ENVIRONMENTAL MONITORING PROGRAM FRAMEWORK FOR MARINE AQUACULTURE IN NOVA SCOTIA

Fisheries and Aquaculture

March 2011

TABLE OF CONTENTS

Environmental Monitoring Program Framework for Marine Aquaculture in Nova Scotia

1. INTRODUCTION

The Nova Scotia Aquaculture Environmental Monitoring Program (EMP) began in the fall of 2002 when the Aquaculture Association of Nova Scotia (AANS) produced a draft plan recommending the Province implement and regulate an EMP for the marine aquaculture industry. This draft plan originated as part of the document *Design of the Environmental Monitoring Program for the Marine Aquaculture Industry in Nova Scotia* (Smith el al., 2002). The Aquaculture Division of Nova Scotia Department of Fisheries & Aquaculture (NSDFA), formerly Nova Scotia Department of Agriculture & Fisheries, accepted the lead role and began coordinating the EMP.

The EMP applies to all marine aquaculture in Nova Scotia. There are 274 marine aquaculture sites in Nova Scotia as of January, 2010 (243 shellfish, 29 finfish, 1 shellfish/finfish and 1 shellfish/marine plants). Not all of these sties are currently active (or growing finfish/shellfish). Many of these sites are opportunities for future site development. Species grown at marine sites in Nova Scotia include salmon, trout, mussels, clams, scallops, quahogs and oysters. There is also significant production of marine plants in Nova Scotia, however, most of that sector is land-based and not subject to marine monitoring. Monitoring of land-based operations (both fresh and salt water) is not included in the EMP at this time.

The EMP examines the relationship between aquaculture and the marine environment. This includes monitoring at both shellfish and finfish sites, active and non-active sites and reference stations. This is the first time that such a program has been carried out for Nova Scotia's diverse aquaculture sector and is the first time that empirical baseline data exists on an industry-wide scale. The EMP is one of the few marine monitoring programs that samples finfish and shellfish operations located in a variety of marine ecosystems (Bay of Fundy, Atlantic coast, Bras d'Or Lakes and Gulf of St. Lawrence) with varied bio-physical conditions (e.g. shallow, deep, hard vs soft-bottom substrate, and varied tidal/current regimes).

The provisions for the EMP are legislated by the Fisheries and Coastal Resources Act (S.48 and S.50). In addition, a Memorandum of Understanding (MOU) has been signed by both the NSDFA and Fisheries and Oceans Canada (DFO) stating responsibilities of each party:

> *"The Parties will co-operate in the development of an industry wide environmental effects monitoring program. Nova Scotia will be responsible for the implementation of the environmental effects monitoring program and the implementation of a follow-up program, where applicable, and will report to Canada in a manner that is mutually agreeable to the Parties."*

The EMP follows a risk-based approach that recognizes increased risk requires increased monitoring. A risk-based approach, based on more than 8 years of empirical data collected across

the spectrum of Nova Scotia aquaculture activities and bay conditions, can be consistently applied to the diverse nature of the industry in the province. This dataset uses a number of monitoring variables to define environmental performance.

Over time, this dataset can be used to identify how each aquaculture site interacts within each particular bay or harbour. All marine sites currently in production are targeted. Those that are larger or more intensive are given higher priority. Sites of potential concern are subject to repeat sampling and, if required, remediation action is implemented. Although this approach is consistent for both finfish and shellfish, it should be recognized that these operations are different with respect to environment-culture interactions, and that management practices are designed to reflect this difference.

Environmental monitoring is an important part of the management of a marine resource industry. NSDFA believes that the growing body of data that has been collected, and will be collected, helps to ensure that aquaculture in Nova Scotia remains environmentally sustainable.

This document is designed as a companion paper to the *Standard Operating Procedures for the Environmental Monitoring of Marine Aquaculture in Nova Scotia* (SOP; PNS, 2010). These documents are intended to be used as a framework and protocol for environmental monitoring of the NS aquaculture industry. From time to time, these documents will be reviewed and adjusted as needed if changes in regulatory approaches occur or if innovations in field methods and technologies develop.

The objective of this document is to detail key components of the NS EMP. These are:

- **Environmental Management Framework –** this section describes the rationale for the regulatory framework and determining appropriate levels of monitoring.
- **Site Management Responses** – this section describes site management responses based on the environmental quality classification reported from a sample location with reference to industry Best Management Practices (BMP).
- **Committees for Regulation and Development of Environmental Management Outcomes** – this section describes the role and responsibilities of the committee to make recommendations on the conduct of the EMP.
- **Annual Schedules** – this section describes the timing deadlines for monitoring and mitigation.
- **Auditing and Reporting** – this section describes the types of auditing that will be performed by NSDFA as well as the reporting requirements for Industry self-monitoring.

2. ENVIRONMENTAL MANAGEMENT FRAMEWORK

The NS EMP lays out a series of principles and criteria to guide the management process and to determine levels of monitoring and mitigation for each aquaculture site. These thresholds, and follow-up action if required, are important to ensure the sustainability of the aquaculture industry in Nova Scotia.

2.1 Monitoring Principles

The information obtained from the monitoring program is valuable both to government and the aquaculture industry. Monitoring should be carried out to:

- ensure compliance with conditions of a site approval;
- ensure environmental quality objectives (EQOs) and other standards are met;
- measure effects on the environment;
- verify and validate mathematical models (if any);
- determine action to be taken; and,
- audit the results of self-monitoring.

2.2 Environmental Quality Objectives, Indicators and Definitions

One of the primary concerns regarding aquaculture impacts on the marine environment is waste production and organic loading of the environment. Organic loading usually results in increased oxygen consumption in the sediments, until benthic oxygen demand is greater than the supply, possibly creating hypoxic or anoxic conditions. The marine Environmental Quality Objective (EQO) is to maintain oxic conditions. However, should oxic conditions not be met, sites must be in compliance with regulatory processes that identify efforts taken to improve site conditions.

Fish habitat concerns increase when sediment conditions become hypoxic and require appropriate site management responses to avoid wide-spread anoxia. Sediment characterized as hypoxic or anoxic exhibit a decreasing abundance and diversity of macrofauna. Sediment levels of sulfide in excess of 1500 micro molar (µM) are generally considered to be anaerobic.

The NS EMP focuses on benthic marine habitat in the immediate vicinity of the aquaculture site. Although sediment sulfide concentration is the key indicator for this EMP, a suite of sediment variables will be measured to validate sulfide. In addition, benthic video collected at each sampling station will be reviewed (see SOP). The criteria for choosing these environmental parameters are:

- Maximize habitat information by providing scientific confidence in the parameters and methods of sampling and analysis used to describe changes to the benthic community structure;
- Provide long-term record of habitat quality with variables that are sensitive to the potential organic enrichment effects of aquaculture;
- Repeatability and consistency in sampling and analysis;
- Clear specification of spatial and temporal bounds;
- Optimize logistics and field efforts while ensuring cost effectiveness;

- Based on discussions at March 2010 workshop (NS EMP Technical Review and Laboratory Demonstration) and subsequent summary report.

Sediment sulfide concentration is one of the key indicators of environmental quality recommended by Wildish et al. (1999). However, other indicators, such as oxidation-reduction potential, porosity and (percent) organic matter will also be used. These variables provide a check on data quality as well as ensure that the depositional-erosional characteristics at farm and reference sites are comparable. In addition, these other indicators will be compiled and processed through the Benthic Enrichment Index (BEI) described below.

2.3 Validation of Benthic Monitoring Data

Multiple techniques will be used to validate data collected as part of the NS EMP. In addition to the BEI (as described in detail below), the relationship between redox and sulfide values as well as porosity and organic matter will be reviewed.

Sulphate reduction and the production of sulfide are closely related to redox. While the relationship weakens somewhat for sediments with an oxic classification, generally speaking, redox acts as a quality control measure on sulfides and vice versa (Grant, 2010).

Measurement of porosity and organic matter serve a dual purpose. First it allows inference of sediment texture to ensure that the deposition-erosional characteristic and farm and reference sites are comparable. Second, they provide an internal check on data quality (Hargrave, 2009).

The BEI provides a multi-variate measure of sediment organic enrichment. The index is correlated with total 'free' sulfides and biological indicators such as macrofauna biodiversity indices that can be altered by increased organic matter sedimentation and the formation of hypoxic or anoxic conditions in sediment. It serves as an internal check by applying more than one method for quality control in monitoring programs using geochemical methods to measure benthic organic enrichment (Hargrave 1994, Shaw 1998, Holmer et al. 2005, Hargrave et al. 2008 a, b).

The index, which incorporates the variables porosity, (percent) organic matter and redox, can be used to verify the degree of benthic organic enrichment in marine sediment based on measures of sulfide (Hargrave, 2009).

Comparison of the relative sensitivity of variables for detecting sediment organic enrichment due to aquaculture has shown that porosity and organic matter are not as good indicators of differences between farm and reference sites as redox, but when combined with measures of redox to calculate the BEI, detection of differences between farm and reference site sediments using BEI approaches obtained using sulfide (Hargrave et al., 1997).

Measurements of porosity and organic matter in an EMP therefore serve more than one purpose. Firstly, they allow inference of sediment texture to ensure that the depositional-erosional characteristics at farm and reference sites are comparable. In addition, they provide an internal check on data quality. Sediments with high porosity should have higher levels of organic content. Over time, as data are collected from the same location, a database will be developed to allow

temporal trends in organic matter to be detected independent of the effect of grain size inferred from measures of porosity. Finally, porosity must be known if the absolute mass of organic matter in surface sediments is to be calculated on a dry weight basis (Hargrave, 2009).

This is required not only for comparisons of organic matter in sediments from farm and reference locations, but to ensure that organic content inventories are being compared on the same basis between locations where porosity differs (Hargrave, 2009).

2.4 Environmental Quality Definitions for Nova Scotia Marine Aquaculture Monitoring

These well established environmental indicators and sampling methods provide a consistent means for ensuring that the EQO of oxic sediment conditions is being met and allow for the classification of sediment conditions into oxic, hypoxic and anoxic categories based on the following Environmental Quality Definitions (EQD):

	Sediment Classification		
Measurement	**Oxic**	**Hypoxic**	**Anoxic**
Sediment colour	Tan to depth > 0.5 cm	Tan to < 0.5 cm with some black sediments at surface	Surface sediments black
Microbial presence	No sulphur bacteria present	Patchy sulphur bacteria	Widespread bacterial mats
Macrofaunal Assemblage	Wide array of infauna and epifauna	Mixed group of mostly small infauna	Small infauna only
Sulfide, µM	**< 750 (A) 750 to 1500 (B)**	**1500 to 3000 (A) 3000 to 6000 (B)**	**> 6000**
Redox (Eh), mV	>100 (A) 100 to -50 (B)	-50 to -100 (A) -100 to -150 (B)	< -150
Organic matter, %	<= reference*	1.5 to 2X ref.	> 2X reference
Porosity, %	<= reference*	1 to 10X ref.	> 10X reference

Figure 1: Environmental Quality Definitions

Modified from the *Design of the Environmental Monitoring Program for the Marine Aquaculture Industry in Nova Scotia, 2002*, by J. Smith, J. Grant, and R. Stuart; and also *Towards a Classification of Organic Enrichment in Marine Aquaculture, 2008,* by Hargrave, B.T. et al.

*Values compared to reference assume that reference and lease sites have similar levels in pre-culture conditions.

2.5 Determining Appropriate Levels of Monitoring

A risk-based approach is required to address that varied potential for impacts based on the interaction of site conditions and culture methods and intensities that vary greatly among finfish and shellfish marine aquaculture operations in Nova Scotia. New sites, and/or expansions, are subject to environmental monitoring as described in the baseline requirements established for each application by NSDFA and DFO.

Determination of appropriate monitoring actions for existing sites is summarized in Figure 2 and is based on the knowledge of varied risk of impact from different culture types in different biophysical conditions throughout Nova Scotia.

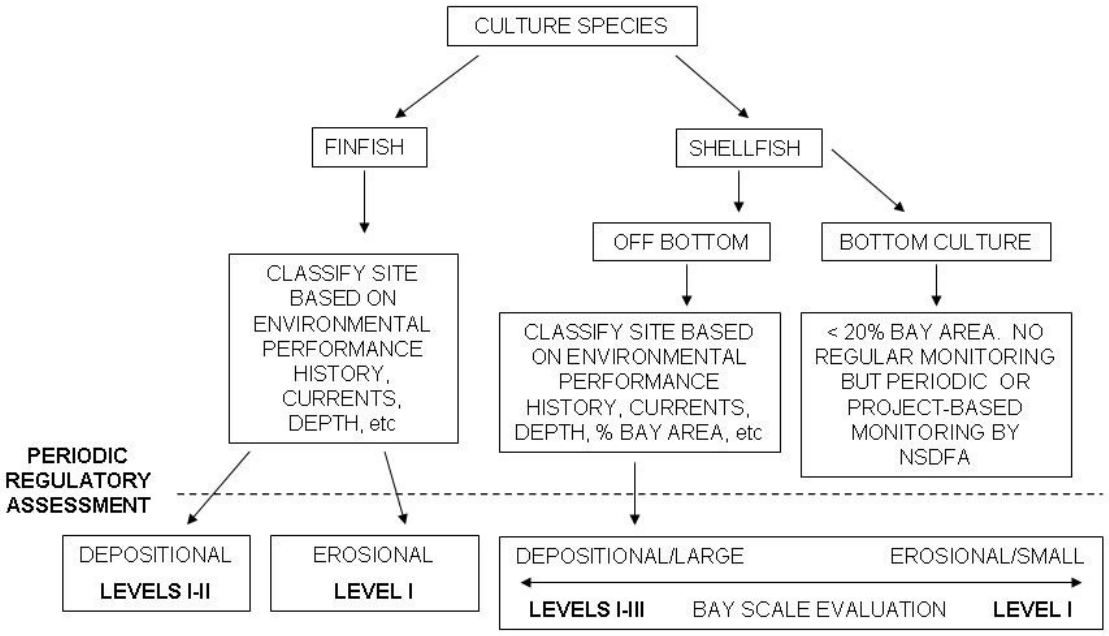

Figure 2: Risk-Based Monitoring Decision Matrix

Up to three levels of monitoring may be required. Detailed methodology is included in the SOP, with a summary below.

Level I – For sites that are considered depositional, based on site characterization and/or past sampling showing elevated sulfide levels, sampling to ensure Oxic conditions are maintained is repeated on an annual basis. New sites will require annual monitoring until determined to be erosional. For sites that are classified erosional, based on site characterization and/or past sampling, basic site sampling to ensure Oxic conditions are maintained is repeated every 1-2 years (less frequently for shellfish), unless a significant increase in production has occurred.

Level II – For sites that are considered Hypoxic B or Anoxic, additional sampling is required to better delineate the affected area and more effectively defining the zone of influence.

Level III – For sites that consistently fail to meet oxic conditions, and which are classified as anoxic, the following enhanced monitoring/assessment actions may be required:

- More sampling stations;
- Seasonal sampling;
- Sediment profiling;
- Current data;
- Carrying capacity/flushing calculations;
- Water quality.

Details and specific conditions of all follow-up monitoring are to be determined by NSDFA and DFO in discussion with site operator.

3. SITE MANAGEMENT RESPONSES

In order to meet the EQO of Oxic sediment conditions, it is important to define a suite of measures that could achieve this goal. These measures include operational BMP's that are determined by industry and considered effective in mitigating potential environmental effects. The industry is expected to follow both standard operational BMP's and enhanced BMP's when sites show evidence of organic loading (see Appendix A).

Site management responses include follow-up monitoring requirements as well as mitigation requirements. The goal of the EMP is to manage impacts of organic enrichment based on station means, used collectively as an indication of site condition.

The monitoring program follows a tiered approach that recognizes increased risk requires an increase in monitoring effort. Various levels of monitoring are triggered based on measurement and verification of EQD's, other environmental sensitivity, and/or the nature of the operation and perceived environmental risk.

Site management responses are based on the classification assigned under the EQD's for sediment conditions with sulfide as the determining variable. Sulfide levels will be based on the mean of three replicate syringe cores from each sampling station. Given that considerable spatial variation is known to occur within aquaculture sites, determination of a site classification is based on the proportion of stations (including assigned historical stations, but not including reference stations) within each sediment classification (Oxic, Hypoxic and Anoxic):

Anoxic: $\geq$ 70% of sampling station with means > than 6000 µm. Otherwise, Hypoxic B

Hypoxic B: $\geq$ 50% of sampling stations with means > than 3000 µm. Otherwise, Hypoxic A

Hypoxic A: $\geq$ 50% of sampling stations with means > than 1500 µm. Otherwise, Oxic

Oxic: Remainder

Figure 3: Decision Thresholds

The following are management responses based on site classification of marine finfish aquaculture sites in Nova Scotia. Responses within the shellfish sector will be similar but more prescribed to the differences between shellfish and finfish growing operations (infrastructure, growing environments, etc).

Oxic

These sites have low environmental effects on the marine sediments. Site operator will continue to follow operational BMP's and Level I monitoring. If a site remains 100% oxic for two production cycles, and there is no significant stocking increase, the EMP would require sampling every 2nd year at the peak of the production cycle.

Hypoxic A
These sites are likely causing adverse environmental effects to the marine sediments under and adjacent to some cage structure. The site operator must adjust appropriate BMP's to improve environmental performance and follow Level I monitoring next sampling season.

Hypoxic B
These sites are likely causing adverse environmental effects to the marine sediments under and adjacent to some cages. The site operator will conduct Level II monitoring and, in addition to following operational BMP's, the site operator will implement additional/enhanced BMP's. A mitigation plan must be submitted to NSDFA for approval and the site operator must provide a strong rationale for maintaining or increasing productions levels.

Anoxic
A site classified as Anoxic is causing adverse environmental effects to the marine sediments of large portions of the site due to the excessive accumulation of organic material. In addition to Level II, and possible Level III monitoring, the site operator will work closely with regulators to resolve the situation.

For sites classified as Hypoxic and Anoxic, the known production history of the site along with historical EMP performance and site characteristics will be an important determination of mitigation options and must be incorporated into site operator's mitigation plan.

Note: DFO will also be reviewing the sampling results for impacts to fish and fish habitat. Based on this review, to stay in compliance with the Fisheries Act, some site operators may require an authorization under Section 35(2) which allows a harmful alteration, disruption or destruction (HADD) of fish habitat.

4. COMMITTEES FOR REGULATION AND DEVELOPMENT OF ENVIRONMENTAL MANAGEMENT OUTCOMES

On an ongoing basis NSDFA consults with the Nova Scotia Aquaculture Environmental Coordinating Committee (NSAECC) which is co-chaired by NSDFA and DFO through the Canada-Nova Scotia MOU. Also under the MOU, NSDFA performs the lead role in management of the NS EMP through an Nova Scotia Aquaculture Environmental Site Management Committee (NSAESMC) which is co-chaired by NSDFA and DFO. In addition, NSDFA is working on a variety of related projects with both regulatory and scientific partners to expand the knowledge base of the potential environmental impacts of aquaculture on our coastal ecosystems. The NS EMP has also been able to get cooperation and assistance from other areas within the NSDFA, including the regional Coastal Resource Coordinators, the Aquaculture Fish Health Unit, the Inland Fisheries Division, and Fisheries Inspectors.

The NSAECC will provide a mechanism for both industry and regulators to provide input to the NS EMP process. Any program revisions will be vetted through this committee. It has representatives from all aquaculture related regulatory agencies such as NSDFA, NSDOE, DFO (Science, Habitat Protection and Sustainable Development, and Aquaculture Management Office), Environment Canada (EC) and representatives of finfish and shellfish industry through the AANS. This body has no regulatory authority to make site specific decisions but is a means of exchanging ideas and making recommendations on the conduct of the EMP.

NSAESMC provides multi-agency review and comment on site-specific results of the NS EMP. This committee interprets the results of the NS EMP and provides site-specific recommendations for any remedial action required. This approach provides a method of integrating the regulatory requirements of all agencies with respect to environmental management.

In summary:

- NSDFA and DFO co-chair the NSAECC;
- NSAECC has representation from NSDFA, NSDOE, DFO, AANS, EC and other provincial and federal government agencies, as needed;
- NSAECC will be the advisory body and forum for information exchange with Industry on EMP matters;
- NSAESMC will be co-chaired by NSDFA and DFO. The committee will review EMP data and make remediation/mitigation recommendations based on EQOs and a risk-based approach;
- NSDFA will perform the lead role on EMP management and will perform the audit function of the EMP, however regulators on the NSAESMC can make any determinations and actions on their own based on their respective legislation and regulations.

5. ANNUAL SCHEDULES

The optimal time for farm monitoring is during conditions of highest organic deposition which is generally from spring to early fall when feeding and waste production are at a peak for both finfish and shellfish and storm conditions are limited.

Monitoring of Nova Scotia marine aquaculture will be conducted between the beginning of June and the end of September. Some Level II monitoring might continue into October and Level III monitoring in winter/spring. Field season planning is organized on a site by site basis depending on the specific characteristics of the site, species grown and timing consistency with previous sampling.

The timing deadlines for monitoring and mitigation response are as follows:

- **Level I monitoring:** The site operator conducts initial monitoring within timeframe specified by NSDFA.
- **Within 14 days of Level I monitoring:** The site operator submits Sulfide/Redox results, coordinate table, logsheets, and video to NSDFA.
- **Within 21 days of Level I monitoring:** The site operator submits Porosity and Percent Organic Matter results to NSDFA.
- **Within 28 days of Level I monitoring:** If the site classification exceeds the Hypoxic B classification, NSDFA and DFO will review the monitoring results and advise the site operator of the requirement for further monitoring and site management responses.
- **Within 35 days of Level I monitoring:** The site operator will conduct follow-up **Level II** monitoring. Monitoring results will be submitted to NSDFA **within 14 days of Level II field work** along with a draft mitigation plan.
- **Within 14 days of receipt of follow-up Level II monitoring results:** NSDFA and DFO will review the monitoring results and draft mitigation plan. NSDFA will follow-up with the site operator and if necessary, meet to discuss additional mitigation.

Site operators are expected to comply with this schedule for the submission of data, materials and, if necessary, mitigation plans. Please submit only finished, final copies of reports, results, coordinates, log sheets and video. Incomplete reports and partial submissions are considered late. Any delays to these timelines would have to be approved by the Director of Aquaculture via written request from the site operator.

6. AUDITING, COMPLIANCE AND REPORTING

Auditing will be conducted by NSDFA on an annual basis on a minimum 20% of total non-NSDFA monitored sites. The purpose of the audit is to ensure that the information submitted is accurate, consistent and reliable enabling government agencies and growers to make sound management decisions. In addition, audits are important to ensure that the proper sampling methodology is being followed.

Audits will consist of one or all of the following components:

- A review of the monitoring practices on each site through examination of the sampling documentation, laboratory analysis, quality assurance and quality control procedures, test results and supporting data.
- Visual observation of the actual monitoring work in progress. This could include on-water observation of the sampling procedures.
- Lab analyses of replicate samples. This may involve additional replicates being collected from a single sampling location. These samples can either be collected by NSDFA or the consultant hired by site operator. If collected by consultant, these replicates will be delivered to NSDFA to be processed in the NSDFA EMP Lab.
- Quality Assurance (QA) of data provided. To continue developing the EMP database of NS Marine aquaculture, all data submitted to NSDFA will be added to the database. Prior to inclusion, the data will be reviewed for outliers and errors. The data will also be processed through quality control measures, such as the BEI.
- NSDFA EMP sampling. NSDFA will conduct onsite monitoring in addition to regular Level I. Farms will be selected throughout the field season for sample collection. These samples will be collected from the same coordinates suggested for Level I or II sampling. NSDFA and the Level I and/or Level II results, as submitted, will be compared. Data collected by auditors will bear relevance to regulatory process.

The principles of transparency and collaboration are tenets of responsible environmental management and described in the original 2002 EMP document (Smith et al., 2002). Therefore, one goal of the NS EMP is to release information on the monitoring results to the public. Information will be made available as a summary of results and in an easily understood manner and the methodology and the reasoning behind measuring such parameters will be explained.

NSDFA will also prepare an annual presentation and summary report on EMP results and responses.

APPENDIX A: Associated Best Management Practices for Marine Finfish Aquaculture - provided by Aquaculture Association of Nova Scotia (AANS)

These BMP's are extracted from New Brunswick Environmental Management Program for the Marine Finfish Cage Aquaculture Industry in New Brunswick (July 2006) as requested by industry representatives within the AANS.

The following Operational Best Management Practices are designed to minimize the organic and inorganic loading from marine finfish cage aquaculture sites and are a requirement of all marine finfish cage aquaculture operators.

Waste Management

- Cage site operators are required to develop and comply with site-specific waste management plans developed by their facility as required by provincial and federal regulators. The aim of the plan is to ensure proper disposal of all waste materials generated at the facility. Categories of waste covered include, but are not limited to: operational debris, hazardous waste, human waste, bio-fouling, fish mortalities, fish feed, waste products from harvesting, etc.

Record Keeping and Reporting

- Marine finfish cage aquaculture site operators are required to maintain production records and report information as required by provincial and federal regulators.
- Environmental monitoring data will be reported to NSDFA within timelines set out above in *Section 5: Annual Schedules.*

Equipment Cleaning (nets, cages, mooring, other equipment)

- It is recommended that no net washing be conducted on-site, and that farmers monitor nets for biofouling organisms during routine mortality dives.
- In some circumstances, maintenance washing of lightly fouled nets still attached to cage structures is allowed on-site; however, once nets are removed they must be brought to shore for cleaning.
- Washing of lightly fouled equipment or nets with washing systems at the site will be conducted only under conditions that maximize dispersal of the dislodged materials away from the site and neighboring sites (e.g. strongest currents).
- Nets will be replaced at least at the beginning of each production cycle, and more often as required.
- No nets or other equipment shall be dropped to the bottom for the purpose of storage or cleaning. In the event of emergency circumstances such as worker safety or fish survival, any nets or equipment dropped to the bottom must be within lease boundaries and must be reported to NSDFA and DFO immediately.
- Sites classified as Hypoxic B, or Anoxic will not conduct any on-site net cleaning.

Equipment Disinfection (nets, cages, mooring, other equipment)

- Steam is the only disinfectant to be used on-site to clean cages and equipment.
- The cages will be cleaned on the aquaculture site prior to transport to the off-site location where the disinfection will take place.
- Only the following disinfecting agents will be used to clean cages at a location other than on the aquaculture site: steam, chlorine-based solutions, iodophor-based solutions, and hydrogen peroxide-based solutions.
- Environment Canada has suggested maximum discharge concentrations for each of the indicated disinfectants so that runoff from the disinfection process should not be deleterious to fish. The release of disinfectant solutions to waters frequented by fish could be considered a violation of Section 36(3) of the federal *Fisheries Act* at concentrations above the following maximum values:
    - Chlorine = 0.02 ppm
    - Iodine = 0.1 ppm
    - Hydrogen peroxide = 0.5 ppm
- During disinfection, the disinfectants will be stored such that any spill is contained and not released to the environment. All reasonable precaution will be taken to avoid releases due to spills.
- Disinfection of cages will only take place during sunny days, especially with chlorine-based solutions. Bright sunshine will aid in decreasing the concentration of chlorine, and speed up the evaporation of other disinfectant solutions.
- Care will be taken to ensure that disinfectant is not applied in excess. Direct discharge of disinfectants other than steam to waters of the province or to marine waters will not occur.
- Disinfectant solutions will be directed only at cage structures, with care taken to avoid over-spraying onto the beach.
- Ample drying time will be allotted to ensure that all disinfectant has completely dried prior to inundation with the next high tide.
- The disinfection of the cages will be spread out over a number of days to reduce the potential for impacts from the disinfectant residues.
- Disinfectant storage will occur in an area not in danger of being inundated by tidal waters or any other water source.
- To whatever extent possible, disinfection events will be coordinated with other growers within the same bay/harbour to spread it out over time and space.

Feed Handling and Storage

- Site staff and feed delivery personnel will take all reasonable precautions to reduce spills during delivery of feed to the site.
- Should a spill of feed occur, cleanup will occur immediately to minimize the loss of feed into the ocean.
- Accurate records will be kept of the amount of feed delivered to the site, stored at the site, fed to the fish, spilled and/or returned unused to the manufacturer. These records will provide a mass balance of feed use at the site.
- The amount of feed on site at any one time will be limited to an amount that can be safely and properly stored at the site.

- Feed will be stored, as much as practically possible at the site in covered areas including hoppers, bins, or buildings so that spills and spoilage are minimized.
- Bags or open containers of feed will not be left exposed or uncovered at the site.
- Any feed that is unusable will be removed from the site as new feed is delivered and disposed of at an approved site.

Feeding Practices

- Amounts of feed given to stock will be based on biomass contained in the pen and environmental conditions present.
- Feeding will be reduced or stopped if conditions such as low temperature, low dissolved oxygen, high tide currents, or heavy weather suggest that utilization of feed by the stock will be affected.
- Site staff will monitor all feeding operations at the facility. Feeding equipment will always be monitored during operations. Staff will closely observe fish feeding behavior.
- The use of underwater video cameras to monitor the feeding activity is recommended for all sites and will be used when available or when required.
- Feeding rates should be reduced or stopped when staff observes changes in fish activity indicating a reduction in appetite and/or if uneaten feed is detected passing through the bottom of the cage nets.
- Feeding will be temporarily reduced or suspended at times of strong currents flowing through the net pens that impact the ability of the fish to eat the feed.
- Hand feeding will be conducted in a manner to ensure an even distribution and reduce the amount of waste feed. Feeding will be slowed or paused if staff observes a reduction in feeding activity.
- Feeding performed with feed blowers will be conducted in a manner to ensure minimum loss of uneaten fish feed. Feeding will be slowed or paused if staff observes a reduction in feeding activity.
- Feeding equipment must be properly maintained to minimize the crushing of the feed pellets that can result in fine feed dust that will not be eaten by the fish. The operator must establish a schedule for the regular maintenance of mechanical feed blowers.
- Mechanical feed blower nozzles must be carefully aimed and controlled to ensure that the feed is being evenly distributed across the surface of the net pen and that no feed is missing the net pen entirely.
- Computer-controlled feeding systems require that a qualified operator be on duty at all times when feed is being administered.
- Detailed records will be kept for each cage of feed type and amount, fish numbers, total fish biomass, water temperature, and growth rates to ensure optimal feed conversion rates are being achieved at the site and that minimal feed losses are occurring.
- Feeding of moist feed will be conducted slowly to ensure that the fish have adequate time to consume the feed being distributed in the net pens.
- Feeding will be timed to coincide with the times of the day that the fish are eating well.
- Close attention will be given to the size of the pellets being used to feed the fish to ensure that the proper size pellets for the size of the fish in the net pens are being utilized.
- All staff must be trained in the above practices. Detailed records of training must be kept for each employee including training received and dates of training.

APPENDIX A1: BEST MANAGEMENT RESPONSE BY SITE CLASSIFICATION

The following are the associated BMP's specific to each site classification:

ANOXIC SITES (>70% of Level I stations > 6000μM)

See NS EMP Environmental Management Response

A site classified as Anoxic is causing significant damage to the marine environment. These sites are in non-compliance with the NSDFA license approval and the federal Fisheries Act. The site operator will be required to work closely with government agencies and follow any specific direction provided. Government directed action could include an expedited harvest program, fallowing, consultation prior to restocking (if applicable), increased monitoring and limitations to future operations (production levels, site layouts, equipment and staff requirements, etc.).

HYPOXIC B SITES (>50% of Level I stations >3000 μM)

See NS EMP Environmental Management Response

In addition to the requirement for an increase in monitoring and reporting to government, a site in Hypoxic B must follow the requirements for the Hypoxic A classification AND follow two or more of the following **Additional Best Management Practices** that are applicable to the site's operations:

- Conduct an audit of site operations in addition to any regularly scheduled auditing.
    - The auditor can be a site manager from another farm operated by the same owner, an experienced salmon grower from within the company or an external third party auditor. The auditor must be recognized by government regulators as a properly qualified auditor.
    - The auditor will examine the operational practices followed on the site for such things as record keeping, feed handling and storage, feeding, equipment cleaning and maintenance, environmental monitoring and waste management and determine if the site's Operational Best Management Practices are being followed.
    - The auditor will file a written report to NSDFA noting any deficiencies observed and make recommendations for improvements in site operations.
    - A production plan must be submitted prior to the next production cycle. Sediment sampling, as outlined and approved by NSDFA, must be completed prior to restocking.

- Modify the harvesting schedule to reduce biomass as soon as possible over degraded parts of the site.
    - If a particular portion of the site is more degraded, the net pens in that area will be harvested first or have its harvesting schedule advanced to reduce the biomass potentially impacting that portion of the site.
    - Increase the fallow period to allow improved site recovery.
    - Earlier harvesting of fish from more degraded portions of the site will provide for a longer fallow period of that area before re-stocking.
    - If no further improvements in site operational practices can be identified and implemented to further reduce organic loading, NSDFA may instruct the site

operator to reduce the size or loading density on the site through an expedited or focused harvest program.

- Review and adjust site set-up and net pen orientation.
    - Tidal currents are not necessarily uniform across a site. A Hypoxic B site will examine the tidal current patterns on the overall lease and cages could be re-positioned to take best advantage of the dispersal provided by stronger currents.
    - If space allows, the net pens will be arranged for subsequent production cycles to avoid further impacts to areas showing adverse environmental conditions.

- The site operator must conduct studies to improve the understanding of the tidal currents on-site and how that could affect organic deposition (e.g. plume delineation, current modeling).
    - Tidal currents are not necessarily uniform across a site. A Hypoxic B site may require the site operator to examine the tidal current patterns on the overall site lease. This could include conducting tidal current measurements and modeling studies to fully understand the tidal currents on the site and how the currents impact dispersion of organic material released from farm operations.
    - If the studies indicate that it would be beneficial for waste dispersion, the site operator will rearrange or re-position the site to take the best advantage of the available currents within lease boundaries.

The site operator will not conduct any on-site equipment or net cleaning and will implement a program of more frequent net changes.

Sites that consistently fail to meet oxic conditions for consecutive years must improve on BMP's submitted within previous mitigation plans.

HYPOXIC A SITES (>50% of Level I stations >1500 µM)
See NS EMP Environmental Management Response

The Approval Holder must undertake one or more of the following **Adjustments to the Operational Best Management Practices** or other appropriate or acceptable measures as identified by the site operator that are applicable to the site's operations:

- Increase the frequency of record keeping from weekly records to daily records.
    - By keeping more detailed and frequent records, the site operator will have better and more complete data for analyzing site operations.
    - Conduct more detailed data analyses.
    - Instead of only looking at overall farm productivity, fish size and growth, feed consumption and feed conversion rates, the site operator will also examine the site data on the basis of cage, feeding technician, cage position within the farm site and environmental condition. Data analysis will be looked at from a site-specific historical perspective, as well as between site operations. Statistical methods should be applied (graphics, trend analysis)

- Evaluate the use of dry feed versus moist feed.
    - The site operator will conduct this evaluation by examining the feeding activities of the fish, feed conversion rates, and/or feed usage per net pen.
    - The site operator will conduct feeding trials with both moist and dry feed and examine the above factors to determine effectiveness.

- Review status of staff training and update as required.
    - The site operator will evaluate the site staff in terms of experience, qualifications, and awareness of site policies and procedures.

- Review equipment maintenance schedule and practices.
    - All equipment will be maintained in good repair and working order. There will be a regular program of inspection and maintenance. All inspection and maintenance activities will be recorded in a log book.

- Review and improve site cleaning practices: frequency, timing, methods, on-site vs. off-site.
    - More frequent on-site cleaning of lightly biofouled equipment will reduce the potential for organic loading impacts.
    - At some sites, on-site net cleaning will be avoided and the site operator should make more frequent net changes.

OXIC SITES: Remainder of sites not included above.
See NS EMP Environmental Management Response

Site is in compliance with NSDFA license approval and operations shall continue as usual.

LIST OF REFERENCES

Grant, J. 2010. *A Summary of the March 2010 NS EMP Techincal Review Workshop and Laboratory Demonstration*. Halifax, Nova Scotia.

Government of Canada. 1985. *Fisheries Act*. R.S., c. F-14, s. 1, s35(2). Canada.

Hargrave, B.T. 1994. A benthic enrichment index, p. 79-91. In B.T. Hargrave (ed.), *Modelling benthic impacts of organic enrichment from marine aquaculture*. Can. Tech. Rep. Fish. Aquat. Sci. 1949: xi + 125 p.

Hargrave, B.T., G.A. Phillips, L.I. Doucette, M.J. White, T.G. Milligan, D.J. Wildish, and R.E. Cranston. 1997. *Assessing benthic impacts of organic enrichment from marine aquaculture*. Water, Air and Soil Poll. 99: 641–650.

Hargrave, B.T., M. Holmer, and C.P. Newcombe. 2008a. *Towards a classification of organic enrichment in marine sediments based on biogeochemical indicators*. Mar. Poll. Bull. 56: 810-824.

Hargrave, B.T., L.I. Doucette, P.J. Cranford, B.A. Law, and T.G. Milligan. 2008b. *Influence of mussel aquaculture on sediment organic enrichment in a nutrient-rich coastal embayment.* Mar. Ecol. Prog. Ser. 365: 137-149.

Hargrave, B.T. 2009. General Service Contract for Nova Scotia Department of Fisheries and Aquaculture: *Scientific defence of the BEI.* Owen Sound, Ontario

Holmer, M., D. Wildish and B. Hargrave. 2005. Organic enrichment from marine aquaculture and effects on sediment biogeochemical processes, p. 181-206. In B.T. Hargrave (Ed.) *Environmental Effects of Marine Finfish Aquaculture*, Springer-Verlag, Berlin.

Province of New Brunswick (PNB), 2006. *New Brunswick Environmental Management Program for the Marine Finfish Cage Aquaculture Industry in New Brunswick.*

Province of Nova Scotia (PNS), 1996. *Fisheries and Coastal Resources Act*. C. 25, S.1, 48 50. Halifax, Nova Scotia.

Province of Nova Scotia (PNS) 2010. *Standard Operating Procedures for the Environmental Monitoring of Marine Aquaculture in Nova Scotia.* Halifax, Nova Scotia.

Shaw, K.R. 1998. *PEI Benthic Survey*. Tech. Rep. Environ. Sci. No. 4, Prince Edward Island Fisheries and Environment, 75 pp.

Smith, J., Grant, J., and Stuart, R. 2002. *Design of the Environmental Monitoring Program for the Marine Aquaculture Industry in Nova Scotia.*

Wildish, D.J., Akagi, H.M., Hamilton, N. and Hargrave, B.T. 1999. *A recommended method for monitoring sediments to detect organic enrichment from mariculture in the Bay of Fundy.* Can. Tech. Rep. Fish. Aquat. Sci. 2286: iii + 31 p.