Proceedings of the Workshop on Harmful Algae Research in the DFO Maritimes Region

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PROCEEDINGS OF THE WORKSHOP ON HARMFUL ALGAE RESEARCH IN THE DFO MARITIMES REGION

by

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ABSTRACT

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Recent funding cutbacks and downsizing at Fisheries and Oceans Canada (DFO), due to Program Review, have resulted in fewer resources available for research and monitoring of toxic algal blooms and phycotoxins. Other government agencies have undergone similar changes. These events have led to a concern about our capability to adequately carry out research and monitoring programs related to harmful algae and phycotoxins in the DFO Maritimes Region. A Workshop was therefore held at the Gulf Fisheries Centre, Moncton, NB, on June 19, 1996, to address this concern. It gathered together 26 participants, from federal and provincial agencies, the aquaculture industry, and the private sector, who have an interest in maintaining a viable program of harmful algal bloom research and monitoring. The goals were to exchange information about current and planned activities, develop partnerships, and identify research activities for the DFO Maritimes Region Science Branch, taking into account needs of the aquaculture industry and current resources. The Workshop conclusions will be integrated into a national plan for research on harmful algae, being developed by the DFO Phycotoxins Working Group (PWG).

Summaries of activities and priorities were given by representatives from the DFO Maritimes Region Science Branch, DFO Inspection Branch, the Prince Edward Island Department of Agriculture, Fisheries and Forestry, the Institute for Marine Biosciences (NRC), the Nova Scotia Aquaculture Association, and the Laurentian Region Science Branch. After discussion, a list of research and monitoring needs was established that included:

- monitoring of harmful algal bloom dynamics for research purposes
- phycotoxin uptake and depuration studies
- development of phycotoxin test kits
- physiological studies of toxic algae
- ballast water discharge
- impacts of phycotoxins on the food web
- phycotoxin kinetic modeling
- fungal control of harmful blooms.

Current funding levels do not permit all of these areas to be adequately covered. However, the Maritimes Region Science program will use the above list of needs to develop a strategy on harmful algae research. Improved communication with Industry and an increased sharing of resources via partnerships were seen as ways to counter the effects of dwindling resources.

RÉSUMÉ

Bates, S.S. et P.D. Keizer. 1966. Proceedings of the Workshop on Harmful Algae Research in the DFO Maritimes Region. Can. Tech. Rep. Fish. Aquat. Sci. 2128: v + 44 p.

Les récentes compressions de ressources financières et humaines pratiquées au ministère des Pêches et des Océans (MPO), par suite de l'Examen des programmes, font qu'il y a moins de ressources pour la recherche et la surveillance des phycotoxines et des proliférations d'algues toxiques. D'autres organismes gouvernementaux ont subi des changements semblables. Cette situation a entraîné certains doutes quant à notre capacité de mener avec succès les programmes de recherche et de surveillance liés aux algues nuisibles et aux phycotoxines dans la Région des Maritimes du MPO. Un atelier a donc été organisé au Centre des pêches du Golfe à Moncton (N.-B.) le 19 juin 1996 afin d'en discuter. L'atelier regroupait 26 participants d'organismes fédéraux et provinciaux, de l'industrie aquicole et du secteur privé qui ont intérêt à ce que soit maintenu un programme viable de recherche et de surveillance des poussées d'algues. L'objet visé était d'échanger de l'information sur les activités courantes et prévues, d'établir des partenariats et de déterminer des activités de recherche que la Direction des sciences du MPO (Région des Maritimes) devrait entreprendre, selon les besoins de l'industrie aquicole et les ressources disponibles. Les conclusions de l'atelier seront intégrées dans un plan national de recherche sur les algues nuisibles que prépare actuellement le Groupe de travail du MPO sur les phycotoxines.

Lors de l'atelier, plusieurs sommaires d'activités et de priorités ont été présentés par des représentants des directions des Sciences et de l'Inspection du MPO (Région des Maritimes), par le ministère de l'Agriculture, des Pêches et des Forêts de l'Î.-P.-É., par l'Institut des biosciences marines (CNRC), par l'Association de l'aquaculture de la Nouvelle-Écosse, et par la Direction des sciences de la Région Laurentienne. Après discussion, on a établi la liste suivante des besoins en activités de recherche et de surveillance:

- surveillance de la dynamique des proliférations d'algues nuisibles aux fins de recherches
- études sur l'assimilation des phycotoxines par les organismes et sur leur assainissement
- élaboration de trousses d'analyse des phycotoxines
- études physiologiques des algues toxiques
- évacuation des eaux de ballast
- incidences des phycotoxines sur le réseau trophique
- modélisation cinétique des phycotoxines
- contrôle mycosique des algues nuisibles.

Les niveaux de financement actuels ne permettent pas d'intervenir dans tous ces domaines de façon adéquate. Cependant, le Programme des sciences de la Région des Maritimes s'inspirera de cette liste de besoins pour établir une stratégie de recherche sur les algues nuisibles. L'amélioration des communications avec l'industrie et le partage accru des ressources par le biais de partenariats ont été proposés comme moyens de contrer les effets de cette baisse de ressources.

Workshop on Harmful Algae Research in the DFO Maritimes Region

Wednesday, June 19, 1996
Gulf Fisheries Centre, Moncton, NB
Miramichi Room, 09:30 - 16:30 h

1.0 Opening of the Workshop

J.S. Loch (Director of Science, Maritimes Region) described the rationale for holding the Workshop, by first providing a brief history of research and monitoring activity on harmful marine algae in the old Gulf and Scotia-Fundy Regions. Prior to the 1987 domoic acid "mussel crisis" on Prince Edward Island (PEI), activity was restricted to the Bay of Fundy and surrounding area. The Inspection Branch sampled for PSP toxins only. Science Branch concentrated its research on PSP toxins in the Bay of Fundy, studying *Alexandrium* bloom distribution and dynamics, and the accumulation of PSP toxins in the food web and the resulting effects on fish survival. Research was also directed at biological oceanographic aspects of non-toxic algal blooms in coastal and offshore waters.

During the 1987 domoic acid outbreak, a multi-agency Analytical Working Group (AWG) was temporarily assembled to coordinate the work being carried out by laboratories at DFO, the National Research Council, and Health Canada involved in the search for the novel toxin. This phycotoxin event demonstrated that the general problem of toxic algae in our coastal waters was more widespread and a more serious threat to human health and to the aquaculture industry than had been previously recognized. The need for an expanded long-term research program rapidly became obvious. New resources were therefore requested and obtained from Treasury Board to boost the research and monitoring capabilities in our region. This resulted in an immediate increase in sampling coverage and frequency by the DFO Inspection Branch to include analysis of domoic acid, as well as PSP toxins, in molluscan shellfish tissue. In addition, a Phytoplankton Monitoring Program was initiated by DFO Science Branch in the old Gulf Region, that, among other things, provided an early warning of impending toxic events. This successful program was eventually transferred to the Inspection Branch. In early 1988, DFO created the national Phycotoxins Working Group (PWG), whose Terms of Reference now include developing advice on planning, coordinating, setting priorities, and managing the program for DFO research on phycotoxins and other aspects of harmful algae blooms.

In recent years, there has been a gradual decline in funding for harmful algae research at DFO. All of the Treasury Board funds originally targeted for this research were eventually absorbed into the general A-base funding structure. The DFO/NSERC University Science Subvention program, which had funded some university research on harmful algae, was phased out in 1995. Recently, the Program Review and early retirement incentives have resulted in further decreases in funding and PY's. Several senior scientists have thus departed, with a consequent loss of expertise. The Inspection Branch Phytoplankton Monitoring Program was terminated in April, 1996. These changes at DFO, along with similar decreases in research emphasis in the area of harmful algae by other federal agencies, have raised questions about our

immediate capability to deal with harmful algal events and our long-term ability to continue carrying out world-class research programs.

This Workshop was therefore convened to gather together those federal and provincial managers and scientists, academics, and commercial and aquaculture industry representatives who are concerned with harmful algae or phycotoxins, and who have an interest in maintaining research or monitoring programs. With the common problem of shrinking resources in every sector, yet with the continuing existence of harmful algae bloom events, this was felt to be an opportune time to identify core issues and to forge partnerships with others working on similar questions.

2.0 Workshop Objectives

- Exchange information about current and planned levels of activity regarding harmful algae monitoring and research.
- Identify and prioritize research activities for the DFO Science Branch, Maritimes Region, taking into account concerns of the aquaculture industry and current or future resources.
- Develop partnerships with other government agencies, universities, and Industry, in order to optimize limited resources and to focus on essential elements.

3.0 Workshop Agenda

The Workshop agenda is given in Appendix 1. The morning was devoted to an exchange of information during short presentations by representatives of DFO Maritimes Region's Science Branch, DFO Inspection Branch, the National Research Council's Institute for Marine Biosciences (Halifax), the Prince Edward Island Department of Agriculture, Fisheries and Forestry, the Aquaculture Association of Nova Scotia, and DFO Laurentian Region's Science Branch. Additional views from the aquaculture industry were then heard during an afternoon discussion session. This was followed by a summary of research and monitoring needs, as expressed by the participants. Time did not permit a prioritization of these needs. This will be completed following a meeting of the PWG, to be held in conjunction with the Fifth Canadian Workshop on Harmful Marine Algae (St. John's, NF, September 11 - 13, 1996). For now, the editors have identified the major requirements for scientific research on harmful marine algae in the Maritimes Region (see Section 6.3).

4.0 Workshop Participants

The list of Workshop participants is given in Appendix 2. Of the 26 participants, 14 were from DFO; 3 from the PEI Department of Agriculture, Fisheries and Forestry; 2 from the NS Department of Fisheries; 1 from the Institute for Marine Biosciences; 3 from private companies; and 3 from the molluscan shellfish aquaculture industry. There was a noticeable lack of representation from the NB Department Fisheries and Aquaculture and from the finfish industry in the southwestern Bay of Fundy, perhaps because of a conflict with the Atlantic Aquaculture

Fair in St. Andrews, NB, the following day. The relatively low representation from the shellfish aquaculture industry should not be construed as a lack of interest on their part. Rather, it was due in part to the fact that Industry members were preoccupied that week with collecting mussel spat, at least on PEI, for the upcoming growing season. Telephone contacts were therefore made with 3 additional aquaculturists: Roger Townshend (PEI), Wayne Somers (PEI), and Phil Drinnan (NS). Their views were noted and tabled at the Workshop. The views of Louis Hanic (University of Prince Edward Island), Andrew Boghen (Université de Moncton), John Cullen (Dalhousie University), Claire Carver (Mallet Environmental Services, NS), Ken Freeman (DFO, Halifax), and Mike Gilgan (DFO, retired) were also collected by telephone or e-mail. Maurice Levasseur (Institute Maurice Lamontagne, Mont Joli, PQ) was invited to give his perspective of the DFO Laurentian Region's Science Branch research program on harmful algae.

5.0 Reports on Research

5.1 DFO Science Branch

Kats Haya (DFO Science, St. Andrews Biological Station), as past president of the PWG, gave an overview of current and proposed research in the Maritimes Region.

5.1.1 Current DFO Phycotoxins Research in the Maritimes Region

- Phytoplankton monitoring in the Southwest Bay of Fundy - applications to salmonid aquaculture industries and shellfisheries (J.L. Martin, St. Andrews Biological Station)
- Determining factors controlling toxin production by *Pseudo-nitzschia pseudodelicatissima* (J. Martin, St. Andrews Biological Station)
- Uptake and depuration of PSP toxins by cultured and wild scallops in the Southwest Bay of Fundy (K. Haya, St. Andrews Biological Station)
- Long-term monitoring - Nova Scotia (P.D. Keizer, Bedford Institute of Oceanography)
- Physiology of *Pseudo-nitzschia multiseries* and *P. pungens* (S.S. Bates, Gulf Fisheries Centre)
- Phycotoxin kinetic modeling (W. Silvert, Bedford Institute of Oceanography)

5.1.2 Overview of Proposed DFO Phycotoxins Research in the Maritimes Region

As part of a national Phycotoxins Working Group activity, multi-year research proposals were submitted by project leaders in DFO Science Branch. The present overview of DFO phycotoxin research in the Maritimes Region summarizes project descriptions of relevant research proposals submitted. The projects were grouped into the phycotoxin categories that were previously developed by the PWG for program review and planning exercises.

5.1.2.1 Methodology and Analytical Support

- **Development of domoic acid test kits** (R. Pocklington). The objectives are to develop a fast and sensitive colorimetric test for domoic acid, isolate enzymes for the development of

amperometric sensors for domoic acid, and to screen *Pseudo-nitzschia* isolates (from water collected in Wadden Sea and the German Bight) for the presence of domoic acid.

- **Investigations into amino acid shellfish toxins** (R. Pocklington). The objectives are to improve analytical procedures for neurotoxins, and provide chemical and analytical support to investigations in populations of diatoms in nature and culture for DFO and non-DFO research programs.

5.1.2.2 Phytoplankton Population Dynamics

- **Continuation of phytoplankton monitoring in the Southwest Bay of Fundy - applications to salmonid aquaculture industries and shellfisheries** (J.L. Martin). A monitoring program was initiated in 1987 in the southwest Bay of Fundy following concern that the relatively new and rapidly expanding salmonid aquaculture industry might result in changes in phytoplankton composition. Objectives of the study are: to establish patterns, trends and possibly predict phytoplankton blooms, particularly those that cause harm, as well as to act as an early warning of harmful or toxic algae for fisheries. Sampling for temperature, salinity, nutrient levels and phytoplankton distribution and abundance will continue at the four sites presently being monitored. The relationship between toxin content from shellfish samples collected by Inspection Branch and algal concentrations is being studied.

- **Continuation of long-term monitoring - Nova Scotia** (P.D. Keizer). Two stations were established in 1992 to: compile a long-term inventory of phytoplankton species; estimate the abundance of the dominant species present; define seasonal maxima and minima and the principle points of inflection in the physical and environmental data; and determine the interannual variation and long-term trends in the data. The following information is collected: depth gradient of salinity, temperature, *in vivo* fluorescence and light; plant nutrients, extracted chlorophyll and phytoplankton samples from three depths and a vertical plankton tow.

- **Toxic and non-toxic phytoplankton bloom dynamics: SW Gulf of St. Lawrence** (S.S. Bates). Several toxic or potentially toxic phytoplankton are found in the southwest Gulf of St. Lawrence, including *Alexandrium excavatum, Dinophysis* spp. and *Pseudo-nitzschia multiseries*. Some baseline information has already been collected about their seasonal and temporal distribution and the proposed study aims to build on these data. A more detailed investigation is proposed for the domoic-acid-producing *P. multiseries*, whose blooms show large interannual variation in Cardigan Bay and New London Bay, PEI. The goal is to document year-to-year variations in *P. multiseries* abundance by studying the biological, chemical and physical factors that may control blooms. Measurements will include: temperature, salinity, nutrients, chlorophyll *a*, fluorescence, phytoplankton composition and abundance (whole water and net samples), sediment cores and photosynthesis.

- **Ballast water and sediment discharges** (D.V. Subba Rao). The study of ballast water introductions and their linkages to algal blooms will: determine the potential for the introduction of harmful algae into coastal zone and mariculture sites in Atlantic Canada

through ballast water and sediment discharges; assess the viability and growth of such algae and evaluate under what conditions they would develop into blooms; bring into culture the suspect harmful species; and establish the linkages between the occurrence of algal blooms and the introduction of these populations in coastal waters.

5.1.2.3 Biological and Biochemical Aspects of Toxin Production

- **Continuation of physiological studies of *Pseudo-nitzschia multiseries* and *P. pungens*** (S.S. Bates). Although considerable progress has been achieved in understanding the control of growth and domoic acid production by *Pseudo-nitzschia multiseries*, there are many gaps to fill. The following are laboratory projects using cultures of *P. multiseries*, *P. pungens* and other potentially-toxic algae that will be isolated from the field and cultured: chemostat growth experiments; sexuality and life history of *P. multiseries* and *P. pungens*; fungal parasites, isolation and testing of other potential domoic acid producers; isolation and culture maintenance of any potential DSP and PSP toxin producers; and application of novel techniques such as immunological and nucleotide probes.

- **Marine toxin dynamics** (J.E. Stewart). Studies to date suggest a major role for some toxins in acquiring micro-nutrients and that this feature may lead to major *in situ* toxin production in fish. This study will examine: the degree to which micro-nutrients influence this feature in various algal strains and in certain microorganisms; the production of excessive levels of domoic acid *in situ* in shellfish; and the composition of the full micro-nutrient acquisition system and the degree to which these systems give a competitive advantage and possibly aid in determining phytoplankton successions.

5.1.2.4 Uptake, Storage and Depuration of Toxins by Marine Organisms

- **Correlation of PSP toxins and domoic acid in shellfish with environmental variables** (J.L. Martin). Paralytic shellfish poisoning (PSP) has been associated with the Bay of Fundy for hundreds of years and shellfish have been monitored since 1943. This represents the longest continuous data set of its kind in the world. There is evidence that there are patterns where toxicity of shellfish are higher during certain years. The results will be compared with various environmental variables such as air and water temperature, salinity, wind direction and speed, river runoff, and lunar tidal or other cycles, for correlations. Environmental variables indicated for PSP will also be applied to domoic acid in molluscan shellfish.

- **Phycotoxins in the food web** (K. Haya). This project is concerned with the impact of toxin producing marine phytoplankton blooms on the wild and cultured shellfish industries. The objectives are to: determine the movement of phycotoxins through the food web; improve prediction and detection of toxic algal blooms; and measure the accumulation and depuration of toxins in wild and cultured shellfish. For example, PSP toxins are found in concentrations exceeding regulatory limits in wild scallop tissues, with the exception of the adductor muscle. Studies will determine if this is due to slow depuration and/or constant accumulation of PSP toxins from cysts in the sediment.
- **Continuation of phycotoxin kinetic modeling** (W. Silvert). Develop and test models of toxin kinetics in shellfish, both to be able to predict toxin levels in shellfish from known

exposure, and to use shellfish data to infer exposure as a consistency check on toxin monitoring. This is a continuation of work initiated in 1992.

5.1.2.5 Effects of Toxins on Marine Organisms

- **Effects of marine toxins on finfish** (K. Haya). This project is concerned with the impact of marine phytoplankton blooms on wild and cultured finfish. Since caged finfish cannot avoid areas of blooms, fish kills could result form direct uptake of the toxin, development of anoxic conditions in the waters, or disruption of gill function. Wild fish kills can result from transfer of toxins through food chains. The objective is to identify the acute and chronic, and lethal and sublethal effects of marine phycotoxins to finfish. Initially, the lethality of domoic acid to finfish will be determined. Knowledge of the lethality to finfish will aid in the assessment of risk of blooms of domoic acid producing diatoms to wild and cultured finfish.

- **Improved methods for investigating the effects of toxic microalgae on bivalve feeding** (D.J. Wildish). The aim is to devise new methods that can be used as standards to indicate potential marketing problems caused by toxic microalgae. Prior studies on the feeding by bivalves have been inadequate in that important variables (e.g., water velocity, temperature) have not been simulated, nor had a standard diet been available. This study seeks to remedy this and, in collaboration with colleagues at IFREMER, Nantes, France, to study the whole sequence of feeding, assimilation, toxin chemistry and decontamination of bivalves which ingest PSP toxins.

5.1.2.6 Fate of Toxins

- **Possible microbial counter-measures and fate of toxins** (J.E. Stewart). Previous work has shown that it is probable that autochthonous microorganisms in certain species of shellfish play a role in clearance (biodegradation) of absorbed toxins; it is feasible to expect that this capacity could be manipulated to enhance and accelerate the clearance of the toxins. This study would entail using several species of molluscan shellfish under conditions in which the toxins levels (domoic acid or possible PSP toxins) in the shellfish are maximized and the most likely associated microorganisms are favoured through varying regimes. The buildup, biodegradation, and clearance of the toxins would be followed; the microbial aspects would be measured and evaluated. Finally, attention would be paid to the possibility of transferring this microbial capacity to shellfish not now possessing it.

5.1.2.7 Physical Oceanography, Chemical Oceanography and Sedimentology

- **Historical record of PSP events from sediment cores** (L. Bugden). A time series of the occurrence and intensity of PSP events over the past few hundred years would permit the examination of several hypotheses relating to the nature or anthropogenically induced changes in toxic phytoplankton bloom dynamics. Such a record may exist in the sediments accumulated in the Bay of Fundy or the Gulf of St. Lawrence, areas where PSP is known to occur on a regular basis. This project proposes to examine sediment cores from these regions to determine if a quantitative signal of PSP occurrence can be obtained from older parts of the cores using various techniques such as cyst staining and counting or, hopefully, newer

and less labour-intensive HPLC methods. If successfully obtained, PSP versus depth within the core signal could be combined with various methods such as Pb-210 to yield a PSP time series which could be related to various environmental variables such as wind, water temperature and freshwater runoff.

5.2 DFO Inspection Branch

Edmond Arsenault (DFO Inspection, Gulf Fisheries Centre) outlined the activities currently being carried out by the Maritimes Region's Inspection Branch as follows:

5.2.1 Overview of the Program

The Inspection Branch's Biotoxin Section, which is part of the Scientific and Technical Services Division, has laboratories located in Halifax, NS, and Moncton, NB. The Section's main activities include the Shellfish Program, Import Program, Quality Management Program (QMP) in the final product, and consumer complaint analyses. For this Workshop, the major emphasis was placed on the Shellfish Program, which monitors for the presence of phycotoxins in shellfish. Inspection's interest in phycotoxins is to provide reasonable assurance that fish products (molluscs, shellfish, etc.), exported from one province to another or from Canada to another country, or sold or imported into Canada for human consumption, contain no harmful phycotoxins above Canadian and/or International tolerances. All actions are related to the content of phycotoxins in the edible portion of fish products.

5.2.2 Phycotoxins Monitoring

Inspection will continue to monitor the phycotoxin content in molluscs from harvest sites, and will continue to verify registered processing plants for compliance to the Quality Management Program. Imported products are also verified for phycotoxin content. When harvest areas are above the Canadian tolerance limit, Inspection contacts DFO's Conservation and Protection (C&P) Branch for area closures and will verify that no contaminated products are present on the marketplace. When violations are identified as part of our QMP program, compliance action is taken against the processing plant.

Inspection currently has 135 sites in the Maritimes Region which are routinely monitored for phycotoxins in molluscs (see Appendices 3 - 9). The monitored phycotoxins include: Paralytic Shellfish Poison (PSP) toxins, Amnesic Shellfish Poison toxin (ASP; domoic acid), and Diarrhetic Shellfish Poison (DSP) toxins.

5.2.2.1 PSP Toxin Monitoring

Of the 135 sites throughout the Maritimes Region, 25 are monitored for PSP toxins in PEI (Appendix 3); 10 of these sites (shown in bold) are monitored throughout the year either

weekly or every two weeks, depending on the season and the harvesting site. The other 15 sites are monitored between May and October, either weekly or every two weeks, depending on the harvesting site. Forty two sites are monitored in New Brunswick (NB) (Appendix 4); 17 sites are monitored throughout the year, either weekly or every two weeks, depending on the season and the harvesting site. The other 25 sites are monitored between May and November either weekly or every two weeks, depending on the harvesting site. Sixty eight sites are monitored in Nova Scotia (NS) (Appendix 5); 2 sites are monitored throughout the year, either bimonthly or monthly, depending on the season. The 66 sites are monitored between April and December, either weekly, bimonthly or monthly, depending on the harvesting site.

5.2.2.2 ASP (Domoic Acid) Toxin Monitoring

Molluscs samples are collected from 110 sites throughout the Maritimes Region. Twenty two sites are monitored in PEI (Appendix 6); 7 sites are monitored throughout the year, either weekly or every two weeks, depending on the season and the harvesting site. The other 15 sites are monitored between September to November, either weekly or every two weeks, depending on the harvesting site. Twenty seven sites are monitored in NB (Appendix 7); 8 sites are monitored throughout the year, either weekly, bimonthly or monthly, depending on the season and the harvesting site. The other 19 sites are monitored between May and November, either bimonthly or monthly, except for October which is monitored weekly. Sixty one sites are monitored in NS (Appendix 8); 2 sites are monitored throughout the year, either bimonthly or monthly, depending on the season and the harvesting site. The other 59 sites are monitored between April and December, either weekly, bimonthly or monthly, depending on the harvesting site.

5.2.2.3 DSP Toxin Monitoring

Five sites in NS (Appendix 9) are monitored either weekly or bimonthly between April and December, depending on the season and the harvesting sits. One site in NB (Rue Pinet, Caraquet Bay), sampled bimonthly, has also recently been added to the list. These sites were chosen because they have a history of DSP toxins being present. Samples are analyzed for DSP toxins from other sites in the Martimes Region as a result of consumer complaints. Once the presence of DSP toxins has been established at a new site, it is added to the list of those monitored for DSP toxins.

5.2.3 Phycotoxin Sample Analysis

The Scientific and Technical Services Division of the Maritimes Region's Inspection Branch conducts Inspection's phycotoxins analyses. The Head, Bioassay Section, is situated in Moncton. Samples collected for ASP and PSP toxins from NS between April and November are analyzed by the Biotoxin and Chemistry Sections in Halifax, while samples for ASP and PSP toxins collected during the remaining part of the year, as well as all samples collected in PEI and NB, are analyzed in Moncton. Samples for DSP toxin analysis are performed in Halifax by the Chemistry Section.

5.2.4 Harmful Algae Monitoring

From 1990 to 1995, Inspection also monitored for the presence of known phytoplankton producers of PSP, ASP and DSP toxins at 32 sites in the old Gulf Region. In April 1996, however, the Phytoplankton Monitoring Program was canceled, as this program was never recognized as being official and could not be relied upon to accurately predict the presence of toxins in the shellfish. All of Inspection Branch's official action must be related to the phycotoxin content in the edible portion of fish products, and not to the presence of toxic phytoplankton in the water column. Canada's international trade in molluscan shellfish, as well as our control of this fishery within Canada, is dependent upon agreements with other Canadian and US agencies, most notably the US National Shellfish Sanitation Program (NSSP), and the Canadian Shellfish Sanitation Program (CSSP; involving DFO and Environment Canada). Because domoic acid producers other than the known *Pseudo-nitzschia* species may exist, it is also possible that this neurotoxin could be present in molluscs without the presence of high counts of *Pseudo-nitzschia multiseries* in the water.

5.2.5 Harmful Algae Research

The long-term strategic direction for the Inspection program is to increase Industry responsibility and compliance. To improve the efficiency and cost effectiveness of the program, therefore, an Industry-government technical working group has been established to review and adjust, as needed, the Molluscan Shellfish Program. Opportunities for developing partnerships pertaining to sampling will be investigated, and strategies for choosing sampling sites and sampling frequency will be developed.

Due to financial restraints, downsizing and the creation of the new Federal Food Agency, Inspection will not be conducting research activities. Inspection will, however, continue to maintain a strong contact with the research community in order to become proactive in monitoring for new phycotoxins that are toxic to humans.

5.3 National Research Council of Canada

Allan Cembella reviewed the phycotoxin research activities and priorities of the National Research Council's Institute for Marine Biosciences (IMB), Halifax, NS. Prior to the 1987 domoic acid "crisis", IMB research on phycotoxins was limited to a collaborative project on the production and purification of PSP toxins to be used in the development of a rapid detection kit for these toxins in shellfish. During the height of the crisis, IMB played a pivotal role in identifying domoic acid as the toxic agent in amnesic shellfish poisoning (ASP) and in tracing its occurrence to the causative organism, *Pseudo-nitzschia multiseries*. Throughout the several years following the crisis, IMB researchers were actively involved in developing methods for the analysis of ASP toxin in shellfish tissues and plankton samples, and in studies on the physiology and toxin production of *P. multiseries*; up to 17 PY's (approximately 20% of the Institute staff) participated in these activities. Intensive work on domoic acid led to the development of a significant program on phycotoxins, which has included work on PSP, DSP, spirolides and brevetoxins, and on the production of analytical standards and reference materials through the

Marine Analytical Chemistry Standards (MACS) Program. Specifically, these now include standards and reference materials for domoic acid, okadaic acid and certain PSP toxins.

Since the passage of the ASP crisis and the implementation of new techniques to deal with a variety of phycotoxin events, such a high level of activity was no longer justified and some personnel were re-targeted to other tasks. However, phycotoxin research will remain an ongoing priority, and IMB still maintains a core competence and expertise that will enable it to respond to challenges. Elements of IMB's Phycotoxin Research Program are outlined in Panel 1. This program is likened to an "insurance policy" for the aquaculture industry in the Maritimes and it is designed to be responsive to Industry priorities while maintaining scientific excellence.

Panel 1.

INSTITUTE FOR MARINE BIOSCIENCES (NRC)
PHYCOTOXINS RESEARCH PROGRAM

The role of IMB in phycotoxins research is referenced to our role in Seafood Safety, particularly as this relates to the economic well-being and productivity of the Canadian aquaculture sector.

Structural Elements	Core Competence and Techniques
BIOORGANIC/NATURAL PRODUCTS CHEMISTRY (Key RO: J.L.C. Wright) T. Hu J. Walter	Fractionation/extraction techniques Preparative LC Bioactives testing Structural elucidation Nuclear magnetic resonance Molecular modeling Biosynthetic pathways
ORGANIC ANALYTICAL CHEMISTRY (Key RO: M.A. Quilliam P. Thibault J. Curtis	High resolution MS and MS/MS Coupled analytical techniques: LC-MS, CE-MS, CE-UV, HPLC-FD Analytical standards and reference materials (MACSP)
MARINE BIOLOGY/BIOCHEMISTRY (Key RO: A.D. Cembella) V. Ewert N. Ross V.M. Bricelj	Bulk toxin production/purification Factors regulating toxin synthesis Identifying novel toxigenic species Toxin transfer kinetics in shellfish Immunofluorescence/flow cytometry HAB dynamics and aquaculture ALERT response Immunodiagnostic/cytotoxicity assays

Field work on harmful algal bloom (HAB) dynamics and phycotoxin distribution relates to aquaculture operations only, and only at targeted aquaculture sites, currently in Mahone Bay, NS, and Ship Harbour, NS. The rapid response team (ALERT) is deployed based on information received from DFO Inspection Branch and on the NS Department of Fisheries' phytoplankton monitoring program (via Shelly Hancock and Claire Carver). It was stressed that it is critical to

have a phytoplankton monitoring program in order to respond to phycotoxin events - such monitoring should therefore continue. Several IMB research priorities on phycotoxins (see Panel 2) are deliberately well aligned with the priorities of the Aquaculture Association of Nova Scotia.

Panel 2.

IMB RESEARCH PRIORITIES ON PHYCOTOXINS

- *Identify the proximal source(s) of DSP toxins in Atlantic shellfish
- *Complete studies on uptake and depuration of phycotoxins, to model kinetics in important shellfish aquaculture species
- *Determine the site of storage, toxin biotransformation, and elimination in various shellfish tissues for different species
- *Assist in the development of alternative assay methods (cytotoxicity and immunodiagnostic), i.e. rapid detection kits
- Establish the biological origin and significance of spirolides in shellfish aquaculture
- Characterize novel (primarily water-soluble) DSP toxin analogues in causative organisms
- Maintain and supplement (e.g., for PSP toxins) the existing phycotoxin analytical standards and reference materials via the MACS Program
- Continue to develop and refine instrumental analytical methods for the analysis of phycotoxins in plankton, shellfish and finfish
- Determine the biosynthetic pathways for key phycotoxins
- Establish the trophic relationships whereby phycotoxins enter marine food webs
- Utilize whole cell assays and thin-sections (TEM) to localize phycotoxins within toxigenic organisms
- Determine how toxin profiles may be used in biogeographic and population genetic studies of HAB species in Atlantic Canada

*Identified as critical research priorities by the Aquaculture Association of Nova Scotia

Areas in which IMB will not play a direct leading role were also outlined (see Panel 3). IMB sees the need to better target what is done within the general scientific community, and to develop strategic partnerships. The importance of program co-ordination among various research agencies and the important role of further cooperation with DFO Science and Inspection to achieve general objectives was stressed. There are opportunities for future coordination of activities with DFO, e.g., in Mahone Bay, NS. Communication channels should remain open with DFO research and inspection personnel, as well as with the Industry and provincial governments.

Panel 3.

AREAS IN WHICH IMB WILL NOT PLAY A DIRECT LEADING ROLE

- Operating and maintaining monitoring programs for HAB species
- Routine analysis of phycotoxins in shellfish, finfish and plankton
- Determining or regulating security limits for human consumption of phycotoxin-contaminated shellfish or finfish
- Designing and operating depuration facilities for toxic shellfish
- Operating mammalian bioassay facilities for toxicity determinations
- Conducting large-scale oceanographic studies of bloom dynamics and distribution
- Establishing the role of bacteria in toxin production in laboratory or field studies
- Determining the pharmacology and kinetics of phycotoxins in mammalian models (neuroreceptors, dosages, etc.)
- Developing or recommending control or mitigation strategies against the deleterious effects of HAB events

5.4 PEI Department of Agriculture, Fisheries and Forestry

Neil MacNair summarized the statistics on PEI's mussel culture (see Panel 4; Appendix 10) and oyster industries (see Panel 5), and provided the province of PEI's viewpoint on research and monitoring needs. It was stated that the PEI molluscan shellfish aquaculture industry has a

great interest in the work of DFO and NRC with respect to phycotoxins, and that there was disappointment that the DFO phytoplankton monitoring program was eliminated.

Panel 4.

PEI MUSSEL CULTURE INDUSTRY

- 100 mussel growers (seed, grow out).
- ≈ 6,000 acres under lease in 18 rivers and bays.
- 1995 production 7,500 tonnes, export value $16 million.
- 4 large processing facilities (>1,000 tonnes), several smaller.
- 400 people employed.
- Disease free stocks.

Panel 5.

PEI OYSTER INDUSTRY
1995 STATUS REPORT

- 1,100 oyster license holders
  - 400 - 500 active.
- 740 private leases (5,351 acres).
- 100 active leaseholders.
- 50 active leaseholders who invest $1,000+/yr.
- 1995 production estimate 3.5 million lbs
  - 15 - 20% production from private leases.

Of relevance to this Workshop is that the province of PEI operates a Mussel Monitoring Program (see Panel 6), which includes a component to monitor for the presence of potentially-

toxic phytoplankton (including *Pseudo-nitzschia multiseries*, *Alexandrium* spp., and *Dinophysis* spp.).

Panel 6.

MUSSEL MONITORING PROGRAM
1982 - 1995

- A technical service to PEI mussel growers and processors.
- A source of information for governments and research agencies.
- Operated in ice-free season since 1982.
- Information on water quality, mussel meat yields, spat fall prediction, predators and “potentially”-toxic phytoplankton.
- Each site was sampled biweekly.

In response to the elimination of DFO’s Phytoplankton Monitoring Program, the Province has initiated discussions with the Inspection Branch regarding cooperation with the Province’s continuing phytoplankton monitoring program during the period from September 1 to November 30 (see Panel 7). This is the most likely time that domoic acid will be detected in molluscan shellfish from northern and eastern PEI.

Panel 7.

MUSSEL MONITORING PROGRAM 1996

- Modifications to program following industry consultation.
- May 15 - July 15
  - spatfall prediction, meat yield, water quality weekly.
- July 15 - September 1
  - spot checks for starfish larvae, potentially-toxic phytoplankton.
- September 1 - November 30
  - potentially-toxic phytoplankton monitoring weekly in cooperation with DFO Inspection.

The Province's monitoring needs (see Panel 8), based on Industry's input, include a long-term commitment to water and meat testing. There is an opportunity for coordinating activities between the Industry, and the Provincial and Federal governments. Training is required if Industry is to take part in sample collection and analysis, e.g., the identification of toxic phytoplankton species. One of Industry's major interests is that there be better exchange of information between Industry and scientists. This could take the form of newsletters. They are interested in keeping abreast with regional, national and international issues regarding toxic algae.

Panel 8.

MONITORING NEEDS

- A long-term commitment to water and meat testing.
- Coordination between Industry, province, and federal departments.
- Industry training in sample collection and analysis.
- Information exchange
  - who is doing what, when, where, and how.

The Industry's research needs (see Panel 9) include continued phycotoxin research by DFO and NRC. Opportunities exist to make this research as cost-efficient as possible by establishing collaborations. A PEI Aquaculture and Fisheries Research Initiative fund has been established to stimulate aquaculture research. A board of directors will be selected to administer the fund and to determine who would be eligible to apply. The Aquaculture Implementation Committee's (AIC) research priority list would guide the selection procedure and distribution of funding.

Panel 9.

RESEARCH NEEDS

- Identification of key priority areas with Industry consistent with the Aquaculture Implementation Committee process.
- Collaboration to carry out research as cost-effectively as possible.
- Need for continued DFO/NRC phycotoxin research.
- Establishment of PEI Aquaculture and Fisheries Research Initiative fund.

5.5 Aquaculture Association of Nova Scotia

Paul Neima, President of the Aquaculture Association of Nova Scotia (AANS), outlined the Nova Scotia molluscan shellfish culture industry's activities and concerns regarding toxic and harmful phytoplankton. The AANS coordinates a phytoplankton monitoring program and a testing program for scallop phycotoxins. For the phytoplankton, vertically-mixed samples are collected at the grow-out sites and sent to Halifax for identification of toxic species; 496 samples were analyzed last year, up from 364 in 1994. Participation in the phytoplankton monitoring program is voluntary. However, as the program provides Industry with an early warning system for impending toxic events and indicates a toxin-free window during which product can safely be sold, producers are encouraged to participate. It is mandatory for Industry to monitor for the presence of phycotoxins in scallops marketed whole or "roe-on".

Up until last year, the phytoplankton and scallop monitoring programs were entirely funded by the government. This year, the programs faced elimination unless alternate funding could be found, with Industry prepared to pay for a portion of the cost. A survey of AANS members showed that continuation of the phytoplankton program was very important (rated 4.3 on a scale of 5.0), and that they were willing to fund a portion of the program. Similarly, the importance of the scallop monitoring program was rated 3.5 out of 5. Consequently, the AANS

applied to operate the programs for another three years and partial funding has recently been secured via the Canada-Nova Scotia Co-operation Agreement on Economic Diversification. The nominal remaining funding comes from the growers via user fees (at 10 - 20% of the sample costs). Even with these user fees, grower interest in the phytoplankton program has increased to 29 participants, up from 21 last year. There are currently 12 participants in the scallop monitoring program. The research priorities identified by the AANS are included in the list indicated by the NRC (see Panel 2).

5.6 Laurentian Region Activities

Maurice Levasseur, of DFO's Maurice Lamontagne Institute (Mont-Joli, Québec), was invited to give his perspective of the Laurentian Region's program on harmful algae. This is an effective program that integrates several researchers into one cohesive program (see Panels 10 and 11). The researchers do not spend full time with the harmful algae program, but contribute their unique expertise (e.g., on bacteria, phytoplankton, zooplankton, larval and adult fish, and remote sensing) to work on specific research questions.

Panel 10.

LAURENTIAN REGION RESEARCH PROGRAM ON HARMFUL ALGAE 1996-1997

1. Actual Status

- Research program on harmful algae since 1993

  M. Levasseur: Scientific coordinator
  J.-C. Therriault: Manager

- All activities on HAB conducted at the Maurice Lamontagne Institute (MLI) are part of the program.

- Position of the Program in the organization chart:

  Division: Ocean Productivity
  Section: Primary Production and Toxic Algae

2. Staff

Researcher: 0.5 PY (M. Levasseur)

Research Assistant: 0.5 PY (S. Michaud - HPLC analysis of PSP toxins)

Technician: 1 PY (E. Bonneau - Monitoring)

More depending on the research projects

Panel 11.

LAURENTIAN REGION RESEARCH ACTIVITIES 1996-1997

1. Monitoring of Harmful Algae (M. Levasseur, E. Bonneau)

- 11 stations are monitored on a weekly basis from May to November (see map, Appendix 11).
- PSP data (from mouse bioassays) are provided by Inspection for these stations.
- 18 potentially-harmful species are presently enumerated.
- Phytoplankton and toxicity data are published in a technical or data report each year.

2. Bacterial production of PSP toxins (M. Levasseur, G. Doucette, S. Gallacher)

- Goal: Assessment of the importance of bacteria as PSP producers in the St. Lawrence.

3. Phycotoxins and reproductive success of copepods (M. Starr, J. Runge)

The Primary Production and Toxic Algae Section of the Laurentian Region's Science Branch monitors for the presence of 18 potentially-harmful algal species at 11 stations in the St. Lawrence estuary (see Appendix 11). Samples are collected by the same contractors who sample molluscs for the Inspection Branch, and at their same sites. It is Inspection's mandate to protect the Industry by measuring the phycotoxin levels in shellfish at 80 - 90 coastal sites. The phytoplankton monitoring information is shared, on a timely basis, with the Inspection Branch. In addition, it is distributed to Industry and the scientific community via yearly technical reports.

The Science Branch monitoring program is designed not only to provide an early warning of toxic events to the Industry. It also identifies phytoplankton (e.g., *Pseudo-nitzschia multiseries, Dinophysis* spp., and ichthyotoxic *Chrysochromulina* sp. and *Gyrodinium aureolum*), whose toxins may not be detected by Inspection's mouse bioassay. In addition, it provides scientific information about bloom dynamics and the composition of harmful algae in the water column at specific locations. This information is used by Inspection to interpret unusual mouse bioassay deaths and by Industry, for example, to establish sites for depuration plants or new harvesting sites. Finally, it enables the discovery of novel harmful algae (e.g., *Gyrodinium aureolum, Alexandrium ostenfeldii*) in Laurentian Region waters.

Monitoring for toxic and harmful algae is a need identified as “critical” to the Laurentian Region (see Panel 12).

Panel 12.

LAURENTIAN REGION RESEARCH ACTIVITIES
FUTURE

Critical :

- Monitoring for toxic / harmful algae
- Algal and bacterial PSP toxin production in the St. Lawrence

  Includes work on : *Alexandrium tamarense*
  Alexandrium ostenfeldii
  Interaction with bacteria

Important :

- Phycotoxins and the reproductive success of copepods
- Phycotoxins and the survival of marine ichthyoplankton

5.7 Contributions from the Private Sector

Julie Marr (MDS Environmental Services) described the development and improvement of analytical methods for phycotoxins. Instrumental methods have been developed for ASP, DSP, and PSP toxins, and are currently in use for monitoring purposes. In addition, the company is currently working on a PSP field test kit based on the use of antibodies. A prototype kit should be available by next year.

Joanne Jellett (Jellett Biotek Ltd.) has developed a commercially-available cytotoxicity test kit, using mouse neuroblastoma cells, that can be applied to field monitoring and laboratory research on sodium channel blocking toxins (e.g., PSP toxins). The Maritime In Vitro Shellfish Test (MIST™) kit for PSP toxins is currently involved in an AOAC inter-laboratory study and international parallel testing with the mouse bioassay.

Joan Manuel (TrisMar Research Inc.) described the remote sensing capabilities that are available for monitoring phytoplankton blooms in coastal bays and estuaries. The company is providing information regarding the relevance of floc/macroaggreate dynamics to aquaculture and toxic algal blooms. It is also testing groundtruthing methodologies for bloom detection and monitoring, using CASI and RADARSAT remote sensing technologies, in collaboration with AGI Ariel Geomatics Inc. and the Institute for Marine Biosciences (IMB, Halifax).

6.0 Identification of Research and Monitoring Needs

The remainder of the Workshop was devoted to a detailed discussion of research and monitoring needs, mainly from the point of view of the aquaculture industry. This also gave other aquaculturists, who were not heard from in the morning's sessions, an opportunity to voice their opinions and concerns. Following is a summary of the major concerns expressed at the Workshop.

6.1 Needs of the Molluscan Aquaculture Industry

6.1.2 Monitoring

It was clear from this Workshop that Industry is interested in maintaining some type of phytoplankton monitoring program. The growers consider this to be a useful management tool, as it serves as an early warning system to allow them to identify toxin-free periods for harvesting and marketing product. The Industry is looking for a long-term commitment from government, and is willing to cost share for the program. Coordination of activities between Industry and government would enable monitoring programs to be more cost effective. Industry also expressed a strong requirement for the existing shellfish phycotoxin monitoring program operated by the Inspection Branch.

Industry expressed concerns regarding government vs Industry responsibility for shellfish sampling at harvesting sites and at processing plants. Although this question is not the direct concern of Science Branch, Industry pointed out that, as far as they are concerned, both Science and Inspection Branches are "government", and Industry does not make distinctions between Branches within the same government agency.

Discussions were held about who should carry out monitoring programs, be they for phytoplankton or for phycotoxins in shellfish tissue. Currently, only the provincial governments of NS and PEI are carrying out or funding (in some capacity) phytoplankton monitoring programs for Industry. In NS, Industry will start supporting a portion of costs, while the phytoplankton program in PEI is entirely funded by the province. A question was therefore raised about the need for a Science phytoplankton monitoring program (see Section 6.2.1). In the case of the Inspection Branch, it monitors for shellfish toxins, but the offshore scallop industry still pays for additional testing in NS (via MDS Environmental Services). The near-shore industry is not yet developed enough to be able to cover the costs of extra testing.

6.1.3 Development of Rapid Test Kits for Phycotoxins

Industry would like to have cheaper, more rapid methods to monitor for phycotoxins in the product at the harvesting site or plant level. Such test kits are currently being developed and tested by the private sector, with assistance from IMB, prior to commercial production. However, there was concern about total reliance on test kits and conventional chemical methods because they are specific for one or a group of phycotoxins, and others would be missed; mouse bioassays are still required to insure the detection of other toxins.

Although most of the expertise for test kit development resides within the private sector and at IMB, progress is being made by DFO Science (R. Pocklington, BIO). A project to develop test kits for domoic acid, using a colorimetric method and amperometric sensors, is proposed on page 3. Other commercially-available kits must be tested in a wide range of field and laboratory situations.

6.1.4 Depuration of Phycotoxins

Industry showed a clear need for studies on the uptake and depuration of phycotoxins by commercially-important species of molluscan shellfish. For example, a major offshore "roe-on" scallop industry has essentially ceased because of the persistence of domoic acid in the scallops. Industry believes that one way to cope with the presence of phycotoxins is to be able to depurate these toxins from the shellfish in an economic and rapid manner. They are therefore interested in identifying factors that might reduce depuration time. Jim Stewart (DFO, Dartmouth) described his research, in which bacteria appeared to degrade domoic acid within mussels but not in scallops. Other studies are required to determine the mechanisms of phycotoxin uptake and depuration on each of the commercially-important species, in order to determine the optimum time and conditions.

In the past, some of this research on phycotoxins depuration has been carried out by local scientists at DFO (K. Haya, E. Kenchington, D. Scarratt, D.V. Subba Rao, R. Pocklington), the Atlantic Veterinary College (I. Novaczek, M. Madhyastha), Dalhousie University (G. Wohlgeschaffen) and IMB (A. Cembella, D. Douglas). However, these studies are published in the scientific literature and Industry expressed the fact that they have not had access to this detailed information. It is therefore necessary to more effectively communicate these results to Industry (see Section 6.1.6).

6.1.5 Fish Kills

In the past several years, kills of aquacultured Atlantic and steelhead salmon have caused severe financial losses to growers in the Bras D'or Lakes of Cape Breton Island, NS. The mortalities are believed to be caused by several possible species of flagellated algal cells (*Mallomonas*, *Mallomonopsis*, *Chryosochromulina bergeri*). Only a minimal amount of work has been done to deal with this problem, mostly to identify the responsible algae and to examine the pathology of the fish. The Cape Breton finfish industry has therefore expressed a strong need for research in this area, in order to minimize further losses.

Similarly, past episodes of PSP toxicity have resulted in mass mortalities of Atlantic herring in the Bay of Fundy. The harmful diatoms *Leptocylindrus minimus* and *Chaetoceros convolutus*, which have killed salmon elsewhere in the world, are also found there in low numbers. Given the right conditions, these diatoms could bloom to dangerous concentrations, and should therefore continue to be monitored.

6.1.6 Communication

One area that Industry felt must be improved is in the exchange of information between Science and Industry. They would like to know "who is doing what, where and why". They indicated that regular updates are required for them to remain current. Growers do not necessarily have the time, finances or inclination to read the detailed scientific literature or to attend scientific conferences. Instead, it was suggested that scientists write general articles for existing Industry news outlets (e.g., "Atlantic Fish Farming", "Northern Aquaculture"), and for the AANS Newsletter. Alternatively, relevant material could be sent to the few shellfish processing plants, to be posted on the bulletin boards that are a common source of information for growers. Computer access is not yet wide-spread enough among growers for them to take advantage of the World Wide Web.

6.2 Needs of Science

6.2.1 Monitoring

Some of the needs of Science for phytoplankton monitoring are similar to those of Industry, but on a different time and space scale. Both are interested in knowing which toxigenic algae are present in the water, and in identifying new phycotoxins and new toxic or harmful phytoplankton species. For example, the source of the domoic acid that contaminated scallops and other shellfish on Georges Bank and along the southwest coast of NS in 1995 is still unknown. Also, we do not know the source of certain DSP toxins in Mahone Bay or Ship Harbour, NS, nor why *Dinophysis* species are not toxic in our waters. For phytoplankton monitoring to act as an Industry early-warning system, a rapid turnaround time is required to identify toxic algal species in samples collected from representative, but wide-spread geographic locations. In contrast, the sample processing time for a Science monitoring program is not as critical because a longer time scale is being considered. Nevertheless, there are examples of Science monitoring having a rapid enough turnaround time to provide a warning of toxic events in the Maritimes Region (e.g., in northern PEI and the southwest Bay of Fundy).

Science is interested in certain fundamental questions that will ultimately help Industry, for example, understanding the mechanisms of toxic bloom development and decline. This requires a multitude of ancillary information to be collected, including physical and chemical oceanographic data. Because of the large year-to-year variability in the intensity, duration and species composition of the blooms, scientific monitoring programs must be carried out for many years in order to discern long-term trends. These field programs need to be supplemented with controlled laboratory experiments, using strains of indigenous toxic algae, in order to study mechanisms of growth and toxin production. All of this information then becomes useful for predicting toxic bloom events, in part via mathematical models of blooms. Finally, Science monitoring programs can develop or adapt new tools for detecting phycotoxins or toxic phytoplankton (e.g., molecular and immunological probes), and provide advice on sampling strategies, procedures and locations in aid of Industry monitoring programs. Despite the differences in monitoring approaches, Science and Industry can mutually benefit by collaborating on sample collection and by sharing information and data.

6.2.2 Impacts of Phycotoxins on the Food Web

While most of the attention has been focused on shellfish species that accumulate the phycotoxins, the ecological impacts of these toxins on predators at other levels of the food web require additional research. Questions thus remain about their effects on zooplankton, fish larvae, and commercial finfish species. The apparent increased frequency and distribution of harmful algal blooms may have important consequences at the ecosystem level.

6.2.3 Physiology of Toxin-producing Phytoplankton

It is important to complement field work with studies on locally-isolated strains of toxic phytoplankton growing under controlled laboratory conditions. Continued research is required to study factors that influence the growth, sexuality, and toxin production of toxigenic phytoplankton, including *Pseudo-nitzschia multiseries*. Similar studies are needed for the domoic-acid-producing *P. pseudodelicatissima*, from the Bay of Fundy, and *P. seriata*, found in most of the Maritime Region. No laboratory studies have been carried out to date on the latter diatom from our waters. Whenever possible, novel harmful or toxic algae should be brought into culture, and a culture collection of these organisms should be maintained. To date, it has unfortunately been impossible for anyone in the world to culture DSP toxin-producing *Dinophysis* species. It would be especially important to be able to culture these latter organisms because species of this genus, although toxic elsewhere in the world, are, for some unknown reason, non-toxic in our waters.

6.2.4 Ballast Water Issues

The introduction of exotic toxic and harmful algal species into our coastal waters via ships' ballast water remains a constant threat to human health and to the aquaculture industry in the Maritimes Region. Other countries have mounted research programs to deal with this potentially-serious situation, and Canada should increase its efforts in this respect

6.2.5 Fungal Controls of Harmful Algal Blooms

The infestation of phytoplankton cells by fungal parasites and viruses is an important natural factor that may control the intensity of toxic algal blooms. The documented presence of oomycete and chytrid fungi in cells of *Pseudo-nitzschia multiseries* in PEI raises questions about their possible role in causing the great decrease in bloom intensity since 1991. Industry has indicated an interest in seeing that the work on *Pseudo-nitzschia* fungal parasites, initiated by DFO (J.C. Smith) and UPEI (L. Hanic), be continued.

6.3 Summary of Research and Monitoring Needs

From the above list of Industry and Science needs, it is obvious that there are a number of issues of importance to both parties. Given the recent downsizing in both funding and personnel at DFO, it is also evident that a careful selection of priorities is required in order to optimize use of the remaining resources. This selection must be made by taking into account the following factors:

- urgency of the need by DFO Science with respect to the DFO mandate
- urgency of the need by Industry
- capacity of the research budget to support the project
- availability of instrumentation and equipment to carry out the project
- expertise of the research personnel available to carry out the work
- possibility to form collaborations or partnerships between Science and Industry or other committed parties.

There was not enough time at the Workshop to prioritize the research and monitoring needs. Nevertheless, following the Workshop, the editors have taken the advice and information provided at the Workshop to identify the major requirements for scientific research on harmful algae in the Maritimes Region. Research needs to be directed at understanding:

- **Mechanisms of phytoplankton bloom dynamics that are responsible for the occurrence of toxic events.**

  This requires field, laboratory and modeling studies to determine the physical, chemical and biological factors that cause a potentially-harmful species of algae to bloom and to produce toxins in our coastal waters. Field and modeling studies are also required to monitor the distribution of these phytoplankton. Data from Industry programs for monitoring the presence of harmful species should be used and information from Science monitoring programs should be made available to Industry in a timely manner. These studies will provide information on the present distribution and on the long-term temporal and spatial trends in the occurrence of potentially-harmful algae and toxic blooms.

- **Algal production of toxins and the identification of potential natural controls on this production.**

  Laboratory studies are needed to determine the mechanisms of toxin production, the factors controlling algal growth, and to identify potential mitigating measures. This includes the identification of natural controls, such as parasitic fungi, and the presence or absence of certain essential nutrients and chemicals in concentrations critical to the control of toxic events.

- **Uptake and depuration of phycotoxins by commercially-harvested and cultured shellfish.**

Laboratory, field and modeling studies are required to determine the mechanisms of phycotoxin uptake and depuration by shellfish. This knowledge is essential for establishing responsible protocols for harvesting and marketing shellfish from areas impacted by a toxic event and for applying possible ameliorative or mitigative procedures.

- **Potential impacts of phycotoxins at the ecosystem level.**

  The scope of phycotoxin impacts needs to be evaluated at the ecosystem level. While most of the attention has been focused on the direct impact of phycotoxins human health, there is evidence that there are lethal and possibly sublethal effects on higher levels of the marine food web, with potential negative influences on commercial fisheries. With the apparent increase in frequency and distribution of toxic events, it is important that we understand their impact on the marine ecosystem. This initiative is consistent with the thrust of the new Canada Oceans Act.

In addition, Industry has identified a number of other needs with which Science may be able to assist:

- **Reliable, cheaper, more rapid, user-friendly methods are required to monitor for phycotoxins in products at the site or plant level.**

  This work is currently being conducted primarily by IMB and the private sector, and a number of products are being tested prior to commercial production. DFO should encourage this work to be continued.

- **Evaluation of sampling protocols at harvesting sites.**

  Science has a potential role in designing proper sampling protocols for obtaining representative samples of product from wild and aquaculture shellfish harvesting sites.

- **Continuation of phytoplankton monitoring by shellfish growers.**

  Shellfish growers consider phytoplankton monitoring to be a useful management tool. Science can assist by evaluating the methods being used and by providing data management capability and ensuring that all information is available to both Industry and Science.

7.0 Summary and Closing of the Workshop

In the past several years, eastern Canada has undergone a gradual, but substantial decrease in research and monitoring activities relating to harmful algal blooms and phycotoxins. This is in part due to budgetary and personnel reductions accompanying Program Review, but it may also reflect a perceived decrease in toxic algal bloom events, especially in eastern PEI. We

must not become complacent, however. These toxic blooms occur in cycles and it is just a matter of time when they, or other novel bloom species, will return. Continued vigilance is warranted, as closures of harvesting areas due to phycotoxins have occurred along the southwest coast of NS, the Bay of Fundy, the Baie des Chaleurs, and northern PEI within the past several years.

Prior to this Workshop, the notion had generally been held that the aquaculture industry had resigned itself, for the most part, to simply having to cope with the inevitable presence of phycotoxins. One grower summed it up in this way: "There's death, taxes and toxins". However, those Industry representatives present at the Workshop expressed a strong need to have research and monitoring continue. In a recent survey carried out by K. Freeman (DFO, Halifax), the presence of phycotoxins was indicated as the second highest biological concern of the growers responding (66.7%; n = 21), after "predation", and tying with "mussel drop-off" (see Appendix 12). Interestingly, "high producers" had a greater concern about phycotoxins than "low producers".

At a time when other countries are increasing their phycotoxin research and monitoring programs, including the training of phytoplankton taxonomists, Canada is tending to decrease its efforts, after having been considered a leader in this area for the past several years. Fortunately, there remains a core of interest and expertise in the Maritimes Region. The challenge is to be able to focus the remaining resources on top priority areas, as identified during this Workshop. This will be all the more effective if federal and provincial agencies, along with the aquaculture industry, can pool their efforts to collaborate on common problems.

Appendix 1. Workshop agenda.

Workshop on
Harmful Algae Monitoring and Research
in the DFO Maritimes Region

Wednesday, June 19, 1996

Fisheries and Oceans Canada

Gulf Fisheries Centre, 343 Archibald St.

Miramichi Room (544)

Moncton, New Brunswick

WORKSHOP OBJECTIVES:

- Exchange information about current and planned levels of activity regarding harmful algae monitoring and research.
- Prioritize research activities for the DFO Science Branch, Maritimes Region, taking into account concerns of the aquaculture industry and current or future resources.
- Develop partnerships with other government agencies, universities, and industry, in order to optimize limited resources and to focus on essential elements.

PROVISIONAL AGENDA

09:30 - 09:35	Opening of the Workshop	J.S. Loch (DFO, Science)
09:35 - 09:40	Introductory remarks by Co-Chairs	Stephen Bates (DFO, Moncton) Paul Keizer (DFO, Dartmouth)

Reports on Research / Monitoring Interests and Activities

09:40 - 09:50	DFO Science Branch	Kats Haya (DFO, St. Andrews)
09:50 - 10:00	DFO Inspection Branch	Edmond Arsenault (DFO, Moncton)

10:00 - 10:10 National Research Council of Canada Allan Cembella (IMB, Halifax)

10:10 - 10:30 **Coffee Break**

10:30 - 10:40 PEI Dept. of Agriculture, Fisheries & Forestry Neil MacNair

10:40 - 10:50 Aquaculture Association of Nova Scotia Paul Neima

10:50 - 11:00 Laurentian Region Activities Maurice Levasseur (DFO, Mt.-Joli)

General Discussion on Research / Monitoring Interests and Activities

11:00 - 12:00 Some items to consider: Paul Keizer, Facilitator

- Interests of other aquaculturists
- Interests of other government agencies
- Interests of Universities and the private sector
- Response to harmful algal bloom events

12:00 - 13:00 **Lunch Break**

Discussion of Research / Monitoring Priorities

13:00 - 14:30 Some items to consider: Stephen Bates / Paul Keizer, Facilitators

- Need for / purpose of phytoplankton monitoring
- Regional phytoplankton monitoring coverage
- Alternative approaches to harmful algal bloom monitoring
- "Targeted" vs. "Longer-term" research
- Role of government vs. private industry
- Role of university research
- Collaborations and partnerships

14:30 - 15:00 **Coffee Break**

Prioritization of Research / Monitoring Activities

15:00 - 16:15 Generation of a list of research / monitoring priorities for DFO Science

- "Critical / essential"
- "Important / longer-range"
- "Desirable"

16:15 - 16:30 Wrap-up Discussion John Pringle (DFO, Dartmouth)

16:30 Closing of the Workshop

Appendix 2. Workshop participants.

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Appendix 3. Prince Edward Island PSP sampling sites visited by DFO Inspection; 1996/97 fiscal year. Sites visited year round are shown in bold.

Area	Sampling Location	Sampling Frequency	Species
1J	Mill River	wk- mid May to Sep; ev 2 wk- Oct & Nov	Mussels/Soft shell clams
2A/3A	Outside Shore Gulf	wk- July & Aug; ev 2 wk- June & Sep	Bar clams
2B	Malpeque Bay -Lennox Channel	wk- mid May to Sep; ev 2 wk- Oct & Nov	Oysters
2K	**Malpeque Bay -Mar Water**	**ev 2 wk yearly**	**Mussels**
2H	Grand River	ev 2 wk- May to Oct	Clams/Oysters
2L	**Darnley Basin**	**wk- June to Sep; ev 2 wk- Oct to May**	**Mussels/Soft shell clams**
3E	**New London Bay**	**wk- June to Sep; ev 2 wk- Oct to May**	**Mussels**
3F/3I	Rustico Bay	ev 2 wk- May to Oct	Soft shell clams/Mussels
3M	**Tracadie Bay**	**wk- June to Sep; ev 2 wk- Oct to May**	**Mussels**
4C	**St. Peter's Bay**	**wk- June to Sep; ev 2 wk- Oct to May**	**Mussels**
5E	Souris River	wk- mid May to Sep; ev 2 wk- Oct	Mussels/Soft shell clams
5G	Rollo Bay	wk- mid May to Sep; ev 2 wk- Oct	Soft shell clams
5K	**Boughton River**	**wk- June to Sep; ev 2 wk- Oct to May**	**Mussels**
5N	**Cardigan River**	**wk- June to Sep; ev 2 wk- Oct to May**	**Mussels**
5O/5P	**Brudenell & Montague Rivers**	**wk- June to Sep; ev 2 wk- Oct to May**	**Mussels**
5Q	**St. Mary's Bay**	**wk- June to Sep; ev 2 wk- Oct to May**	**Mussels**
5T	**Murray River**	**wk- June to Sep; ev 2 wk- Oct to May**	**Mussels**
6C	Pinette River	wk- July to Sep; ev 2 wk- May, June, Oct	Soft shell clams
7C	Orwell River	wk- July to Sep; ev 2 wk- May, June, Oct	Soft shell clams/Oysters
7F	East River	wk- July to Sep; ev 2 wk- May, June, Oct	Oysters/Soft shell clams
7G	North River	wk- June; ev 2 wk- May & July	Oysters
7I	West River	ev 2 wk- June to Oct	Mussels
9C/9D	Summerside Hrb./Wilmot River	wk- mid May to mid Oct	Oysters/Soft shell clams
9G	Percival River	wk- mid May to mid Oct	Mussels/Quahaugs
9I/9H	Northumberland Strait	wk- mid June to Aug	Bar clams

Appendix 4. New Brunswick PSP sampling sites visited by DFO Inspection; 1996/97 fiscal year. Sites visited year round are shown in bold.

Area	Sampling Location	Sampling Frequency	Species
NB 2B	Pointe Verte	wk-May to mid Nov	Mussels
NB 2G	Stonehaven	wk-May to mid Nov	Mussels
NB 3B	Rue Pinet	wk-May to mid Nov	Clams/Oysters
NB 3E	Baie St Simon Nord	wk-May to mid Nov	Clams
NB 3H	Baie De Lameque	wk-May to mid Nov	Mussels/Clams
NB 3M	Chiasson Office	wk-May to mid Nov	Clams
NB 4A	Wishart Point	wk-May to mid Nov	Mussels/Oysters
NB 4D	Ile Portage / Neguac	wk-May to mid Nov	Oysters
NB 4F	Bay Du Vin	wk-May to Nov	Oysters
NB 4G	Egg Island	wk-May to Nov	Oysters
NB 4H	**Baie Ste Anne**	**wk-May to Mar**	**Mussels**
NB 5D	Cap St Louis (Kouchibouguac)	wk-May to Nov	Oysters
NB 5E	Richibucto Harbour	wk-May to Nov	Mussels
NB 6D	Bouctouche Harbour	wk-May to Nov	Mussels/Oysters
NB 6F	**Cocagne Harbour**	**wk-May to Nov; ev 2 wk-Dec to Mar**	**Clams**
NB 7B	**Shediac Bay**	**wk-May to Nov; ev 2 wk-Dec to Mar**	**Mussels**
NB 7G	Amos Point	wk-May to Nov	Mussels
NB 7K	Baie Verte	wk-May to Nov	Mussels
NB09A	**Lepreau Basin**	**wk-May to Nov; ev 2 wk-Dec to Mar**	**Clams**
NB09A	**Lepreau Basin**	**ev 2 wk-May to Nov; monthly-Dec to Mar**	**Mussels**
NB10A	**Lepreau Harbour**	**wk-May to Oct; monthly-Nov to Apr**	**Clams**
NB13A	Crow Harbour	ev 2 wk-mid May to mid Sep	Clams
NB13B	**Red Head Harbour**	**wk-Apr to Nov; ev 2 wk-Dec to Mar**	**Clams**
NB14B	Simmons Cove	ev 2 wk-June to Aug	Clams
NB14C	Hills Island	ev 2 wk-mid Apr to mid Nov	Clams
NB15A	**Letete Passage**	**wk-May to Oct; monthly Nov to Apr**	**Clams**
NB16B	**Bar Road**	**wk-May to Oct; monthly Nov to Apr**	**Clams**
NB16A	**Bar Road**	**ev 2 wk-May to Oct; monthly Nov to Apr**	**Mussels**
NB17A	Clam Cove	wk-June to Sep	Clams
NB17B	Deep Cove	ev 2 wk-May to Oct	Clams
NB17C	**Duck Cove**	**wk-May to Oct; monthly Nov to Apr**	**Clams**
NB17D	**Stuart Town**	**wk-May to Oct; monthly Nov to Apr**	**Clams**
NB17E	Harbour Delute	ev 2 wk-mid June to mid Oct	Clams
NB18A	**Northern Harbour**	**wk-May to Oct; monthly Nov to Apr**	**Clams**
NB19A	Ingalls Head	wk-mid May to Sep	Clams
NB19B	**Cheneys Passage**	**ev 2 wk-June to Nov; monthly Apr & May**	**Mussels**
NB19C	**Ross Island Thor.**	**wk-Apr to Oct; ev 2 wk-Nov to Mar**	**Clams**
NB19C	Nantucket Island	ev 2 wk-Apr to Oct	Clams
NB19E	**Woodwards Cove**	**wk-Apr to Mar**	**Clams**
NB19F	**Cow Passage**	**wk-Apr to Nov; ev 2 wk Dec to Mar**	**Clams**
NB16A	Magaguadavic River	ev 2 wk-mid May to mid Oct	Clams
NB16C	Oak Bay	wk-June to Sep; monthly May & Oct	Clams

Appendix 5. (Part 1) Nova Scotia PSP sampling sites visited by DFO Inspection; 1996/97 fiscal year. Sites visited year round are shown in bold.

Area	Sampling Location	Sampling Frequency	Species
NS # 01	Pugwash River	ev 2 wk-mid Apr to mid Dec	Oysters
NS # 01	Wallace River	ev 2 wk-mid Apr to mid Dec	Mussels
NS # 02	Tatamagouche Bay	ev 2 wk-mid Apr to mid Dec	Mussels
NS # 02	Caribou Harbour	ev 2 wk-mid Apr to mid Dec	Mussels
NS # 03	Merigomish	ev 2 wk-mid Apr to mid Dec	Mussels
NS # 03	Little Harbour	ev 2 wk-mid Apr to mid Dec	Mussels
NS # 04	Havre Boucher	ev 2 wk-mid Apr to mid Dec	Mussels
NS # 04	Port Hood	ev 2 wk-mid Apr to mid Dec	Mussels
NS # 04	Long Pond	ev 2 wk-mid Apr to mid Dec	Mussels
NS # 06	North Harbour	ev 2 wk-June to Sep; monthly-Apr, May, Oct, Nov & Dec	Mussels
NS # 06	Jersey Cove	ev 2 wk-May to Oct; monthly-Apr, Nov & Dec	Mussels
NS # 07	Big Harbour	ev 2 wk-June to Oct; monthly-Apr, May, Nov & Dec	Mussels
NS # 07	Evan's Island	monthly-Apr to Dec	Mussels/Oysters
NS # 08	Main-A-Dieu	monthly-Apr to Dec	Mussels
NS # 08	Fourchu	monthly-Apr to Dec	Mussels/Clams
NS # 08	Morien Bay	monthly-Apr to Dec	Mussels/Clams
NS # 09	Lennox Passage	ev 2 wk-mid Apr to mid Nov; monthly-Dec	Mussels
NS # 09	West Arichat	monthly-Apr to Dec	Mussels/Clams
NS # 10	Whitehead	ev 2 wk-May to Sep; monthly-Apr, Oct to Dec	Mussels
NS # 10	Guysborough	monthly-Apr to Dec	Mussels
NS # 11	Country Harbour	wk-May to Oct; monthly-Apr, Nov & Dec	Mussels/Scallops
NS # 11	Marie Joseph	monthly-Apr to Dec	Mussels
NS # 11	Pope's Harbour	ev 2 wk-May to Sep; monthly-Apr, Oct to Dec	Mussels
NS # 11	Ship Harbour	wk-May to Oct; monthly-Apr, Nov & Dec	Mussels/Scallops
NS # 11	West Jeddore	monthly-Apr to Dec	Mussels/Clams
NS # 12	Pleasant Point	wk-May to July; ev 2 wk-Aug to Oct; monthly-Apr, Nov & Dec	Mussels
NS # 12	Chezzetcook	ev 2 wk-May to Sep; monthly-Apr, Oct to Dec	Mussels/Clams
NS # 13	Sambro (Basin)	ev 2 wk-May to Oct; monthly-Apr, Nov & Dec	Mussels
NS # 13	Blind Bay	wk-May to Oct; monthly-Apr, Nov & Dec	Mussels/Scallops
NS # 13	Perrang Cove	ev 2 wk-May to Oct; monthly-Apr, Nov & Dec	Mussels
NS # 20	Five Islands	ev 2 wk-May to Oct; monthly-Apr, Nov & Dec	Mussels/Clams

Appendix 5. (Part 2) Nova Scotia PSP sampling sites visited by DFO Inspection; 1996/97 fiscal year. Sites visited year round are shown in bold.

Area	Sampling Location	Sampling Frequency	Species
NS #19	Hampton	monthly-July to Oct	Mussels
NS #19	Parker's Cove	monthly-July to Nov	Mussels
NS #17	**Centreville**	**ev 2 wk-Apr to Oct; monthly-Nov to Mar**	**Mussels**
NS #17	**Culloden**	**ev 2 wk-May to Nov; monthly-Dec to Apr**	**Mussels**
NS #18	Smith's Cove	ev 2 wk-June to Oct; monthly-Apr, May, Nov & Dec	Clams
NS #18	Joggins	ev 2 wk-May to Oct; monthly-Apr, Nov & Dec	Clams
NS #18	Thorne's Cove	ev 2 wk-July & Aug	Clams
NS #18	Deep Brook	ev 2 wk-July & Aug	Clams
NS #18	Rattling Beach	wk-June to mid Sep	Clams/Mussels
NS #16	New Edinburgh	wk- June to Sep; ev 2 wk-May & Oct; monthly-Nov	Mussels
NS #16	Belliveau Cove	ev 2 wk-July to Sep; monthly-June & Oct	Mussels
NS #16	Grosses Coques	ev 2 wk-July to Sep; monthly-June	Mussels
NS #16	Little Brook	ev 2 wk-Sep; monthly-June & Aug	Mussels
NS #16	Meteghan	monthly-June to Oct	Clams
NS #16	Henderson's Brook	ev 2 wk-July; monthly-Sep	Razor clams
NS #16	Timpany Lane	monthly-June, Aug & Sep	Clams
NS #17	Freeport	monthly-July, Aug & Oct	Clams
NS #16	Yarmouth Bar	monthly-May to Aug; ev 2 wk Sep	Clams
NS #15	Cook's Beach	monthly-Apr to Oct	Clams
NS #15	Argyle	monthly-May to Oct	Mussels
NS #15	Pubnico	monthly-June to Oct	Mussels
NS #15	Lobster Bay Aquaculture	wk-Aug to Dec; ev 2 wk-July	Belon/Scallops
NS #15	Dr.'s Cove	monthly-June to Sep	Mussels
NS #15	Newellton	monthly-June to Sep	Mussels
NS #15	Sebim Beach	monthly-June to Sep	Clams
NS #15	Smithville	monthly-June to Aug	Mussels
NS #15	Sandy Point	ev 2 wk-May to Sep	Mussels
NS #15	Cranes Point	monthly-June to Sep	Mussels
NS #15	McNutts Island	ev 2 wk-July; monthly-Aug	Mussels
NS #15	Jordan Bay	monthly-June to Sep	Mussels
NS #14	Jones Harbour	monthly-May to Sep	Mussels
NS #14	Little Harbour Lake	ev 2 wk-Apr to Aug; wk-Sep & Oct	Clams
NS #14	Offshore	wk-May to Oct	Clams
NS #14	Port Mouton	monthly-May to Oct	Mussels
NS #14	Port Medway	ev 2 wk-May to Sep	Mussels
NS #13	Dublin	monthly-May to Sep	Mussels
NS #13	Indian Point Marine Farms	wk-Apr to Dec	Mussels/Scallops
NS #13	Mahone Bay East	wk-May to Nov	Mussels/Scallops

Appendix 6. Prince Edward Island ASP sampling sites visited by DFO Inspection; 1996/97 fiscal year. Sites visited year round are shown in bold.

Area	Sampling Location	Sampling Frequency	Species
1J	Mill River	wk-Sep to Nov	Mussels/Soft shell clams
2B	Malpeque Bay -Lennox Channel	wk-Sep to Nov	Oysters
2K	**Malpeque Bay -March Water**	**ev 2 wk-May to Mar**	**Mussels**
2H	Grand River	ev 2 wk-Sep & Oct	Clams/Oysters
2L	**Darnley Basin**	**wk-Sep & Nov; ev 2 wk-May to Aug & Dec to Mar**	**Mussels/Soft shell clams**
3E	**New London Bay**	**wk-Sep & Nov; ev 2 wk-mid Apr to Aug & Dec to Mar**	**Mussels**
3F/3I	Rustico Bay	ev 2 wk-July to Nov	Soft shell clams/ Mussels
3M	**Tracadie Bay**	**wk-Sep to Nov; ev 2 wk-May to Aug & Dec to Mar**	**Mussels**
4C	St. Peter's Bay	wk-Sep to Nov; ev 2 wk-July, Aug, & Dec	Mussels
5E	Souris River	wk-Sep to mid Nov	Mussels/Soft shell clams
5G	Rollo Bay	wk-Sep to mid Nov	Soft shell clams
5K	Boughton River	wk-Sep to Nov; ev 2 wk-July & Aug	Mussels
5N	**Cardigan River**	**wk-Sep to Nov; ev 2 wk-Mid Apr to Aug & Dec to Mar**	**Mussels**
5O/5P	**Brudenell & Montague Rivers**	**wk-Sep to Nov; ev 2 wk-Mid Apr to Aug & Dec to Mar**	**Mussels**
5Q	**St. Mary's Bay**	**wk-Sep to Nov; ev 2 wk-Mid Apr to Aug & Dec to Mar**	**Mussels**
5T	Murray Rivers	wk-Sep to mid Dec	Mussels
6C	Pinette River	wk-Sep to mid Nov	Soft shell clams
7C	Orwell River	wk-Sep to mid Nov	Soft shell clams/Oysters
7F	East River	wk-Sep to mid Nov	Oysters/Soft shell clams
7I	West River	ev 2 wk-Sep to Nov	Mussels
9C/9D	Summerside Hrb./Wilmot River	wk-Sep to mid Oct	Oysters/Soft shell clams
9G	Percival River	wk-Sep; ev 2 wk-Oct & Nov	Mussels/Quahaugs

Appendix 7. New Brunswick ASP sampling sites visited by DFO Inspection; 1996/97 fiscal year. Sites visited year round are shown in bold.

Area	Sampling Location	Sampling Frequency	Species
NB 2B	Pointe Verte	ev 2 wk-mid May to Nov except wk Oct	Mussels
NB 2G	Stonehaven	ev 2 wk-mid May to Nov except wk Oct	Mussels
NB 3B	Rue Pinet	ev 2 wk-mid May to Nov except wk Oct	Clams/Oysters
NB 3E	Baie St Simon Nord	ev 2 wk-mid May to Nov except wk Oct	Clams
NB 3H	Baie De Lameque	ev 2 wk-mid May to Nov except wk Oct	Mussels/Clams
NB 3M	Chiasson Office	ev 2 wk-mid May to Nov except wk Oct	Clams
NB 4A	Wishart Point	ev 2 wk-mid May to Nov except wk Oct	Mussels/Oysters
NB 4D	Ile Portage / Neguac	ev 2 wk-mid May to Nov except wk Oct	Oysters
NB 4F	Bay Du Vin	ev 2 wk-May to Nov except wk Oct	Oysters
NB 4G	Egg Island	ev 2 wk-May to Nov except wk Oct	Oysters
NB 4H	**Baie Ste Anne**	**ev 2 wk-mid May to Mar except wk Oct**	**Mussels**
NB 5D	Cap St Louis (Kouchibouguac)	ev 2 wk-mid May to Nov except wk Oct	Oysters
NB 5E	Richibucto Harbour	ev 2 wk-mid May to Nov except wk Oct	Mussels
NB 6D	Bouctouche Harbour	ev 2 wk-mid May to Nov except wk Oct	Mussels/Oysters
NB 6F	Cocagne Harbour	ev 2 wk-mid May to Nov except wk Oct	Clams
NB 7B	**Shediac Bay**	**ev 2 wk-mid May to Mar except wk Oct**	**Mussels**
NB 7G	Amos Point	ev 2 wk-mid May to Dec except wk Oct	Mussels
NB 7K	Baie Verte	ev 2 wk-mid May to Nov except wk Oct	Mussels
NB09A	Lepreau Basin	ev 2 wk-May to Nov; monthly-Dec to Apr	Mussels
NB10A	**Lepreau Harbour**	**ev 2 wk-May to Oct; monthly-Nov & Apr**	**Clams**
NB15A	**Letete Passage**	**wk-May to Oct; monthly Nov to Apr**	**Clams**
NB16B	**Bar Road**	**ev 2 wk-May to Oct; monthly Nov to Apr**	**Clams**
NB16A	**Bar Road**	**ev 2 wk-May to Oct; monthly Nov to Apr**	**Mussels**
NB17C	**Duck Cove**	**wk-May to Oct; monthly Nov to Apr**	**Clams**
NB17D	**Stuart Town**	**wk-May to Oct; monthly Nov to Apr**	**Clams**
NB19B	Cheneys Passage	ev 2 wk-June to Oct; monthly Apr, May & Nov	Mussels
NB19C	Ross Island Thor.	monthly Dec to Mar	Clams

Appendix 8. (Part 1) Nova Scotia ASP sampling sites visited by DFO Inspection; 1996/97 fiscal year.

Area	Sampling Location	Sampling Frequency	Species
NS # 01	Pugwash River	ev 2 wk-Oct & Nov; monthly-Apr to Aug & Dec	Oysters
NS # 01	Wallace River	ev 2 wk-Oct & Nov; monthly-Apr to Aug & Dec	Mussels
NS # 02	Tatamagouche Bay	ev 2 wk-Oct & Nov; monthly-Apr to Aug & Dec	Mussels
NS # 02	Caribou Harbour	ev 2 wk-Oct & Nov; monthly-Apr to Aug & Dec	Mussels
NS # 03	Merigomish	ev 2 wk-Oct & Nov; monthly-Apr to Aug & Dec	Mussels
NS # 03	Little Harbour	ev 2 wk-Oct & Nov; monthly-Apr to Aug & Dec	Mussels
NS # 04	Havre Boucher	ev 2 wk-Oct & Nov; monthly-Apr to Aug & Dec	Mussels
NS # 04	Port Hood	ev 2 wk-Oct & Nov; monthly-Apr to Aug & Dec	Mussels
NS # 04	Long Pond	ev 2 wk-Oct & Nov; monthly-Apr to Aug & Dec	Mussels
NS # 06	North Harbour	monthly-Apr to Dec	Mussels
NS # 06	Jersey Cove	monthly-Apr to Dec	Mussels
NS # 07	Big Harbour	monthly-Apr to Dec	Mussels
NS # 07	Evan's Island	monthly-Apr to Dec	Mussels/Oysters
NS # 08	Main-A-Dieu	monthly-Apr to Dec	Mussels
NS # 08	Fourchu	monthly-Apr to Dec	Mussels/Clams
NS # 08	Morien Bay	monthly-Apr to Dec	Mussels/Clams
NS # 09	Lennox Passage	monthly-Apr to Dec	Mussels
NS # 09	West Arichat	monthly-Apr to Dec	Mussels/Clams
NS # 10	Whitehead	monthly-Apr to Dec	Mussels
NS # 10	Guysborough	monthly-Apr to Dec	Mussels
NS # 11	Country Harbour	ev 2 wk-May to Oct; monthly-Apr, Nov & Dec	Mussels/Scallop
NS # 11	Marie Joseph	monthly-Apr to Dec	Mussels
NS # 11	Pope's Harbour	monthly-Apr to Dec	Mussels
NS # 11	Ship Harbour	ev 2 wk-May to Oct; monthly-Apr, Nov & Dec	Mussels/Scallop
NS # 11	West Jeddore	monthly-Apr to Dec	Mussels/Clams
NS # 12	Pleasant Point	monthly-Apr to Dec	Mussels
NS # 12	Chezzetcook	monthly-Apr to Dec	Mussels/Clams
NS # 13	Sambro (Basin)	monthly-Apr to Dec	Mussels
NS # 13	Blind Bay	ev 2 wk-May to Oct; monthly-Apr, Nov & Dec	Mussels/Scallop
NS # 20	Five Islands	monthly-Apr to Dec	Mussels/Clams

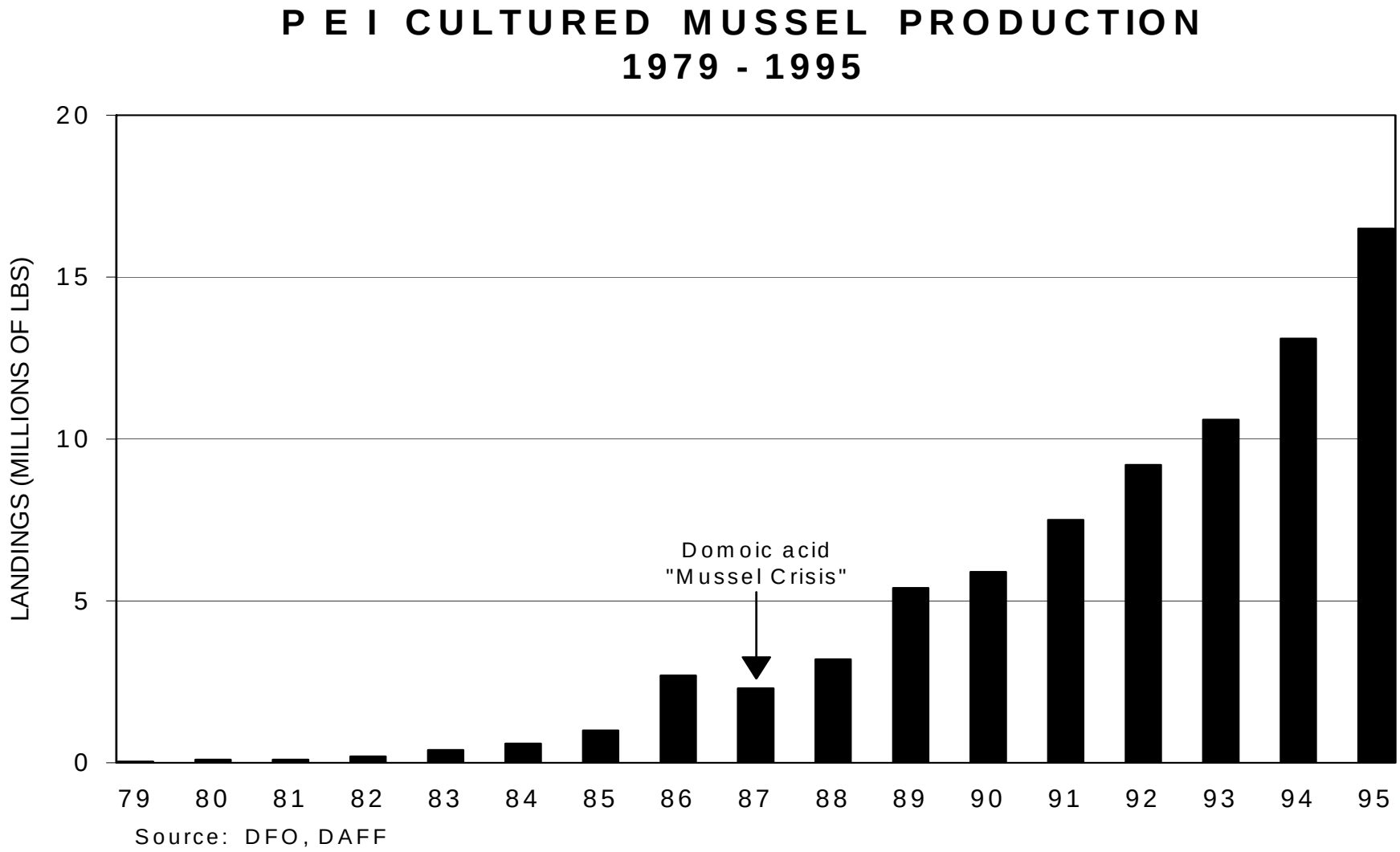
Appendix 8. (Part 2) Nova Scotia ASP sampling sites visited by DFO Inspection; 1996/97 fiscal year. Sites visited year round are shown in bold.

Area	Sampling Location	Sampling Frequency	Species
NS #19	Hampton	monthly-Aug to Oct	Mussels
NS #19	Parker's Cove	monthly-July to Nov	Mussels
NS #17	**Centreville**	**ev 2 wk-Apr to Sep; monthly-Nov to Mar**	**Mussels**
NS #17	**Culloden**	**monthly-Apr to Mar**	**Mussels**
NS #18	Smith's Cove	monthly-Apr to Dec	Clams
NS #18	Joggins	monthly-Apr to June & Sep to Dec	Clams
NS #18	Rattling Beach	monthly-June to Aug	Clams/Mussels
NS #16	New Edinburgh	ev 2 wk-May to Sep; monthly-Apr & Nov	Mussels
NS #16	Belliveau Cove	monthly-July & Oct	Mussels
NS #16	Grosses Coques	ev 2 wk-Sep; monthly-June	Mussels
NS #16	Little Brook	monthly-Aug & Sep	Mussels
NS #16	Meteghan	monthly-July to Sep	Clams
NS #16	Timpany Lane	monthly-June & Aug	Clams
NS #16	Yarmouth Bar	ev 2 wk Sep	Clams
NS #15	Cook's Beach	monthly-Apr to Aug	Clams
NS #15	Argyle	monthly-May	Mussels
NS #15	Pubnico	monthly-June, July & Sep	Mussels
NS #15	Lobster Bay Aquaculture	wk-Aug to Dec; ev 2 wk-July	Belon/Scallops
NS #15	Dr.'s Cove	monthly-Aug & Sep	Mussels
NS #15	Newellton	monthly-June, July & Sep	Mussels
NS #15	Smithville	monthly-June & July	Mussels
NS #15	Sandy Point	monthly-May to Sep	Mussels
NS #15	Cranes Point	monthly-June & July	Mussels
NS #14	Jones Harbour	monthly-May	Mussels
NS #14	Little Harbour Lake	ev 2 wk-Apr to Aug; wk-Sep & Oct	Clams
NS #14	Offshor	wk-May to Oct	Clams
NS #14	Port Mouton	monthly-May to Aug	Mussels
NS #14	Port Medway	monthly-May to Sep	Mussels
NS #13	Dublin	monthly-May, Aug & Sep	Mussels
NS #13	Indian Point Marine Farms	ev 2 wk-Apr to Dec	Mussels/Scallops
NS #13	Mahone Bay East	wk-May to Nov	Mussels/Scallops

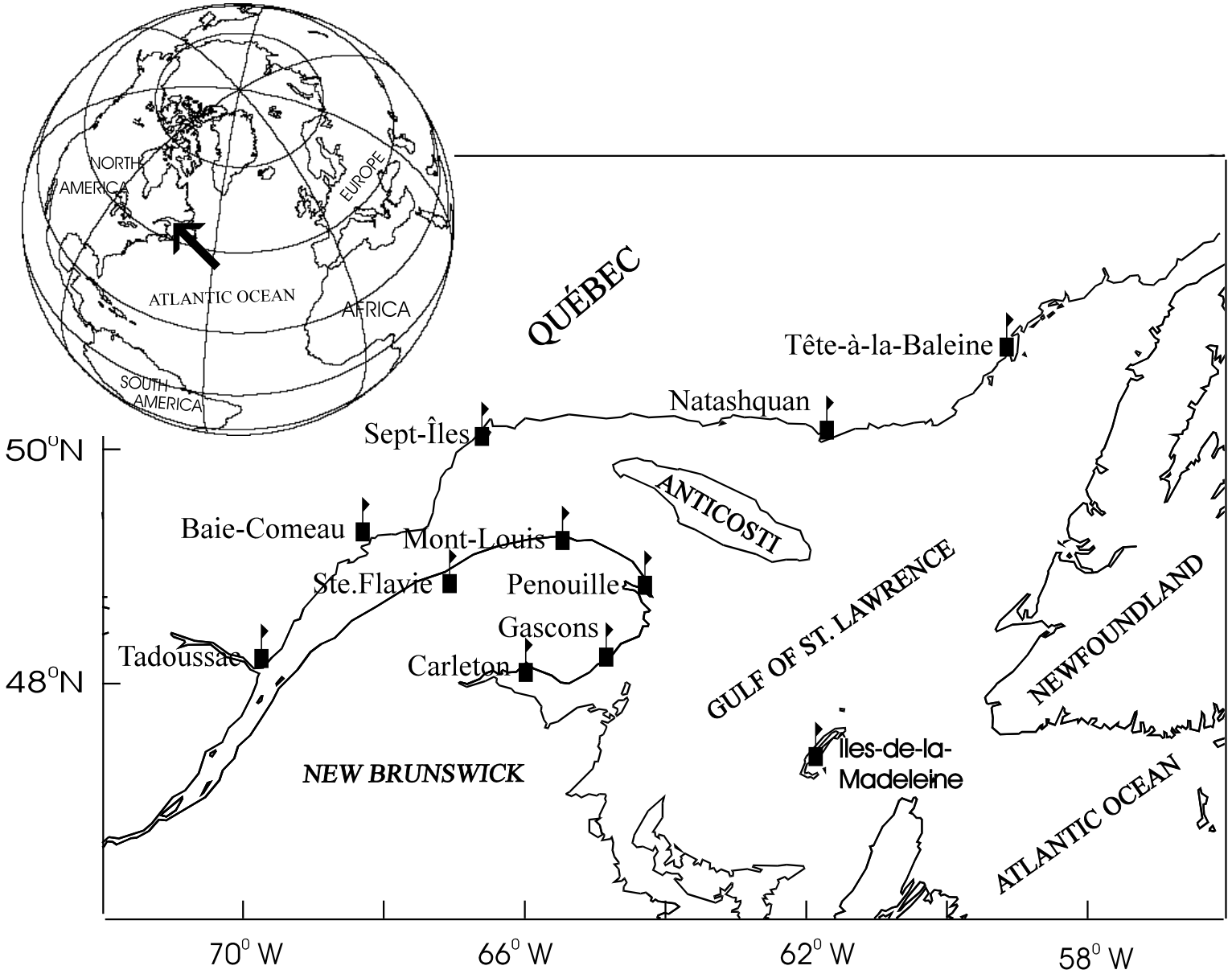
Appendix 9. Maritimes DSP sampling sites visited by DFO Inspection; 1996/97 fiscal year.

Area	Sampling Location	Sampling Frequency	Species
NS # 11	Ship Harbour	wk-May to Oct; ev 2 wk-Nov; monthly Apr & Dec	Mussels/Scallops
NS # 13	Blind Bay	wk-May to Oct; ev 2 wk-Nov; monthly Apr & Dec	Mussels/Scallops
NS # 13	Indian Point	wk-May to mid Nov	Mussels
NS # 15	Cook's Beach	ev 2 wk-June to Oct	Clams
NS # 18	Moose River	ev 2 wk-June to Oct	Mussels
NB 3B	Rue Pinet	ev 2 wk-Jul to Nov	Clams/oysters

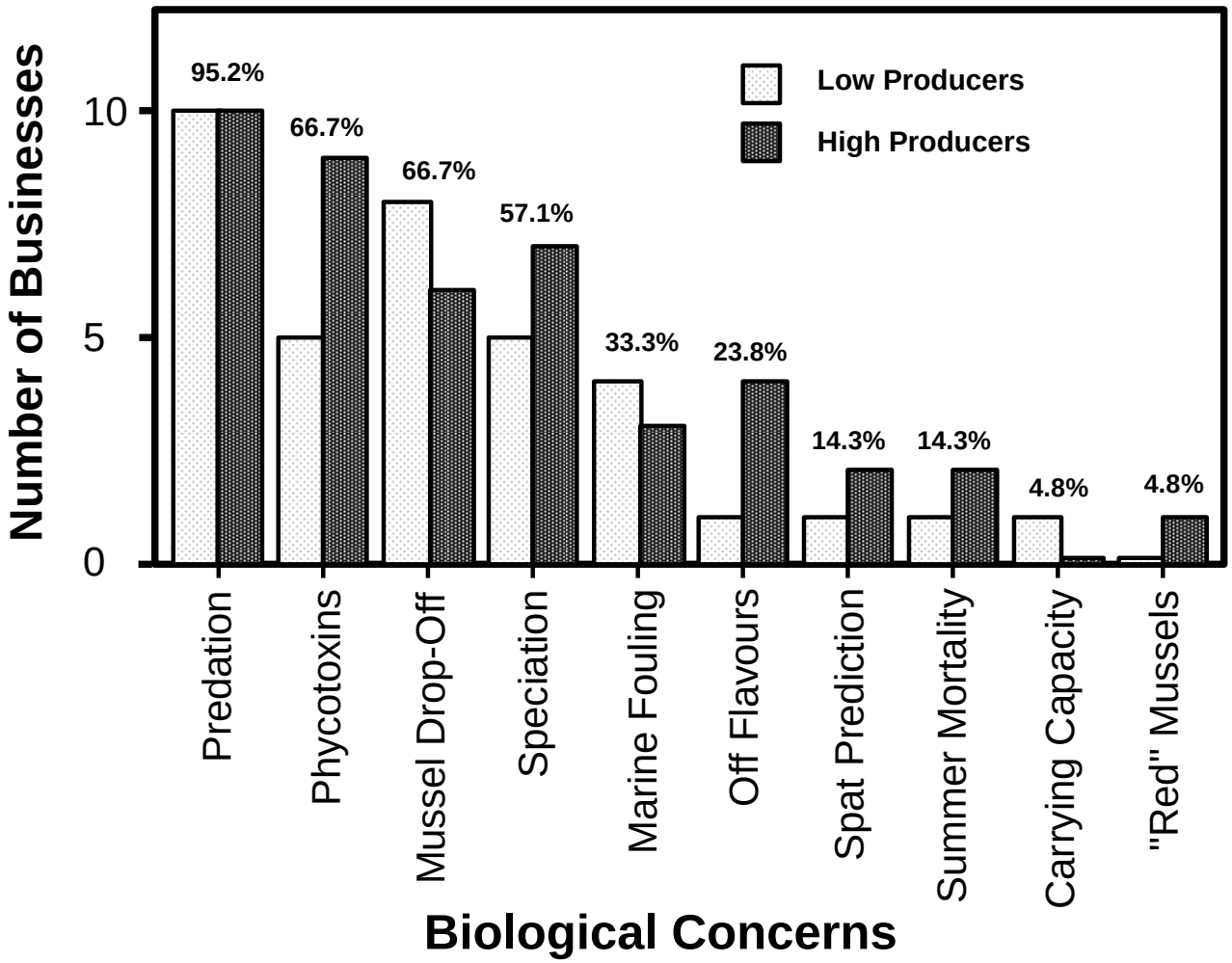
Appendix 10. PEI cultured mussel production; 1979 - 1995.



Appendix 11. Phytoplankton monitoring sites sampled by the Maurice Lamontagne Institute, Laurentian Region.



Appendix 12. Biological concerns of High and Low producers of molluscan shellfish (21 businesses). Percentages of businesses concerned for combined Low and High Producers above double bars.



Source: K.R. Freeman. 1996. An examination of biological and other factors affecting mussel aquaculture development in the Scotia-Fundy Region of Nova Scotia. Can. Tech. Rep. Fish. Aquat. Sci. 2125.