategies.

The management strategy for sea lice control has five principal components:

- separation of generations;
- annual fallowing of production sites;
- early harvest of two sea-winter fish;
- targeted treatment regimes, including synchronous treatments; and
- agreed husbandry practices (including fish health, quality and environmental issues).

Together, these components work to reduce the development of infestations and to ensure the most effective treatment of developing infestations. They minimise lice levels whilst controlling reliance on, and reducing use of, veterinary medicines. When lice levels exceed pre-set treatment figures (the treatment trigger level), advice is given to treat the affected stock. These are designed to minimise any risk of transmission of sea lice from fish farms to wild sea trout stocks. The current treatment trigger level is 0.3 – 0.5 egg-bearing (ovigerous) female lice per fish during spring. Outside the critical spring period, the treatment trigger level is set at 2.0 egg-bearing female lice per fish. Where numbers of mobile lice are high, treatments are triggered even in the absence of egg-bearing females.

- Level 2: In addition to the above redox is measured at the sample stations.
- Level 3: In addition to 1 and 2, a quantitative and qualitative investigation of benthic macro-faunal invertebrates at the sample stations.

The level implemented will depend on the tonnage of fish at the site and the current speed (Table 8).

It is accepted that there will be an "allowable zone of impact" around the cages with three levels of acceptable impact: standard, transitional and light. The benthic conditions should not fall below these impact levels, which are assigned to specific zones from the cages (Table 9).

The benthic conditions 100 m from the cages should not be different from the control site conditions and the benthic conditions directly under the cages should not become

TABLE 8

Level of benthic monitoring to be carried out at salmon farms in Ireland depending on mean current speed and annual production (McMahon, 2000)

Production (tonnes)	Mean current speed (cm s^{-1})		
	<0.1	<0.5	>10
0 - 499	Level 1	Level 1	Level 1
500 – 999	Level 2	Level 1	Level 1
>1 000	Level 3	Level 3	Level 2

TABLE 9
Acceptable levels of benthic impact in the 'allowable zone of impact', Ireland, (McMahon, 2000)

Benthic conditions	Impact level		
	Standard 0 – 20m from cages	**Transitional 20 – 50m from cages**	**Light 50–100m from cages**
Visual observations	Scattered feed pellets	Occasional feed pellets	No feed pellets
Bacterial mats	Occasional patches	Absent	Absent
Fauna	Diverse with increasing number of species present. Stage II infauna predominate	Stage II communities dominate with greater diversity with distance from cage	Normal or Stage III community predominate
RPD	Not <1cm	>1cm	Ambient redox depth

anoxic. Should the monitoring results show that the benthic impact is unacceptable the farmer must submit a Benthic Amelioration Plan to the DCMNR.

NEW ZEALAND

The Australian and New Zealand Environment Conservation Council (ANZECC) have developed a set of guidelines that provide a framework for water quality monitoring[50]. These guidelines identify environment quality objectives, recommend indicators and detail the protocols and sampling strategy to be followed. They also include sea bed and sediment quality objectives. It is recommended that the online information should be consulted, as the applications detailed in this report are liable to change, especially as the current management of aquaculture in New Zealand has undergone a recent and comprehensive reforming process. New Zealand does not apply a generic approach to the monitoring of salmon farming, and the choice of which determinand to include and the frequency of the sampling program is at the discretion of the regional council and will be stipulated in the resource consent.

Due to the sectoral nature of aquaculture management in New Zealand and as responsibility has been devolved down to regional and local authorities the areas where salmon farms operate all apply different approaches and so will be considered separately. An overview of each area follows.

Big Glory Bay, Stewart Island

Salmon farms operating in Big Glory Bay will have been granted consents under the previous legislative arrangement, having been at the site since the early 1990s. Conditions attached to the original licence, granted in 1991, required records to be kept of level of production, the use of therapeutants, amount of feed used, periodic monitoring by divers of the sea floor under the farm and the prohibition of TBT use as an anti-foulant. The cages were to be at least 50m from the shore and in water at least 12m deep. Following a HAB in 1995, a nitrogen model was used to predict conditions and on the basis of this licence conditions were amended to include a restriction on the levels of nitrogen in the feed used on an annual basis. This effectively put an upper limit on the amount of food that could be discharged and was estimated for the Bay as a whole and was divided out among all licensees.

This approach was further refined in 1995 when a Bay-wide monitoring and management programme based on the nitrogen model was implemented. This programme included the nitrogen introduced into the system from the farm, either directly from feed input or released from the sediment on the sea floor, and also incorporated the nitrogen removed from the system from the increasing number of mussel farms. During the summer months, monthly samples of concentrations of nitrogen, phosphorus and dissolved oxygen are measured at locations in the Bay and outside in open water. An annual video survey of a transect running under the farm is

[50] www.environment.gov.au/water/quality/nwqms/pubs/wqg-contents.pdf

taken and the variation in the epifauna assessed qualitatively. The farmer also monitors methane and sulphide levels for operational purposes.

Akaroa Harbour

A salmon farm has been operating here since 1984 and has had the original licence converted to a coastal permit under the Aquaculture Reform Act (2004), valid until 2025. Two consents are attached to this permit; consent to discharge feed into the waterbody and consent for a refuge should a HAB occur at the farm site. The refuge area is diver surveyed to identify sensitive areas within the refuge where the farm may not locate to. The sea bed of the refuge area will be monitored during and after the cages have been relocated there. The accumulation of waste underneath the cages is monitored every six months by the regional council.

Marlborough Sounds

An annual monitoring programme is carried out on the six cage sites surveying the benthic and water column impacts.

Benthic monitoring

Qualitative and quantitative analysis of grab samples is carried out. A ‘zones’ approach is used to assess compliance with the resource consent conditions based on a conceptual model that identifies an acceptable level of benthic impact based on environmental quality standards. Three zones are identified in the vicinity of the farm where a certain level of impact is permitted. This zonation reflects site-specific conditions such as current flow and the dispersive pattern of farm wastes. Samples are collected beneath the cages and along a transect running down current from the farm. A control site is also sampled. Sub-samples are analysed for macro-fauna, grain size and organic content. Visual observations and semi-quantitative assessments are made on the depth of the redox potential discontinuity layer, sediment odour and texture. Zinc concentration of the sediment beneath the cages is also measured. Redox potential is measured using a platinum electrode, sulphides are measured using a silver/sulphide electrode probe. Video surveys by a remote operated vehicle of the sea floor below and around the farm are qualitatively assessed for epifauna and the presence of bacterial mats. In addition to the annual survey every two years a shallow sub-tidal/inter-tidal survey is conducted along two transects inshore of the farm.

Water column monitoring. The coastal permit holder routinely monitors dissolved oxygen concentrations in the water column as part of the operational procedures.

The ANZECC guidelines list biological assessment objectives for ecosystem protection that regional councils should apply and gives instructions on how to implement them (Table 10). The guidelines also list the impacts (or as referred to ‘water quality issues’ even though it includes benthic impacts), how to assess the level of impact, which determinand to use and the protocol to apply (Table 11). All determinands have trigger values assigned. Once the trigger value has been breached action is initiated to return the receiving environment to acceptable levels.

NORWAY

The licensing process applies a generic approach to all salmon farms. The license requires the farmer to record each month the operational activities of the farm at three levels of detail as listed in Table 12. These records are compiled annually into a report that is submitted to the Directorate of Fisheries, the enforcing agency.

Supplemental to the licensing records, a monthly sea lice report is submitted to the local District Veterinary Officer on the 15^{th} of each month. Sea lice counts are taken fortnightly at sea temperatures greater than or equal to 4°C (Dow, 2004). Thresholds for late winter and early spring are currently 0.5 gravid females or two mobile lice per fish (Boxaspen, 2006).

TABLE 10
Biological assessment objectives for different management situations and the recommended methods and indicators, New Zealand

Assessment objective	Application	Recommended determinand	Essential or desired attributes of the determinand to be employed
Broad scale assessment of ecosystem 'health' (catchment, regional, or larger scale)	Water quality on a catchment or regional basis	Rapid bio-assessment	Comparative measures of biological community composition. Measure rapidly and cheaply, quick turn around of results Have a diagnostic value
Early detection of short or long term changes	Sites of special interest (potential point source pollution event)	Laboratory based: direct toxicity assessment Field based: biomarkers, bioaccumulation, spatial disturbance gradients in relevant quantitative biological indicators.	Sensitivity to the type of contaminant expected Respond and measure rapidly Demonstrate a high degree of constancy in time and space.
	Water quality on a regional basis in response to specific pressure	Rapid bio-assessment	Comparative measures of biological community composition. Measure rapidly and cheaply, quick turn around of results Have a diagnostic value
Biodiversity or ecosystem level response	Sites of special interest	Detailed quantitative regionally comparative investigations of communities possibly with species level taxonomic resolution. Direct and comparative measurement of the ecosystem	Direct measures of diversity (using species level identification). Direct measures of ecosystem function (community metabolism). Use of surrogate measures for ecosystem biodiversity where relationship between surrogate and biodiversity has been shown. Have a diagnostic value.
	Water quality at sites and on a regional basis	Direct and comparative measurement of the ecosystem process of concern Rapid bio-assessment	Direct measures of diversity (using species level identification). Direct measures of ecosystem function (community metabolism). Use of surrogate measures for ecosystem biodiversity where relationship between surrogate and biodiversity has been shown. Have a diagnostic value

TABLE 11
Assessing impact level, New Zealand

Environment quality issue	Suitable biological determinand or assessment approach	Protocol*
General inorganic (including metals) and organic contaminants. Early detection of short or longer term changes from substances in solution/ water column	Biomarkers (chemical/biochemical changes in an organism)	1B (i) (ii)
	Direct toxicity assessment	Section 8.3.6 (Vol 2)
General inorganic (including metals) and organic contaminants. Early detection of short or longer term changes from substances deposited (sediments).	'Whole sediment' laboratory toxicity assessment	2A Section 8.3.6
	Bioaccumulation/biomarkers (for organisms that feed through ingestion of sediment), other sub-lethal including behavioural responses.	2B (i) (ii)
Suspended solids in the water column	Sea grass depth distribution	6
Effects of organotins	Imposex in marine gastropods	9
Nutrient inputs	Sea grass depth distribution	6
	Frequency of algal blooms	7
	Density of capitellids	8
	In-water light climate	These indicators and protocols are not currently available in the guidelines, but are listed and considered to be easily and quickly developed with additional resourcing
	Filter feeder densities	
	Sediment nutrient status	
	Coral reef trophic status	
Broad scale assessment of ecosystem 'health' (non-specific degradation).	Habitat distributions	
	Assemblage distributions	

* The codes in this column refer to protocols that are listed by title in section 8.1.3 of Volume 2. Summary descriptions of these protocols with reference to important source documents are provided in Appendix 3, Volume 2 of the ANZECC Guidelines**.

** www.deh.gov.au/water/quality/nwqms

TABLE 12
Licence records, Norway, (after Maroni 2000)

Level	Record
Licence level	Handling and delivery of dead fish
	Purchases of ready-made feed and fish meal
	Consumption of net impregnating agents
Site level	State of health, diagnostic tests and treatment
	Number of lice on salmonids
	Use of medicinal products (type and name, quantity used and treatment period)
	Use of chemicals (type and name, quantity used and consumption period)
	Catches made during fishing for monitoring or recovery purposes (escapes)
Unit/sea cage level	Stocking (number, species, origin, stocking time and average live weight)
	Fish density kgm-3 (live weight)
	Net depth
	Consumption of feed
	Escapes
	Slaughtered quantity and quantity of dead/dying fish removed

Installation requirements

The NYTEK regulations were drawn up to address the environmental impacts arising from escaping fish. Salmon farm installations are assessed according to site-specific conditions. These are categorised according to wave height and current speed and the level of forces exerted on the cages. A dynamic model, 'ConMotion' is used to predict the forces at each site and creates a tension map for each site's cage infrastructure, informing on site-specific needs. Table 13 presents how the 25 different site classifications have been determined and how they are categorised according to the exposure level of the site. The category informs the specifications for all components of the installation. The NYTEK regulation certificate is valid for three years and the enforcing agency is the Directorate of Fisheries.

Environmental monitoring requirements

Around 15 percent of Norwegian salmon farms are inspected each year by authorised personnel from the Directorate of Fisheries. The inspection is based on the monthly records as stipulated in the license, the lice records and all measurements taken in accordance with the MOM system. A detailed evaluation of the environmental reports

TABLE 13
NYTEK regulation classification system, Norway

Classification of site conditions					
	Current velocity m/s				
Wave Height m	a 0.3	b 0.5	c 1.0	d 1.5	e >1.5
A 0.5	Aa	Ab	Ac	Ad	Ae
B1.0	Ba	Bb	Bc	Bd	Be
C 2.0	Ca	Cb	Cc	Cd	Ce
D 3.0	Da	Db	Dc	Dd	De
E >3.0	Ea	Eb	Ec	Ed	Ee

Site Category	Increasing current speed ⟶					
1	Aa	Ab				Increasing wave height
	Ba					
2			Ac	Ad	Ae	
		Bb	Bc	Bd	Be	↓
	Ca					
3		Cb	Cc	Cd	Ce	
	Da					
4		Db	Dc	Dd	De	
	Ea	Eb	Ec	Ed	Ee	

for each farm is conducted and these findings are then compiled into a national report, which is cross-checked with other sources of information (Maroni, 2000). Environmental monitoring is carried out in accordance with Norwegian Standard NS9410 (investigations B and C) and NS 9423 (investigation C) by independent experts and consultants. The focus is on benthic impact with sediment samples being collected by grabs. Water column monitoring receives little attention, with oxygen concentration being the only water column parameter recorded in the C investigations. Table 14 summarises the parameters and methodology for the two monitoring investigations.

UNITED KINGDOM

Scotland has adopted a policy of self-monitoring with regular auditing of a proportion of all sites by the regulatory authority, SEPA. The monitoring strategy, sampling and program design is flexible and will vary depending on the site profile and sensitivities and is subject to regular reviews. SEPA provide a comprehensive set of guidelines[51] relating to all aspects of the required environmental monitoring and set Environmental Quality Standards (EQS). SEPA apply a limiting factor approach using predictive models, e.g. DEPOMOD (Cromey *et al.,* 2002a; 2002b). A pre-licence baseline study of the site is undertaken to determine site sensitivity allowing consent conditions to be matched to the carrying capacity of the location. Post-licence monitoring during the farm's operational phase occurs during pre-stocking, production fallowing and medicines application. Monitoring also occurs after removal or reduction of fish biomass to assess site recovery. The monitoring strategy is developed to monitor consent compliance and environmental assessment. Consent compliance monitoring is outlined in Box 11.

BOX 11

Consent compliance monitoring

- **Record returns**. These detail medicinal treatments, feed used and biomass at individual sites.
- **Cage inspections and record audits**. Inspection of records kept of stock held, medicinal treatments, chemical storage facilities, disposal facilities for dead fish and solid waste, net-washing facilities and disposal of net washings.
- **Discharge monitoring**. Samples of water from within the cages during chemical treatment may be analysed and compared to recommended concentrations.
- **Sampling of chemicals**. Samples will be taken of medicines and other chemicals.
- **Feed and fish tissue sampling.** Samples will be taken of feed and fish tissue, which will be analysed for residues.

Environmental monitoring is carried out to:
- validate and verify mathematical models;
- ensure EQSs are being met;
- measure impacts on the environment;
- assess the need for remedial action;
- audit the results of self monitoring.

The sampling strategy is developed to measure the environmental impacts that may arise from organic wastes from fish feed and fish faeces, nutrients in the water column and medicines and chemicals. Environmental monitoring may be carried out locally around the farm or regionally (a whole sea loch or coastal system) depending on the impacts under investigation.

[51] www.sepa.org.uk/pdf/guidance/fishfarmmanual.asp

TABLE 14
Norwegian environmental monitoring methodology

Zone		Determinand**		Methods employed	EQS		Frequency		Investigator
B	Local and intermediate	Presence of macro infauna		Quantitative assessment of sediment for presence or absence of macro infauna after 1mm sieve.	Yes.** Presence=0 Absence=1 Mean sample score - ≤0.5 EC 1-3 >0.5 EC 4		The frequency of the complete B investigation:		External consultant
							DEX1	Every second year	
		pH and redox		Electrodes inserted directly into sediment immediately after sampling in grabs Measurements are taken at 1cm depth.	Yes*** Mean score ≤1=EC1, <1≤2=EC2 <2 ≤ 3=EC3, > 3=EC4		DEX2	Every year	
							DEX3	Twice a year Spring and Autumn)	
		Sensory Sediment variables. Due to the subjective nature of these variables their scores are combined and combined EQS applied	Colour	Subjective visual assessment of sediment samples	No. Light grey, brown=0 Dk brown, black=2	Combined scores giving EC. Mean score as for pH and redox			
			Odour and consistency	Subjective olfactory assessment of sediment samples	No No smell=0 Slight smell=2 Strong smell=4				
			Gas ebullition	Quantitative assessment of sediment for presence or absence of gas bubbles	No Absent=0 Present=4				
			Sludge layer thickness	Top layer of overlying sludge measured through transparent core.	No 0-2cm=0, 2-4cm=1 4=6cm=2 6-8cm=3 >8cm=4				
C	Intermediate and regional	Quantitative and qualitative assessment of benthic fauna		According to NS9423, NS9410 and the Norwegian Pollution Control Authority	Yes. EQS are set according to NS9410 and by the Norwegian Pollution Control Authority.		At the discretion of the local authority.		Expert consultant
		Organic content of sediment							
		Particle size of sediment							
		Sensory sediment variables as in B investigation							
		Oxygen content of the water column							

* DEX = Degree of Exploitation, **Environmental Condition where EC 1-3 = acceptable conditions, EC4= unacceptable conditions. *** Based on a scoring system detailed in Hansen *et al,* (2001)
** In this report determinand is defined as a constituent or property of the environment which is determined through measurement or analysis

SEPA base environmental monitoring on the mixing zone concept. Within an "Allowable Zone of Effects" (AZE), a certain level of impact is permitted but higher environmental standards must be met outside the AZE thus giving two quality standards for several determinands. Two separate modelling approaches to assign the AZE are used for water column monitoring and sea bed monitoring. In all cases the sea bed AZE is determined by site specific criteria using the autoDEPOMOD modelling package. Previous to this the AZE was defined according to set limits developed according to ADRIS (1991), which for the water column AZE was 100 m in all directions from the cages and for benthic impacts was 25 m in all directions. This fixed AZE approach still applies to farm sites where consents were determined before the modelling approach was adopted.

Monitoring is scaled to farm size, hydrographic character and site sensitivity, with least monitoring being required from low biomass or highly dispersive sites. The environmental monitoring methodology as applied to water column and benthic impacts is outlined below.

Water column monitoring[52]

Water column monitoring focuses on nutrient levels, dissolved oxygen and medicines and chemicals. The frequency and level of detail involved is directly related to biomass of fish and the sensitivity of the receiving environment in relation to flushing time of the waterbody. The frequency of sampling and methodology employed is summarised in Tables 15 and 16. The recommended strategies for monitoring these are outlined below.

TABLE 15
Water column nutrient sampling intensity, United Kingdom

Farm biomass and site character	Survey level	Sampling location	Frequency
<1 000 tonnes	No regular monitoring required		
>1 000 tonnes flushing time < 3 days	SEPA sampling Category 1	4 stations: 1 up-tide from cages 1 beside cages 1 down-tide from cages 1 control	Bi-annually, 1 winter survey 1 summer survey
	Local operator sampling	4 stations: 1 25 m up-tide 1 at cages 1 25 m down-tide 1 control	Bi-annually, 1 winter survey 1 summer survey
>1 000 tonnes flushing time >3 days	SEPA sampling Category 2	8 stations: 3 up-tide from cages 1 at cages 3 down-tide from cages 1 control	Bi-annually, 1 winter survey 1 summer survey
	Local operator sampling	8 stations: 2 at 100m, 50 m and 2 5 m from cages, up-tide and down-tide 1 at cages 1 control	Bi-annually, 1 winter survey 1 summer survey

Nutrients

The recommended strategy for monitoring nutrient levels involves the following components:

- Define the boundaries of the waterbody being investigated.
- Ascertain flushing time, tidal volume and total volume where possible.

[52] www.sepa.org.uk/pdf/guidance/fish_farm_manual/annex/E.pdf

TABLE 16
Water column parameters and sampling methodology, United Kingdom

Determinand	Methods employed*	EQS
Salinity	Standard probe reading	<40
Temperature	Standard probe reading	No EQS
Ammonia	Standard colourimetric method	
Nitrate	Standard spectrophotometrically at 543 nm	168 µg/l
Nitrite	As nitrate	As nitrate
Phosphate	Standard spectrophotometrically at 850 nm	6.2 µg/l
Chlorophyll	Standard fluorimeter reading at 430 nm.	10 µg/l
Dissolved oxygen	Winkler titration or vertical profiles can be taken using a probe at 5 m intervals.	≥70% (average)
Copper		5 µg/l
Medicines and chemicals**		Yes

* At each station samples are taken at the top and middle of the water column, except for the deepest part of the basin and at the cages where samples are collected from 3 depths***.
** www.sepa.org.uk/pdf/guidance/fish_farm_manual/annex/A.pdf

*** www.sepa.org.uk/pdf/guidance/fish_farm_manual/annexE.pdf

- Use the United Kingdom of Great Britain and Northern Ireland Marine Fish Farm Database[53] to determine total consented biomass farmed in the system.
- Rank systems in order of biomass/flushed volume.
- Monitor peak winter nutrients (nitrogen and phosphorus) and chlorophyll according to ranking in sensitivity/biomass table.
- Assess nutrients and chlorophyll against standards included in the UWWT Directive, OSPAR agreements and other relevant standards.
- Review monitoring annually and increase or decrease according to monitoring results.

Dissolved oxygen
The recommended strategy for monitoring dissolved oxygen involves the following components:
- The extent of DO monitoring will be determined according to biomass and local hydrography.
- DO will be monitored on a coastal system basis.
- DO will be monitored in the area around the cages and the wider loch basin area.

Medicines and chemicals
Some environmental monitoring is carried out close to or within the cage and in specific locations from the cage group, but the main method of regulation is through predictive modelling. Water samples are used to check predictions. The use of vaccines has lead to a decrease in the use of anti-microbial agents and these are not viewed as a priority for monitoring. Copper levels, derived from anti-foulant treatments, outwith the AZE must comply with the EQS for this metal.

Sea bed monitoring[54]
Benthic monitoring operates within the following framework:
- Sea bed monitoring is done locally around cage groups.
- Monitoring requirements depend on site specific biomass and local hydrography.
- Sea bed monitoring is mainly carried out as self monitoring by the operator.
- SEPA audit a proportion of the operator's self-monitoring.

[53] www.sepa.org.uk/spri/index.htm
[54] www.sepa.org.uk/pdf/guidance/fish_farm_manual/annex/F.pdf

- Sediment standards are set in the AZE for the biological and chemical indicators[55].

Sediments are monitored for medicines and chemicals likely to accumulate for comparison with sediment action levels. Monitoring of the sea bed focuses on waste deposition, medicines and chemicals. The frequency and level of detail required is determined by which survey strategy is applicable. There are six categories of benthic survey, applied according to biomass and whether the location is a new site or an existing one and if in-feeds are used (Table 17).

The six survey categories differ in the number of sample stations incorporated in each (Table 18). All surveys, except the visual monitoring survey, are analysed for benthic infauna, redox (Eh), organic carbon, particle size analysis and a visual description of the sediment.

TABLE 17
Summary of sea bed monitoring strategies, United Kingdom

Biomass (tonnes)	New site	Existing site with increasing biomass and/or infeeds	Consent monitoring only
0-1000 *	Standard baseline	Standard or Site specific monitoring	Standard or site specific monitoring
>1000	Extended baseline survey	Extended or site specific monitoring	Extended or site specific monitoring

* A visual monitoring survey may be carried out for sites <500 T, those over hard substrates and any site were detailed visual data is required e.g. near natural heritage designations (SAC, SPA).

TABLE 18
Monitoring levels of the six survey categories, United Kingdom

Survey	Monitoring level
Visual monitoring survey	One 50 m transect running along the predominate current direction, with stations at 5m intervals. Video taken by diver or Remotely Operated Vehicle (ROV), still photographs taken at each station.
Standard baseline survey	Samples are taken from two stations, 100m apart, near the proposed location of the cages. Two reference stations are sampled outwith the proposed area (ideally 500 m – 1 km away).
Extended baseline survey	Samples are taken along two transects, one running down current, one up current, with stations at the cage edge, 50 m and 100 m away in both directions. Two reference stations are sampled outwith the proposed area (ideally 500 m – 1 km away).
Standard monitoring survey	Samples are taken from two stations lying along the current direction, one within 5 m of the cages, one at the edge of the AZE. Two reference stations are sampled outwith the proposed area (ideally 500 m – 1 km away).
Extended monitoring survey	Samples are taken along two transects, one running down current, one up current, with stations at the cage edge, 50 m and 100 m away in both directions. Two reference stations are sampled outwith the proposed area (ideally 500 m – 1 km away).
Site specific monitoring survey	Four stations are sampled along a transect, (direction of the transect is site specific), at the cage edge, 10 m inside the AZE, at the edge of the AZE, 10 m beyond the AZE. Two reference stations are sampled outwith the proposed area (ideally 500 m – 1 km away).

The timing of the sea bed monitoring is normally within 1 month of peak biomass, preferably between 1 May and 31 October except for the baseline monitoring which occurs before production begins. All sampling locations are recorded and fixed according to Differential Global Position Fixing or Range Position Fixing Systems, to ensure subsequent re-sampling of stations. All samples are taken using a Van Veen Grab, with a minimum sample of 0.02 m^2, with five replicates taken for biological analysis and two taken for chemical analysis. Sea bed monitoring of in-feed residues is carried out annually and if this coincides with the sea bed monitoring, then samples can be taken from the benthic replicates. In feed residue monitoring methodology is outlined in Table 19.

The methodology used in the sea bed monitoring sample analysis is summarised in Table 20 and the sediment quality criteria Table 21.

[55] www.sepa.org.uk/pdf/guidance/fish_farm_manual/annex/A.pdf

TABLE 19
In-feed residue monitoring strategy, United Kingdom

In-Feed residue	Timing	Location	Collection of samples	Analysis
Slice™[3]	Between 110 and 130 days after cessation of treatment	Samples taken from 2 stations on a transect following the current direction at the cage edge and 100m distant	Replicates of three sediment cores of up to 5cm depth. If coinciding with monitoring then sub samples of grabs are acceptable.	Samples analysed by accredited laboratory.
Calicide™[4]	Between 10 and 30 days after cessation of treatment.			

TABLE 20
Sea bed monitoring sample analysis, United Kingdom

Determinand	Methodology
Visual	Qualitative assessment. Colour: black brown, etc Consistency: sand, mud, etc Texture: soft, firm, etc. Presence of feed pellets and/or Beggiatoa
Redox	Two profiles are taken per sample at 1 cm intervals immediately on collection using a portable redox meter.
Organic Carbon	Samples are taken from 50ml of the top 2 cm of the sample. Procedure in Allen et al. (1974) is recommended for analysis.
Particle Size Analysis	Samples of 100 ml are taken from the top 20 cm and analysed by dry sieving or laser granulometry.
Benthic infauna	Grab samples are washed through a 1 mm sieve and preserved in buffered formalin. Fauna are identified to the lowest taxon possible and the data presented as a species abundance matrix e.g. Shannon-Weiner

TABLE 21
Sediment quality criteria and action levels* , United Kingdom

Component	Determinand	Action Level within AZE		Action level outside AZE
Benthos	Number of Taxa	Less than 2 polychaete taxa present		Must be at least 50% of reference station value
Benthos	Number of Taxa	Two or more replicates with no taxa present		
Benthos	Abundance	Organic enrichment polychaetes present in abnormally low densities.		Organic enrichment polychaetes must not exceed 200% of reference station value.
Benthos	Shannon-Weiner Diversity	N/A		Must be at least 60% of reference station value.
Benthos	Infaunal Trophic Index	N/A		Must be at least 50% of reference station value.
Sea Bed	*Beggiatoa*	N/A		Mats present
Sea bed	Feed pellets	Accumulations of pellets		Pellets present
Sediment	Teflubenzuron	10.0 mg/kg dry wt/5 cm core applied as a average in the AZE.		2.0 μg/kg dry wt/5 cm core
Sediment	Copper	*Probable effects* 270 mg/kg dry sediment	*Possible effects* 108 mg/kg dry sediment	34 mg/kg dry sediment
Sediment	Zinc	*Probable effects* 410 mg/kg dry sediment	*Possible effects* 270 mg/kg dry sediment	150 mg/kg dry sediment
Sediment	Free sulphide	4800mg kg^{-1} (dry wt)		3200 mg kg^{-1} (dry wt)
Sediment	Organic carbon	9%		
Sediment	Redox potential	Values lower than -150 mV (as a depth profile average) or values lower than -125 mV (in surface sediments 0 – 3 cm).		
Sediment	Loss on ignition	27%		

* www.sepa.org.uk/pdf/guidance/fish_farm_manual/annex/A.pdf

Self-regulation and voluntary monitoring

Currently the control and monitoring of sea lice does not fall under the remit of the regulatory authorities, but this will soon change with the implementation of the Aquaculture and Fisheries (Scotland) Bill (2006). The present arrangement is contained in The Code of Good Practice for Scottish Finfish Aquaculture[56], (CoGP), which specifies the 'National Strategy for the Control of Sea Lice on Scottish Salmon Farms'.

[56] www.scottishsalmon.co.uk/aboutus/codes.asp

Box 12 outlines the main actions included in the strategy. This strategy lays down the guiding principles and procedures to follow such as the formation of farm management areas, agreement on treatment criteria and strategic coordinated treatments within these areas. The CoGP is a voluntary code, drawn up by collaboration between industry, government, regulators and related stakeholders. Compliance is assured through certification and annual audits are performed and the audit results are to be made publicly available.

BOX 12
United Kingdom sea lice strategy

The National Sea Lice Strategy has developed a code of practice for salmon farmers, instructing on the following areas:

Defining the farm management area. See Annex 6 of the CoGP.

Identifying all the salmon farmers in the areas and obtaining written undertakings to observe the provisions of the Strategy. Each defined Management Area will have a farmer appointed as coordinator to aid cooperation and exchange of information between all farmers regarding sea lice control and treatments.

Forming a farm management group. Each area will have a farm management group. This group will agree the basis for sea lice monitoring and treatments, oversee and coordinate monitoring and treatment activities.

Agreeing the monitoring protocol and frequency of monitoring. Each area will have a regular monitoring procedure and the results will be communicated weekly to all farms in the area by the coordinator.

Agreeing the timing and criteria for treatments. Coordinated treatments will be carried out in early spring and early winter. The primary objective will be a target of zero adult female lice on farmed fish in the spring period when wild salmonids are migrating.

Carrying out the treatments. Treatments will be carried out promptly and in accordance with the principles of Integrated Sea Lice Management.

Performance review. Annual review meetings will be convened by farm management groups to evaluate the performance of farm in the areas. Auditing compliance will be carried out by independent UKAS accredited bodies, as part of the CoGP audit procedure.

The Scottish National Sea Lice Treatment Strategy has the following elements:

Lice numbers on all the farms in one area should be monitored regularly. The basis for the monitoring protocol is as follows:

- weekly monitoring is necessary throughout the year.
- cages and fish should be sampled at random.
- personnel carrying out lice counts should have appropriate training in lice recognition and recording and demonstrate post-training competence.
- where there are more than five cages per site, five fish should be sampled from each of five cages to give a total of 25 fish.
- where a site contains less than five cages, all cages should be sampled to give a total of 25 fish. A similar number of fish should be selected from each pen.
- minimum recording requirements during lice counts are *Lepeophtheirus salmonis* chalimus, non-gravid mobiles[57] and gravid females[58] plus *Caligus elongatus* mobiles.

[57] non egg-bearing louse (male or female)
[58] egg-bearing female louse

Farm management groups should aim to reduce as far as possible the risk of infection to wild juvenile salmonids. Suggested thresholds for the treatment of farmed salmon for *L. salmonis* are as follows:

- during the period February to June inclusive, coinciding with the appearance of wild juvenile salmonids in the sea, the criterion for treatment is an average of 0.5 adult female *L. salmonis* per fish.
- during the period July to January inclusive, the criterion for treatment is an average of 1.0 adult female *L. salmonis* per fish.
- treatment for episodic *C. elongatus* infestations should be applied, as appropriate, to protect the welfare of farmed fish.

UNITED STATES OF AMERICA

In the United States of America responsibility for carrying out environmental monitoring is found at State level. Two States are involved in salmon culture, Washington and Maine. The situation in the two States is described separately.

Washington State

In the State of Washington, the Department of Ecology is responsible for monitoring and compliance of salmon culture operations. The Recommended Interim Guidelines for the Management of Salmon Net-pen Culture in Puget Sound (Weston 1986) have been adopted as the basis of environmental assessment of salmon culture sites. The application of the guidelines is based on annual production, as follows:

- class I – up to 20,000 lbs (~9 tonnes) per year;
- class II – 20,000 – 100,000 lbs (~9 – ~45 tonnes) per year;
- class III – more than 100,000 lbs (~45 tonnes) per year.

These categories, in conjunction with current data, also form the basis for recommending minimum depth beneath salmon cages.

Three types of survey are described within the guidelines – a site characterisation survey, a baseline survey and annual monitoring (Weston, 1986). The following description of survey types is adapted form the SAIC interim Guidelines (Weston, 1986). Monitoring in Washington is largely carried out by consultants.

Site characterisation survey

This survey is performed prior to the permit application. It should provide the information necessary to enable State and local authorities to evaluate the potential effects of the environmental effects. It should provide the proponent with critical information in determining the site's suitability for the proposed project. Sediment chemistry and benthic infaunal information is not requested, as the precise net-pen location is unknown. The components of this survey are detailed in Table 3.4.1.

Baseline survey

A baseline aims to characterise the benthic conditions at salmon net-pen sites, prior to being altered by culturing activities. Ideally this survey should take place following the deployment of the cages, but prior to stocking. Class III operations require a baseline survey, whereas Class I and II operations do not. Details of the baseline survey are listed in Table 22.

Annual monitoring

The annual monitoring programme is designed to monitor potential changes in both water and sediment quality following the commencement of culturing operations. The collation of such data enables regular reviews on the annual monitoring programme. The elements of the annual monitoring programme are detailed in Table 22. Detail on the sampling protocol for each element is provided in Table 23.

TABLE 22
Details of components of the Site Characterisation Survey, Baseline survey and Annual Monitoring Survey as applied in Washington State, the United States of America

	Site Characterisation Survey	Baseline Survey	Annual Monitoring
Class I <20 000 lbs/yr, ~9 tonnes	• Consultation with State and local authorities • Bathymetric survey • Hydrographic survey • Current velocity and direction • Visual survey	N/A	N/A
Class II 20 000-100 000 lbs/yr, 9-45 tonnes	• Consultation with State and local authorities • Bathymetric survey • Hydrographic survey • Current velocity and direction • Visual survey	N/A	• Benthic Survey - Diver survey
Class III > 100 000 lbs/yr, ~45 tonnes	• Consultation with State and local authorities • Bathymetric survey • Hydrographic survey - Current velocity and direction - Drogue tracking - Vertical hydrographic profiling • Visual survey	• Sediment chemistry • Benthic infaunal sampling	• Benthic survey - Diver survey - Sediment chemistry - Benthic infauna sampling • Water quality sampling • Current velocity and direction

In addition to annual monitoring survey data and information, the annual report should contain a full description of site operations including:

- site configuration and details of any significant changes;
- production and stocking density;
- type of feed and feeding methods;
- details of antibiotic use;
- use of antifoulants;
- interactions with wild bird and marine mammals.

The survey work is carried out by professional biologists or consultants that are not employed by the farm company. Usually this involves biologists at the M.Sc. or Ph.D. level.

The methods employed in the surveys through the Interim Guidelines have not been formally assessed for practicality, cost effectiveness or scientific robustness. However, the methods represent "best professional judgment" and the guidelines have been widely reviewed by relevant agencies, NGO's and industry representatives.

State of Maine

A standard aquaculture lease application for a new salmon net pen facility requires a Environmental Baseline Field Survey to be carried out. The aim of this survey is to assess the existing environmental conditions prior to commencement of culture operations. More than one survey may be carried out by applicants but one of them must take place between 1 April and 15 November. Components of the Baseline Field Survey are detailed in Table 24.

Once culturing operations have commenced the farm operates under a MePDES permit (administered by the Department of Environmental Protection DEP, Maine State). This permit details the requirements for routine operational monitoring. All permitted facilities must 'conduct periodic monitoring of ambient water quality, benthic analysis, biological assessment and video/photo surveys. Two monitoring levels are defined (Table 25) based on location:

- **Level I** Those facilities located in the waters of Cobscook Bay, North or inland of West Quoddy Head in Lubec;
- **Level II** Those facilities located in waters between West Quoddy Head in the Lubec and Naskeag Point in Brooklin that are covered by this General Permit.

TABLE 23

Details of sampling protocol for environmental assessment of salmon aquaculture in Washington State, the United States of America, (SAIC guidelines, Weston 1986)

	Aim	Location and timing of sampling	Number of samples and replicates, where applicable	Analysis/ Notes
Bathymetric Surveys **SCS***	*To characterise the bathymetry of the proposed site (area within 300 ft of the cage perimeter)*			
Hydrographic Surveys **SCS and AM***	Current velocity and direction **AM**	Centre of cages – near surface (6 feet) and mid-depth	Measurements over 1 complete tidal cycle. Minimum of ten evenly spaced measurements at each depth. Mean current speed is determined as arithmetic average of the ten measurements	Not during spring or neap tides. During the report weather conditions should be noted. During **AM** single current measurement 20 ft down current of the cages
	Drogue tracking – *to estimate the potential fate of particulate material and the potential for eddy circulation*	2 drogues to be released from centre of site. One is set at 6 feet, one at mid-depth	Drogue trajectory should be followed for a minimum of 8 hrs	
	Vertical hydrographic profile – *to evaluate intensity of water stratification*	Centre of proposed site. Measurements should be made at 1, 10, 20, 30 and then 30 ft intervals to a maximum depth of 3 ft above sea floor		Where possible any existing information on the site should be provided
Diver/Visual Surveys **SCS and AM**	Applies to sites where the depth is under the cages or within 300 ft of the site is less than 75 ft. *To determine the presence of habitats of special significance (HAS).*	**Site Characterisation Survey**		
		Exact location and number of transects should be established on consultation with State officials.	Where most of the area is less than 75 feet, 3-5 transects of 200 ft long	Surveys should establish details on substrate type, presence of Beggiatoa mats and presence/density of any HAS
	*To estimate the extent of solid accumulation (**AM** only)*	**Annual Monitoring**		
		4 transects, at least 200 ft long, starting from the centre of each side of the cage array.		Depth and extent of solid accumulation at 20 ft intervals along the transect. Presence and density of Beggiatoa mats and any HAS
Benthic Infauna **BS* and AM**		Stations should be established on a transect down current of the cages. Stations set at cage perimeter and at distances of 20, 50, 100 and 200 ft	Diver cores with area at least 0.01 m^2, or grab/box corer with area of at least 0.1 m^2. Samples should be sieved at 1.0 mm	All organisms should be identified to lowest taxonomic level, species where possible
Sediment Chemistry **BS and AM**		See location for benthic infauna	3 replicate diver cores, or 3 replicate grab samples	Analysis –TOC, T Kjeldahl N, particle size distribution. Eh discontinuity. Cores to 2 in.
Water Quality **AM**	*In order to document the effect of culture activity on dissolved oxygen and nutrient on the water column*	Should be conducted in July-September annually, within the hour of slack tide. 3 stations – 100 ft up current of cages, 20 ft and 100ft down current of cages	3 replicates at each station, at a depth midway between surface and bottom of cage nets	Analysis – dissolved oxygen, temperature, salinity, pH, ammonia, nitrite/nitrate, concentration of unionised ammonia. Loading estimates for ammonia and nitrite/ nitrate

* SCS – Site Characterisation Survey, BS – Baseline monitoring, AM – Annual Monitoring.

TABLE 24
Components of Environmental Baseline Field Survey as applied to new salmon facility applications in the State of Maine, United States of America

Component/objectives		Methodology/ equipment	Location and timing of sampling	Number of surveys/samples	Notes
Diver Survey – *to determine relative abundance of fauna/flora, sediment type and unique features of substrate*		Video camera preferred but still shots taken at 10 m intervals may be used. Remote video or stills camera to be used where the site is too deep for SCUBA	Video transect in direction of prevailing current, through the centre of the proposed site	Number of transects will be determined by DMR	The diver should document the flora and fauna and note relative abundance (abundant, common or rare)
Hydrography – *to measure current speed and direction and to predict the fate of waste feed and faecal material*		Subsurface current meter preferred but flow meters may be used with surface direction estimated	Current should be measured at 3 depths – surface, net pen bottom and 1 m above the sea floor. A 15-minute sample from each depth every hour for a period of 16 hours. An average tide should be used		
Water Quality – *to measure water temperature, salinity and dissolved oxygen during peak stratification*		Water samples may be taken, or an electronic membrane probe may be used. The preferred methodology for oxygen determination is 'Winkler Titration' but electronic membrane method is acceptable	Measurements should be made on two occasions, with one between 15 Aug and 15 Sept and should be over 2 tidal cycles. 1 profile should be taken within two hours of sunrise Detailed dissolved oxygen profile should be taken at the centre of the site (consisting of ten equally spaced samples over depth range). Temperature and salinity should also be measured		
Benthic Analysis – *to establish substrate reference data for future assessment of benthic impact*		A systematic sediment sampling plan should be prepared, which covers the proposed area of the site, plus 60 m in each tidal direction.	An array of single sediment core samples should be taken in order to fully characterise the substrate of the proposed site. Consultation with MDEP is recommended prior to implementation of the sampling plan		Samples to be used for sediment grain size and chemical and biological analysis
Infauna – *to establish reference data of existing benthic infauna prior to commencement of culture activities*		Samples to be sieved through 1.0 mm sieve. Benthic infauna cores used by diver should have area of at least 81 cm2. Cores may be collected from a grab or box corer and should have an area of 0.1 m^2.	Single core samples to be taken in accordance with proposed sediment sampling plan		Infauna to be identified to species or lowest taxonomic level. General characterisation of the community should be included.
Sediments	Sediment grain size	Wet sieving method described by Buchanan (1984)	Single core samples should be taken according to sediment sampling plan. The exact location for each core should be noted and reported.		Depth of core, unconsolidated organic material should be noted
	Redox discontinuity depth	To be measured from a plexiglas corer			
	Depth of unconsolidated organic matter	Determined by visual inspection			
	Total organic Carbon (TOC)	Unconsolidated matter and top 2 cm of inorganic sediment to be used. 30 g minimum sample. Methods: Puget Sound Estuary Program 1986			

The permit details two mixing zones at the facility as follows:

- **Water column mixing zone** defined as the entire area (from surface to water column/substrate interface) encompassing the net pen facility and extending out for 30 m from the perimeter of the cage array.
- **Sediment Mixing Zone** defined as the sea floor area directly under the area of the facility and extending out for 30 m from the perimeter of the cage array.

The permit states that beyond these allocated zones, farm operations shall not create conditions that may be harmful to aquatic life or any impairment to the receiving waters and its designated uses. Absolute allocation of mixing zones may be altered for individual sites. This is designed to reflect the effect of currents in that area, however, the area of the offset mixing zones must not be larger than that defined by the cage array.

The permit requires annual monitoring of ambient water quality within the Water Column Mixing Zone, at a far-field site (30 m down-stream of cages) at each group of cages, between 1 June and 31 October. Monitoring requirements are detailed in Table 25.

In some situations, two years of routine monitoring may show a facility to be in compliance with the regulatory standards, if this occurs the near-field (within 5 m of the cages) water quality monitoring frequency may then be reduced from two to one per month for Level I and from one per week to two per month for Level II.

In addition to water quality monitoring, each cage facility is required to carry out routine monitoring of the sediment and benthic infauna. Farmers are also required to carry out two video or stills photography (in colour) monitoring surveys per year, in April /May and in August. These surveys should provide an evaluation of the sea floor beneath and adjacent to each cage array. Requirements of the video surveys are detailed in Table 25 and consist of a series of 60 m transects. However the permit requires that multiple evaluations should be carried out where the size and layout of the cage arrays precludes coverage by one transect.

The MePDES requires that information on reference stations must be kept in order to provide comparative information on both water quality and benthic conditions. The DEP may require repeat or on-going reference monitoring in order to assess the results of the routine monitoring. The reference stations should be selected that best represent local ambient conditions and are not under the influence of culturing activities or other uses of the waterbody. The reference site should be at least 100 m away from the farm, in a direction perpendicular to that of the prevailing currents. A benthic reference station should be selected that has similar sediment characteristics to those at the farm site, if necessary one reference station per sediment type should be chosen. For each sediment type, three benthic samples are required at the reference stations.

The MEPDES permit has a number of Impact Thresholds[59] with respect to the sediment and benthic monitoring and video surveys. The DEP uses these thresholds to determine if discharges from the farm operations are causing impairment of the State's water quality criteria. There are a number of criteria for both within and beyond the sediment mixing zone. The details of these thresholds are provided in Table 26. The department requires that an operator must notify the DEP once any warning levels (see Table 26) for the Sediment Mixing Zone have been exceeded. The facility is then required to review operations and propose changes required to ensure that impact level is not exceeded. Where subsequent monitoring indicates that warning levels are further exceeded or that impact levels are exceeded, the facility must notify DEP and include a plan and implementation schedule for modification of operations at the site. The restocking of cages is prohibited until the plan is approved and implemented. Further monitoring may be required to determine the effectiveness of the measures.

[59] www.maine.gov/dep/blwq/docstand/aquaculture/MEG130000.pdf

Maine has three classes for marine and estuarine waters but there is little difference between the uses or the qualities of the various classes. All attain the minimum water quality standards for fishing and swimming established in the federal Clean Water Act. Most support the same set of designated uses with some modest variations in their description.

Class A waters allow impoundments and very restricted discharges, so the risk of degradation while quite small, does increase since there is some small human intervention in the maintenance of the ecosystem. Classes B and SB have fewer restrictions on activities but still maintain high water quality criteria. Finally, Classes C and SC have the least restrictions on use and the lowest water quality criteria. Classes C and SC waters are still good quality, but the margin for error before significant degradation might occur in these waters in the event of an additional stress being introduced (such as a spill or a drought) is the least[60].

Assessment of the impact of farm operations on the environment in Maine, particularly for semi-quantitative parameters, relies on comparison with data on the baseline conditions and reference stations. The methods employed have been assessed externally (on two occasions since 1987) for practicality, cost effectiveness and scientific robustness. The most recent version of the MePDES permit was developed through a public process and now contains a number of new parameters, such as redox and sulphide. These new parameters are currently being reviewed for efficacy. Contractors and consultants must possess appropriate certification from the State regulatory agencies. Agency staff can carry out random spot checks on how field monitoring is being conducted.

Field measurements may be carried out by farmers, consultants or regulators. Under the previous system operators paid a monitoring tax ($0.01 per pound harvested). This tax was paid to the State who then employed a third party to carry out most of the monitoring under the supervision of the State. 2003 saw the beginning of self-monitoring by the industry, where some monitoring is carried out by the company and some by contractors.

Modelling approaches

In Maine, modelling approaches are occasionally employed to identify potential problems and to design monitoring appropriate monitoring. At the present time, models are not used in enforcement or decision-making.

Ecological standards

Ecological Quality Standards have been set in Washington State for water (WAC 173-201) and benthos (WAC 173-204). The permit system in Maine (MePDES) defines a Warning and Impact Level system for a number of sediment parameters (see Table 26).

CONCLUSIONS

All of the countries studied have systems in place to monitor the effects that salmon farms have on the receiving environment. In general, the degree of monitoring in terms of frequency and or sampling amount or complexity is dependent on perceived risk, taking into account the scale of operations and the sensitivity of the receiving waterbody.

Benthos and sediments

Benthic effects are the easiest to detect and quantify and are therefore those that have received both the most academic study and regulatory attention. In general, the

[60] www.maine.gov/dep/blwq/docmonitoring/classification/

TABLE 25

Near-field, far-field and reference station water quality monitoring requirements, sediment and benthic monitoring and video survey requirements for the State of Maine finfish cage annual monitoring, Maine United States of America

Determinand	Location/Timing	Monitoring Level		Methods/Notes
		I	II	
Near Field water quality – at locations within 5 m down current of stocked cages, should represent maximum impact of operations.				
Dissolved oxygen concentration (DO) (mg/l)	(i) Samples to be taken at mid-netpen depth, mid-water column depth and 1 m above the sea floor for all parameters (ii) Samples to be taken within 1 hr of slack water before 0900hrs	2/mth	1/wk	If DO levels are below 6 mg/l in any of the samples additional samples should be taken.
Dissolved oxygen saturation (%)				If DO saturation is less than 85% in Class SB5 waters or less than 70% in Class SC waters, far-field monitoring shall be conducted
Salinity (‰)				
Temperature (°C)				30 cm Secchi disk to be used and viewed using viewing scope. Average of depth at disappearance and reappearance.
Transparency (m)				
Far-field and reference station – samples to be taken at a position 30 m immediately down-current of stocked cages and at a reference station				
Dissolved oxygen concentration, DO (mg/l)	(i) Vertical profiles with parameters measured at intervals of 1m or less. (ii) Minimum, average and maximum value of each parameter to be reported (iii) Samples to be taken within 1 hr of slack water before 0900hrs	1/yr in Aug	2/yr - Aug and Sept	If DO saturation at the far field stations is less than 85% in Class SB waters or less than 70% in Class SC additional samples should be taken, samples should also be taken at reference station at comparable depth, time and tide.
Dissolved oxygen saturation (%)				
Salinity (in ‰)				
Temperature (° C)				30 cm Secchi disk to be used and viewed using viewing scope. Average of depth at disappearance and reappearance.
Transparency (m)				
Sediment and benthic monitoring – to be carried out at same time as video monitoring, along the same transect as described for video monitoring				
Redox potential (mV)	(i) Minimum of four stations along the transect – two on either side of the cage array (ii) One location 30 m away on either side of the cages, one location within the mixing zone (iii) At each location a minimum of three samples taken perpendicular to transect spaced at distances reflecting and within the lateral extent of greatest benthic impact (iv) If grab samples used for sediment analysis sub-samples, no more than ¼ should be removed	Apr-May and Aug-Oct		Cores of top 3 cm
Sulfide (uM)				
Anoxic sediment, gas formation and Beggiatoa				
Azoic conditions (per 0.1 square m)		1/5yrs in Aug/Oct as minimum		May also be required if warning levels are exceeded. . Single cores 4 inches or greater in diameter and inserted to resistance or 15 cm. Depth of core shall be reported. Samples sieved through 1.0 mm sieve. Taxa measurements to include presence, absolute and relative abundance and Shannon-Weiner Diversity Index
Infauna (per 0.1 square m)				
Sediment grain size (%)		When taxa measured		
TOC (mg/g)				
Copper – total metal (mg/kg dry wgt)		1/2yrs		Cores must be of top 2 cm. Should be measured when fish biomass is at maximum
Zinc – total metal (mg/kg dry wgt)				
Medications used (µg/kg dry wgt)		Within 1mth of use		Tests should include analysis for primary metabolites
Video (or photographic) monitoring				
Parameters: sediment type and colour, erosional or depositional areas, flora and fauna, presence of feed pellets, presence and appearance of Beggiatoa mats, presence of black sediments, out-gassing	Transect beneath cages: 60 m transect up-current from edge of cages; 60 m transect down-current from edge of cages	2 /yr		The department may waive the spring monitoring if the previous autumn survey indicates warning levels have not been exceeded. Beginning and end of each transect should be located by GPS. Images should provide 1 m^2 of sea floor coverage

TABLE 26
Sediment warning levels, Maine United States of America

Determinand	Sediment mixing zone (or within 30 m of cages)		Beyond sediment mixing zone (≥ 30 m from cages)
	Warning Level	Impact limit	Impact limit
Redox potential	Mean 100 – 0 mV nhe[6]	Mean < 100 mV nhe	Report level
Sulfide	Mean 1300-6 000 µM	Mean > 6 000 uM	Report level
Beggiatoa coverage	≥ 25 % photo coverage	≥ 50 % photo coverage	Compelling evidence[7]
Anoxic sediments	≥ 25 % photo coverage	≥ 50 % photo coverage	Compelling evidence
Pollution tolerant taxa	No. individuals in single taxa > 70 %	Report information	
Pollution sensitive taxa[8]	> 50 % reduction in mean abundance of taxa not identified as pollution tolerant[9]	Report information	SB waters – Significant reduction in mean number of listed taxa as compared to mean baseline or ref site SC waters – unsuitable for any species of indigenous fish, or structure and function of resident biological community is not maintained
Taxa richness	> 25 % reduction in total number of all taxa compared to mean baseline or reference site	Report information	SB waters – Significant reduction in mean number of total taxa as compared to mean baseline or ref site SC waters – unsuitable for any species of indigenous fish, or structure and function of resident biological community is not maintained
Azoic conditions	> 50 % reduction in total abundance compared to mean baseline or ref site	Absence of fauna	

methods used in Norway are designed to give quick and regular feedback but, for the higher frequency assessments, rely on relatively crude and subjective determinations. The annual macrofaunal survey, however, appears to be similar to that carried out in other countries so the overall level of environmental information should be good. Scottish sites are usually monitored every second year at peak biomass and the range of determinands studied is quite comprehensive. In particular there is a considerable emphasis on the measurement (and modelling) of in-feed sea lice medicines. In Ireland the Level 2 monitoring for medium sized sites consists of visual measurements and redox, which is a lower standard than in several other countries for similar sized sites. Large farms (>1 000 tonnes) require macrofaunal surveys (level 3). The benthic monitoring protocols in Chile, British Columbia (BC), Canada, and Washington State in the United States of America are broadly similar to those in Scotland, with both macrofaunal and biogeochemical determinands. This also applies to Maine, the United States of America, where Sediment Action Levels are clearly defined. Several countries have followed the EQS or Action Level approach, but there are a variety of different determinands so a comparison of standards is not possible. Nevertheless the approaches taken are very good and, if policing is adequate, are an extremely useful regulatory tool. An outlier is New Brunswick: this system relies heavily on sediment sulphide measurements as the key indicator of sediment condition.

In New Zealand, the situation is more complex as specific monitoring conditions are applied on a site by site basis but the suite of recommended determinands do appear to give very good environmental information. Modelling of benthic impacts takes place in most countries, particularly Scotland and Canada (BC), but at the moment only in Scotland is the modelling approach embedded in regulation.

Water column

Water column impacts generally refer to the release of nutrients and the reduction in ambient oxygen levels. As nutrient measurements require long time-series to be meaningful, several countries approach this by modelling e.g. Norway and Scotland. In most countries some measurements of oxygen profile with depth is required. While this may occasionally provide useful information, particularly if benthic oxygen demand is very strong and ambient currents are weak, occasional spot measurements of transient oxygen profiles are not likely to be particularly robust as indicators of impact.

Monitoring sea lice

Norway has lead the way on sea lice monitoring for many years with monitoring by State veterinarians and compulsory treatment trigger levels, although other countries, e.g. Scotland, are now taking this issue more seriously. Ireland and Canada also have regulations on lice burdens. There is still frustration that much of the data collected by farmers on lice is confidential and not available to public scrutiny. Similarly, data on medication frequency is not easily available.

Escapes

Escapes of farmed salmon are recognised to be a problem of particular importance when con-specifics are present and interbreeding may occur. Norway has recently taken a robust approach to regulation of escapes and assessing engineering standards of cage structures (NYTEK). In Scotland, reporting of escapes to the government is mandatory and in general farmers must have contingency plans for escapes. However, standards for containment across salmon growing countries are generally weak[61]

[61] www.worldwildlife.org/what/globalmarkets/fishing/

Assessing the effectiveness of the EIA and environmental monitoring process

The primary objective of EIA is an impartial assessment of the potential for environmental and societal costs and benefits of a development. Through a process of identifying the key hazards and mitigation, it should result in the consent of developments where there has been a transparent and systematic cost benefit analysis allowing development with net societal benefits within a policy framework. In this section we assess the technical appropriateness and effectiveness of the EIA and environmental monitoring processes, both regulatory and practical, in each of the countries using a variety of information sources both published and elicited through a questionnaire (Appendix 1). It must be stated that the rather poor response to the questionnaire has not made a robust assessment of stakeholder perceptions possible.

CANADA

In Canada, both federal and provincial government have responsibilities for aquaculture activities. At the provincial level a number of agencies may be involved in site approval, production licensing and environmental monitoring. There is recognition that greater harmonisation is required between regional and federal government in terms of aquaculture governance. At present the National Aquaculture Framework Agreement is pending and should provide consistency in policy across Canada.

In general most regulator and industry representatives agree that optimum measurements are being taken to protect the environment. Some scientists, however, would like to see a wider range of measurements and effects taken into account as part of the EIA process.

Feedback Mechanisms

Industry representatives believe that environmental monitoring has confirmed that well located farms have good environmental performance and that it does contribute to improved site selection. However, optimum production levels are often only determined by trial and error. It has been suggested that accelerated monitoring, perhaps three or four times per year, could be useful in determining if management practices are effective and if production levels are appropriate. Harmonisation of the governance (within provinces and with federal government) of aquaculture should serve to improve the effectiveness of feedback mechanisms in improving site selection and farm development.

Mitigation Measures

In British Columbia a maximum allowable chemical standards is set, which farms must not exceed at peak production. When these standards are exceeded the farm is not allowed to re-stock until levels return to below the allowable level. In some occasions this has resulted in extensive operational adjustments in order for site operators to ensure that they remain below the allowable levels.

In New Brunswick, a mitigation and remediation process is built in to the Environmental Monitoring Program. The process is based on compliance with the MEQO set for finfish aquaculture sites – sediment sulphide concentration - and is described above. Remediation Plans are drawn up for sites that receive a poor rating during the annual monitoring programme. A number of recommendations may be made as part of such plans, these include, but are not limited to:

- increased environmental monitoring;
- changes to site management and operations;
- review of harvesting strategies;
- retraining of site staff.

Implementation of such plans has been relatively successful and resulted in improvements to benthic conditions in many cases.

Stakeholder perceptions

In general, industry representatives consider that all reasonable steps are currently being taken in order to assess the environmental impact of aquaculture activities. Many companies feel they abide closely with environmental regulations in order to protect the environment they work in. However, some variation in commitment to environmental ethics does exist across the industry sector. There is also a concern that the current process largely serves to restrict aquaculture expansion, rather than to improve management practices.

CHILE

The approach applied in the EIA process in Chile is technically appropriate and Resolution 404/2003 provides a detailed description on the methodologies to be used. In 2005 the OECD reported that the "EIA system is well established and has proved active and influential" (OECD 2005). The main issue with the system at present is that the regulatory authorities lack adequate financial and staff resources to ensure full and effective enforcements of the system (OECD, 2005; Leon, 2006). There is a feeling that the process of environmental monitoring of salmon farm impacts requires more effective data and information collection. This could help inform and improve the management of sites.

Feedback mechanisms

Feedback mechanisms (when the regulatory system is effective) appear to be working within the system. Within the Chilean salmon industry there are examples where sites that show poor environmental performance have switched to less intensive species (i.e. shellfish species), while salmon farms are moving into deeper sites with greater current speeds. There has also been a trend for salmon farms that are in environmentally good sites to increase capacity.

Mitigation measures

Within the Environmental monitoring system there is a mandatory mitigation strategy based on the presence of anaerobic sediments within the farm site area. Where anaerobic conditions are detected two years consecutively production capacity must be reduced by 30 percent. These measures will be applied annually until aerobic conditions are restored (RAMA, 2001). Some stakeholders are of the opinion that the level of accomplishment of the system is low and there is little information on how successful the measures are.

Regular reviews

RAMA (Environmental Regulation on Aquaculture) was initiated in 2001 and was under revision in 2006. The methodologies applied to Preliminary Site Descriptions and Environmental Information as detailed by Resolution 404/2003 are reviewed every two years.

Stakeholder Perceptions

The general perception is that the current regulatory system has the potential to be an effective tool. However, the enforcement of the system is hampered by the lack of financial resources and adequately trained staff. This has been of particular concern to the public and the scientific community (Leon, 2006). The system also lacks an auditing system, which would improve the confidence in the system.

IRELAND

The Marine Institute, created under the 1991 Marine Institute Act, a section of DCMNR, is the national agency that primarily carries out the environmental monitoring associated with salmon farming. As the DCMNR also issues and enforces the licensing system there are direct linkages between licence requirements and environmental monitoring and implementation. The statutory monitoring of sea lice levels and benthic impacts of salmon farming is collected and analysed by the Marine Institute and the results are given to the farm usually between 5–10 days after the inspection. The monitoring programme is based on that implemented by SEPA in Scotland, where it has evolved through application at a large number of sites. The level and frequency of the monitoring programme to be applied to each site is assigned on a case-by-case basis, commensurate with the particular conditions at the site location. This means that the monitoring programme is tailored to each site.

Water column monitoring has been carried out on salmon farms since the 1980's. A review of the water quality data collected between 1985 and 1997 indicated that there was no detectable change in the levels of inorganic nutrients and it was proposed that water column sampling would be conducted only in the winter months (McMahon, 2000). This is consistent with the operation of salmon farming in Ireland. Irish farms tend to be located in areas of high flushing rates, resulting in rapid dispersion of dissolved substances, with half of all salmon farms licensed to produce less than 500 tonnes, i.e. relatively small by global industry standards.

Benthic monitoring results are compiled into an annual report submitted to the DCMNR. Should this highlight unacceptable impacts, the farmer must implement a Benthic Amelioration Plan. This plan addresses the impact by including at least one of the following:

- moving cages away from the area of impact to another location within the licensed area;
- reduction in tonnage at the site;
- use a different feed formulation to reduce the feed conversion ratio.

The implementation of this plan reduces the level of impact and allows the recovery of the benthic environment.

The sea lice management strategy has five principal components:

- separation of generations;
- annual fallowing of sites;
- early harvest of two-sea-winter fish;
- targeted treatment regimes, including synchronous treatments;
- agreed husbandry practices.

Together, these components work to reduce the development of sea lice infestations and ensure their most effective treatment. The separation of generations and annual fallowing prevent the vertical transmission of infestations from one generation of fish to another. The early harvest of two-sea-winter fish removes a potential reservoir of lice and the complimentary husbandry and synchronous treatments enhance the efficacy of treatment regimes. The setting of treatment triggers is integral to the effectiveness of this approach. Over the period since the initiation of a Single Bay Management (SBM) in 1998, treatment trigger levels have progressively reduced from an initial starting point of two ovigerous females to the current 0.3–0.5 ovigerous females per fish. This is an indication of the effectiveness and appropriateness of the strategy.

Effective mitigation
The Irish approach to mitigating the environmental impacts of established salmon farms is based on a positive feedback system stemming from the monitoring programmes e.g. triggering treatments or requiring the implementation of Benthic Amelioration Plans.

Regular reviews
The environmental monitoring system operating in Ireland is under constant review, with one of the more recent initiatives informing on incorporating the approach of Integrated Coastal Zone Management, (CLAMS). The complete regulatory approach and methodology applied is currently undergoing review.

NEW ZEALAND
The Australian and New Zealand Environment Conservation Council (ANZECC) published the revised Australian and New Zealand guidelines for fresh and marine water quality in 2000[62]. These guidelines provide the basis on which all environmental monitoring is conducted in relation to salmon farming in New Zealand. The core concept of these guidelines is identifying "environmental values", which are determined by the local community and regional councils. These values are further defined by Water Quality Objectives, specific to the aquatic environment in that region. Determinands are then selected and trigger values assigned to each to assess the impact of the activity and whether action is required. These guidelines are extensive and to aid use 'Guideline Packages' are provided for common issues such as HABs. For salmon farming a package relating to maintaining aquatic ecosystems would include water quality objectives for nutrients and decreased levels of dissolved oxygen. For each objective, determinands are listed (e.g. total phosphorus, total nitrogen, chlorophyll a, dissolved oxygen) and assigned a trigger value. This trigger value may either be a threshold level or an acceptable range of values. Alternatives to trigger values are also given for more complex water quality issues, for example a whole waterbody may be assigned a target load for nutrients.

Effective mitigation
The environmental regulatory and impact management system in New Zealand is based on a comprehensive array of EQS's, site specific "Water Quality Objectives" all with trigger values, that are either a single threshold or a range of values that once exceeded remedial action is required. This foundation should ensure a focused mitigation regime. The allocation of areas specifically for salmon farming contains most impacts into discreet regions. When conditions exceed the EQS the salmon cages are moved to a pre-assigned refuge area, within the AMA until the conditions return to acceptable levels. As this process adds another layer of managerial complexity, and as conditions at the refuge site are usually sub-optimal for the farmer, there is an inherent incentive to maintain the EQS's at the farm site. In developing a system whereby salmon farming is restricted to a defined area, (they cannot simply move away and establish a new site when EQS's are exceeded, as in Norway), the farmer is forced to operate within the capacity of the AMA.

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[62] www.deh.gov.au/water/quality/nwqms

Regular reviews

The current system is under constant scrutiny, having been completely reviewed in 2004. The level of detail and timescale is at the discretion of the regional councils and will be stipulated in their Regional Coastal Plans.

Stakeholder Perceptions

The previous system in operation was perceived to be so complex and slow that it was restricting the expansion and productivity of the industry unnecessarily. High demand for space for aquaculture in some parts of the country and the demands placed on statutory bodies in terms of expertise for auditing environmental impact assessments led to a backlog of applications for marine farming permits. This, and the precautionary approach to assessment of environmental effects where information was inadequate, was perceived as compromising the development of the industry. Furthermore, the two-permit system led to situations in which applicants who had gone to the expense of conducting an assessment of environmental effects, and been granted a coastal permit, found their applications for marine farming permits subsequently rejected by the Ministry of Fisheries because of conflict with fisheries interests. As the current system is still in its infancy stakeholders are applying a 'wait and see' approach before commenting.

NORWAY

The main focus of environmental monitoring and EIA is directed at evaluating the effects of organic waste on the benthic environment.

The MOM monitoring programme on which NS9410 is based was tested and validated in over 200 investigations in Norway. This has ensured that the process is robust, fit for purpose and cost effective. The sampling methodology for the B investigation is designed so that all samples may be collected in a small open boat in rough weather conditions. A big advantage is that determinands can be quantified immediately and the results given to the farmer on the same day - determinands that require laboratory analysis are excluded. However, by omitting determinands that require more than one day's analysis, this level runs the risk of using subjective or imprecise measurements, although using determinands in concert will make the results robust and by taking many samples the final determination of the environmental condition increases in reliability.

The C-investigation is a more complex investigation and its main purpose is to monitor the long-term changes in the sediment along a transect running from the local through intermediate to regional zones. Environmental impacts in the intermediate and regional zones are less tolerated than those in the local zone. The benthic macrofaunal determinands included in this investigation are sensitive enough to detect subtle impacts and are based on established ecology of organically enriched sediments (Pearson and Rosenberg, 1978; Pearson, Gray and Johannessen, 1983; Gray, 1992; Hansen *et al*, 2001). It is performed according to NS9423, the Norwegian Standard for sampling and investigation of benthic infauna and NS9410. The sampling frequency is set by the County Governor Department of Environmental Affairs.

At all fish farms prevalence data for sea lice must be recorded at least every second week when the water temperature exceeds 4°C and the results are reported to the Norwegian Food Safety Authority. If the number of lice per fish exceeds the threshold limits the fish farmer is required to delouse at the farm.

Feedback mechanisms

The B investigation gives an instantaneous result on the sea bed conditions in the vicinity of and under the farm. The results from the three sets of variables are combined and the degree of exploitation of the site is determined in accordance with the set EQS's.

Should the Environmental Condition (EC) of the site be considered 'unacceptable' the farmer can immediately set in place management practices to reduce the environmental impact and return the site to an "acceptable" EC.

Effective mitigation

When "unacceptable" environment conditions are found the usual method of mitigating the impact has been to abandon the site and relocate to a different area. Increasingly this has meant that farms are moving into more exposed areas with greater flushing rates, which minimises the impact of the organic loading and so reduces the benthic impact. However by moving cages that were not designed to withstand the exposed conditions the number of farmed fish escaping escalated. This created a situation where the farmed fish were in direct contact with wild stocks leading to increasing levels of genetic impacts. The NYTEK regulations were developed as a direct response to mitigate against these impacts. However, as they are not due to be fully implemented until 2008 the effectiveness of these regulations cannot be ascertained. Alternatives to relocating are lowering production levels or fallowing sites and this is now the norm.

Regular reviews

All Norwegian standards are reviewed every five years.

Stakeholder perceptions

Stakeholders perceive the EIA process as a means of showing that they are complying with environmental regulations and managing the industry to minimise negative impacts generated from farming activities. However, the farmer's interest in environmental impacts is usually restricted to the immediate location of the farm site.

UNITED KINGDOM

Environmental monitoring

SEPA is the competent authority for regulating pollution originating from salmon farms, duties assigned to it under the Environment Act 1995, the Control of Pollution Act (CoPA) 1974 and the CAR regulations which have replaced CoPA. It also has special responsibilities designated under the Birds and Habitats directives. This requires SEPA to take a long-term, holistic approach to the protection of the environment and associated monitoring, (Henderson and Davies, 2000). Before a "Consent to Discharge" is granted Scottish Natural Heritage (SNH) is consulted, so including a nature conservation remit into the process. In granting a "Consent to Discharge", SEPA set out conditions and restrictions on the salmon farm which control the amount of wastes and chemicals entering the receiving environment. These conditions are set on a site-specific basis, based on expert judgement and well-established science. EQS's are set for all determinands and environmental monitoring regimes are devised to promote Best Environmental Practice (BEP), considering water column, sediment and biological characteristics. This holistic, site-specific approach ensures the technical appropriateness of the monitoring regime as it is tailored for the particular sensitivities of individual sites. Consent conditions are based on the carrying capacity of the site location, aiming to balance fish biomass with associated environmental impacts. Carrying capacity is assessed on site characteristics; existing environmental stress, dispersion and flushing patterns, previous management history and any conservation designations (*e.g.* Special Areas of Conservation). Deposition models (autoDEPOMOD and DEPOMOD, Cromey *et al*., 2002a, 2002b) are used to assist in predicting the level of impacts and carrying capacity. Models are also used to control chemicals and therapeutants, using short and long term dispersion models on a case by case basis.

Sea lice monitoring

Until the Aquaculture and Fisheries (Scotland) Bill (2006) is implemented, sea lice monitoring continues under the regime as detailed in the CoGP. This code was developed with input from industry, regulators, government and related stakeholders and is based on defining discrete management areas, Area Management Agreements are developed to address the specific needs of each area. These areas are defined according to farmers experience and local knowledge, as hydrodynamic models, capable of predicting dispersion of fish disease and parasites, are poorly developed. A tidal excursion model was established by Fisheries Research Services (FRS) in 1998 to manage the outbreak of infectious salmon anaemia. However this model produced management areas that were too large to apply a single management plan to and a pragmatic approach lead to the proposed units being further divided. However the National Sea Lice Strategy has been drawn up under the Tripartite Working Group concordat[63] with farmers working alongside wild fishery interests such as the Association of Fishery Boards, which ensures the resultant Area Management Agreements are appropriate and fit for purpose. Monitoring occurs weekly, carried out by trained farm staff with regular visits by Fishery Board staff. The monitoring results are communicated within seven days of sampling to all farms in the management area and this information directly influences the future management regimes of the farms. This feedback system ensures that a rapid response can be taken in the event of the lice level criteria being exceeded.

Effective mitigation

Setting a cap on the biomass permitted on each site, on the basis of the assimilative capacity of the environment, constrains the environmental impacts from the outset. The main regulatory body, SEPA, applies the precautionary approach to environmental monitoring and the setting of EQSs. In general, impacts have been proven to be of a transient nature. The frequent monitoring of sea lice levels and rapid turnaround of results means the sea lice strategy can be effective in managing lice levels on farmed fish. Non-participation by some farmers has now been addressed with the Aquaculture and Fisheries (Scotland) Bill (2006), which establishes statutory monitoring and management procedures in relation to lice levels on farms.

Regular reviews

The complete regulatory framework is routinely reviewed by SEPA involving external academic consultants. Employing an iterative system ensures that the consent conditions set are appropriate. Responsibility for conducting these reviews lies with the Aquaculture Project Management Group who co-ordinate with the Scottish Government in reviewing how the industry is regulated. The sea lice monitoring strategy has just undergone a comprehensive review resulting in the Aquaculture and Fisheries (Scotland) Bill (2006) which was subject to public consultation at an early stage of drafting.

Stakeholder perceptions

Industry views the current regulatory regime as too precautionary and unnecessarily complex. The high degree of regulation in comparison with competing countries such as Norway and Chile, and the financial burden this places on salmon farm companies, may make Scotland less competitive in the global marketplace.

UNITED STATES OF AMERICA

In general, there is agreement between industry, regulators and researchers that the optimum measures are being taken to protect the environment. Some aspects of the

[63] www.scotland.gov.uk/Topics/Fisheries/Fish-Shellfish/18677/14726

process are viewed to be less effective (such as Washington State's sediment TOC program). In Washington, the Department of Natural Resources has the opportunity, through the leasing process, to add additional monitoring measures (through its Plan of Operations) to the lease requirements as set by the regulatory agencies.

The regulatory agencies (DEP) in the State of Maine feel that much of the current monitoring requirements (the most recent MePDES permit system, initiated in 2003) are excessive and often unnecessary. The system is very bureaucratic, which results in slower response times. The new system has also seen the previous cooperative nature between industry and regulators replaced with legal defensiveness. There is a feeling that under the new permit the environment may, in some ways, be worse off since farmers are more reluctant to learn new techniques to improve efficiency and lessen environmental impact. Monitoring could be more strategically targeted, as it was under the pre-2003 system, while providing the same level of environmental protection.

Feedback mechanisms

In the United States of America there are good feedback mechanisms that can inform better site selection and aquaculture performance. Interaction largely occurs between the state regulators and companies involved with professional biologists. The system is designed to identify the sites that are unlikely to meet environmental standards at an early stage. This way site configuration and management can be optimised to help achieve the necessary standards. In some cases application of up-to-date husbandry and technology approaches has meant that marginal sites can increase capacity.

Mitigation measures

In some cases, such as prevention of escapes and reduction of metal contamination, there have been effective mitigation measures to reduce impact on the environment. Other mitigation may involve site abandonment, where a farm is found to be grossly out of compliance. However, mitigation may also simply involve monitoring of the impact. Measures that may be recommended include site reconfiguration, reduction of load through improved feed loss rates, net cleaning and fallowing.

Regular reviews to legal requirements for EIA

In Washington State, legal requirements for EIAs (through the NPDES scheme), monitoring practices and procedures are reviewed every five years. In Maine, the legal requirements are reviewed periodically. Three reviews (two external) have been carried out since 1987 and another is scheduled for 2008.

Stakeholder perceptions

The EIA process is often conducted at both the federal level and the State level. The industry regards the EIA and monitoring processes as fair and rigorous, but they are considered to be very costly and time consuming. Large companies may have to employ several people that are dedicated to the environmental monitoring of their sites. To this end many industry representatives feel that the process is not efficient. The industry also views much of the process as a paper filing exercise with few tangible benefits. There is also a feeling that mitigation measures are often not implemented.

CONCLUSIONS

In the initial period of development of the salmon industry, site selection was often ad hoc with few environmental considerations and relatively undeveloped regulatory machinery, competence and resources. It is clear from the above analysis that in all salmon-growing countries there are now well-developed regulations and sufficient regulatory competence and resources to implement these. The exception may be Chile where while the regulatory framework appears sound, the practical application of these regulations in a very quickly expanding industry may require greater resources. However, between all countries, including Chile, there is a regular cross-comparison of standards and regulatory techniques, often through staff transfers or academic visits, and this should be further encouraged so that industry and regulators can compare concepts and practices and adopt the best after-adaptation to local environmental conditions.

Improvements to the EIA and environmental monitoring process

The EIA and environmental monitoring approaches followed in each country have strengths and weakness in meeting their objectives. In this section we attempt to identify any constraints relating to technical/scientific, financial, social and legal issues involved in the EIA process and suggest improvements that may be applied to these areas for each country. A synthesis table (Table 27), has been complied to highlight the varying approaches taken.

CANADA

There is recognition within the Canadian aquaculture sector that there is a lack of harmonisation between federal and regional roles in regulating aquaculture activities. A National Aquaculture Framework Agreement is expected to alleviate some of these issues and may help to reduce duplication of effort in some areas. The major constraints within the industry are the cost and time implication of EIA's and routine monitoring.

Better communication between industry and NGO's, with a focus on common issues, such as improving the sustainability and transparency of the industry, is desirable. The industry feels that, ideally, poorly performing sites should be relocated to more appropriate locations. This should result in a reduction of environmental impacts. However, this process is often hampered by NGO involvement. Aquaculture is not widely supported as a method of food production in Canada. This could be improved by a combination of greater industry transparency, better political support and improved public education.

On the research side there is a need to focus and better coordinate research efforts in order to prioritise and develop the needs of the industry and for improved sustainability. There is a lack of appropriately qualified scientific personnel, particularly in the area of benthic ecology and this is regarded as a major issue for the EIA and environmental monitoring processes in Canada. At present, in British Columbia, there are only a handful of well-known invertebrate taxonomists that are able to process and analyse benthic samples. Staff and resources are also an issue at government agency level, particularly as the industry is growing rapidly. Targeted capacity building is required at the university and research level. This should facilitate the scientific needs for the industry as well as providing much needed personnel.

Currently there is a reliance on chemical standards in EIA's and environmental monitoring. There is a need for biological standards within both processes. Far field affects are given little consideration at present. Current research in this field needs to be evaluated and appropriate guidelines and standards need to be incorporated into the regulations where applicable.

Collation of relevant environmental data can be costly and time-consuming and this is a major constraint for the industry. Such constraints are likely to increase substantially as the salmon industry is moved offshore into deeper waters (from 40-80 m to 200 m plus). Traditionally, equipment, such as grabs, are easily deployed from small or medium sized vessels. As the industry moves into deeper water such operations may become technically more difficult, as well as more costly.

More frequent monitoring has been suggested, particularly in the New Brunswick area, as a more efficient method of gaining information on farm's environmental performance.

This is particularly relevant for farms that consistently perform badly and should facilitate quicker implementation of remedial action and thus reduce environmental impact.

CHILE

In 2005 the "Environmental Performance Review of Chile" was published on behalf of the Organisation for Economic Cooperation and Development (OECD) and the Economic Commission for Latin America and the Caribbean (ECLAC) (OECD, 2005). A number of recommendations were put forward for salmon farming including:

- strengthen enforcement capacity of the relevant agencies;
- adoption of "polluter pays" principle in accordance with the FLE;
- adopt an integrated management plan for coastal areas;
- improve environmental and health management of salmon farming.

Several of these recommendations mirror the concerns of both the general public and the scientific community within Chile, particularly in regard to the enforcement of environmental regulations. There is a belief that within the enforcement agencies there is a lack or resources, in terms of adequately trained staff and technology. This has resulted in limited effective enforcement and monitoring. Training is also lacking for farm personnel. Chile has adequate laws and detailed methodologies to monitor and protect the environment, but additional resources are required to fully implement the regulations (Leon, 2006). There is also a need for improved monitoring and auditing of the current system. Improved skills base is required for regulatory agency personnel in order to improve analysis and interpretation of monitoring results.

Greater awareness of the potential impacts of salmon culture is required on the part of the industry. In addition, the current regulatory system does not take account of other potential impacts, such as, far-field environmental impacts, sanitary conditions and implications and impacts on sea mammals. There is inflexibility in the current legal system and regulations should be modified to take account of other impacts. Some stakeholders feel that the regulatory tools need to be strengthened in order to have a greater influence on the future development of aquaculture.

IRELAND

Salmon farms in Ireland are located along the west coast of the country, in highly flushed sites and are generally of a small size in comparison to other countries. The expansion of the industry is restricted more by outbreaks of disease and a lack of suitable sites than by environmental constraints. Ireland has not applied a "carrying capacity" approach in its policy regarding siting of salmon farms and the EIA process does not adequately consider the cumulative impacts caused by several farms in close proximity (Porter, 2005). Adding the element of "carrying capacity" to the regulation of the Irish industry would link the production of the farm with the sensitivity of the receiving environment and so improving the effectiveness of the monitoring regimes. Due to the shortage of suitable locations for farming operations there is a growing pressure to develop offshore sites. However there are no regulations regarding installation requirements, such as the Norwegian NYTEK regulations, which may mean cages of inadequate standard are placed in high energy sites, which may result in increasing levels of escapes.

NEW ZEALAND

The environmental management of salmon farming in New Zealand has been substantially revised and rationalised through the Resource Management Act (1991) and more recently, the Aquaculture Reform Act (2004). The implementation of the controls in this new approach led to a moratorium on new farms between November 2001 and December 2004, to allow regional councils to establish the necessary infrastructure to carry out the amendments and designate Aquaculture Management Areas. As this approach is so recent, no improvements have yet been identified but these may become apparent in time.

NORWAY

The benthic impacts of salmon farms have been addressed by NS9410, the MOM system and relocation of cages. However, the MOM system does not address the genetic impacts of escaped farmed fish, parasite and/or disease transference to wild stocks and the impacts of chemicals and anti-foulant compounds.

A model for dispersion of sea lice has been developed but needs further validation and the NYTEK regulations are the first step Norway has taken to reduce the number of escaping fish by establishing basic requirements for cage structure.

Environmental monitoring has emphasis on local, small-scale measurements which up till now has covered the most important impacts. Today fish farms are seldom allowed to relocate due to unacceptable benthic conditions; other mitigating methods such as reducing the production or changing the position of the farm within the site are used. However, the cumulative impacts of salmon farming on regional basis need to be addressed, both with regard to benthic and pelagic effects as the level of production continues to grow annually by 6–10 percent. A model for predicting regional phytoplankton concentrations has been developed (NORWECOM) but needs further validation.

UNITED KINGDOM

Some of the models used to predict impacts are untested/validated for high-energy sites and in these cases SEPA have set an arbitrary upper limit for site biomass:

> *In particular, in view of the potential to under-estimate impacts, there is a significant degree of uncertainty associated with very large production units and SEPA has therefore adopted an upper size limit of 2 500 tonnes biomass until it has more confidence in model predictions at this level of production.*[64]

This precautionary limit will likely be revised when the appropriate model validation or other research is carried out, as there is a continuing demand from industry for larger sites with their economies of scale.

In order to improve the understanding of both nutrient flows and disease organisms in Scottish waters, significant improvements are required in hydrodynamic modelling in order to improve regulation of assimilative capacity and disease transmission between wild and farmed, and farmed and farmed stocks.

UNITED STATES OF AMERICA

Public perception of the aquaculture industry in the United States of America is an issue. Aquaculture as a method of food production is seen as being unsustainable. This view is partly cultivated by NGOs. Communication levels, both within the sector and to other interested parties (NGOs and general public) needs to be improved through reduction in mutual distrust: public understanding of the industry's environmental and social costs and benefits is a significant block on the rational development of the industry. A system that encourages all stakeholders to contribute to solving the industry's problems and constraints is required. Engaging stakeholders is more likely to produce beneficial outcomes than litigation.

The cost of monitoring and permitting is excessive in the United States of America, particularly for small operators. The system has effectively meant that only large

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[64] www.sepa.org.uk/pdf/guidance/fish_farm_manual/main/5.pdf

companies can operate, as they often have to employ dedicated staff to deal with monitoring and permitting regulatory requirements. In Maine there are currently no small operators and the industry has consolidated.

In the State of Maine, the industry fears that monitoring findings will be misused or inappropriately applied by the regulatory system before validation has taken place. Operators are now reluctant to monitor anything other than the legal minimum. The financial and regulatory burden of the current system has reduced the ability of the industry and the regulatory agencies to invest in essential research and development. It is believed that some of the environmental permit conditions could be relaxed, without reducing the protection to the environment, but may help to improve the ability to invest in experimentation. A more efficient system could be gained from a more strategic approach to monitoring.

In Washington State, there has been no recent expansion in the industry, largely because of opposition from NGO's, other developers and the public. Similar comments relating to industry stakeholder engagement to those made for the State of Maine are also relevant here.

SUMMARY

A general weakness across countries is the focus on individual sites sometimes at the expense of consideration of cumulative impacts at the regional scale. In order for such considerations to be effective there is a general need for improved modelling and long term data sets against which to test these models. These are generally expensive and require vision as their benefits are necessarily only realized after many years owing to typically high levels of inter-annual variability in coastal ecosystems.

Embedding aquaculture in a coherent system of integrated coastal zone management (ICZM) is an oft-repeated aspiration, but progress is inevitably slow owing to the multi-sectoral approach in most legislatures. Allocation of space to salmon farming and then allocating that space to individual companies presents problems and is especially difficult when there is already pressure for expansion or enlargement of the industry.

A common thread amongst countries is the desire (or policy) of encouraging salmon farming to move from sheltered coastal inlets to more exposed coastal sites – often termed "offshore" but not to be confused with truly offshore development, perhaps out of sight of land. However, the risks of such policies must be better analysed as the typically harder habitats encountered may in fact be highly sensitive to fish farm wastes (Hall-Spencer *et al*., 2006). The following text is condensed from the abstract of that paper:

> 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 three fish farms located over maerl revealed a build-up of waste organic matter and 10 to 100-fold higher abundances of scavenging fauna than on six reference maerl beds. Visible waste was noted up to 100 m from cage edges and all three farms caused significant reductions in live maerl cover, upon which this habitat depends. Relocation of fish farms to areas with strong currents is unlikely to prevent detrimental effects to the structure and organization 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.

Also, placing cages in ever more exposed areas has created a situation where escaping fish are considered as the most detrimental impact, with benthic and water column impacts of lesser importance, but most environmental monitoring practices are still largely based on assessing benthic impacts. In all the countries studied (except New Zealand) there was pressure for the industry to relocate to offshore sites. To address this situation a review of regulatory priorities, informed by new research, needs to be undertaken to determine the potential environmental impacts and to identify appropriate indicators and procedures.

Clearly, regulations need to be developed that better understand the impacts of salmon farming in highly dispersive areas and hard substratum sea bed habitats.

There is some concern regarding the Quality Assurance of the various monitoring regimes – in order for the public to have confidence in the environmental performance of the industry, it is vital that all stages of the regulatory process are transparent and robustly documented.

Ultimately, links between regulators and the industry must be strong, as both have common interests: regulators have statutory obligations to protect the environment but also to consent legitimate development that brings socio-economic benefit; the industry needs both a clean environment and to ensure good public perception of environmental standards in order to sell its product. As regulators must act against serious infringements, and when this happens the infringement generally becomes public knowledge – damaging the whole sector – it is in the industry's best interest to protect itself against farmers with poor environmental standards. This has given impetus to the development of industry associations with Codes of Practice that can require members to achieve standards higher than the statutory minimum. Such schemes can only gain public confidence if they are seen to be independently audited with public reporting. The Scottish Salmon Producers Association is currently implementing such a scheme and it is likely that similar associations in other countries will be closely monitoring the success of this.

Little information was found regarding a regulatory approach to the proportion of wild fish derived feed in salmon diets – indeed this aspect is generally missing from the EIA process despite it having a high environmental cost and being the subject of public concern. As salmon account for a considerable share of fish meal/oil it might be appropriate for regulations to be developed on levels of incorporation. On the other hand, this is a rapidly moving target and the fish feed industry already substitute with vegetable products to a large extent and many include assurances of the sustainability of the fisheries used. Although this is clearly an important area, increasing the credibility of sustainability accreditations might be the most appropriate solution.

Conclusions

- All countries studied have a regulatory system in place for a systematic study of the costs and benefits of a proposed new salmon farm (EIA). The EIA system has an emphasis on highlighting potentially negative environmental impacts, socio-economic costs and benefits are generally not part of the EIA process and the accepted content of the resultant ES[65] does not specify their inclusion. However in some countries e.g. Scotland, a brief socio-economic analysis is often included.
- Socio-economic benefits are often seen as implicit in EIA, but a more rigorous and explicit approach to assessing socio-economic costs and benefits would be very helpful in allowing decision-makers to balance these against any environmental costs.
- All countries have regulations regarding the monitoring of existing salmon farms to ensure compliance with a variety of environmental standards.
- Salmon farming is expanding rapidly in Chile. While regulations and standards exist, there is a perception that regulatory authorities have insufficient resources to adequately monitor performance and police compliance.
- In most countries there is a perception that regulation does offer protection to the environment. In most cases farmers regard the regulatory process as relatively slow and bureaucratic. This is particularly the case in the United States of America where responders to a questionnaire indicated that development was stifled by the complex regulatory regime.
- In all countries, but particularly in North America, greater dialogue between all stakeholders in a non-litigious arena would be highly beneficial, as there appears to be considerable mistrust between the industry, the regulators and NGO's.
- Interchange of scientists and regulators between salmon growing countries and the willingness to learn from regulatory developments, should be strongly supported.
- All countries need to put greater effort into determining impacts at the waterbody rather than site scale. This requires modelling approaches backed up by long time-series measurements for validation and calibration.
- Improvements in technologies for preventing escapes and in regulation should follow the Norwegian example. Escapes of farmed fish must be reported on a statutory basis, particularly in Atlantic areas.
- Sea lice are a threat to wild populations. Compulsory delousing should be implemented in all jurisdictions (following Norway) and a robust framework of basin-scale co-operation between farmers and wild fish interests regarding synchronous stocking and treatment should be encouraged to minimise medicine use.
- Environmental data collected at farms should be placed in the public domain to increase confidence in the regulatory process.

[65] www.europa.eu/environment/eia/full-legal-text/9711.htm

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TABLE 27
Synthesis table

Environmental monitoring		Norway	United Kingdom	Ireland	Canada	United States of America	Chile	New Zealand
Environmental impact assessment								
When		Prior to consenting a new site or increasing an existing one.	Prior to consenting a new site or increasing an existing one.	If a salmon farm is considered to have a 'significant' effect on the environment.	Prior to consenting of a new site and modification of existing site	Prior to consenting of a new site and modification of existing site	Prior to consenting of a new site	When applying for a new coastal permit or renewing an existing one.
Criteria/Threshold level determining whether an EIA is required		Floating / movable cages ≥48,000m³ permanently sited cages ≥36,000m³	All farms located in a 'sensitive' area and all new farms or existing farms whose biomass ≥100tonnes or cage surface area ≥1000m²	Each farm is considered on a case-by-case basis, the final decision resting with the Minister of the Marine.	Most finfish farms require an EA prior to consent	Most finfish farms require assessment prior to consent	In some cases a DIA may be required but a full EIA is required where additional factors are identified (see Box 2.6.1)	All salmon farms require an EIA as part of their coastal permit to operate.
Sediment related impacts – Determinand	Organic sediment loading	Every month, every second month or every third mo nth depending on degree of exploitation.						
	Video transect survey		Annually, between 01/05 – 31/10 within 1 month of peak biomass. Extent of survey level dependant on biomass and flushing time.	Annually during peak biomass or within 30 days after harvesting of a year class.		Twice a year Maine. Annually WA	Annually during peak biomass	The ANZECC guidelines list comprehensive monitoring guidelines which each region adapts for their particular requirements. New Zealand does not apply a generic approach to all farms but tailors the determinands to be recorded for each farm. The ANZECC guidelines includes all the determinands listed here as well as others
	Presence of macro infauna	Twice a year, every year or every second year depending on level of exploitation			Annually between 1/8 -31/101 NB – part of visual survey			
	pH and redox				Annually within 30 days of peak biomass BC/ Annually between 1/8 -31/101 NB	Twice per year - Apr-May and Aug-Oct Maine. Annually WA		
	Colour, odour and presence of gas in sediment, sediment consistency and thickness				Annually between 1/8 -31/101 NB – part of visual survey			
	Quantitative and qualitative assessment of benthic fauna	Frequency at the discretion of the local authority			Annually within 30 days of peak biomass BC	Once in five years as minimum in Aug- Oct (Maine). Annually WA	Annually during peak biomass	
	Organic content							
	Particle size							

TABLE 27
Synthesis table (Continued)

Environmental monitoring			Norway	United Kingdom	Ireland	Canada	United States of America	Chile	New Zealand
Environmental Impact Assessment									
Sediment related impacts	Determinand	In feed medicine residue		Annually, between 01/05 – 31/10 within 1 month of peak biomass. Extent of survey level dependant on biomass and flushing time.			Within 1 month of use Maine		The ANZECC guidelines list comprehensive monitoring guidelines which each region adapts for their particular requirements. New Zealand does not apply a generic approach to all farms but tailors the determinands to be recorded for each farm. The ANZECC guidelines includes all the determinands listed here as well as others
		Copper Zinc Total volatile solids				Annually within 30 days of peak biomass BC	Once every two years Maine		
		Total Kjeldahl Nitrogen					Annually WA		
		Free Sulphide				Annually within 30 days of peak biomass BC/ Annually between 1/8 -31/101 NB	Twice per year - Apr-May and Aug-Oct Maine		
		Presence of feed pellets/faeces			Annually during peak biomass or within 30 days after harvesting of a year class.	Annually between 1/8 -31/101 NB – part of visual survey	Annually WA		
		% Beggiatoa					Twice per year - Apr-May and Aug-Oct Maine. Annually WA		
	Treatment trigger level/EQS		Yes	Yes	Yes	Yes	Yes	Yes	Yes
	Statutory/ voluntary		Statutory	Statutory	Statutory	Statutory	Statutory	Statutory	Statutory
	Personnel involved		Qualified consultants	SEPA	Qualified consultant approved by DCMNR.	Consultants	Consultants	Consultants	Qualified consultant and/or Regional Council appointed staff.
	Feedback mechanism		Yes	Yes	Yes		Yes	Yes	Yes

TABLE 27
Synthesis Table (Continued)

Environmental monitoring			Norway	United Kingdom	Ireland	Canada	United States of America	Chile	New Zealand
Environmental impact assessment									
Water column related impacts	Determinand	Oxygen content	Frequency of measurement at the discretion of the local authority	Bi-annually, 1 winter survey, 1 summer survey.		No water column determinands monitored as part of annual monitoring (BC or NB)	2/month or 1/wk on site or 1/yr or 2/yr in Aug/Sep2 Maine. Annually WA	Annually	The ANZECC guidelines list comprehensive monitoring guidelines which each region adapts for their particular requirements. New Zealand does not apply a generic approach to all farms but tailors the determinands to be recorded for each farm. The ANZECC guidelines includes all the determinands listed here as well as others
		Salinity			Measured monthly between December and March each year.			Not measured as part of statutory monitoring	
		Temperature							
		Ammonia					Annually WA		
		Nitrate							
		Nitrite							
		Phosphate							
		Chlorophyll							
		Copper							
		Medicines and chemicals						Not measured as part of statutory monitoring	
	Treatment Trigger level/EQS		Yes	Yes	Yes	N/A	No	No	Yes
	Statutory/voluntary		Statutory	Statutory	Statutory	N/A	Statutory	No	Statutory
	Personnel involved		Qualified consultants	SEPA	Qualified consultant approved by DCMNR.	N/A	Consultants and Regulators	Consultants	Qualified consultant and/or Regional Council appointed staff.
	Feedback mechanism		Yes	Yes	Yes	N/A	Yes	No	Yes
Sea lice related impacts	Determinand		Number of gravid females or mobile lice per fish. Monthly at sea temperatures below 4oC, fortnightly at temperatures ≥4oC.	Number of gravid females or mobile lice per fish. Weekly counts throughout the year.	Number of gravid females or mobile lice per fish. 14 counts per year, with bi-monthly counts between March and May.	Sea lice impacts not monitored as part of annual monitoring (BC or NB)	Sea lice impacts not monitored as part of annual monitoring	At present Chile does not monitor sea lice as part of statutory monitoring	New Zealand does not routinely monitor sea lice levels.
	Treatment trigger level		0.5 gravid females, 2 mobile lice per fish during late winter to early spring	0.5 adult female per fish during February to June 1 adult female per fish during July to January	0.3-0.5 ovigerous females per fish during spring. 2 ovigerous females per fish outwith the spring period.			N/A	N/A
	Statutory/voluntary		Statutory	Voluntary*	Statutory	N/A	N/A	N/A	N/A
	Personnel involved		Farm staff	Farm Staff	The Marine Institute	N/A	N/A	N/A	N/A
	Feedback mechanism		Yes	Yes	Yes	N/A	N/A	N/A	N/A

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Appendix 1

QUESTIONNAIRE

SCOTTISH ASSOCIATION *for* MARINE SCIENCE

ENVIRONMENTAL IMPACT ASSESSMENT: SALMON FARMING MARINE CAGE AQUACULTURE CASE STUDY (SALEIA)

Dear colleague

SAMS are conducting a review of the EIA process and environmental monitoring for salmon marine cage farms in Canada, Chile, Ireland, New Zealand, Norway, Scotland and the United States of America on behalf of the Food and Agriculture Organization of the United Nations, Fisheries Department, Rome. I would be very grateful for your input with respect to current practices in Country. I would also be grateful if you could recommend other experts who you consider may have useful contributions to make. All inputs will be acknowledged in our final report and a consulted experts list will be included as an additional output in this study.

I would be very grateful if you could complete the following questionnaire. Please feel free to expand on any point or to skip areas where you feel you do not have sufficient background.

Please feel free to pass this questionnaire to anyone who has an interest in monitoring salmon cage aquaculture in Country.

Sincere thanks for your co-operation in this project. An early response would be very helpful, preferably by 30 October 2006.

Please return your questionnaire to:

Dr Kenneth D. Black
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Section 0 Your background

1. Please provide details of your title, name, affiliation, country, email.

(the boxes will expand to fit your responses)

2. How would you describe your role in the EIA monitoring process? (indicate (x) all that apply)

Policy maker	
Regulator	
Scientist	
Researcher	
Industry representative	
Farmer	
NGO	
Other	
Comment	

Section 1. What are the requirements for EIA and monitoring of salmon farms?

Statutory Requirements:
We wish to compile and review the legal/regulatory requirements for conducting Environmental Impact Assessments and presenting Environmental Statements for

1. A proposed new salmon farm development
2. A change of practice on an established salmon farm (i.e. expansion)
3. Regular environmental monitoring (as recommended in the particular E.S.)

3. Can you provide or direct us to sources for this information in Country?

Voluntary Requirements:
4. Do you have any information or know of sources for soft law based recommended practices for carrying out Environmental Impact Assessments and the related environmental monitoring (i.e. codes of practice, voluntary agreements, certification schemes etc.) in Country?

Section 2. How are EIAs done in Practice

We wish to establish the methodologies used in carrying out Environmental Impact Assessments and related environmental monitoring in Country.

5. In general, is there a requirement to collect new data for the preparation of Environmental Statements? If so, which are the most common types of data that are required (e.g., benthic, side scan, nutrient concentrations, water currents)

6. Are modelling approaches used? If so, give examples.

7. If field sampling is required, are sampling methods and equipment prescribed? If not are there any common standards?

8. Are there norms for the degree of replication, the numbers of stations and/or the duration of observation?

9. How is Quality Assurance addressed for field sampling and analysis?

10. Are their prescribed or standardised methods for data interpretation, analysis and presentation?

11. Have these methods been assessed for practicality, cost effectiveness and scientific robustness?

12. Have Ecological Quality Standards been set for benthos or water column?

13. Who carries out any field measurements: the farmers, their consultants, the regulators or others?

14. What are the most important constraints on recurrent monitoring practices – e.g. money, expertise, bureaucracy, access to sites others?

Section 3.
Assessing Effectiveness

15. Is there general agreement between industry, regulators and researchers that the optimum measurements are being made to protect the environment? What is your opinion?

16. Are there good feedback mechanisms between environmental monitoring and improved site selection, aquaculture performance and farm development (including scale)? If there are, how do they work in practice both at the level of the individual farm and at regional or national policy level?

17. Are mitigation measures recommended by the EIA process actually implemented and do they reduce impacts on environmental quality? Give examples if appropriate.

18. Have Environmental Quality Objectives been set? Is there effective environmental monitoring to ensure they are met?

19. Are the legal requirements for EIAs, monitoring practices and procedures regularly reviewed?

20. Do stakeholders have very different perception of the effectiveness of the EIA process? If you are a stakeholder, please describe your views and those of others if appropriate.

Section 4.
Suggested Improvements.

21. Can you identify any constraints relating to technical/scientific, financial, social and legal issues involved in the EIA process?
Can you suggest improvements which may be applied to these areas?

22. In your view, what are the needs for capacity building, competency development and collaboration between producers, producer organizations, EIA and monitoring experts, regulators, NGOs, certifiers, etc. in Country?

23. In your view, which are the most important environmental interactions/effects of salmon culture in Country? Please rank these with 1 as the most serious issue.

Generic issue	Rank (comments)
Benthic/sediment effects	
Nutrients/Water column/Pelagic	
Medicines, chemicals	
Escapes	
Sealice/diesases	
Other	

24. In your view are the most serious impacts well avoided or minimized with current EIA implementation in Country? Can you suggest any improvement to the EIA system and to other regulatory processes or to monitoring?

25. Do you have any other comments related to the way in which the salmon aquaculture industry is regulated in Country?

26. Who else should we send this questionnaire to?

Thank you very much for contributing to this study.

Appendix 2

LIST OF RESPONDENTS

The authors are very grateful to the following stakeholders who responded to the questionnaire:

Canada
Tara Dagget (Sweeney International Management Corp)
Eric Greer (Ministry of Environment)
Kristi Super (Panfish)
Ed Parker (New Brunswick Dept of Environment)

Chile
Jorge Bermúdez (Faculty of Law, Universidad Catolica de Valparaiso)
Alex Brown (FAO Consultant)
Alejandro Clement (Marine Biologist, Plancton Andino)
Jorge M León (WWF Consultant, Universidad Austral de Chile)

Ireland
No respondents

New Zealand
Don Morrisey (National Institute of Water and Atmospheric Research Ltd)

Norway
Arne Ervik (Institute of Marine research, Bergen)

United Kingdom
Sally Davies (Scottish Sea Farms)
Andrew Wallace (Association of District Salmon Fisheries Boards)
Neil Auchterlonie (Scottish Salmon Producers Organisation)

United States of America
Kenneth Brooks (Aquatic Environmental Sciences)
Elizabeth Ellis (Washington Department of Natural Resources)
Jack Rensel (Rensel Associates Aquatic Science)
John Sowles (Maine Dept of Marine Resources)