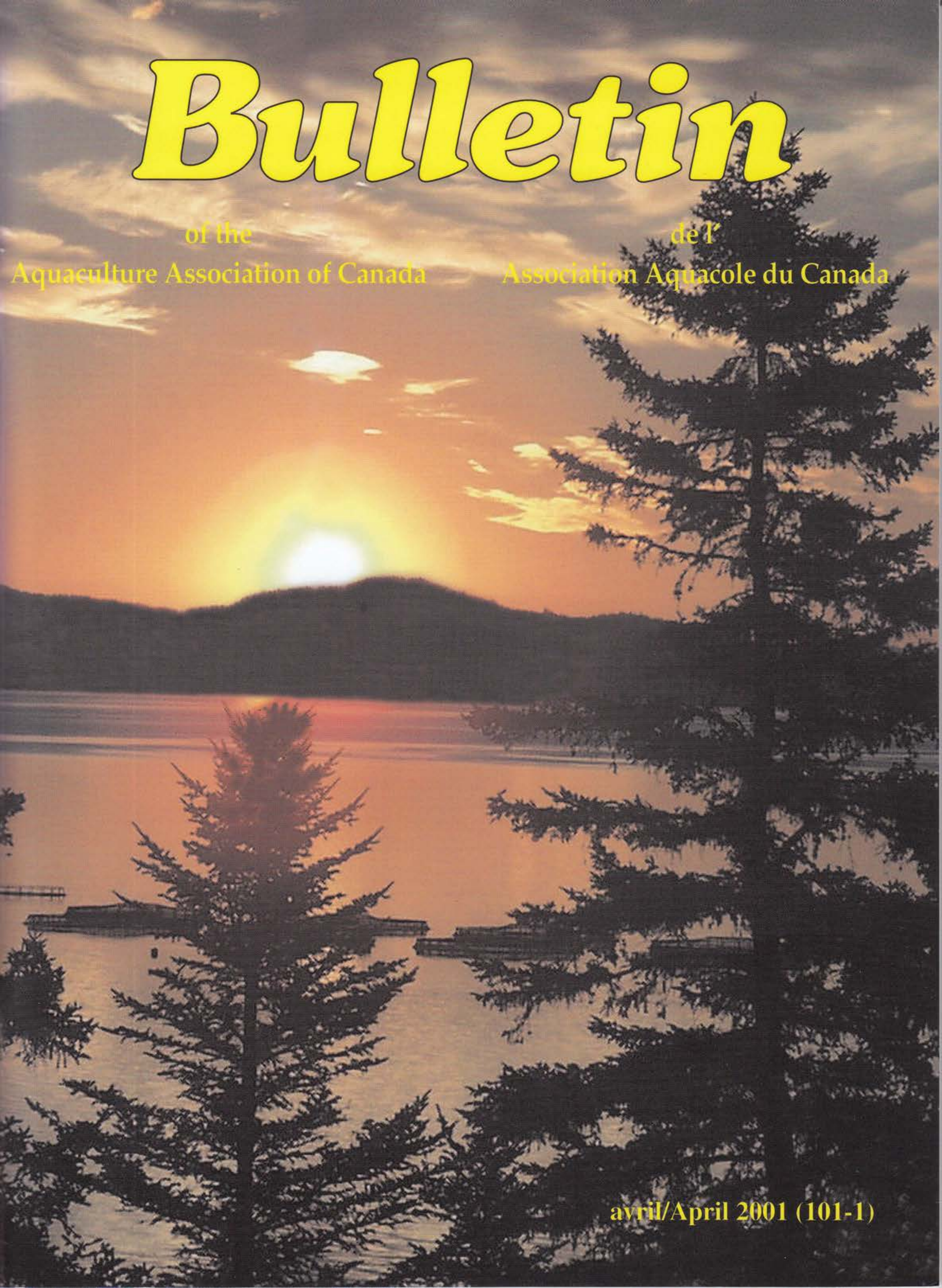
# Bulletin

of the
Aquaculture Association of Canada

de l'
Association Aquacole du Canada



avril/April 2001 (101-1)

# Bulletin de l'Association aquacole du Canada

**avril 2001 (101-1)**

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***Cover:*** *Partial solar eclipse as the sun rises in the heart of eastern Canada's Atlantic salmon culture industry. Net pens such as these scattered across Passamaquoddy Bay have steadily increased in number since the industry began in 1978, encroaching on the vistas of upland owners and coastal environment traditionally coveted by the harvest fisheries as well as recreational, navigational and other interests. Photo by Dave Aiken.*

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**From the Guest Editor**

# Aquaculture and Its Place in Integrated Coastal Zone Management

With the theme of the 17th Annual Meeting of the Aquaculture Association of Canada being "*Aquaculture in the New Millennium: Innovation and Sustainability*", Aquaculture Canada 2000 provided an ideal opportunity to explore a paradigm shift occurring in the management of aquaculture. The idea behind this special session was that we are in the midst of a change in the way we manage our activities in the coastal zone and river drainages. Traditionally we have managed coastal activities in isolation, considering the viability of a new pulp and paper mill on a particular river estuary, for example, without thinking about its impact on other uses of that estuary. When populations living along the coast were small and activities were few, this approach worked reasonably well. Now that more of us are living and making our living along the coast, a new management paradigm is required. The concept of integrated coastal zone management (ICZM) seeks to bring all stakeholders, including local residents, managers of local industries, politicians and environmental groups, to a common table to make decisions about which activities are to be pursued in a particular locale, and how to ensure they can co-exist without compromising each other or the health of the ecosystem that supports them. ICZM, sometimes shortened to ICM or even IM, only entered the western lexicon in the mid 1960s and is now developing rapidly.[1,2] Concurrently, culture of finfish and shellfish is a major industry in the Canadian coastal zone now and is projected to become much larger over the next 20 years. Clearly therefore, aquaculturists will find themselves at ICZM tables across the land. In this larger context, what are likely to be the difficult issues and potential conflicts, what do aquaculturists need to know about local economics and politics, and how do we measure the success of our choices and learn to make better choices?

To address these questions, we invited six experts to speak on different aspects of the place of aquaculture in integrated coastal zone management in a special session which I had the great pleasure of chairing. Details of these presentations, and three others included in the related session on "*Interactions between Aquaculture and the Environment*" chaired by Dr. Gilles Miron, follow this brief introduction.

Keynote speaker Dr. Harald Rosenthal began the session on "*Aquaculture and its place in Integrated Coastal Zone Management*" with a tour de force co-authored by colleagues Drs. Jacqueline McGlade and Stefan Gollasch. This paper introduced some of the environmental concerns being raised by both aquaculturists and other sectors in the coastal zone, along with some evolving ideas on decision frameworks for addressing these issues. Explored were new developments in measuring the capacity of a local environ to sustain aquaculture as well as other activities relying on the same resources. Recent examples show us that an understanding of how the ecosystem functions can allow us to adjust management strategies or develop mitigation measures to avoid both direct problems and some very subtle, indirect consequences of poor management practices. Harald needs no introduction to the Canadian aquaculture community, in which he has been an active contributor for many years, but for newcomers Dr. Rosenthal is an internationally recognized authority on the impacts of human activities on coastal zone ecology. Presently based at the University of Kiel in Germany, Dr. Rosenthal worked for many years in Canada and is involved in many bilateral and multinational research initiatives. Of course, environmental issues are only one aspect to be considered in the role of aquaculture in integrated management. The second speaker of the day, Dr. Maurice Beaudin, went on to explore the socio-economic scope and benefits of the aquaculture sector in Atlantic Canada in a talk entitled "*La contribution de l'industrie aquicole à l'économie des régions côtières de la côte est canadienne*". Dr. Beaudin is an expert on regional development issues in Maritime Canada and presently serves as assistant director for the Canadian Institute for Research on Regional Development (CIRRD) at l'Université de Moncton. The third presentation provided a perspective from the level of the community, provided by another well-known friend of the Canadian aquaculture community who has contributed to ventures in aquatic farming and appropriate technology throughout North America, Central America and Europe for over 25 years. Mr. Brian Ives argued eloquently, in his presentation on "*The Politics of Aquatic Farming —*

*Development as if People Mattered*", that the shift from resource management by centralized governments to coastal communities offers real opportunities for bold new initiatives in which aquaculture can be, and should be, integral.

The remaining presentations in the special session on Aquaculture and its place in ICZM provided three different perspectives on the present state of integrating aquaculture with other activities in the coastal zone. Dr. André St-Hilaire, manager of the Richibucto Environment and Resource Enhancement Project, spoke on "*The Place of Aquaculture — An East Coast Perspective*". With co-authors Drs. Boghen, Courtenay and Koutitonsky, Dr. St-Hilaire has been working since 1995 to provide residents of the Richibucto River in New Brunswick with the science they have requested in support of integrated management of key activities including oyster culture, fishing and peat moss harvesting. Harkening back to a theme introduced by Dr. Rosenthal in his keynote address, Dr. St-Hilaire provided further concrete examples of the need for basic science as the bedrock upon which integrated management must be built. A perspective from the Canadian west coast was provided by Mr. Ed Black, whose credentials include over 15 years of work with industry and governments on three continents to manage the interactions between aquaculture and the environment, and establishment, with others, of the ICES working group on environmental interactions of aquaculture. Mr. Black showed how British Columbia has adopted a dynamic management framework for the establishment of aquaculture sites which seeks to accommodate constantly changing priorities in resource access. The session on Aquaculture and its place in ICZM ended with a First Nations' perspective, contributed by Mr. Jeff Thomas of Snuneymux$^{w}$ (Nanaimo) First Nation, British Columbia, entitled *First Nations Aquaculture in British Columbia—Opportunities and Challenges*. Mr. Thomas showed how the collapse of traditional harvest fisheries and the resulting shift to aquaculture has changed the lives of many First Nations people, opening new opportunities but also raising new issues requiring negotiation around British Columbia treaty process tables. Speaking from personal experience, Mr. Thomas gave up 30 years of fishing herring, salmon and shrimp along the southern coast of British Columbia to become involved in product development with Unique Seafoods, a shellfish processing company operated by Nanaimo First Nations.

This special session generated many useful discussions at AC2000, some of which have continued and grown since the conference. Many thanks to all of the presenters for their excellent talks and summaries, to all of the conference participants who joined us, and to Dr. Andrew Boghen, whose brainchild this session was. Andrew, who served as AAC president and chair of the AC2000 conference in Moncton NB, has been exploring these ideas of a more holistic approach to aquaculture management in his own research on the Richibucto River.[3]

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# The Role of Aquaculture in Integrated Coastal Zone Management

*Harald Rosenthal, Jacqueline McGlade and Stefan Gollasch*

Aquaculture remains the fastest growing sector within fisheries and will continue to develop in coastal waters. The paper provides an overview of major international efforts to minimize environmental impacts associated with aquaculture amd considers possible types of interactions with other coastal users. Examples of "scenario building" and harmonius integrated coastal management programs from different parts of the world are given.

## Introduction

In many discussions on integrated coastal zone management it is emphasised that the following aspects must be considered: 1) strengthening cross-sectoral management frameworks in the coastal zone, 2) preserving the functioning of the natural resource system that maintains the resources, and 3) maintenance or enhancement of the productivity of the coastal systems through intelligent resource allocation.

The aims are to avoid certain economic developments in coastal areas that make the investor and end-user more vulnerable to the high variability and uncertainty of changes in the natural system, and vice versa, to ensure these processes do not become hazards to their activity. In this context sustainable use of coastal systems may be achieved by:

- maintaining the functional integrity of the coastal resource system (whereby integrity includes undergoing constant change but maintaining consistent viability),
- reducing resource use conflicts among stakeholders in the coastal zone,
- maintaining the "health" of the environment (whereby "health" must not be interpreted from the point of view of human civilisation but from the functionality of the components typical for the ecosystem in question), and
- facilitating the progress of multi-sectoral development through awareness campaigns and consensus building.[1]

A practical example of growing concerns regarding the interaction of coastal resource users is provided in this contribution, while also introducing an optional approach to properly addressing these issues through the development of decision support systems.

## Increasing Resource Use Conflicts Exemplified by Interactions between the Aquaculture and Shipping Industries

Aquaculture in coastal waters is one use of coastal resources that receives much public attention. It is considered by non-governmental organisations (NGOS) as being one of the potentially huge waste generators in the coastal zone that interferes with the development of numerous activities such as fisheries, tourism, and rural settlements. This image of aquaculture persists despite the fact that serious attempts to minimise and control environmental impacts have been made and have achieved impressive results.[2-5] These achievements range from predictive modelling of waste dispersal and benthic impacts (facilitating establishing limits), to drastic reductions in the use of antimicrobials and substantially reduced output of nutrients per unit biomass of fish produced. With the growth of the aquaculture industry, there is certainly a need for further improvements, in particular when dealing with escaped fish that might interact with natural populations. Here, promising concepts to reduce risks of species interaction have been proposed for salmonids that use their homing instinct to recover most of those accidentally released from fish farms. This concept needs to be studied further and its possibilities explored under a variety of habitat and environmental conditions.

Aquaculture is presently the fastest growing sector in aquatic food production and will certainly continue to grow in the new millennium. With increasing numbers of farms, aquaculture will encounter an increasing number of interactions with other coastal users. It will therefore need, not only to adjust its performance to environmentally friendly operation, but also to formulate and aggressively present its needs for protection from inadequate environmental mismanagement by other stakeholders which were allowed, in the past, to pollute as they were the only water resource user in many areas.

In parallel with the growth of the industry, conflicts have also grown and are likely to further increase. This is not only because of increased pollution risks but also because of a) the increasing competition for goods and services in the coastal zone, and b) increasing proximity to other resource users which may have been unrestricted or unregulated despite their potential direct negative effect on aquaculture. One of the aquatic resource users recently recognised as a potential threat to the aquaculture industry is the shipping industry which can transmit parasites, diseases and nuisance species in large quantities from a variety of taxa through deliberate release of ballast water. Several recent studies indicate that a globalisation of trade and markets is met by increasing ship traffic.[6-8] The following examples provide some insight into the dimension of the problem by asking the question "Why do invasions continue to occur when the transport vector has long been in place?"

First of all, the scenarios in which the transfer of non-native species may be successful have drastically changed in recent years. Some of these changes are:

- Increasing number of aquaculture activities along the coasts,
- Increasing density of aquaculture units near shipping routes (infrastructure),
- Increasing sea traffic (globalisation of markets; more ships and routes),
- Increasing speed of ships, resulting in shortened transfer times,
- Increasing size of ships (larger ballast volumes, more oxygen available),
- Changing strategies of ballast water management (cleaner water in tanks),
- Changing human population density in the coastal zone (e.g., nutrient output),
- Increasing poverty in small coastal communities (lack of infrastructure),
- Lack of satisfactory hygienic conditions in many harbours around the world,
- Changing donor and receiving environments (habitat modifications and climate change).

Modern ships are faster, larger, and carry more ballast water than ever before. Survival and the number of specimens transferred have greatly increased. An estimated 10-12 billion tonnes of ballast water are traded annually across the oceans while about 4000 species are in intercontinental transit daily. These species include a) micro-algae which can be involved in toxic algal blooms, b) disease agents and parasites that can destroy entire aquaculture industries locally or regionally while also forcing the industry to use more chemicals for treating and combating new invasions that are harmful to their operation.[9]

A recent event indicates there is a high likelihood that the Asiatic sealice, *Caligus flexispina*, has been introduced into the Southern Hemisphere (Chile) via bulk carriers which arrive from Japan in full ballast to load wood chips for the pulp and paper industry. Between November 1998 and March 1999, this new sealice infestation was claimed to have caused a mortality of 15,000 tonnes of Atlantic salmon. The industry is now forced to use chemicals to combat this parasite, thereby not only adding to the cost of production and increasing the risk of periodic epizootic mortalities, but also being unintentionally exposed to environmental critics for using more chemicals, a necessity now imposed on the industry by other, uncontrolled "polluters".

The introduction of the zebra mussel to the Great Lakes and its spread to the Mississippi drainage system has affected native unionid bivalves in that system, thereby threatening the use of these native clams to obtain implant material for the pearl oyster industry. Recently, new seaweeds have been introduced, most likely with hull fouling and/or ballast water, to Chile as well as to Norway. These are spreading rapidly and provide additional fouling organisms on cage nettings. This certainly adds to the maintenance costs and, in severe cases, can cause reduced current flow through cages, limiting water exchange and oxygen supply.

These few examples may stand for many others. Further information on transfers and introductions that may cause harm to aquaculture, fisheries and tourism can be obtained from the recently completed report *Testing Monitoring Systems for Risk Assessment of Harmful Introductions by Ships to European Waters* which resulted from an European Union Concerted Action.[8]

Although shipping is only one of the extensive water resource users in coastal and open sea waters that interfere with aquaculture, there are many others such as agriculture, tourism, industrial and rural developments.

## Development of Decision Support Systems for Integrated Coastal Zone Management

### *Dealing with uncertainty*

Considering the complexity of coastal systems and the diverse uses and user needs (as outlined above), natural scientists have difficulties dealing with the huge uncertainty associated with any of the natural resources that form the basis for goods and services to varying degrees. Managers wish to safeguard one development against others because it is their goal to maximise the resource utility and profits achievable from their investment. Little interest exists among average stakeholders to optimise resource exploitation through intelligent resource partitioning. Multiple use concepts are rarely taken into account by scientists or by regional and local planners. Conflicts are generally dealt with as they occur rather than being anticipated.

Uncertainty is not merely the spread of data around some arbitrary means, but rather a systemic form of error that can swamp an otherwise easily calculated random counterpart. Achieving certainty then, even in a quantitative science, relies largely on managing the different sorts of uncertainty that affect performance. Because uncertainty cannot be removed it has to be clarified.

One of the major difficulties in integrated coastal zone management is that it is highly interdisciplinary, involving fields of varying states of maturity and with very different practices in their theoretical approach and social dimension.[10] A societal dimension increases the problems in policy-related research issues and their accompanying uncertainties. Science is judged by the public, including bureaucrats, on its performance in sensitive areas such as the economic returns on foreign aid, returns from the exploitation of natural resources, and the dangers of environmental hazards associated with these activities. All involve much uncertainty. In aquaculture this encompasses not only the uncertainty of prevailing weather conditions which may, in unusually cold springs, reduce growth rates and delay harvests, but also the risks of unforeseen toxic algal blooms caused either naturally or by accidental releases of toxic species from ships. There are further environmental uncertainties as well as uncertainties in the market place (price trends, emerging competitors from other regions and their marketing strategy). Furthermore, there are activities near aquaculture by a number of coastal users that may endanger the aquaculture operation (e.g., oil spills, increasing volumes of sewage effluent from rapidly growing settlements, short-term operational failure of sewage treatment plants; social unrest and accompanying risks (e.g., vandalism). There is a need to create more awareness of the type of risks and uncertainties involved in these activities and to initiate the development of a set of assessment procedures that help to qualify and quantify (wherever possible) the associated long-term and short-term risks. The following evaluation tool is one example that can help identify levels of risk while creating more awareness of ways to reduce risks and optimise the utility of aquatic resources among coastal stakeholders, planners and policy makers.


**Figure 1. Various activities and their interaction in a coastal area are dealt with in coastal transects (of which there may be many in a pre-determined distance along the coastline). These transects are zoned into sections that can be flexibly designed (in their geographical size), the dimensions of which are issue-dependent. Zones may extend from the upland and midland to lowland, intertidal, inshore, foreshore and offshore areas.**

## SimCoast: A Tool for Consensus Building by Stakeholders and Planners

Three key intelligent system techniques are potentially useful for sustainable coastal zone management and the principal concepts of these have been clearly described by McGlade:[11] neural networks, expert systems, and generic algorithms. However, interactions between these methods and other approaches such as fuzzy logic and issue analysis are also of importance to give users the ability to exploit a variety of combined uncertainty and imprecision in the knowledge and data base.

SimCoast™ is such a fuzzy logic, rule-based, expert system in which a combination of a fuzzy logic and issue analysis has been used to produce a soft intelligence system for multi-objective decision-making. It is, therefore, designed to enable researchers, managers and decision-makers to create and evaluate different policy scenarios for coastal zone management. It is highly flexible, multi-sectoral in its approach and interdisciplinary, combining worldwide expertise and local knowledge to set the reasoning tools for the decision process.

The basic idea in SimCoast™ is to encode the experts' knowledge of different models into the overall system in as flexible a manner as needed. The data for each model are organised as an inference net, where nodes can represent evidence to support other nodes that represent the ideas or hypotheses of other experts. Each model inside SimCoast™ can be encoded as a network of connections or relations between evidence and hypotheses. SimCoast™ is thus not a pure probabilistic system because it uses fuzzy logic and certainty factors for combining evidence.

Rule definitions and information collection occurs during the planning process of any activity in the coastal zone. Mostly, workshops will help to identify stakeholder needs and interactions and will therefore have different foci (e.g., fisheries, urbanisation, aquaculture, shipping and ballast water) and aims (e.g., policy development). All the information collected in the expert system is made available in an electronic library of "books", maps, models, images and other formats. The sequence of steps taken can be divided into two main elements: administration and processing. The administration section provides access to database information from previous inputs, drawing on other experiences worldwide where similar scenarios may have been evaluated, so that the quality of the decision process is enhanced taking comparative scenarios into account. The processing section covers a complete run of the decision support system from setting up the transects (Fig. 1), defining policy targets, identifying and mapping key features and activities onto the transect, rule generation (through consensus discussions) and modifications, running the inference engine, defuzzifying the results, presenting the principal component analysis, and the final influence diagram.

Figure 2 shows how key features can be assigned (or if a full list is available, selected) in each zone while they are mapped onto the transect diagram. A zone is selected by clicking on the zone picture or zone name button, and the key feature is selected by clicking on one of the generic feature icons. In Figure 2 selection has been restricted to "transport, shipping, ballast water and exotic species".

The rules are used to create a set of normalised values of the effects of each activity on itself and each other within each zone (Fig. 3) even if the activity occurs in another transect zone. The values then make up a symmetric N X N matrix, which becomes the input data set for singular value decomposition (SVD). SVD is an analysis that attempts to seek out the patterns in the variance in the data and thereby explain the relative importance of each activity by zone or tar-


**Figure 2. Specific sections of the coastal transect (e.g., from lowland to inshore) can be collected to focus on individual problems that only affect these zones (e.g., effects of the release of toxic algal cysts from shipping ballast water on MPAs (marine protected areas) and/or aquaculture (e.g., shellfish farms). Scenarios involve all activities or only those considered to be relevant to the issue (see icon identifiers in the pull-down menu under the section of the intertidal zone).**

get. The results are then displayed both on the final transect screen (Fig. 4) and as output tables and graphs.

Given the targeted user community of SimCoast™ the system initially gives only the first dominant insights in combinations of interacting factors as these will enable policy-makers and planners to see the relative impacts of the various activities. However it is always possible to examine the entire structure of all interacting factors. SimCoast™ can therefore be considered as one of the possible tools that managers and planners may use in scenario building to achieve a more comprehensive appreciation of possible risks and interactions involved among specific coastal activities.

## Conclusions

Through timely and goal-oriented research, and through concerted efforts by industry and scientists, modern aquaculture has become a branch of the food production sector that can now be operated in an environmentally-friendly manner, if existing knowledge is properly applied. Our understanding of possible interactions with the environment has greatly improved, although there is room for further improvement in most areas. With the growth of the industry, it has also become obvious that conflicts with already established users of coastal resources will increase and that aquaculture will have to take the needs of these stakeholders into account in its own management practices. It has also become obvious that aquaculture must demand better environmental control of the activities of competitive resource users to safeguard aquaculture from environmental mismanagement by these users.

Taking ballast water management issues as an example, there are new threats to aquaculture operations every day. These are no longer local issues but can only be solved through international co-operation and agreements. It is obvious that co-management between regulatory agencies and stakeholders has become a necessity to safeguard aquaculture and other users of coastal waters.

There is a need to develop adequate tools for consensus building and for risk assessment. Several such tools have recently become available. SimCoast™ has been presented as one example that can be used not only to visualise the risk factors associated with the transfer of exotic species but also to assess the likely environmental and economic impacts on local coastal habitats and on aquaculture. Incorporating individual risk assessment models, which are used for each of the activities, enables consensus building and priority setting. These can be numerical models if crisp data are available or scenario settings using fuzzy logic for cases in which uncertain data or anecdotal information has to be used in assessing scenarios and options. Such systems can certainly help to "think globally" while "acting locally".


**Figure 3. Display example of SimCoast™ in rule formulation. Changing the size term for feature, activity or impact, or modifying the certainty factor can modify any rule displayed in the current rule set diagram.**


*This work was partially made possible through two European Concerted Actions dealing with "Testing Monitoring Systems for Risk Assessment of Harmful Introductions by Ships to European Waters (MAS3-CT97-0111) and "SimCoast™". Components of this research summary have especially been contributed by members of the ICES Working Group on "Environmental Interactions of Mariculture". Part of the work was also supported through the Canada-Germany scientific and technical Cupertino agreement. Special thanks go to Dr. Howard Bottrell and Mr. John*

*Marshall of the SimCoast™-team for providing the visualisation tools, manuals and graphics and Edward Black (BC, Canada) for providing continued input into the development of mitigation strategies of environmental effects derived from aquacuture.*

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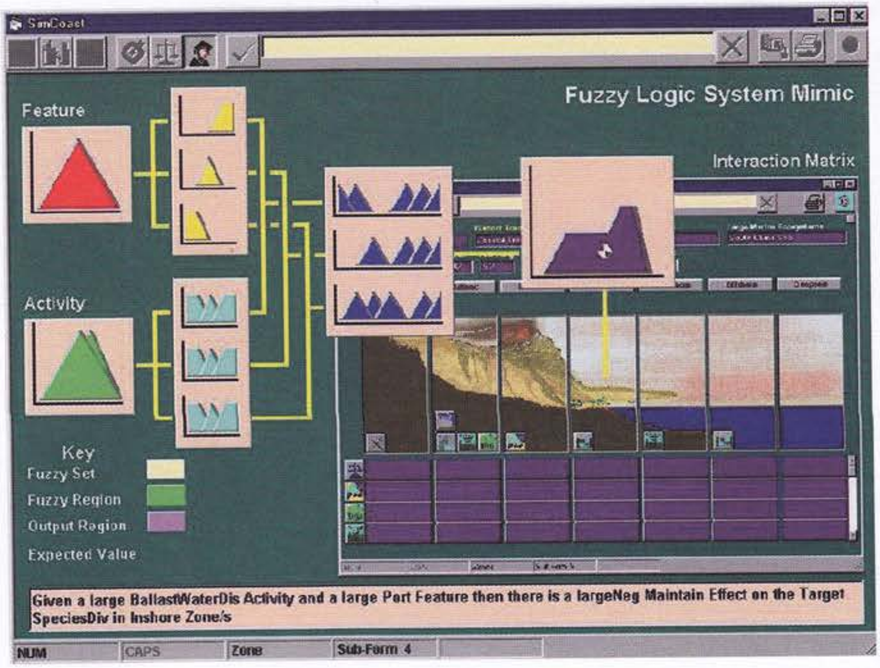


**Figure 4. Visualisation of an initial summary of the fuzzy logic initial risk assessment between features and activities in the coastal areas as they affect the intertidal zone.**

# La Contribution de l'Industrie Aquacole à l'Économie des Régions Côtières de la Côte Est Canadienne

*Maurice Beaudin*

Cet article porte sur l'état des lieux industriel, technologique, commercial et socio-économique de la filière aquacole dans l'est du Canada. Présentant d'abord le profil des secteurs de la production et des services et fournitures à l'industrie, l'auteur analyse ensuite les retombées économiques, ainsi que les interactions entre la production aquacole et les autres volets de la filière, notamment la recherche et développement (transferts de technologie), la formation, ainsi que le cadre de soutien privé et institutionnel à l'industrie. Il conclut sur l'évidence d'une nouvelle filière en stade initial de développement, susceptible de compenser ou à tout le moins de servir de complément intéressant aux pêches traditionnelles. Rien ne laisse toutefois présager que les emplois de type «aquacoles» bénéficient avant tout aux travailleurs évincés du secteur traditionnel des pêcheries. La multiplication et l'expansion des entreprises aquacoles servent de toute évidence à complémenter un secteur traditionnel des produits marins en phase de rationalisation au plan de l'emploi. D'où l'importance accrue de l'activité aquacole pour nombre de communautés en mal de diversification économique. Cette communication vise ainsi à établir un profil à la fois provincial et sectoriel de l'industrie aquacole au Canada atlantique et dans l'est du Québec, non sans avoir esquissé les principaux développements au niveau international. Nous verrons par ailleurs à circonscrire la filière aquacole dans cet espace régional et à en estimer la contribution au plan économique. Il s'agira de voir comment cette industrie peut aider à diversifier les économies côtières en complémentant, dans une certaine mesure, le secteur traditionnel des pêcheries, lui-même en pleine transition.

## Introduction

L'élevage ou la culture d'espèces aquatiques a pris un essor considérable dans le monde depuis deux décennies. La production aquacole affiche une croissance annuelle moyenne de plus de 10 % depuis 1984, ce qui en fait le secteur de production vivrière à la croissance la plus rapide au monde.[1] En l'espace de dix ans seulement, soit de 1988 à 1998, la part des produits aquacoles dans l'ensemble de la production halieutique mondiale progressait de 12 % à 26 %, donnant ainsi le ton au commerce international des produits marins.

Reconnu depuis longtemps comme une grande puissance halieutique, le Canada demeure un leader (6e rang mondial) en matière de commercialisation de produits marins. Ses exportations ont augmenté de 2,5 à 3,2 milliards de dollars au cours des années 1990, et ce, en dépit des moratoires sur le poisson de fond. Pour autant, le Canada n'a réussi que tardivement à mettre en place une véritable industrie aquacole. Mais des progrès rapides ont été réalisés dans certains segments tels l'élevage du saumon et la culture de moules. Des efforts intenses sont par ailleurs menés sur un nombre grandissant d'espèces en vue d'une production commerciale.

Sur la côte est canadienne, où l'industrie halieutique a été déstabilisée par la crise du poisson de fond, le secteur aquacole connaît un développement intéressant.[2] Bien que le saumon d'élevage représente à lui seul 70% de la production aquacole en valeur, on y observe une relative diversité sur les plans sectoriel et géographique. La truiticulture, la mytiliculture et l'ostréiculture sont déjà bien implantées dans les Maritimes et un nombre grandissant de permis sont alloués pour la production d'espèces nouvelles comme les palourdes, l'oursin vert, le pétoncle, la morue, l'aiglefin, le turbot, le flétan, l'omble chevalier, ...). Déjà, plus d'une trentaine de permis, dont la moitié en Nouvelle-Écosse, ont été alloués pour la production commerciale d'oursins verts. Ces productions toutes aussi diverses et géographiquement réparties sont soit au stade commercial, soit en phase expérimentale. À Terre-Neuve, par exemple, la production commerciale de morue d'élevage atteignait 235 000 livres en 1999.(3) En Nouvelle-Écosse, où la production aquacole est la plus diversifiée, on note une remarquable progression des coquillages (moule, huître américaine et européenne, la palourde et le pétoncle); de 1995 à 1999, cette production a évolué de 548 T à 1 762 T, pour des valeurs respectives de 1,0 M$ à 3,5 M$. Le Québec s'affiche par son importante production dulcicole, avec comme produits-phare la truite arc-en-ciel et l'omble de fontaine (respectivement 6 et 7 millions $ de ventes en 1998).

En dépit, donc, d'une forte dominance du secteur salmonicole, les profils provinciaux en matière d'aquiculture sont relativement nuancés et sont appelés à se diversifier davantage. Aspect tangible de l'évolution en cours, la part de la production aquacole en rapport de la production halieutique traditionnelle (pêches de capture) est en hausse et atteint un seuil fort respectable dans plusieurs régions. Par ailleurs, la production aquacole nécessite une grande variété d'intrants (équipements et services spécialisés), ce qui lui confère une importance additionnelle en ce qui a trait à la diversification économique régionale. Au point où les gouvernements tentent par tous les moyens de raviver ce secteur en vue de pallier au manque d'opportunités d'emploi dans certains milieux côtiers.

## L'aquiculture et l'intensification du commerce international des produits marins

La production aquacole mondiale, toutes espèces confondues, a connu une expansion phénoménale au cours de la dernière décennie. Le tonnage mondial rapporté de production d'élevage et de culture marine (algues exclues) est en effet passé de 11,7 millions de tonnes (MT) en 1988 à 28,8 MT en 1997; la valeur marchande de cette production a plus que doublée, soit de 21,2 à 45,5 milliard $US.(4) Près d'un tiers du poisson que nous mangeons provient actuellement de l'aquiculture.

Cette formidable expansion n'est pas du hasard. L'accessibilité accrue à de nouvelles technologies, dans le domaine de la biologie marine notamment, qui permet une croissance plus rapide et mieux contrôlée d'espèces aquatiques, ainsi que l'expansion des marchés pour les produits de la mer expliquent à première vue le dynamisme inhérent à cette industrie. Mais bien d'autres facteurs soutiennent ces développements. On pense à la stagnation - au déclin, dans certains cas, des pêches de capture, ce qui ouvre d'importantes possibilités commerciales pour l'industrie aquacole en vue de répondre à la demande. On notera aussi l'amélioration des conditions de stockage et surtout de distribution, qui non seulement accélèrent les flux import-export mais facilitent la vente au détail. L'intégration et la modernisation des circuits de distribution-commercialisation, ainsi que l'internationalisation de normes de qualité (HACCP) rendent par ailleurs accessibles aux consommateurs une variété grandissante de produits de qualité, et ce, à prix abordable. Plus récemment, les gouvernements des pays industrialisés y voient un moyen de diversifier certaines économies régionales jusque-là trop dépendantes des ressources naturelles locales; les gouvernements des pays tiers y voient un excellent pourvoyeur de devises fortes, susceptible en plus de bénéficier des transferts technologiques.

Si bien que depuis une quinzaine d'années, les produits d'origine aquacole ont littéralement soutenu la croissance du commerce mondial des produits marins. Plusieurs produits d'élevage ou de culture, notamment la crevette, le saumon de l'Atlantique, les poissons à chair blanche, tel le tilapia, et certains mollusques (huître, pétoncle, mye) ont intégré rapidement le commerce international des produits de la mer, dont le volume atteint 23 millions de tonnes en 1997, soit trois fois le volume commercialisé en 1976. Tout aussi significatif est l'évolution de la part de la production halieutique mondiale entrant dans le circuit import-export (commerce international): de 30 % qu'elle était en 1986, elle atteignait 38 % en 1997. Il s'agit d'un seuil élevé, considérant que 10 % seulement de la production mondiale de viande bovine se retrouve sur les marchés internationaux.(5)

Au registre des principaux produits d'élevage figurent différentes espèces de carpe (13,3 MT en 1997), dont les 4/5 produites en Chine; les myes et palourdes, incluant la clovisse du Japon (3,2 MT); l'huître creuse du Pacifique et européenne (3,1 MT); les poissons d'eau douce (2,0 MT); le pétoncle ou coquille St-Jacques (1,3 MT); ainsi que les saumons et truites (1,2 MT, dont 52% de saumon de l'Atlantique). On notera la production montante de certaines espèces qui se sont taillées une place de choix dans le commerce international des produits marins. Parmi elles figure la crevette d'eau chaude (942 000 T en 1997), ainsi que le tilapia (659 000 T). Le tilapia est considéré comme un substitut intéressant aux poissons de fond traditionnels; il est devenu, après la crevette et le saumon, le troisième produit d'élevage à l'importation aux États-Unis (Marine Resource Specialist-Economics, Mississippi State University, Coastal Research and Extension Centre). À cela s'ajoutent des productions relativement importantes de dorade (435 000 T), de moule bleue (401 000 T), de perche (251 000 T), de loup de mer ou catfish (238 000 T) et d'anguille (233 000 T). Cette liste exclut les productions d'algues et de plantes marines (7 MT; 5 milliards de $US), dont une part non-négligeable de la production entre dans la composition de produits industriels, pharmaceutiques ou esthétiques.

## La place du Canada dans l'aquiculture mondiale

Bien qu'il figure au registre des principaux exportateurs de poisson (6e rang mondial en 1998), le Canada n'arrive qu'au 23e rang pour ce qui est de la production halieutique (pêches de capture). Notre pays affiche en 1998 une production aquacole estimée à 92 000 tonnes, soit l'équivalent de 0,3 % de la production mondiale en tonnage. Ce sont de loin les pays asiatiques qui dominent tant pour ce qui est du tonnage que pour la valeur. Le Canada arrive au 22e rang avec seulement 0,3 % du tonnage mondial, mais 0,6 % de la valeur totale des produits d'origine aquacole. La valeur unitaire moyenne des produits d'origine aquacole est particulièrement élevée au Canada qui occupe de fait le 4e rang à ce chapitre, derrière le Japon, le Chili et la Thaïlande. En moyenne, les produits aquacoles canadiens affichent une valeur marchande de $3.12 US le kilo en 1998 ($3.00 pour l'Est canadien), comparativement à $2.77 en Norvège, $2.24 en France et $1.75 aux États-Unis. Au niveau international, la moyenne s'établit à $1.53 US le Kg (compilations obtenues à partir des données sur la production aquacole mondiale, FAO, ainsi que Pêches et Océans Canada).

En matière de production aquacole, les progrès ont été rapides au Canada. Globalement, le volume a augmenté de 21 500 à plus de 92 000 tonnes entre 1988 et 1998; la valeur progressait de 105 à 428 millions de $ canadiens. La part des produits d'origine aquacole n'a cessé d'augmenter et équivaut aujourd'hui à 9,5 % du tonnage débarqué de poisson et fruits de mer, mais à 27 % de la valeur de la production halieutique traditionnelle. Cet apport est particulièrement évident pour ce qui est des poissons d'élevage, une performance redevable surtout au saumon de l'Atlantique dont la production a augmenté de 3 400 à 58 300 tonnes (de 34 à 348 millions $). On mentionnera également les efforts de diversification, notamment en conchyliculture.

## L'industrie aquacole dans l'est canadien: au-delà de la complémentarité

La contribution de l'industrie aquacole à l'économie des zones côtières n'est pas toujours reconnue à sa juste valeur. Cette industrie, il est vrai, n'en est qu'au stade embryonnaire dans plusieurs secteurs côtiers et les liens interindustriels ne sont pas clairement établis. Sa contribution est néanmoins hautement significative, d'autant plus qu'elle s'avère être un complément sur mesure en vue de pallier au déclin de la ressource traditionnelle, tout en aidant à diversifier l'emploi régional.

Il est d'autre part souvent argumenté que l'activité aquacole s'avère un complément à l'industrie traditionnelle des pêches. Par le fait même, on ne reconnaît pas pleinement ce secteur toujours empreint de tradition côtière, mais soutenu de plus en plus par l'innovation. Car l'activité aquacole est devenue particulièrement " high-tech " et sa gestion davantage calquée sur celle des entreprises de la nouvelle économie. Il suffit de voir l'intégration (verticale et horizontale) des leaders dans ce secteur, de même que des nombreux liens inter-industriels - une entreprise salmonicole typique fait affaires avec plus de 200 fournisseurs,[6] pour constater le caractère spécifique de cette industrie. On peut en dire autant pour ce qui est de la réglementation et de ses besoins techniques, aussi bien qu'en recherche et développement. En sus du capital de risque qui souvent fait défaut chez les PME du secteur, l'industrie aquacole a besoin de techniques nouvelles (mise au point de nourriture et de vaccins, conception d'enceintes marines ou de bassins), de matériel automatisé, de technologie de récolte et d'information, etc.

C'est pourquoi nous devons envisager l'apport de cette industrie non pas en complément du secteur traditionnel des pêches, mais plutôt dans un contexte de filière, c'est-à-dire, de la préparation des sites et de l'ensemencement jusqu'à la vente au consommateur. Cette contribution se doit par ailleurs d'être considérée dans le contexte régional. Il s'agit en fait d'un secteur typiquement côtier, donc familier aux milieux traditionnels des pêches, bien que la filière aquacole, comme nous le verrons, dépasse largement le cadre strictement maritime. L'encadrement et le soutien logistique à l'industrie des pêches (centres de gestion et de protection des espèces, de recherche et développement, de formation, ainsi que les entreprises de soutien) sont essentiellement localisés dans les centres régionaux. De même en est-il des réseaux de distribution-commercialisation des produits de la mer, ainsi que de nombreux services spécialisés.

En termes économiques, il faut voir la contribution du secteur aquacole sous divers angles: d'abord en terme de production locale, surtout lorsqu'elle est "travaillée" (valeur ajoutée) et exportée; puis par les emplois et revenus qu'elle procure, autant ceux de nature traditionnelle que ceux liés aux activités incorporant davantage de connaissances. Ce ne sont toutefois que les retombées directes les plus visibles.

Comme on sait, ce secteur nécessite un flux continu d'intrants industriels, technologiques et commerciaux aux divers paliers de la filière, et ce, à toutes les étapes de production. L'appui logistique peut aller de l'évaluation scientifique et technique des sites de production jusqu'au contrôle des maladies, en passant par la fourniture d'équipements et d'autres services spécialisés tels l'amélioration génétique, la reproduction, l'incubation, l'alevinage et la nutrition. Voyons pour l'Est canadien en quoi consiste l'apport du secteur aquacole.

### L'apport en terme de production

Alors que les provinces de l'Est canadien contribuent entre 70-80% (en valeur) de la pêche traditionnelle au Canada, leur production aquacole représente une part plus modeste de la production aquacole, soit entre 40-50%. Le niveau de production n'a toutefois cessé d'augmenter, passant de 9 000 T en 1988 à 16 000 T en 1990, pour dépasser le cap des 39 000 T en 1998; la valeur atteint 178,6 millions $ en 1998, une hausse de 81% sur 1990.

Bien que les poissons, en particulier le saumon, dominent au chapitre du volume (55%) comme de la valeur (85%), on assiste à une évolution graduelle des espèces invertébrées telles les moules et les huîtres. Voir tableau 1.

La production aquacole de bivalves a progressé d'un niveau de 6 400 T en 1988 à 17 700 T en 1998; la valeur marchande pour ce groupe d'espèces a augmenté de 10,4 à 25,7 millions $. Il s'agit d'une intéressante progression compte tenu du fait qu'il s'agit souvent d'activités encore modulées par le traditionalisme lié aux pêcheries. C'est le cas notamment dans le secteur des huîtres où la grande

**Tableau 1. Production aquacole selon les principales espèces et la province, 1998.**

| | T-N | N-É | Î-P-É | N-B | QC | Est canadien 1998 | Est canadien 1990 |
|---|---|---|---|---|---|---|---|
| **Quantité (t.m.) en 1998** | | | | | | | |
| Saumon atl. | 401 | 1,785 | | 14 232 | 14 | 16 432 | 7 835 |
| Moule | 946 | 835 | 12 459 | 680 | 99 | 15 019 | 3 598 |
| Truite | 1 364 | 1 038 | | 550 | 1 200 | 4 152 | 1 873 |
| Huître | | 377 | 1 974 | 286 | | 2 637 | 2 698 |
| Aut. Espèces | 16 | 31 | 100 | | 787 | 934 | 199 |
| **Poissons** | 1 765 | 2 823 | 99 | 14 782 | 1 994 | 21 463 | 9 798 |
| **Invertebrés** | 962 | 1 243 | 14 433 | 966 | 106 | 17 710 | 6 405 |
| **Total** | **2 727** | **4 066** | **14 532** | **15 748** | **2 100** | **39 173** | **16 203** |
| **Valeur ('000 $) en 1998** | | | | | | | |
| Saumon atl. | 2 925 | 10 540 | | 106 678 | 106 | 120 249 | 74 641 |
| Moule | 7 116 | 6 095 | 15 110 | 6 100 | 134 | 34 555 | 13 418 |
| Truite | 815 | 1 458 | | 1 455 | 6 753 | 10 481 | 3 964 |
| Huître | | 1 186 | 4 447 | 788 | | 6 421 | 5 262 |
| Aut. Espèces | 85 | 158 | 883 | | 5 791 | 6 917 | 1 626 |
| **Poissons** | 10 041 | 16 635 | 882 | 112 778 | 12 623 | 152 959 | 88 059 |
| **Invertebrés** | 900 | 2 802 | 19 557 | 2 243 | 162 | 25 664 | 10 362 |
| **Total** | **10 941** | **19 437** | **20 439** | **115 021** | **12 784** | **178 623** | **98 911** |

Sources: Pêches et Océans Canada, Statistiques annuelles; pour le Québec, Cahier sur la production aquacole, par P. Lauzier, printemps 2000.

**Tableau 2. Production aquacole versus production traditionnelle — Est canadien, 1990-1998.**

| | Production aquacile (vol) en % des débarquements traditionnels | | | Production aquacole (val) en % des débarquements traditionnels | | |
|---|---|---|---|---|---|---|
| | Poissons | Mollusques et Crustacés | Toutes les espèces | Poissons | Mollusques et Crustacés | Toutes les Espèces |
| 1990 | 0,9 | 2,8 | **1,2** | 18,8 | 2,2 | **10,5** |
| 1992 | 1,7 | 2,7 | **1,9** | 25,9 | 1,4 | **11,1** |
| 1994 | 3,7 | 3,3 | **3,5** | 56,1 | 1,3 | **11,1** |
| 1996 | 5,3 | 4,4 | **4,9** | 66,6 | 1,9 | **14,0** |
| 1997 | 6,2 | 4,2 | **5,2** | 76,7 | 1,9 | **15,3** |
| 1998 | 5,1 | 5,1 | **5,1** | 60,1 | 2,4 | **13,2** |

Source : Compilation de l'auteur d'après les données de Pêches et Océans.

majorité des détenteurs de permis d'exploitation ne dépassent pas le stade d'une simple cueillette. De nombreuses concessions demeurent en effet non productives. À l'Île du Prince Édouard, par exemple, sur 500 locataires à bail, une centaine seulement y dirigeraient des activités commerciales. Le rapport semble encore moins élevé au Nouveau-Brunswick où une trentaine d'ostréiculteurs tout au plus sont considérés sur une base commerciale, alors qu'on y dénombre près de 400 permis d'exploitation (Renseignements obtenus lors de discussions avec divers intervenants de l'industrie). Selon les scientifiques, il y aurait dans les Maritimes quelque 1 800 zones ostréicoles à bail occupant près de 5 000 hectares; si toutes les concessions étaient exploitées à leur pleine capacité et si tous les bons sites non utilisés étaient mis en production, la production annuelle d'huîtres atteindrait 125 000 tonnes.[7] On est loin des 2 600 tonnes rapportées en 1998 par le secteur ostréicole des Maritimes.

On peut visualiser l'apport relatif du secteur aquacole sous un autre angle, en le comparant aux pêches traditionnelles. Nous avons à cet effet préparé un tableau récapitulatif pour l'est canadien, et ce, pour les années 1990 à 1998. Le tableau 2 montre en effet une part accrue de la production d'origine aquacole, sa part relative en volume ayant augmentée de 1.2% en 1990 à plus de 5% en 1997 et 1998. Cette part est plus élevée en terme de valeur, oscillant entre 13 et 15 % au cours des dernières années. Il s'agit donc d'un apport plus que substantiel, même en considérant la chute des débarquements de poisson de fond.

### *L'apport économique direct en termes d'emplois et de revenus*

Il est relativement aisé d'établir le profil de l'industrie salmonicole en région puisqu'elle est concentrée dans le sud-ouest du Nouveau-Brunswick, parce qu'il s'agit d'une industrie hautement capitalistique et en conséquence fortement intégrée, et aussi parce qu'il s'agit d'une industrie grandement orientée vers l'exportation. Nous connaissons assez bien les liens ou interactions que cette industrie peut avoir avec les autres secteurs de l'économie, notamment pour ce qui est des besoins logistiques (industriels, technologiques, commerciaux, distribution, etc.). Il est difficile, par contre, d'évaluer le niveau d'emploi et de revenus générés par les autres secteurs qui sont plus éparpillés géographiquement et plus fragmentés; certaines activités traditionnelles demeurent plus ou moins reconnues économiquement, et d'autres plus récentes sont au stade embryonnaire ou simplement au stade expérimental.

Une enquête exhaustive menée en 1995 sur l'industrie canadienne de l'aquiculture établissait à 2 350 le nombre d'emplois directement liés à l'aquiculture dans l'Est canadien. Les deux tiers de ces emplois étaient à temps plein, le reste à temps partiel ou saisonnier.[8] Or, la production aquacole a augmenté de 35% en volume depuis. À la lumière de ces résultats, tout en tenant compte à la fois de l'augmentation de la production dans les secteurs piscicole et conchylicole, de même que des informations plus récentes émanant des agences provinciales, il nous est permis d'établir à environ

**Tableau 3. Estimation de l'emploi direct dans l'industrie aquacole selon la province, 1999.**

| | Selon Rapport de 1995[a] | | | Augmentation de la production aquacole (vol) 1995-1998 | Emploi maximum pour l'année 1999[b] |
|---|---|---|---|---|---|
| | Pisciculture | Conchyliculture | Emploi total | | |
| T-N | 131 | 156 | 287 | 171% | 470[c] |
| Î-P-É | 24 | 261 | 285 | 56% | 1 300[d] |
| N-É | 192 | 297 | 489 | 125% | 850[e] |
| N-B | 848 | 260 | 1 062 | Stable | 1 500[f] |
| QC | 145 | 36 | 181 | 110% | 250[g] |
| **Est canadien** | **1 340** | **1 010** | **2 350** | **35%** | **4 370** |

[a] Enquête de STATCAN sur l'industrie canadienne de l'aquiculture, 1995.

[b] Emploi direct, à temps plein ou partiel (saisonnier); estimation basée sur les informations diverses fournies par les départements provinciaux des pêches et en tenant compte de l'augmentation de la production depuis 1995.

[c] Selon le *Seafood Industry - Year in Review*, 1999.

[d] Il y aurait environ 1 000 emplois dans le secteur des moules uniquement (d'après le ministère des Pêches, de l'Aquaculture et de l'Environnement); l'Î-P-É produit également 2,000 tonnes d'huîtres, soit les trois quarts de la production ostréicole des Maritimes.

[e] Le rapport du ministère, *Nova Scotia Fishery profile*, évalue en 1999 à 1,104 le nombre d'emplois liés directement à l'aquiculture, mais la grande majorité sont à temps partiel. Nous estimons que tout au plus 850 emplois sont directement liés à la production aquacole.

[f] La production salmonicole au N.-B. a quelque peu fléchie en raison du virus ISA, mais la production conchylicole a pratiquement doublée depuis 1994.

[g] Le niveau d'emploi dans le secteur aquacole est difficile à évaluer en raison du stade embryonnaire de plusieurs activités et également en raison du grand nombre de petits exploitants dans le domaine dulcicole; sur 224 exploitants aquacoles au Québec, 184 sont orientés vers la production en eau douce. On dénombre par ailleurs 368 U-Fish.

4 370 le nombre actuel d'emplois saisonniers ou à plein temps liés à la production aquacole dans les cinq provinces de l'est canadien. Ce chiffre n'est évidemment qu'une simple estimation basée sur diverses sources d'informations et pondérée en fonction de l'augmentation de la production. Voir tableau 3.

Nous ferons observer que le Directoire canadien de l'aquiculture - 2000 établit entre 9 000 et 15 000 le nombre d'emplois liés directement au secteur aquacole au Canada.[(9)] Comme les provinces de l'est comptent pour 42% environ de la production nationale (en volume comme en valeur), la main-d'œuvre aquacole dans cette partie du pays se chiffrerait en moyenne à 5 040, soit 15% de plus que nos propres estimations. Nos estimations semblent également aller de pair avec celles de Pêches et Océans qui, par voix de communiqué, affirmait récemment que le secteur aquacole au pays emploie plus de 14 000 travailleurs, dont 7 000 directement liés à la production d'élevage.[(10)]

## *Les retombées indirectes*

Outre les emplois directs, l'industrie aquacole crée des emplois induits chez ses fournisseurs de matériel et d'équipements (bateaux et moteurs, cages, aliments pour poisson, emballages, etc.). De nombreux services sont aussi offerts à l'industrie, notamment pour les soins vétérinaires, la collecte de semences, le trans-

**Tableau 4. Contribution estimée de l'industrie aquacole selon la province, 1998.**

| | Emplois | | | Revenus ('000 $) | | |
|---|---|---|---|---|---|---|
| | Emploi direct estimé | Emplois induits[a] | Emploi total estimé | Revenu total d'exploitation[b] | Revenus induits[c] | Revenus liés à la production aquacole |
| T-N | 470 | 313 | 783 | 9 780 | 6 520 | 16 300 |
| Î-P-É | 1 300 | 867 | 2 167 | 19 200 | 12 800 | 32 000 |
| N-É | 850 | 567 | 1 417 | 17 350 | 11 567 | 28 917 |
| N-B | 1 500 | 1 000 | 2 500 | 178 800 | 119 200 | 298 000 |
| QC | 250 | 167 | 417 | 6 400 | 4 267 | 16 667 |
| **Est canadien** | **4 370** | **2 914** | **7 284** | **231 710** | **154 473** | **386 183** |

[a] Chaque emploi direct génère 2/3 d'un emploi indirect.

[b] D'après Statistique Canada, Compte de valeur ajoutée - Industrie de l'aquaculture, 1998.

[c] Multiplicateur similaire à celui pour l'emploi.

port et la commercialisation des produits,...). Selon les études les plus sérieuses en ce domaine, chaque emploi direct créé dans l'aquiculture entraîne la création de 2/3 d'un emploi indirect dans les secteurs induits. Le multiplicateur d'emploi varierait cependant selon le type d'activités (i.e., le secteur conchylicole nécessiterait davantage de main-d'œuvre pour une même production que, disons, dans le secteur salmonicole) et également selon le niveau de maturité du secteur. Plus le secteur est mature ou développé, mieux il est réseauté et plus grandes sont les retombées régionales et provinciales au plan économique.(11)

En adoptant ce ratio moyen de 0,66, on évalue ainsi à 2 914 le nombre d'emplois induits liés directement à la production aquacole dans l'Est canadien, ce qui porte le nombre total d'emplois à 7 284. Il s'agit d'un apport important, en particulier dans les Maritimes, d'autant plus que ces emplois sont largement concentrés dans les collectivités côtières aux prises avec des problèmes chroniques de chômage. Il appert également que la main-d'œuvre liée à cette industrie est particulièrement jeune, la moitié des travailleurs ayant moins de 30 ans.(12)

Le foisonnement d'entreprises offrant des produits et services à l'industrie aquacole témoigne de ses besoins multiples et souvent complexes. Une enquête de Pêches et Océans estimait en 1992 à 435 le nombre d'entreprises au Canada fournissant des biens et des services à l'industrie aquacole.(13) D'après l'annuaire des entreprises de Canadian Aquaculture 2000, ce nombre serait passé à 969 en 1998. On compterait par ailleurs près d'une centaine de groupes ou d'agences de formation liés pour la plupart avec les institutions publiques post-secondaires (universités et collèges communautaires), ainsi que 172 groupes ou unités de recherche voués entièrement ou en partie au développement de l'industrie aquacole. Une cinquantaine d'associations chapeaute cette industrie, du niveau local et régional au niveau international.

Toujours selon le Canadian Aquaculture Directory, on dénombrerait 1 927 producteurs aquacoles dans l'Est canadien. Ce nombre inclut une grande variété d'opérations, allant de l'étang à poisson pour touristes (U-Fish) aux sites modernes de production d'élevage du saumon, en passant par les baux d'exploitation pour les huîtres, les sites de production de moule, les sites de reproduction, ainsi que divers projets exploratoires sur de nouvelles espèces telles l'oursin, le flétan, la morue. Or, l'industrie fait appel à plusieurs centaines de fournisseurs (le répertoire en identifie 464) dans des domaines aussi variés que la maintenance d'équipements et le traitement des eaux, aux services de consultation, en passant par la fourniture d'aliments pour poisson et d'alevins, ainsi que le contrôle des maladies. Fait intéressant, la majorité des fournisseurs répertoriés sont localisés en milieu urbain, dans les principaux centres régionaux, bien qu'une foule de petits centres soient également représentés.

Enfin, si l'industrie aquacole bénéficie d'un encadrement technique et scientifique particulièrement élaboré, elle ne peut que s'épanouir à l'intérieur d'un cadre législatif et réglementaire rigoureux, et ce, pour deux raisons essentielles. D'une part, pour s'assurer à la fois du respect de l'environnement et du droit d'utilisation de l'espace côtier - comme il a été démontré lors du récent conflit dans l'industrie du saumon d'élevage en Colombie-Britannique.; d'autre part, pour s'assurer de la qualité et de la salubrité des produits d'origine aquacole, d'autant plus que la science permet déjà de reproduire des espèces modifiées génétiquement, et ce, même à l'Île du Prince Édouard. L'entreprise Aqua Bounty Farms de l'Î-P-É a récemment mis au point une technique (par modification génétique) permettant de multiplier par six la vitesse de croissance du saumon. C'est dire la poussée technologique qui accompagne ce secteur d'activité et dont le Canada semble avoir de bons acquis.(14) Des considérations environnementales, juridiques et éthiques sont donc à l'ordre du jour, ce qui nécessite un encadrement serré de la part des gouvernements. Au point où il est à se demander si l'industrie n'est pas freinée dans son développement par une réglementation excessive.(15)

Enfin, il ne faut pas sous-estimer l'apport résultant des transferts technologiques et de la formation. Les quelques centres spécialisés en études marines et en aquaculture oeuvrant au sein de l'université Memorial à Terre-Neuve constituent un exemple intéressant des liens étroits pouvant exister entre l'industrie aquacole et le vecteur institutionnel. Des exemples de partenariat entre gouvernements/institutions/entreprises sont de plus en plus fréquents dans les différentes provinces et témoignent d'une volonté ferme de développer l'ensemble de la filière aquacole afin d'en maximiser les retombées socio-économiques. La dernière initiative du gouvernement fédéral visant des investissements de 75 millions $ en vue de renforcer et de stimuler le secteur aquacole au Canada s'inscrit dans cette dynamique renouvelée envers un secteur à fort potentiel en pleine mutation. Le programme en question, étalé sur cinq ans (2000-2005), « vise à resserrer les liens entre tous les ordres de gouvernement, les communautés scientifiques et universitaires ainsi que l'industrie afin d'assurer le développement d'une industrie aquacole compétitive et diversifiée ».(16) Voyant ce regain d'intérêt à la fois du secteur privé, des agences publiques et des gouvernements envers le domaine aquacole et des produits marins en général, il est à parier que les prévisions pour les moins optimistes du ministre de Pêches et Océans, Herb Dhaliwal - ventes de production de 1,5 milliards $ d'ici 2005 pour le Canada, sont en voie d'être réalisées.

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# The Politics of Aquatic Farming: Development as if People Mattered — A Community-Based Approach to Redefining the Commons

*Brian Ives*

In aquaculture, as in agriculture, farming is conducted at a variety of levels, from the small family farm to the large, corporate, vertically-integrated agribusiness. This results in many styles of farm management and types of working protocols. On the surface this makes for a complex picture, but there are common threads that run throughout the aquaculture industry. Environmental issues and food quality must be discussed with consumers — as good stewards and responsible corporate citizens, we can do no less. To begin looking at these important issues and community economic development as a "true" tool to regional stability, rather than a government euphemism, will be a significant challenge for all of us in the coming years.

First, I have to tell you that I have laboured to write this paper. It was difficult because we have been discussing the same issues for close to 15 years and the issues appear to be getting more complex. Maybe in order to find simplicity we have to redefine the questions, rather than continuing to answer the wrong questions. I don't believe that controversy surrounding aquaculture and community development is bad. It is the continuing confrontation that serves no purpose.

Some years ago at Voluntary Planning, an organisation of 700 volunteers in Nova Scotia, we decided to better define our role in a planning process within the fishing communities, rather than spending most of our time dealing with the "day-to-day" crisis facing some communities. As we are all aware, there are numerous groups addressing the concerns of coastal development. For any association and/or agency to have a "position paper" on aquaculture development, it will be necessary to look at all aspects of coastal development that fall under provincial jurisdiction.

The following discussion is presented only as an illustration — a starting point.

## The Need for a Plan

To begin looking at community economic development as a "true" tool to regional stability, rather than a government euphemism, will be the significant challenge for all of us in the coming years.

In Atlantic Canada, we have to pause and evaluate the task before us. We have always thought that Ottawa would "bail us out" and this has led to an economic strategy (or lack thereof) that has evolved into a management-by-crisis situation, a process that depends more on the politics of the day, than on planning.

Instead of arriving at defined answers, we should be asking more questions. What do small isolated communities (need) want and how do they identify their needs and priorities? From this exercise, we can make some interesting observations:

1. There is a sense that some of the social and economic travesties we have experienced/created over the past 2 to 4 decades have caught up with us. People are frustrated because they have not been listened to and are now less willing to compromise with government.
2. The process has been exclusive (some would say elitist) and the inclusion of all stakeholders is now critical.
3. To achieve conflict resolution in many communities will require skilled facilitators from within the community, rather than some of the traditional methods that the aquaculture industry has used.
4. There is a need for full accountability — a monitoring process of government and committees that grow out of crisis management. If we look at some of the results from lease ap-

plications, the agenda of the farmer is often quite different from that of the government.

The government's principal role should be to build the infrastructure required to foster the healthy, long-term growth of the community. In order for this to happen, the government must learn to be an effective listener. Often what a community needs is simply the tools to get the job done — "not to be helped, in spite of itself". Instead, what often comes back from Ottawa or the provincial capital is quite different than what the community initially asked for! This has often been the case in the traditional fisheries and this issue may be the principal concern in coastal communities: How will the government deal with aquaculture development down the road? It is much easier for the community to say no — now!

An example of planning may lie in the way an aquaculture industry develops within the region under the regulations of the two levels of government. Hopefully this will be easier in the future if the aquaculture industry works closely with the community first, rather than working with the government first and then going to the community. Creating working community-based aquaculture models could and would go a long way to dealing with the concerns about aquaculture. Where are the good news aquaculture stories? Of course, there are many, but we need to define them rather than just saying that aquaculture is creating jobs. Small communities are more than just places where people work.

Aquaculture is using a common property (the water), but it is not necessarily taking anything else from the common resource. In fact, it can be argued that aquaculture is in a position to put something back into the common resource. So why is there such a resistance to change in coastal communities and why it is questioned whether aquatic farming is a meaningful way to use the commons?

Obviously, many people have concerns related to how the use of the commons is re-defined. I feel there is an instinctual fear that by "freeing up" the commons we will do the same thing as we have done to the fisheries or other natural resources. And herein lies the principal reason for concern. For example, there is concern that now that natural fish stocks have been misused and/or poorly managed, that aquaculture companies will be allowed to harvest live juvenile stock (e.g., scallop) from the ocean in order to facilitate the development of aquaculture. It is my feeling that the aquaculture industry should strongly resist this type of development. We have to start "putting something back" instead of continuing to take from the ecosystem. The aquaculture industry has to develop the proper infrastructure, using agriculture models, to enhance natural stocks, not fisheries management practises.

Production from aquatic farming should, or could, be viewed as the biological monitor of the health of coastal waters. Instead of relying on the government to monitor coastal pollution, which they have not done well and now may be unable to afford, aquatic farmers could assume some of this responsibility. Data collection is an important day-to-day aspect of farming operations and we should have some means of consolidating all this regional information. In the past, our approach to science and marine technology has been somewhat linear, but now it is time to look at solutions in a more holistic manner and have the solutions come from within the community.

Let's look at a couple of scenarios in which aquaculture can be viewed as part of the strategic plan of coastal development, rather than just another coastal problem. In Atlantic Canada, many small coastal villages and towns have a very ineffective manner of dealing with domestic sewage. To fully develop the infrastructure for sewage treatment will cost millions of dollars. So, little will happen, and because it is not a real priority, communities convince themselves that they can't afford to do the job!

Shellfish could become an integral component of the environmental monitoring of bays and harbours and indeed, in some cases, could help clean up the coastal waters from industrial and domestic pollution. Extensive rearing of shellfish would also allow fishers to harvest wild stock, using their traditional harvesting practises, and then place the animals outside the polluted waters, and re-harvest the stock for sale 1 to 2 years hence. The cultivation of macro algae could also aid in cleansing the waters. Thus, water, our most valued natural resource, should be treated as a commodity!

Millions of gallons of water, often polluted, are "dumped" into the watersheds every day, with no commitment to use it wisely. Why couldn't aquatic farmers develop designed wetlands — areas that could deal with sewage and clean the water for re-use by the aquaculture industry? The technology is available and there examples where it has been successfully implemented. We only need the will to look at the issues in a more collective and creative way — a "type" of extensive, sustainable polyculture.

What has happened in the past is that aquaculture issues have been dealt with in the same manner as problems in the traditional fisheries — management by crisis rather than using a strategic planning process that is more mindful of long-term needs. Planning has not been an operative concept within the fisheries and coastal communities. We know this to be true, because we are currently paying the price.

We also have to deal with coastal user conflicts and the process of handling such conflicts can no longer be left to the traditional users and regulators. The process must be more inclusive, and inclusiveness must be defined within each community.

Some time back, I saw a proposal that had been developed by a group in the United States. In Maine and Massachusetts, there is at present an evaluation of the potential to establish cod hatcheries to enhance coastal cod stocks by introducing millions of juveniles into the Gulf of Maine. A crazy idea you say. Maybe. But what happens if such a venture shows promise and Canadians chose to ignore the potential opportunity?

Groundfish hatcheries could be a viable solution to rebuilding wild stocks. They thought so in the late 1880s when fisheries science and enhancement were both in their infancy and the challenges of the day dictated that marine fish hatcheries be built for enhancement purposes. Some 10-15 years from now, if the cod stocks are healthy again on Georges Bank, Canadians will once agin work the northern section (20%) of the grounds for "their fish". But Americans, because of their stocking programme, may want to lay claim to the cod on Canadian grounds and they will be able to "prove" that the fish originated from their enhancement programme. Legally, partly because of Canada's efforts in the early 1970s with the commercial fisheries of Atlantic salmon in the North Atlantic, the Americans will be able to make a case, using a precedent that was defined by Canada in the International Court. Maybe this scenario is an exaggeration, but the solution to fisheries and aquaculture problems should be based on planning, not management by crisis. The shellfish hatchery technology that we now use in aquaculture could be an integral part of the needed infrastructure. Could aquaculture become a modest part of the solution and the environmental conscience of the coastal communities?

## Processing Sector

It is important to let the consumer know that all of the fish and shellfish production that comes out of the water is being fully used — that we will no longer tolerate fish "waste"and that the entire fish is used in the production of some type of by-product, so that all of the biomass that comes from the ocean is used, not just the part that produces an immediate return. In agriculture, it is often said of pig processing that everything is processed but the squeal.

## Implementation

The ideas are easy to talk about, but where do we obtain the funds to develop such an initiative? First, the aquaculture industry must start investing in itself. Gone are the days when we should be developing business plans and expecting funds to come from Ottawa. As well, the process must be more inclusive so that a broader perspective from other coastal industries, such as agriculture and tourism, can add their knowledge to the "design and implementation" plan. We need to set up community-based, self-directed funds, *vis a vis* guaranteed community bonds. By investing in ourselves, we will achieve a sense of "ownership" and pride that has escaped us since earlier this century. The problem, in part, has been that we have sent our pension funds and RSPs to Toronto, to be managed by people who do not have the same level of commitment to the Atlantic Region. A percentage of this money, particularly from the civil service and private sector unions in the region, should be allocated to regional development. Plans such as the Caisse Populaire programme in Quebec, the McCamby Report (Working Ventures) and a regional venture capital corporation are needed within the region. Credit unions should be allowed and encouraged to offer the same services as the large corporate banks in Canada.

Rural Canada is nervous —it has been abandoned. When you see what has happened to its forests; when you see what is happening to its farm lands; when you see what has happened to its fisheries; when you see what is happening to its communities — you simply say: "Let's wait and see before approving more development".

Sustainable aquatic farming should be a principal participant in the development of coastal communities. However, it is imperative that the aquaculture industry work more closely with others in the local community in order for effective planning to occur. This, indeed, will be the greatest challenge in developing a successful plan. Aquaculture can and should be an important aspect of rural Canada's future development.

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# The Richibucto Environment and Resource Enhancement Project: A Focus on Aquaculture

*A. St-Hilaire, A. D. Boghen, S.C. Courtenay and V.G. Koutitonsky*

The Richibucto Environment and Resource Enhancement Project (REREP) is a multistakeholder project initiated in 1995 to contribute towards the social, recreational and economic well being of the residents of the Richibucto River basin. Specific goals of the project include improving the environmental quality of the river, estuary and harbour for the sustenance of existing and anticipated activities which include fishing and aquaculture. In particular, oyster culture is a major industry in the area and is projected to expand in the immediate future. Managing aquaculture and other activities to be sustainable requires a thorough understanding of the physics of water movement and the components and interactions of the ecosystem. REREP seeks to provide the Richibucto community with the science it has asked for and requires for integrated management.

## Introduction

In recent years much attention has been attributed to interactions between aquaculture and the environment. Environmental issues have impacted and are becoming paramount in determining the rate of growth of the aquaculture industry. In eastern New Brunswick, serious efforts are being made to develop a strong shellfish industry. And while the blue mussel, (*Mytilus edulis*) and the American oyster (*Crassostrea virginica*) remain major cash crops, new bivalve species such as soft-shell clams (*Mya arenaria*) and surf clams (*Spisula solidissima*) are vigorously being investigated for aquaculture.

The synergy between aquaculture and other major resource-based and secondary industries is an area that must be rigorously explored. On the one hand the degradation of water quality in coastal regions could be detrimental to shellfish production and/or quality, while on the other hand, different resource users (agriculture, processing plants, peat mining, etc.) including new and/or established aquaculture operations may be contributing to increasing levels of organic pollution. Producers, environmentalists and scientists representing different institutions, are seeking innovative approaches in working together to reduce and mitigate threats to estuarine ecosystems.

The concept of sustainable development has become a key element in the management of estuaries and their river systems. Integrating the management of such waters may in fact be the only way to minimise and control potential conflicts between aquaculture and other industries that share a common resource. One attempt at integrating a number of activities in an estuary in which there is an important aquaculture component, is the Richibucto Environment and Resource Enhancement Project (REREP).

REREP was initiated in 1995 by the Environmental Sciences Research Centre (ESRC) of the Université de Moncton in conjunction with a number of partners, including the Department of Fisheries and Oceans Canada, Environment Canada and various provincial departments. The specific objectives of REREP were established only after a series of extensive public consultations were undertaken with the main stakeholders of the watershed (local town representatives, leaders of First Nation communities, fishers and aquaculturists).

From the outset, it was recognized that, first and foremost, the project had to reflect the priorities and concerns of all the affected parties. It was recognized that an "integrated approach" needed to be sensitive to the political, economic and social realities of the region. While the long term objective was to contribute towards social, recreational and economic benefits for the residents of the area, the more immediate and short term aims were:

- Identification of some of the factors that contribute towards the deterioration of the aquatic environment,
- Proposal of appropriate rehabilitative measures to address and correct some of the problems that were identified,
- Application of newly-gained information that would be helpful for the development of strategies for the enhancement of certain targeted species ei-

ther through aquaculture or by improved fishery management.

During Phase I of the project (1996-2000), the scientific program attempted, at the very least to begin filling in some of the gaps in the knowledge base of the Richibucto ecosystem. Several fisheries and aquaculture-related projects were undertaken. The remainder of this paper provides a very brief overview of some of these projects.

## Study Area

The Richibucto watershed covers approximately 1300 km² and is located in southeastern New Brunswick (Fig. 1). Its drainage system is complex and includes a number of rivers and tributaries. The Richibucto and St-Charles Rivers, each one draining into the Richibucto Harbour, are the two main rivers constituting the system. In addition, a network of associated tributaries contribute significantly to freshwater inflow. The Richibucto estuary ultimately drains into the Northumberland Strait via the main Richibucto Gully, situated between the North and South Richibucto Dunes (Fig. 1).

Richibucto Harbour is a shallow body of water fed primarily by two freshwater networks: The Richibucto River and the Northwest Branch, which is the confluent of the St-Charles River and Aldouane

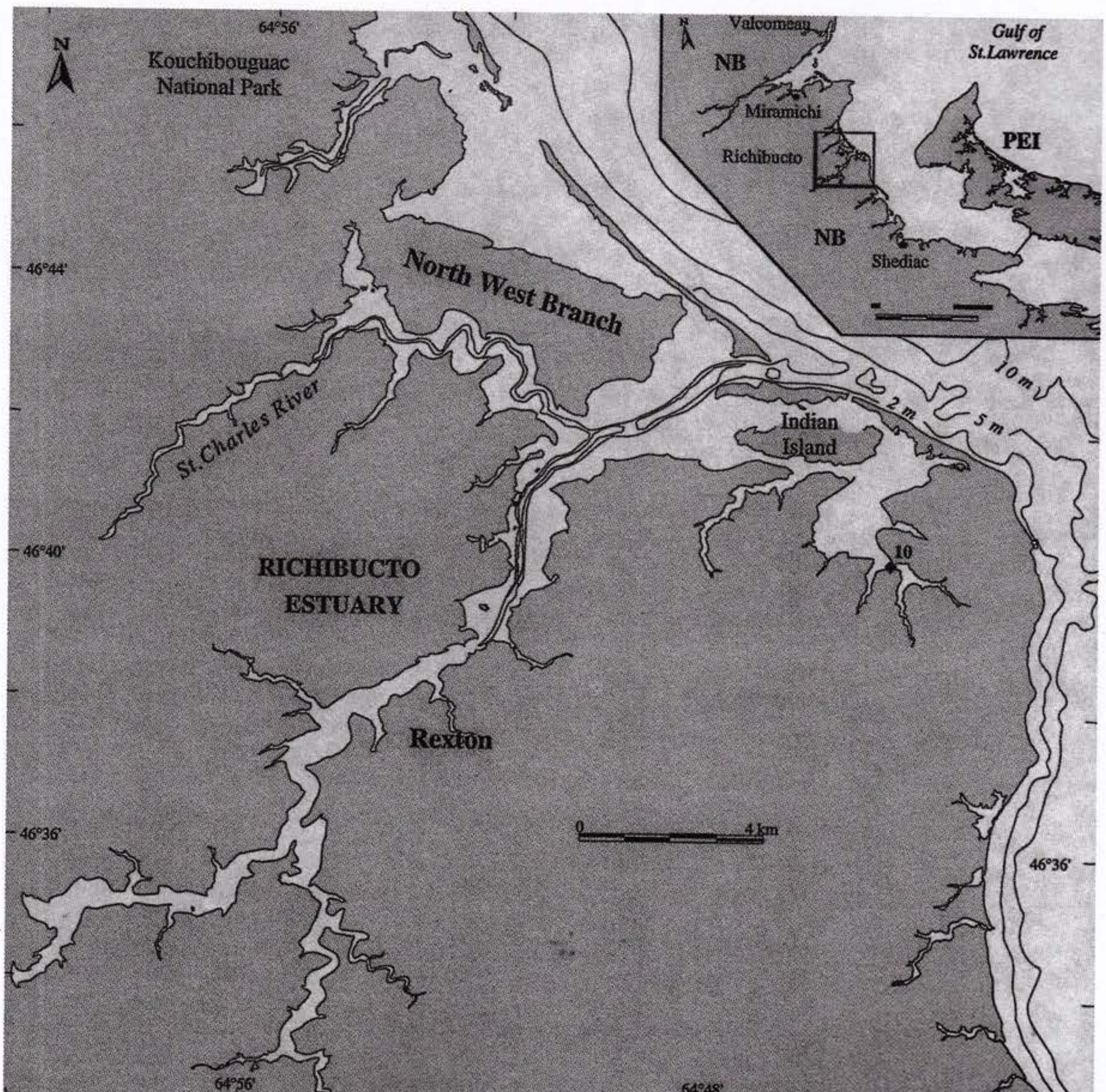


**Figure 1. Richibucto Estuary**

**Table 1. Historical landings of fish mostly harvested in estuaries in DFO Statistical District 76, which includes the Richibucto Estuary.**

| Year | Alewives (Gaspareau) | | Smelts | | Eels | |
|---|---|---|---|---|---|---|
| | Landings (MT) | Value (1000 $) | Landings (MT) | Value (1000 $) | Landings (MT) | Value (1000 $) |
| 1984 | 507 | 157 | 125 | 56 | 67 | 106 |
| 1985 | 1427 | 210 | 156 | 176 | 104 | 194 |
| 1986 | 389 | 66 | 277 | 298 | 94 | 219 |
| 1987 | 1152 | 114 | 331 | 233 | 105 | 311 |
| 1988 | 902 | 96 | 268 | 222 | 130 | 389 |
| 1989 | 803 | 215 | 281 | 205 | 108 | 346 |
| 1990 | 718 | 66 | 155 | 139 | 45 | 147 |
| 1991 | 587 | 71 | 199 | 176 | 49 | 169 |
| 1992 | 396 | 61 | 207 | 143 | 52 | 183 |
| 1993 | 754 | 88 | 215 | 174 | 26 | 96 |

River. The main Richibucto River is approximately 35 km long while the Aldouane River is about 10 km long and is fed by only one tributary, the Little Aldouane. The drainage basin is rectangular in shape with an average elevation of about 45.5 m above mean sea level.[1]

The watershed includes the two municipalities of Rexton and Richibucto, the First Nation communities of Big Cove and Indian Island, and a number of smaller parishes.

Aquaculture operations are mostly located in the Northwest Branch and Richibucto Harbour, along the north shore and adjacent to Indian Island. Most of the aquaculture leases are for oysters that are either cultured on the bottom, on submerged tables or in floating cages.

## Historic Biological Information and Statistics

During the initial public consultation process in 1996, it was clearly established through existing literature as well as from the stakeholders themselves, that the Richibucto watershed was as a potentially rich ecosystem, historically characterized by high biodiversity and abundant commercial and non-commercial aquatic species. Concern was expressed that species were rapidly declining in both numbers as well as diversity. In fact, data landings confirm that a number of important commercial fish species peaked in the late 1980s, and, generally speaking, have been declining ever since (Table 1).

Angling, an activity which had always occupied an important place in the Richibucto and one that was once highly valued by the stakeholders both as a recreational activity and an industry-linked endeavour, has likewise dropped significantly. Angling for Atlantic salmon (*Salmo salar*), and striped bass (*Morone saxatilis*) for example, have both been severely restricted in recent years and surveys completed in 1994[2] suggest that salmon numbers in the Richibucto River are currently very low. Given the decline of both commercial and recreational fish populations, the Richibucto has been identified as an area where the possibility of shellfish aquaculture could prove to be very attractive. One reason for optimism about the potential for aquaculture development in this region was the recognition that local populations of oysters and clams had previously been fished in the area over many years indicating suitable conditions for growth. The decline of commercial and recreational fishery activities represent important incentives for looking at aquaculture development as a suitable economic complement to these activities.

At the same time, an increasing number of anthropogenic stresses contribute to the overall degradation in water quality. This, at the present time, translates into conditional and permanent closures to shellfish harvesting and intensive aquaculture. Attention to such issues with a rehabilitative focus in mind, parallelled efforts in working towards the development of an aquaculture industry in the region.

## REREP Projects

Based on the available historic information and various concerns raised by the stakeholders during the public meetings, an Action Plan was drafted on behalf

**Table 2. REREP Projects**

| Project | Period | Objective | Stakeholder |
|---|---|---|---|
| Impact of ice on potential bivalve growout sites | 1995-1998 | Monitor ice conditions on potential grow-out sites | Indian Island First Nation |
| Soft-shell clam pilot project | 1998-1999 | To monitor growth conditions and predation at selected test sites around Indian Island | Indian Island First Nation |
| Investigations to establish a broodstock-conditioning oyster program in the Petite Aldouane River | 1997-1998 | To conduct an evaluation of the conditioning responses of adult oysters maintained in different microenvironments of broodstock-population enhancement | Aquaculture industry (Aquaculture Acadienne Ltd.) |
| Growth and condition of oysters in floating cages near Indian Island | 1999-2000 | To monitor growth and health conditions of oysters in floating cages. Pilot-scale program | Indian Island First Nation |
| Implications of the presence of parasites in oyster culture | 1995-1999 | The attraction and effects of the flat worm *Urastoma cyprinae* on the American oyster *Crassostrea virginica* | Aquaculture industry |
| Comparisons of oyster grow-out sites in the Richibucto estuary and in the Richibucto River | 1995-2000 | To verify if the grow-out sites for oysters may be commercially viable upstream of Rexton, adjacent to Big Cove | Big Cove First Nation, aquaculture industry (Aquaculture Acadienne Ltd.) |
| Study of the early life stages of striped bass | 1996-1999 | To verify if a local spawning population exists in the Richibucto Estuary and develop a better understanding of the species' ecology | Richibucto River Association, local anglers, Native communities of Big Cove and Indian Island |
| Impact of peat moss harvesting | 1996-2000 | To monitor the physical and biological conditions in an estuarine area where peat was spilled | Malpec Peat Moss, aquaculture industry Richibucto River Association |
| Diet of white perch | 1999 | To verify the diet and distribution of juvenile white perch, and compare with its cousin, the striped bass | Richibucto River Association, local anglers, Native communities of Big Cove and Indian Island |
| Physical oceanography | 1996-2000 | To understand the circulation and exchange of water masses in the estuary | Aquaculture industry, fishers, angling population, Native communities of Big Cove and Indian Island |
| Water quality in the Richibucto River system | 1999 | Assessment of the level of bacterial contamination in the Richibucto River System | Aquaculture industry, Native communities of Big Cove and Indian Island |
| Development of marine environmental quality indicators | 1999-2000 | To test whether developmental abnormalities in larval fish are a sensitive indicator of MEQ | Aquaculture industry, local communities and industries |

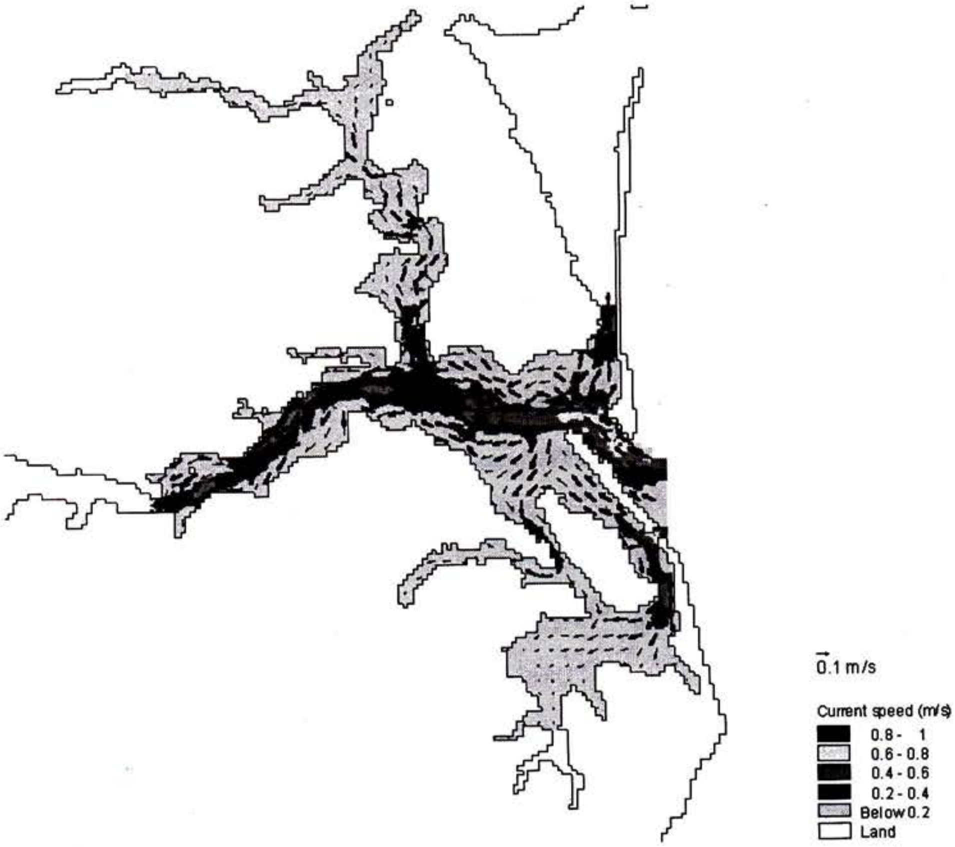


**Figure 2. An example of hydrodynamic model output in Richibucto: Flood currents.**

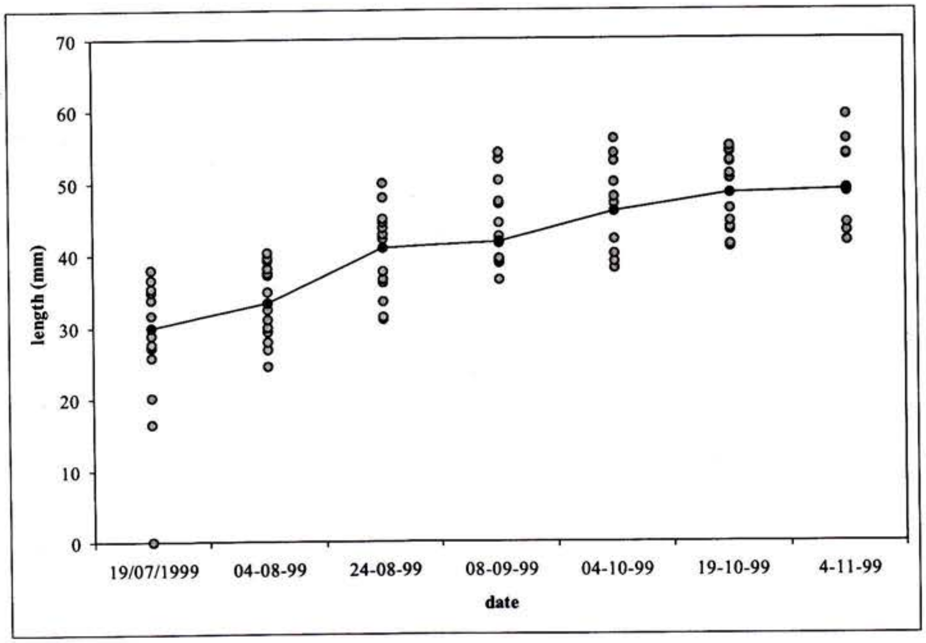


**Figure 3. Oyster growth for site 1 (black markers represent the median).**

of a local environmental association — The Richibucto River Association,[3] which coincided for the most part with the overall aims and goals of REREP. To achieve the RRA's and REREP's specific objectives, the projects were community-based and always conducted in a spirit of co-operative partnerships, both with local industries as well as various other stakeholders[4] (Table 2).

In accordance with the original objectives that REREP set for itself, and as explained above, certain initiatives dealt with the acquisition of useful scientific background information about the ecosystem, while other efforts were directed at obtaining data that would contribute towards the development of resource-based industries such as aquaculture. Table 2 provides a list of some of the major REREP initiatives. A capsular look at a few of the more important projects, specifically related to aquaculture are discussed in later sections.

**Figure 4. Cages near Indian Island are being prepared for clams**

### *Physical oceanography*

As the REREP program evolved in its efforts to collect technical and scientific information about the Richibucto ecosystem, it was obvious that there was as a serious requirement for an improved understanding of the physical oceanography of the region. Successful commercial aquaculture operations ultimately depend on the water renewal of a system, which is in turn controlled by a complex combination of hydrodynamic processes (tides, freshwater flows, etc.).

Early work performed by Gregory et al.,[5] suggested, through simple tidal prism calculations, that the mean volume of water entering the estuary on a flood tide or leaving on an ebb tide is $26.2 \times 10^6$ m$^3$. This implied that the typical ratio of tidal to freshwater input in the estuary is approximately 86:1. Descriptive physical oceanography data were also gathered by St-Hilaire et al.[4] The authors demonstrated that salt water migrated upstream at least 42 km from the South Richibucto Dune, to Browns Yard (Fig. 1).

To verify the accuracy of these calculations and to obtain an even more detailed understanding of the hydrodynamics of the system, a modelling approach, supported by field measurements, has recently been undertaken. A major field study involving time series measurements of water levels, current velocity and directions, temperature and salinity at 10 locations in the estuary, was completed during the summer of 1999. The data are currently being processed and will be used to initiate, force, calibrate and validate a 3D hydrodynamic model. Preliminary results[6] suggest that this approach will ultimately provide a better and much more accurate profile of the circulation and the flushing mechanisms and rates over a range of meteorological and hydrologic conditions (Fig. 2). Such information, along with other biological data to be integrated with the actual findings, are considered vital for defining the carrying capacity of the watershed and subsequently the limits of aquaculture development in the Richibucto.

### *Aquaculture projects*

A number of aquaculture-related projects have been initiated by REREP in collaboration with local stakeholders (see Table 2). One key stakeholder is the MicMaq First Nation of Indian Island. Located on the southern shore of the Richibucto Harbour, near Baie-du-Village, Indian Island is a small community where natural resource-based industries represent an important source of employment.

Aquaculture development has become a major priority for the community of Indian Island. To assist them in meeting this objective, REREP has, over the last several years, explored the possibility of developing the culture, of not only more traditional bivalves such as the American oyster *Crassostrea virginica* (Fig. 2), but also some non-traditional species, including the bar clam *Spisula solidissima* and soft shell clam *Mya arenaria*.

The bar clam displays great commercial potential for aquaculture because it is a very fast-growing organism for which there is a high market demand. Information on the species' ecology, especially as it relates to appropriate grow-out techniques is lacking. One aspect in particular which is fairly unique to the Atlantic coast, is concerned with the presence and possible effects of winter ice on grow-out opportunities. To this end, a three-phase study was conducted to acquire a better understanding of the impact of ice behaviour on site selection. Critical information relating to various parameters has been collected and we now have a fuller appreciation of the potential advantages of certain sites and the possible influences of ice characteristics including thickness, formation, fluctuation under different conditions, presence of frazil ice and general breakup.

Work on soft-shell clams was initiated two years ago. Last year clams from another region were introduced to five sites in the Richibucto region. Growth, physiological indices, predation, and the impact of the surrounding environment were monitored. The program provided useful baseline information and is expected to continue with special focus on larval recruitment. (Fig. 4).

A pilot-scale oyster-culture program using floating cages was likewise initiated in 1999 and expanded in 2000. Various parameters were monitored and preliminary findings suggest that there is sufficient justification to warrant the transfer from pilot-scale level to a commercial scale in 2001.

## Conclusion and Future Work

As REREP embarks into Phase II of its program, the initial objectives remain as pertinent as in the beginning. Information on the physical and biological oceanography initiatives that have already been undertaken and will persist, will undoubtedly contribute significantly to the critical foundations for all aquaculture-related projects. Their contribution to the overall information bank as it applies to the environment and overall health of the Richibucto ecosystem are vital. The aquaculture component of REREP is at a critical stage and the transfer of oyster culture from pilot to commercial scale, at Indian Island by way of example, offers exciting challenges.

Once the hydrodynamic model as discussed earlier is tested and validated, we will be able to assess much better the implications of water movement on water quality and food availability at established as well as newly-proposed aquaculture sites.

3D water quality and eutrophication numerical models integrated into the broader 3D hydrodynamic model will be applied. Field measurements of selected biochemical parameters will be required for validating the numerical models. With such information in hand, we will be able to assess the biological carrying capacity of the estuary, fully taking into consideration the potential cumulative impacts and limitations imposed on the rate of growth of commercial culture sites.

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# Aquaculture
# and Integrated Resource Use

*Edward Black*

Since the mid 1980s, management of aquaculture on Canada's west coast has undergone an evolution. Driven in part by the contentious issue of salmon farming, the management of aquaculture has changed from siting farms in areas where industry thought aquaculture would be viable, to siting farms in areas where conflict with upland owners and other marine resource users would be minimized, to siting criteria that now include both environmental capability and socio-economic suitability A number of the tools developed to help with these evaluations will be examined. All of this follows much of the traditional sectoral approach to fisheries management. This approach however, appears to be undergoing an evolution. The new paradigm for siting views aquaculture as part of a much broader mix of marine resource users within which aquaculture is an equally valid participant in coastal development and use. The move to implement this new model of marine resource management has been driven in part from changes in management of wild fisheries, first nations participation in fisheries management and a new role for coastal communities in management of the coastal zone. This evolution of fisheries management on the west coast demonstrates both what can work and what will not work in the modern milleau of resource management.

Patterns of resource use constantly evolve. Resource managers must recognize this and manage in a way that allows this to happen. To do that they must recognize changes that are underway in resource use and identify the new demands these changes will have on the ecosystem and the way in which it should be managed. The growth of aquaculture is one example of the evolution in the pattern of coastal resource use. Aquaculture also provides an example of the ways resource managers have to change their practices to meet the challenges of effectively husbanding the coastal zone environment.

Over the past three decades there has been a shift in the technologies used to supply fish for human diets. Global production in the capture fisheries is stable or declining, while aquaculture production is expanding by about 10-15% per year with no evidence that the rate of growth will decline in the foreseeable future. In 1998, aquaculture contributed approximately 31% of the world fisheries production.(1) This shift in the basis of fisheries production is mirrored by changes in Canada's fisheries on both the Pacific and Atlantic Coasts. In Atlantic Canada, the 1988 capture fisheries were worth $1017 million dollars and aquaculture production was worth $43.8 million. In 1999 those fisheries were worth $1294 million and $159 million, respectively. On the Pacific coast, over the same period, the capture fisheries decreased in value from $770 to $295 million while aquaculture increased from $55.7 to $238 million.(2)

There is a growing body of literature demonstrating the types of environmental changes aquaculture can effect in coastal areas. Equally important is that many other coastal activities negatively affect both the coastal environment and the aquaculture practiced there. Consequently, not all the potential uses of coastal areas can be developed to their maximum extent. Governments have the ability and obligation to enable, over time, the best stream of sustainable economic benefits from coastal resources for their citizens. To effectively manage coastal zone activities, governments need to recognize that the mix of uses of the environment is determined by ecological, social and economic factors. Managing for only one or two of these factors is an inadequate basis upon which to manage human activities at the sea's margin. While governments can manage in the context of these three sets of factors, they do not have the ability to influence each these factors equally. Globalization of commerce and international trade agreements have re-


SALMON AQUACULTURE
POTENTIAL RELOCATION SITES
Lucan Islands
Map 1: Aquaculture Tenures
and Shellfish Beds
Buffers
Finfish Farm (3km)
Shellfish Farm
or Shellfish Bed (125m)
Intertidal Shellfish Bed (300m)
Non-Buffered Features
Other Finfish Farm
Indicated Potential Site
Other Potential Site
Bathymetry (10m interval to 50m)
Contours (20m interval)
Scale 1:40000
0km
1km
2km
Source:
Provincial Coastal Resource
Information Management System
Prepared by: Land Use Coordination Office
Province of British Columbia
04/17/00
CHRISTIE PASSAGE
BALAKLAVA ISLAND
BROWNING PASSAGE
PORT ALEXANDER
C H A N N E L

**Figure 1. A hypothetical example of feature-based resource interest mapping for existing shellfish and finfish leases. A potential new (relocation) finfish site is indicated. No conflicts are apparent with this group of existing resources/uses.**

duced the ability of individual governments to modify many of the economic influences determining the resultant mix of resource uses, even though it is these economic factors that deliver many of the benefits from the use of our natural resources. As a consequence, in the context of the economic environment, husbandry of natural resources and social leadership are the basis on which governments maximize the sustainable benefits for their populace. This paper will examine the British Columbia experience in managing aquaculture and other coastal resources, and suggest how management of the coastal zone in other jurisdictions might be approached.

The financial benefits from aquaculture are an important part of fisheries opportunities. The problem for resource managers is how to create the best sustainable stream of benefits from aquaculture opportunities within existing social and environmental constraints. Public opinion polls commissioned in 1999 by the Office of the Commissioner of Aquaculture Development showed that the public at large perceives aquaculture as an acceptable use of marine resources. Aquaculture, however, is not distributed evenly across the population of Canada or British Columbia. It is practiced in a few specific environments directly impacting on only a small portion of the aquatic habitat and population of British Columbia. To ensure environmental and social changes brought about in these areas are well managed, the Province has done environmental impact reviews[3] and created a licensing protocol that consults with affected populations and environmental management agencies.[4] Key to making this system work is identification of sites capable of supporting economically-viable aquaculture while causing the least social discomfort.

The approach taken to defining aquaculture siting in BC is to respond to commercial opportunities as perceived by the business communities and expressed as an application to lease aquatic lands for aquaculture. The government, in deciding if an aquaculture development will proceed, examines the site for its environmental capability to support the type and level of activity proposed (capability). It also looks at other potential uses for the area and how the proposal will affect existing uses (suitability). To do this a number of tools have been developed. These tools are under constant review and are upgraded or replaced as the knowledge base for managing the resources improves.

Early efforts at fish farm siting in BC looked at the basic requirements (temperature, salinity, oxygen concentrations etc.) of the animal to be grown, as well as a numbers of other biophysical criteria including the site's proximity to seal and sea-lion haul-out areas, areas with known congregations of seabirds, and salmonid bearing streams. Using the bio-physical requirements of salmonids as a focus, information from large portions of the BC coast were compiled and mapped.[5] Those compilations and maps were made available to the public to assist applicants in defining potentially acceptable sites before they went to the effort of making a formal application. The information in the bio-physical publications only commented on the capability of the general area (scale of kilometers). Applicants were also asked to supply bio-physical information (on the scale of tens of meters) that addressed the capability of the specific site under application. Initially both types of information were used to make a qualitative assessment of the capability of a site to support sustainable fish culture. This approach to site assessment underwent an evolution through the 1980s and 1990s. Mathematical models taken from the published literature were combined with site- specific information on currents and proposed levels of production to make a crude estimate of the potential for sediment buildup under proposed cage systems. The sedimentation models used had been tested for their predictive capability in Scotland and Chile.

An important aspect of the approach taken in BC was that it acknowledged the need for changes in resource use over time. Sedimentation was the most extreme form of site degradation likely to be witnessed as a result of a decision to use an area for fish farming. There was no published information on how long it would take for a site to return to its pristine state after fish farming ceased. Qualitative observations by the author at sites used for log handling in BC suggests that the recovery from the sedimentation of bark and wood chips at those sites requires a number of decades for recovery. The studies of sediments at fish farms demonstrated a very rapid recovery.[6,7] Lightly impacted sites recovered within a year, moderately impacted sites took between one and two years, and the most severely impacted site recovered within four years. The implication is that post-operative opportunity costs are small and limited to one or two years in most instances. Few sites were heavily impacted because heavy sedimentation affects water quality, which in

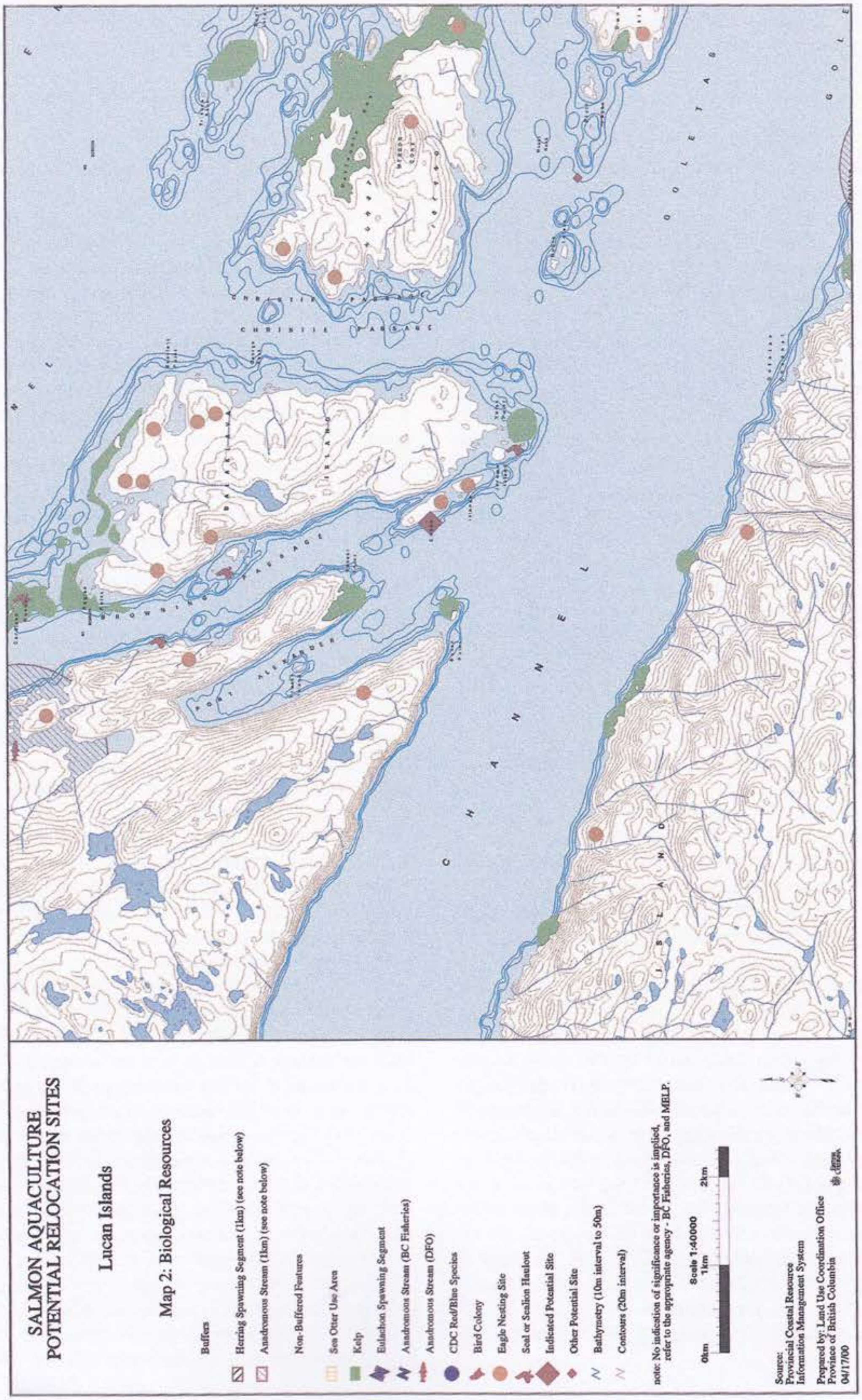

SALMON AQUACULTURE
POTENTIAL RELOCATION SITES
Lucan Islands
Map 2: Biological Resources
Buffers
Herring Spawning Segment (1km) (see note below)
Anadromous Stream (1km) (see note below)
Non-Buffered Features
Sea Otter Use Area
Kelp
Eulachon Spawning Segment
Anadromous Stream (BC Fisheries)
Anadromous Stream (DFO)
CDC Red/Blue Species
Bird Colony
Eagle Nesting Site
Seal or Sealion Haulout
Indicated Potential Site
Other Potential Site
Bathymetry (10m interval to 50m)
Contours (20m interval)
note: No indication of significance or importance is implied,
refer to the appropriate agency - BC Fisheries, DFO, and MELP.
Scale 1:40000
0km
1km
2km
Source:
Provincial Coastal Resource
Information Management System
Prepared by: Land Use Coordination Office
Province of British Columbia
04/17/00
CHANNEL
BROWNING PASSAGE
PORT ALEXANDER
CHRISTIE PASSAGE

**Figure 2. A hypothetical example of feature-based resource interest mapping for identified biological resources. A potential new (relocation) finfish site is indicated. No conflicts are apparent with this group of existing resources/uses.**

turn affects the health of the fish and compromises the economic viability of a fish farm.

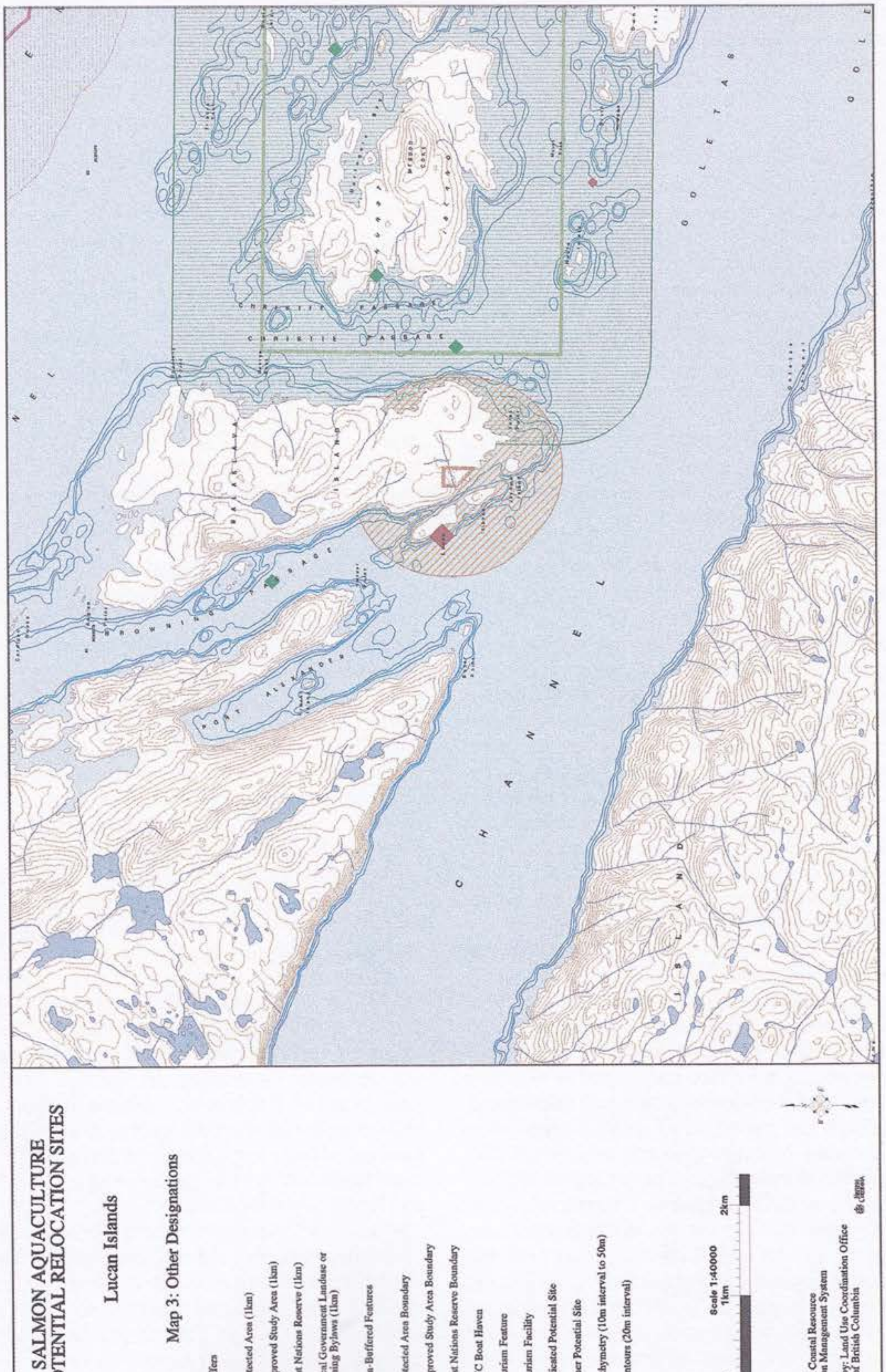
A more sophisticated approach has been taken to defining site capability for shellfish culture in BC. The implicit assumption has been that sedimentation effects from shellfish culture are no worse than those of finfish culture and may be considerably less extreme as shellfish culture does not employ food additives and antimicrobial agents. Further, if the effects of culture activities did not affect the cultured animals it was thought to be safe for the surrounding environment. Brown[8] developed and tested a predictive model for shellfish growth in local waters. It was based on the development of a habitat suitability index that was predictive for growth and survivorship of the cultured animals. That model was then expanded[9] to cover a number of types of culture activities (intertidal and deep water culture) and species (Pacific oyster, Japanese scallop and Manila clam). Based on that work an inventory of capability for shellfish culture was developed for a number of areas in BC.

Site suitability is in many ways a more difficult factor to determine as it involves integrating perceptions of desirable resource use by special interest groups, First Nations, and local communities, as well as provincial and federal policy on marine resource use. Two mechanisms are used to achieve this end. One is site suitability mapping; the other is an extensive referral system for applications.

When site suitability mapping was started in the late 1980s, local communities, special interest groups, and First Nations were invited to participate in a mapping exercise to identify coastal areas of particular importance for their use. Such a mapping exercise might involve as many as 44 agencies and interest groups.[10] Once their interests were accounted for, areas not otherwise spoken for were then considered as available for aquaculture development. While well intentioned, this approach had the effect of ranking aquaculture second to other potential resource uses rather than treating aquaculture as an equal player whose application for a site would be judged on it merits relative to other competing uses for that site. While this resource use mapping was occurring, another process also began designating marine protected areas. This process was designed, in part, to ensure that adequate resources were protected for parks and recreational use of marine resources. If marine protected areas were excluded as possible sites for aquaculture and recreational/tourism interest groups were included in the suitability mapping exercise, these resource users would be double dipping from the resource base for the same user group. Further areas identified by resource users in the suitability mapping exercise were extensive, often covering many kilometers of shoreline in each area identified by each interest group. In the 1990s there was a move away from this approach to mapping resource features and protected areas. This had the advantage of specifically showing protected areas, special resources such as salmon bearing streams, special fisheries areas, as well as bird and mammal aggregation areas (Figs. 1 and 3). Around these protected zones, buffer zones could be identified of a size consistent with maintaining those resources if aquaculture affected them or might be affected by them (Fig. 2).

Having identified, in terms of existing capability and suitability factors, the broad resource use context in which a new resource use (a new aquaculture site) is proposed, it remains to be determined how the proposed use fits into longer-term resource plans. In Canada, at least four levels of government have an opinion and affect resource planning: federal, provincial, local and First Nations. There are many areas where more than one level of government has a mandate to affect resource planning and they do not always agree on what the best mix of resource uses might be. Where there was a difference of opinion, the more senior level of government with a mandate for the resource usually took the lead in determining its use. This has led to resentment in small coastal communities about distant forces controlling the fate of local resources. In some ways, this resentment is similar to that generated by the absentee landlord of the borough system in England in the 18th and early 19th century. Things are changing, however, and modern integrated resource use decisions try to integrate opinions from stakeholders and all levels of government. It is recognized that resource decisions must not be made solely at the national or local level, but by an integrated management team that must be inclusive of all stakeholders and levels of government.

When such a management team is constituted with a clear role, authority, and responsibilities it can work very effectively. An example of an integrated management team managing multiple resources can be seen in the West Coast Vancouver Island Clam Management Board. This organization is composed of stakeholders of both the local capture and culture fisheries, local government, First Nations, provincial and


SALMON AQUACULTURE
POTENTIAL RELOCATION SITES
Lucan Islands
Map 3: Other Designations
Buffers
Protected Area (1km)
Approved Study Area (1km)
First Nations Reserve (1km)
Local Government Landuse or Zoning Bylaws (1km)
Non-Buffered Features
Protected Area Boundary
Approved Study Area Boundary
First Nations Reserve Boundary
CYC Boat Haven
Tourism Feature
Tourism Facility
Indicated Potential Site
Other Potential Site
Bathymetry (10m interval to 50m)
Contours (20m interval)
Scale 1:40000
0km
1km
2km
Source:
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CHANNEL
ISLAND
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ISLAND
CHRISTIE PASSAGE
GOLETAS

**Figure 3. A hypothetical example of feature-based resource interest mapping of resources not covered in Figures 1 or 2. A potential new (relocation) finfish site is indicated. Because the proposed new site is within the buffer zone for a hypothetical First Nation reserve the site would not be leased unless some written agreement could be obtained from that First Nation.**

federal governments. Decisions by this board are arrived at by consensus. For a number of years it has been the primary source of recommendations for the annual and in-season management scheme for 5 clam species which were previously managed by the federal government alone. The board has been very successful at reducing inter-sectoral tensions, limiting poaching, and directing fishing effort. Its success has resulted in the provincial government considering deriving its management advice for local oyster and marine plant stocks from the same or a similar organization.

Integrated resource management using the type of tools used in British Columbia has the flexibility to respond to changing social, economic, and resource use patterns. It is not a simple approach to implement, however. To be successful there needs to be a clear definition of objectives, roles, authority, and responsibility for the management team. As well, there has to be a commitment by all levels of government and user groups to engage in consensus-based decision making. Experience in British Columbia, however, has made it clear that such an approach has potential benefits for resource users, governments and the resource. Resource users gain the ability to directly influence the amount and timing of their access to the resource, as well as gaining the ability to identify new approaches to their use of the resource. Federal and provincial governments find this approach helps to reduce the cost of monitoring and improved effectiveness of enforcement of rules and regulations. Local governments and First Nations have more influence on factors affecting resource use, local investment, and employment. All parties benefit from the increased opportunity to negotiate changes and to increase understanding between user groups. The big winner, however, is the environment, where this approach increases control over the cumulative impact of man's on the ecosystem.

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# Aboriginal Shellfish Aquaculture

*Jeff Thomas*

Thank you for the invitation to participate in Aquaculture Canada 2000. My name is Jeff Thomas of Snuneymux[w] (Nanaimo) First Nation, British Columbia. At present, I am a displaced fisher, my last 15 years being involved in the salmon seining industry. Over the last 30 years I have been involved also in the gillnet, troll, shrimp and herring fisheries. With the decline of a lot of our stocks, I am no longer participating in any of our fisheries though there is still fishing going on today. Many fishermen like myself are no longer involved because of limited openings with limited quotas — mostly in the salmon industry. First Nations, along our long, vast BC coast were hit particularly hard, today facing 60 to 80 percent unemployment.

Today I work for Unique Seafoods of Nanaimo in the area of product development. We are a shellfish processing company, our main products being the Pacific oyster, Manila clam and littleneck clam. Our annual shipping year would be around a million pounds (450 000 kg) per year of Manila clams and 150 000 dozen of Pacific oysters per year. Shippings of littleneck clams are small throughout the year as the customer demand is for Manila clams. Shellfish are sent to mainland USA, Alaska, and Hawaii.

Another interesting aspect of our business is depuration — the use of ultraviolet light to cleanse clams of fecal contamination. A number of our beaches next to cities and mills have been polluted over the years. Depuration allows us to still access the shellfish from these beaches. The company obtains shellfish products from First Nations along the coast, aquaculture farmers, and DFO-regulated openings of the wild fishery.

A big thing happening now in British Columbia is the British Columbia Treaty Process — for First Nations, a process that is long overdue. Being the first people of this land, there are a lot of issues front and center that have been of great concern to us for the last one hundred years. The land question, resources, and self-government are some of the important topics in major discussion at our treaty tables today. For a lot of First Nations in BC, the process moves far too slowly; in Nanaimo we have been at the table now for seven years and haven't yet reached an agreement in principle. After that is reached, negotiations will begin between the Nanaimo First Nation, the federal government and the provincial government to reach consensus on all the issues. We hope to be finished in the next couple of years. These discussions today are very important to us because of the situation we face in the fishing industry. We've played a big part in the salmon fishery for the last 100 years. With recent declines in many fish stocks, we now face 60 to 80 percent unemployment in this industry.

For those of us who are displaced fishers, what can we do? There is a great interest for us in aquaculture. We already have a land base bordering the waters of First Nations. Some of the First Nations that I'm involved with have 5 to 10 reserves fronting water. Having been mostly involved in the salmon industry, we have to learn new trades to become aquaculturists. Besides learning what needs to be done, we also have to work with various BC ministries that deal with these fisheries — the Department of Fisheries, Ministry of Fisheries, BC Lands and Assets, and also the BC Treaty Commission. As you can see, many of us still have a lot of work to do. In the very near future, though, we hope to become one of the major players in BC's aquaculture industry.

Another group that works hard for us in the area of fisheries is the BC Aboriginal Fisheries Commission. We come together from across the province to work on various issues. As we have many types of fisheries in BC, we also have many issues to work on collectively.

The last topic of my presentation is something we have been talking about and trying to organize: an Aboriginal shellfish organization. This is intended to be a central place where we can work together on key topics such as shellfish issues, types of shellfish, areas, seeding, harvesting, pollution and marketing. At present we are already quite active in this industry with some First Nations putting out 200 000 to 600 000 pounds (90 000 to 270 000 kg) of Manila clams per year. Working collectively we could increase this production considerably, not only in shellfish but in all areas of aquaculture.

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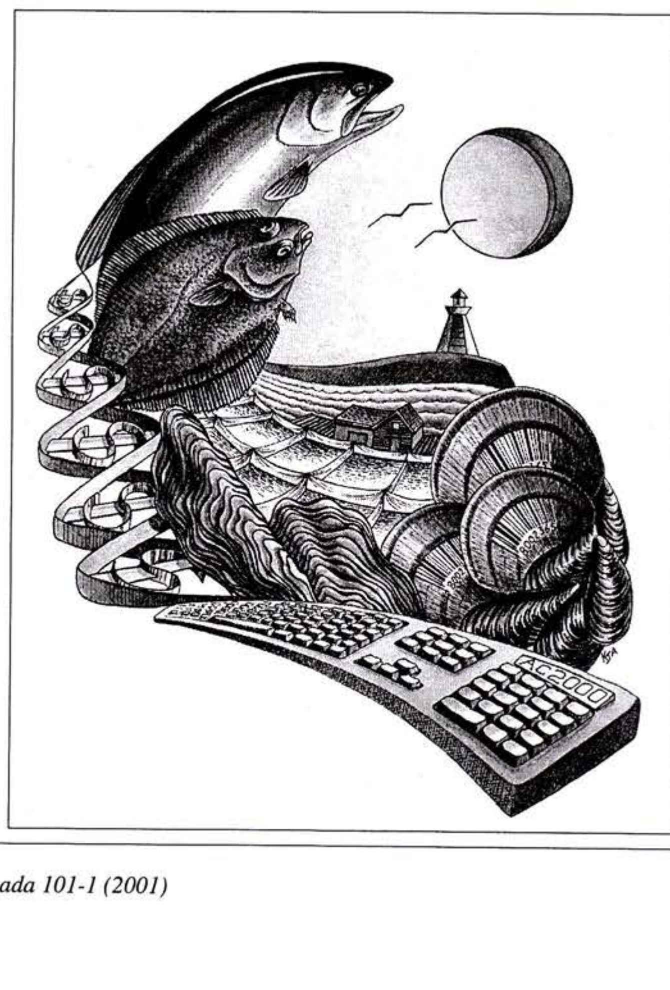
## Introduction

# Interactions Between Aquaculture and the Environment

The $17^{th}$ Annual Meeting of the Aquaculture Association was held May 28-31, 2000 in Moncton, New Brunswick. A special session entitled "Interaction between aquaculture and the environment" was presented on May 30. This session was designed to show aquaculture participants positive and negative effects of aquaculture activities in the aquatic environment. A total of 4 communications were presented from which three came from invited speakers. Our keynote speaker, Dr. Roger Mann, focussed on the role of oyster reefs in maintaining the stability of the aquatic ecosystem, as well as maintaining good water quality, and the benefits of restoring oyster reefs as a management tool (fishery enhancement and other prospects). The second speaker, Dr. David Wildish, presented results from an 8-month monitoring study on geochemical changes in sediments underneath salmon farms and its possible implications for the benthic environment. The third invited communication came from Dr. James Stewart. Dr. Stewart presented an interesting European approach that actors who work in the marine environment should learn to use to better manage our coastal zone.

I would like to express my thanks to the above persons who accepted the invitation and agreed to share their ideas by publishing their paper in the *Bulletin of the Aquaculture Association of Canada*.

*Gilles Miron, professor*
*Département de biologie, Université de Moncton*



# Restoration of the Oyster Resource in Chesapeake Bay: The Role of Oyster Reefs in Population Enhancement, Water Quality Improvement and Support of Diverse Species-Rich Communities

*Roger Mann*

Restoration of the oyster *Crassostrea virginica* resource to the Chesapeake Bay is a widely supported goal. The role of the oyster in restoration through benthic-pelagic coupling is examined in the context of current and projected watershed management problems, agricultural and urban development with associated nutrient and sediment erosion issues, in the entire Chesapeake Bay watershed. Efforts to date have focused on rebuilding three-dimensional reef structures, often with oyster broodstock enhancement, in predominantly small estuaries with retentive circulation to provide demonstration of increased resultant recruitment. Fishery enhancement activity is then based on local increases in recruitment. Such examples are used to increase public awareness of the success of restoration processes and increase long-term participation in such programs by schools, non profit and civic organizations, and commercial and recreational fishing groups.

The history of the decline of the oyster populations of the Chesapeake Bay has been described many times. The story extends from the pioneering surveys of Baylor,[1] to the commentaries of de Broca,[2] Ingersoll,[3] and Brooks,[4] to later monographs of Hargis and Haven and co-authors,[5-7] to extensive descriptions of disease related losses since 1960, to the summaries of Governor-appointed working panels in both Virginia (in 1994) and more recently in Maryland (1998-1999). There is a groundswell of support for oyster restoration for both ecological purposes, based in the growing realization of the role of the species in benthic-pelagic coupling,[8-10] and fishery restoration. Indeed, these efforts have been celebrated as central to a national effort to restore habitat structure (oyster reefs) as part of both oyster enhancement programs and in support of essential fish habitat restoration.[11] The scientific community, with the support of the political establishments of the Chesapeake Bay states, has been challenged to reverse the long-term trends of decline and effect a ten-fold increase in the Bay population by 2010. The response to this challenge has many components including the need for physical restoration of oyster habitat as described earlier. Such efforts however, need to be sensitive to both environmental limitations and the biology of the target species.

Given the long-term commitment to oyster restoration as an ecological benefit, two immediate questions arise: what form should the restored habitat take, and where should we put it? Oysters are reef-forming organisms; indeed an oyster reef is both a biological feature and a geological feature in estuarine systems. The oyster reefs in the Chesapeake Bay were formed over the past 10 000 years as the bay was inundated by rising sea level. We have increasing evidence to suggest that reefs supported complex communities of invertebrates and associated resident and transient fish populations. Also, we know from numerous historical accounts and formal navigation charts that reefs were intertidal as late as the middle of the nineteenth century. Vertical relief is now markedly absent from most reefs in the Chesapeake Bay; indeed recent calculations based on stock assessment by the author and Dr. James Wesson of the Virginia Marine Resources Commission indicate that shell substrate on most productive oyster bottom in the Virginia portion of the bay is so limited that if it was spread out as a uniform layer it would, in most reef locations, be less than 3 cm thick! Three-dimensional reefs arguably offer many attractive options for restoration — but where do we build them? Fortunately, the comprehensive pre-1900 surveys of Winslow in Maryland and Baylor in Virginia provide superb substrate maps of the former and currently productive oyster regions in the respective states. These maps document the end product of 10 000 years of reef accretion and allow restoration to place newly constructed reefs on the footprints of former natural reefs; however, the choice of location of restoration efforts within the enormous bounds offered by this extensive archive of data is subject to a number of major constrictions.

Oysters in the Chesapeake Bay are currently restricted to relatively low salinity regions by the endemic diseases *Haplosporidium nelsoni* (MSX) and *Perkinsus marinus* (Dermo). This would argue for placement in the upstream sections of rivers. Unfortunately, these regions are also characterized by extreme estuarine conditions of high turbidity. Adult oysters can grow in these locations despite these high suspended inorganic particle loads because they posses highly developed particle sorting capability on the gills and labial palps.[12-15] This allows them to reject the inorganic particles as pseudofeces and maintain ingestion of organic particles; however, these same conditions are perilous for the larval phase of the oyster because they do not have a comparable particle sorting capability.[15] Indeed there are strong arguments to suggest that oyster larval growth and survival in Chesapeake Bay is compromised by the combination of low salinity and high turbidity in that when larvae encounter water column conditions in which available food is essentially diluted by significant quantities of inorganic material they functionally starve, despite an apparently adequate absolute concentration of food, because the relative food concentration is low. Further, larval viability in these high turbidity regions may be compromised by origination from adult populations that reside in suboptimal salinities.[16] The cumulative limitations of origin, turbidity, and food result in larval survival and recruitment being very sensitive to marginal changes in any one of the above environmental variables, with the result that recruitment varies by orders of magnitude on an interannual basis.[17-20]

Although regions of high turbidity have always existed in the Bay sub-estuaries, they were likely much smaller and spatially limited in pre-colonial times. This was when the water sheds were more forested, there was an absence of extensive agriculture, and extensive sea-grass beds and three-dimensional oyster reefs limited the effect of wind fetch on sediment suspension.[21-23] Indeed, the often quoted logs of Captain John Smith in his early voyages on the James River describing how he could see the river bottom beneath his modest trans-oceanic sailing vessel attest to water clarity in the mesohaline zones currently occupied by oyster populations. Turbidity levels are likely to have been exacerbated by the loss of suspension-feeding oysters which may have been crucial in reducing turbidity.[8] Therefore, there is likely to be a negative feedback between the removal of oysters (first overharvesting and now a combination of harvesting and diseases) and turbidity becoming ever less conducive to oyster larval survival. Other cumulative effects (arguably many years or even decades) stem from non-point source runoff of sediment, mostly associated with agricultural practices in the Bay watershed. While the widespread adoption of no-till farming in combination with buffer zones has accelerated amelioration of non-point source issues, there remains a proverbial "long way to go" in eliminating this challenge to resident filter feeders in the recipient waters of the Bay. Both non-point and point-source runoff add nutrients to the Bay ecosystem, and there is a politically stated and strongly supported ongoing effort to reduce nutrient input to the Bay, thereby decreasing associated eutrophication and its ecologically debilitating endpoints (e.g., seasonal hypoxia in deeper waters of the Bay, undesirable algal blooms, and more). Subsumed within these parallel efforts there is need to consider the confounding influences of turbidity and nutrient enrichment. Consider that in the absence of a significant turbidity problem nutrient reduction policies are essential to reduce hypoxia because there is inadequate benthic pelagic coupling to remove the resultant phytoplankton by filter feeding —the oyster populations, once the great benthic-pelagic couplers, are no longer present in sufficient numbers.[8] Ironically, current watershed management practices that emphasize nutrient reduction policies in excess of concomitant sediment load reduction may serve to exacerbate larval survival in receiving waters. In summary, the reef placement issue has obvious limitations—downstream limitations of disease and the upstream limitations of turbidity dictate a clear mid-estuarine region within which efforts should be focused.

Under the guidance of the Shellfish Replenishment Program at the Virginia Marine Resources Commission a reef-based restoration effort was initiated in the Piankatank River in 1993 with construction of a single reef at Palace Bar (site A on Figure 1). This site was chosen because the river is small (thus any effect of restoration would arguably be seen in comparison with background variability), has trap-type retentive circulation that is enhanced by the spit structure at its mouth, and a small tidal range. In addition the watershed is devoid of urban development and has only limited agricultural activity, both of which minimize undesired run-off. Construction is described in Bartol and Mann.[24] No broodstock addition was effected at the site, which has been intensively studied since that time in terms of oyster recruitment and growth,[25] dis-

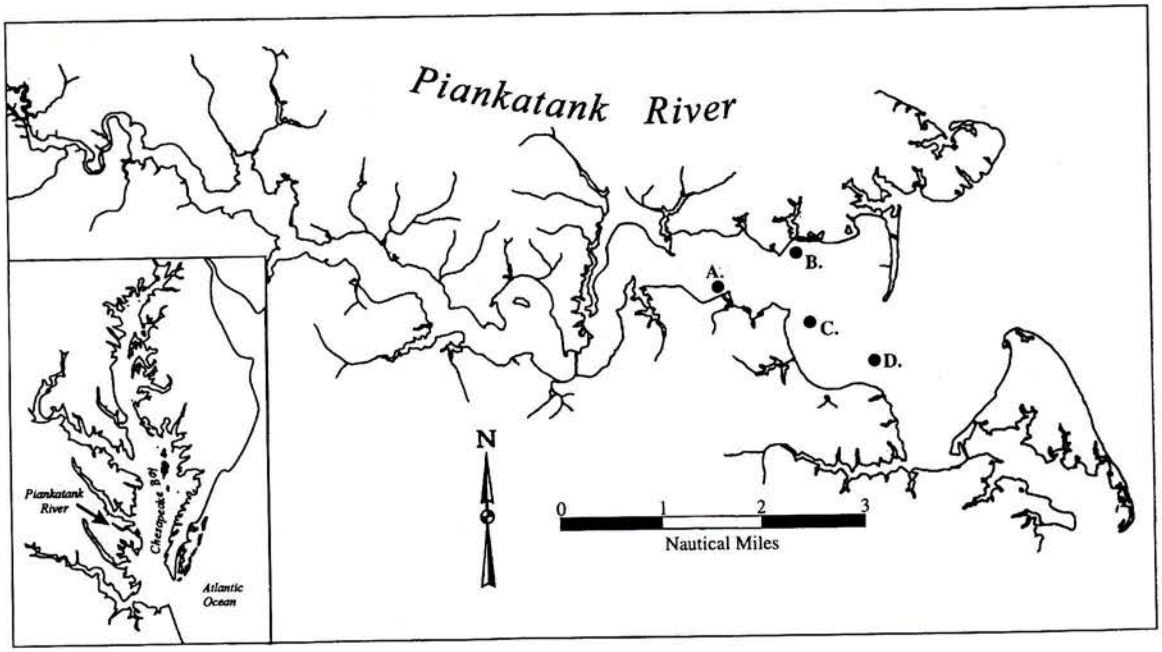



**Figure 1. The Piankatank River on the western shore of the Chesapeake Bay. A is the site of the original 1993 reef, with B, C and D being sites of additional reefs constructed from 1997 onwards. Note the small size of the watershed, and the spit on the northern shore of the mouth of the estuary which contributes to retentive circulation of water and entrained larvae.**

ease progression in recruited oysters,[26] and development of associated fish and benthic communities.[27,28]

Since 1996 further reefs have been constructed. Within Chesapeake Bay, reefs were added in the Great Wicomico in 1996, and Coan River and Yeocomico River in 1997. Reefs have been constructed in Lynnhaven Bay and at Fisherman's Island at the southern tip of the Eastern Shore in 1995-1996. The Great Wicomico reef was the subject of intense evaluation in the summer of 1997.[29] The Great Wicomico River, although small, was regularly identified as a region of high oyster spatfall prior to the decimation of resident oyster populations by the combined effects of Tropical Storm Agnes in 1972 followed by MSX and *Perkinsus*. The circulation of the river, like that of the Piankatank, served to retain planktonic oyster larvae originating within the river (a factor also influencing the choice of the Coan, Yeocomico and Lynnhaven as reef sites). The lack of resident oysters in the river was confirmed by surveys in late 1995. A chain of unexpected circumstances led to the use of the Great Wicomico reef as a broodstock enhancement site. In late 1996 the Virginia Marine Resources Commission (the regulatory body in Virginia) voted to open the oyster fishery in Pocomoke and Tangier Sounds with a quota not to exceed 2500 bushels (88 100 L) of oysters, to buy back the oysters at US$20/bushel, and transfer them to the Great Wicomico reef. Together with buy-boat transfer charges, this decision approved expenditure in excess of US$50 000, a sum similar to construction cost for the reef itself. The transfer resulted in a resident oyster population with a very high reproductive potential because of the high density of large oysters. Estimated egg production was 4.5 billion eggs per square meter, or about 45 times more than that of oyster populations on the reefs constructed on the Piankatank River, and at least one order of magnitude higher in spawning potential in terms of numbers of eggs produced than any extant reef in the Chesapeake Bay! This analysis provoked the question: "Is the added initial cost of broodstock planting worth it?" The conceptual problem can be answered as follows: If the intent of sanctuaries is to develop actively breeding populations with higher than typical resistance there is good argument for aggregating the few remaining oysters from disease-endemic areas where they are so sparse that fertilization efficiency of freely released eggs is minimal or absent. What about the practical answer? Based on data obtained for summer 1997 observations, I suggest the answer is probably also yes.

It is notable that, in the donor locations, extant oyster population density is too low to effect reasonable probability of fertilization success and subsequent recruitment. Calculations of estimated fecundity of the resultant Great Wicomico reef population suggest that oyster egg production from this source is within an order of magnitude of total egg production in the Great Wicomico River prior to Tropical Storm Agnes. Field studies in 1997 indicated spawning by reef oysters from July through September, while plankton tows recorded oyster larval concentrations as high of $37\,362 \pm 4380\ m^{-3}$ on June 23! Such values are orders of magnitude higher than those typically recorded in Virginia subestuaries of the Chesapeake Bay in the past three decades, and strongly endorse a premise of aggregating large oysters to increase fertilization efficiency. Drifter studies suggest strong local retention of larvae, a suggestion reinforced by marked increases in local oyster spatfall on both shellstring collectors and bottom substrate in comparison to years prior to 1997. While disease was evident in the population — *Perkinsus* prevalence increased from 32% in June to 100% in July and intensity increased from June to September — the Great Wicomico effort demonstrates that a choice of location where local circulation promotes larval retention with the combination of reef construction and broodstock enhancement can provide an accelerated method for oyster population restoration. Following the above observation in the Great Wicomico, other reef sites have been added in the Piankatank (Fig. 1, B through D) that are also part of a broodstock enhancement program using large oysters collected from high salinity regions of the Bay where disease pressure remains high. Similar efforts are underway in two small tributaries of the Potomac River (the Coan and Yeocomico), the Elizabeth River, Pungoteague Creek on the Bay side of the Easter Shore of Virginia, and Lynnhaven Bay on the south shore of the Chesapeake Bay mouth. In addition, reefs of various substrate types have been constructed at Fisherman's Island at the southern tip of the Easter Shore of Virginia and are the site of continuing intense study by Mark Luckenbach and collaborators based at the Virginia Institute of Marine Science Wachapreague laboratory.

So we have a promising approach to restoration of oysters in small trap-type estuaries. But, it is important to emphasize that restoration benefits other species in addition to oysters.[27,28,30] Oysters improve water quality by removing a portion of the phytoplankton standing stock, and they provide a structured habitat that may increase production of finfish and decapod crustaceans such as crabs.[31] Extrapolations from laboratory filtration rates,[8,32,33] direct field measurements[34] and models[9] demonstrate the role of oysters as cornerstone organisms whose ability to reduce phytoplankton contributes to reduction of eutrophication in coastal waters.

Inevitably the question arises as to the applicability of these small studies to larger subestuaries in the Chesapeake Bay and to the mid-Atlantic in general. Scale is a daunting issue for restoration, not just in terms of spatial and temporal coverage, but equally so in terms of money and continued public support over extended periods. In Virginia we have recently begun a bold program that addresses the next step in scale. The Virginia Oyster Heritage Program proposes to restore oyster resources in the lower Rappahannock River by employing reef-building techniques previously developed in small subestuaries. A comprehensive survey of the current status of the resident lower Rappahannock oyster stocks in terms of absolute abundance, demographics, and disease status was completed in the fall of 1999. Reef construction began in the spring of 2000 and continues as this manuscript is being written. This is an exciting time and reports of progress with this venture will be the subject of future articles. In examining the issue of scale in context of restoration of oyster populations in the entire Chesapeake Bay some numbers illustrate that this will be a long-term effort. The Chesapeake Bay is 298 km long (185 miles), has a surface area of 8484 $km^2$ (3277 sq. miles) and has a volume of $71.5 \times 10^9\ m^3$. The combined watersheds of the subestuaries of the Bay stretch from the Appalachian Mountains in the west to near the Canadian border in the north. The resident population of the watershed is approximately 15 million, but with growth projections as high as another 3 million over the coming 20 years. Whereas 90% of the watershed was forested during early Colonial times that number is nearer 60% today. All of these numbers illustrate pressures upstream, which are concentrated downstream in the regions of restoration effort, often with sufficient geographical removal to have the source of the problem fail to appreciate the impact when it is "not in my back yard." We have a long way to go, but education and citizen involvement are becoming the strongest tools to ensure a long term and successful effort in restoration.

*The Virginia oyster restoration effort involves active collaboration of a number of workers, and it is a pleasure to acknowledge the contributions of my colleagues Mark Luckenbach, Juliana Harding, Melissa Southworth, Ian Bartol, James Wesson, Francis O'Beirn, and Janet Nestlerode. Financial support for field efforts have been provided by general funds from the Virginia General Assembly to the Virginia Institute of Marine Science and the Virginia Marine Resources Commission, and grant funds from the National Oceanic and Atmospheric Administration (through the Virginia Department of Environmental Quality) and the Environmental Protection Agency. Partial support to the author during the period of manuscript preparation was provided by National Science Foundation grant* *number OCE-9810624. Support to present the manuscript at the session "Interaction between Aquaculture and the Environment" at Aquaculture Canada 2000 was provided by the Aquaculture Association of Canada. The invitation to present the manuscript by convener Prof. Gilles Miron is gratefully acknowledged. This is contribution number 2379 from the Virginia Institute of Marine Science.*

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# A Case for a Comprehensive Environmental Data Base as a Tool for Integrated Coastal Zone Planning and Management

*James E. Stewart*

Aquaculture has become a significant competitor for space in coastal and freshwater areas producing approximately 25% of the harvest of the sea and freshwater areas. The need for large areas with healthy environmental conditions for aquaculture and the negative consequences for the industry when the environment is impaired are illustrated briefly. It is argued that in order to accommodate all existing and potential participants in the aquatic environments appropriately, the complete picture of the activities of all users of the environment, including aquaculture, must be assembled and used collectively to gauge the entire result. To accomplish this it is recommended that a comprehensive environmental data base, together with the appropriate tools to analyse and access it, is essential and should be organized to permit planning and management on an area-wide basis thereby avoiding piecemeal evaluations that fail to take into account the total impact of all of the activities in that area (bay, inlet, fjord, or estuary). An existing model, the Norwegian LENKA Project, is described and it is suggested that this system, modified to suit local conditions and requirements, could serve this purpose and meet the needs of integrated coastal zone planning and management.

## Introduction

Aquaculture has become a significant competitor worldwide for space in coastal and freshwater areas, producing about 29 million tonnes or approximately 25% of the food harvested from the sea and freshwater areas.[1] To be accepted, it must be demonstrated convincingly that aquaculture will not jeopardize other legitimate uses of the coastal, brackish or freshwater zones through causing unacceptable changes to the environment. As aquaculturists are among the first to suffer the consequences of environmental deterioration, their concern for the environment should be equal to or greater than that of those wishing to preserve it for other purposes.

The importance of the environment to the health of the animals in it, cultured or wild, is illustrated in Figure 1.[2] The collision of the host with an infectious agent does not necessarily result in an infection or widespread disease. If the animal is in good health, sustained by high standards of husbandry in an adequate environment, the prospects for resisting infection are excellent. Thus the outcome of the interaction depends largely upon balance; if this balance is impaired significantly the health of the animal will also be impaired often leading to fatal consequences. Obviously, the environment is one of the more important controlling factors in this equation.

A cursory survey of the literature reveals a number of instances where environmental deterioration has had a decisive negative influence on aquaculture ventures. The massive production of shrimp is an example, particularly in southeast Asia, where mangrove swamps and low-lying rice fields near coastal regions have been used to produce billions of dollars worth of shrimp. Much of the methodology in use has caused such environmental damage that after about 10 years many sites are abandoned and the production is moved elsewhere.[3,4] Environmental damage on this scale deprives the local people not only of the shrimp production, but also the fisheries which previously were provided by the now eliminated mangrove swamps and the rice from the fields which are unfit for production until the salts have been washed out. These relatively severe ecological, social and technological problems affecting certain forms of aquaculture have been recognized by the United Nations Food and Agricultural Organization. This body has called for interdisciplinary research to understand the problems holistically and additional specialized research to address specific environmental problems.[5]

Other problems associated with environmental deterioration described earlier[6] include adverse effects on pearl culture in Japan brought about by "senescence of the culture grounds" attributed to faecal accumulations on the bay floor as a result of prolonged intensive culture at the sites; termination of production for 2 years at more than 20 salmon farms in Norway after the introduction of smolts carrying furunculosis (caused by a biotype of *Aeromonas salmonicida* more virulent than any previously experienced in Norway) with losses estimated at US$100 million. Major problems and production losses at salmon farms in Europe and eastern Canada have been caused also by parasitic sea lice whose numbers increase with continuous occupation of farm sites, and by the occurrence of algal blooms such as those of *Heterosigma* sp. and *Chaetoceros* sp. which affected salmon farms in the well protected, but poorly flushed Sechelt Inlet in British Columbia in 1989. The obvious conclusion is that a minimum condition for the existence of a healthy and thriving aquaculture industry must be a healthy aquatic environment.[6,7] As aquaculture ventures represent only one of the competitors for space in the coastal marine environment, and thus have limited influence on its overall disposition, the question becomes one of how the best interests and desires of all the competitors can be met.

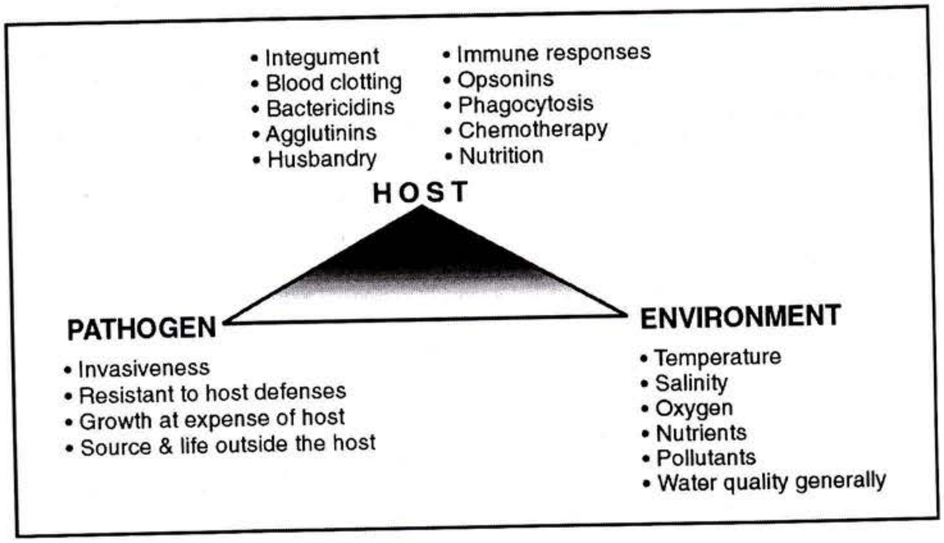


**Figure 1. Host/pathogen/environment characteristics and interactions affecting infectious diseases. Redrawn from Stewart.[2]**

The various major environmental participants are represented in Figure 2 as 4 groups arranged in the form of a diamond. All of the users have particular interests and ambitions and all, unfortunately, in the course of exercising their rights and enjoying their privileges, contribute their share of inputs and problems which leave the environment less than pristine. Again, just as with the host/pathogen/environment relationship, the problems and their solutions involve balance. Each participant must recognize not only their rights, but also those of others and accept responsibility for their own contributions to environmental problems. It is clear that only a balanced, cooperative, integrated management approach can achieve the environmental health everyone needs and desires. To be able to achieve this balance it is essential that the complete picture regarding the area-wide use of the environment be assembled and made available to all participants. Without this complete picture, applications for permission to use the environment can only be dealt with on an individual and necessarily piecemeal basis, an approach that, inevitably, will lead to major shortcomings and environmental conflicts.

## Norwegian Approach

The environmental issues that have become more evident locally with the advent of aquaculture also suggest the need for cooperative approaches which can lead to the balance referred to above. An attractive example of what is possible has been provided by the Norwegians who, in the 1980s, recognized that their coastal zone was under severe and increasing pressure. Their rapidly expanding aquaculture industry also was adding to the pressure on inherently sensitive, and in some cases already stressed, environments and had brought increased and intensified competition for coastal space, especially in southern Norway. Recognition of the problems resulted in the Norwegian Parliamentary White Paper No. 65 (1986-87) that set the following objectives for a national aquaculture policy: "A policy for aquaculture must aim to promote the development of a profitable aquaculture with the ability to grow" and "such expansion must be prepared for. This is a matter of making special efforts within a number of areas, such as

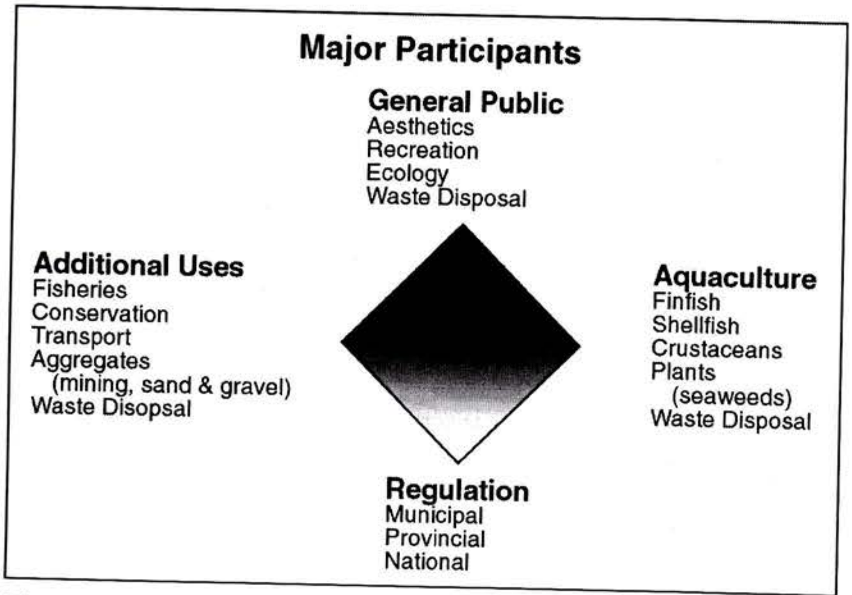


**Figure 2. Balance in the marine environment.**

ensuring the supply of smolt, continuing the struggle against disease, reducing and preventing pollution, technological development, improving quality assurance, and product development".[8]

These objectives and the belief that many conflicts could be resolved through application of a well thought-out policy for local action led to the establishment of the LENKA project for a three-year term beginning in 1987. It was a collaborative project that involved three national ministries (Fisheries, Environment, and Local Government and Labour), a number of directorates and agencies at the county level, and the municipalities. The LENKA acronym was developed from the following Norwegian words:

L = Landsomfattende
E = Egnethetsvurdering (av den)
N = Norske
K = Kystone (og Vassdrage)
A = Akvakultur

which means: "Nationwide analysis of the suitability (of the) Norwegian coastal zone and watercourses (freshwater) for aquaculture".

Thus LENKA is not a coastal zone management system in itself. Instead it is a planning tool to provide the information base on aquatic capacity to aid in making wise and rational choices among the many possible uses of the aquatic environment. The stated aims of the LENKA Project were:

- To contribute to the continued positive development and growth of the aquaculture industry with minimal conflicts with other utilization and conservation interests;
- To contribute to the county and municipal planning in the coastal areas and watercourses;
- To contribute to the siting of aquaculture activities.

The LENKA system provides primarily, to the municipalities and counties, a comprehensive picture of the aquatic environment and a tool for analyzing the consequences of various possible actions. As a result, it can be used to illustrate the extent to which room exists for increased activities in the context of sustainable development.[9] The work in the three-year term of LENKA was preparatory and was divided between

**Table 1. LENKA Classification System.**

| Environment | Areas Already In Use | Infrastructure | Special Areas |
|---|---|---|---|
| Pollution | Settlements | Roads | Protection zones for salmonids |
| Temperature | Leisure use | Electricity | Seabirds and others |
| Icing | Harbours | Processing plants | Heritage areas |
| Exposure | Scale of fisheries | Health and advisory services | Environmental protection and open-air areas (recreation) |
| Depths | Shipping traffic | Waste treatment | Spawning areas |
| Salinity | Defense interests | Other | Existing fish farms |
| | Other uses | | Other special areas of concern, e.g., reindeer |

the two senior levels of government. The national authorities prepared jointly, advisory material for use in planning and locating aquaculture activities. At the county level, descriptions of marine areas and rivers for evaluation of their suitability and capacity for aquaculture were produced largely from existing information sources; these evaluations were in part based upon maps of the hydrographic and environmental conditions as well as industrial, conservation, fishing, recreational and other activities occurring in the LENKA zone. In addition, the counties prepared reports that were needed for, and could be utilized in, planning at the county and municipal level. The LENKA system was devised specifically to ensure that all relevant bodies were included and, further, to take full advantage of existing systems, legislation, regulations and authorities.

LENKA addressed five types of coastal zone management concerns:[8]

- Pollution
- Organizational problems
- Genetic depletion (or alteration)
- Conflict resolution in the use of coastal space
- Economic assessment of the potential for aquaculture

The LENKA method, although initially intended for assessing open net cage farming, can be modified readily for other forms of marine farming and other uses of the marine environment. Its central feature is to specify the capacity of defined areas to absorb organic and nutrient loadings without adverse effects. To be able to do this without fear of challenge would, of course, have required lengthy and intensive studies to produce the appropriate indices. As completion of such studies was not possible in the three-year term of LENKA, an empirical and pragmatic approach was adopted to ~~be~~ used as an interim measure until such indices could be developed.

As a substitute, results from thorough studies, over a period of 5 years, of 150 fish farms scattered along the Norwegian coast were used to determine the relationship of the environmental impacts to productivity, management and locality. Individual types of coastal zone subdivisions were classified into A, B or C areas according to assumed water exchanges based mainly upon topography. It was then possible to derive quantitative indices for the production of fish in tonnes per square kilometer for each of the A, B or C areas. This categorization together with elaborations, additions and refinements is central to the LENKA methodology.

The Norwegian coastal zone was then partitioned into homogeneous LENKA zones based largely on topography plus inputs from hydrography and oceanography. Fjords, fjord basins and archipelagoes are examples of such zones. Zonal boundaries on dry land followed watershed boundaries so that all land areas in a given zone would drain to the sea in the same zone.

The next step produced overall pictures of the characteristics and multiple uses of the zones of most importance to fish farming. Data were classified into four separate groups (Environment, Areas Already in Use, Infrastructure, Special Areas — see Table 1). These four groups of parameters, after being recorded and mapped, were used to make deductions from the areas available for farming and/or used to grade the LENKA zones on a scale of 1 to 5 as to their suitability for fish farming. All of the environmental information and the various derivatives of it were computerized and made available regionally for use by all interested parties. It was also the information base employed by authorities in straightforward calculations to determine the quantity of farmed products that could be raised in a LENKA zone without causing environmental problems or conflicts of interest with other users.

Thus the LENKA Project assembled Norwegian coastal data in an easily-used, computerized form, which was publicly available and adequate for managers of the coastal zone not only to gauge opportunities for aquaculture, but also to resolve competitions for space in the coastal environment. As there is no model or system currently available anywhere to predict or indicate limits to the assimilative capacity of the different culture locations or the full consequences of exceeding these limits, the attractiveness and advantages of applying the pragmatic, but logically based LENKA system is apparent. Its main attribute is that it provides for informed decision-making thereby allowing rational development to proceed in a regulated, albeit conservative, manner while offering maximum flexibility and the opportunity for change as more is learned. Although the existence of such a consolidated information system does not guarantee wise decision making it is highly probable that application of it or similar systems would have avoided much of the environmental damage and its consequences in the examples described in the Introduction.

## Area Management

These examples of environmental problems interfering with aquaculture operations also emphasize that the need to manage the environment on a comprehensive and integrated basis encompassing whole inlets, bays, fjords and archipelagoes is paramount. Examples drawn largely from salmon net-cage farming illustrate the extent to which this thinking has advanced. In Europe (especially Ireland, Scotland and Norway), which produces over 80% of the world's farmed salmon, single bay management is practiced widely and combines year-class separation and fallowing in an effort to break disease cycles — initially, it was begun to combat sea lice and furunculosis.[7] It is practiced in British Columbia largely in areas where all farms are owned by a single company. Because Chile, to date, has not had the disease problems experienced elsewhere and its coast is more open and the bays less well defined the application is more difficult and thus single bay management has not been practiced widely there.

Recently added impetus to the concept of area-wide environmental management was provided by the disease, infectious salmon anaemia (ISA). This viral infection, which has caused major losses among cultured salmon, was first diagnosed in Norway in 1984,[10] subsequently in New Brunswick in 1997[11,12] and then in Scotland in 1998.[13] The major losses plus the occurrence of the virus in and its transmission over long ranges via seawater has forced operators and regulators to consider even more stringent measures in relation to single bay management approaches. Intensive consideration of the problem in Scotland by the Joint Government/Industry Working Group (JWG) on infectious salmon anaemia (ISA),[14] established to identify measures required to prevent or minimize the impact of further outbreaks of ISA, brought forth recommendations of two broad types: 1) practical measures to minimize the risk from ISA; these encompassed both husbandry practices and area management, and 2) pointers to research needs of the industry and diagnostic services; these included aspects of disease transmission, efficacy and environmental acceptability of chemical and physical disinfection methods, waste management and laboratory techniques for detection and diagnosis. It was intended that the majority of the practical husbandry and management recommendations be implemented by incorporation into Codes of Practice and some through the medium of new legislation. Among the prime recommendations was one dealing specifically with management areas: "The hydrographically defined Infected Zones, Surveillance Zones, Management Areas, Fallowing Zones and 40-km Surveillance Areas are based on simple yet fundamental, aspects of the oceanographic conditions found in Scottish waters. They are able to take into account specific local conditions, and can also be applied widely to the entire Scottish industry. They should be adopted as the basis for dealing with outbreaks of any water-borne disease, as well as forming the basis for a sustainable and planned approach to managing the industry in future. However, they must first be scrutinised on a case by case basis to take into account local conditions and the planned occupancy of farms." In addition to the comprehensive report of the JWG,[14] the Scottish authorities have also issued a detailed advisory guide for disinfection [Disinfection Guide (Version II)] giving instructions related to ISA based upon procedures encompassing current scientific knowledge and practical experience.[15]

## General

For Canadians, over and above the problems and considerations discussed so far, there is the need to comply with the provisions of the Canadian Environmental Assessment Act (CEAA). This act, proclaimed in 1995, was legally judged in 1999 to apply also to the aquaculture industry. When CEAA is triggered, the act requires that an assessment of the operation be made showing that there will be no detrimental environmental effect. The two principal triggers for the Department of Fisheries and Oceans are those operations or applications which require 1) approval under the Navigable Waters Protection Act and/or 2) authorization to harmfully alter, disrupt or destroy fish habitat. As there is no "grandfathering" this act applies to all existing and future operations. The data on the site, the operational details and environmental impacts upon which a regulatory judgement will be based are to be supplied by the operators or applicants at their expense.

In such a case, the advantages to both the regulators and the applicants of having a publicly available, comprehensive, computerized, area-wide, environmental data base are obvious. Its existence would ensure that the regulators were provided with the relevant information to gauge where and to what extent a new or existing operation would fit. Additionally, it would provide invaluable information and context to any applicants who with an understanding of the rules could judge for themselves how well their application might fit into the local scene and what additional environmental information they would have to collect to satisfy the regulatory requirements.

The system which could be envisaged as being relevant and valuable on the Canadian scene would appear to be one that reflects the best elements of the LENKA Project, but need not necessarily be identical to it. For example, instead of drawing up separate and discrete LENKA zones in the Maritime Provinces, it may be satisfactory to utilize districts based on individual bays, inlets and archipelagoes in the well developed county system as the basic units for assembly of the computerized environmental data base for planning and management purposes. Once the data are organized at the county level it would be relatively simple to amalgamate individual data bases into a provincial data base which would provide a sufficiently comprehensive matrix for wider regional planning and management. It would be of paramount importance for all computerized data bases to use a common technical language, be publicly available and user friendly.

Although such a venture would at first glance appear to be a daunting task, it is in fact quite realizable in a reasonable period at a relatively low cost. The Norwegians beginning in 1987 completed the LENKA project for their entire country in three years at a total cost of US$7 million. Although the LENKA project and this article were sparked by the environmental considerations related to aquaculture, the advantages in using such a data base, equipped with the appropriate tools, for wider, integrated, coastal zone management are clear. Its existence would reduce or avoid many of the disputes which have risen already and are sure to increase. Its value as a tool for making rational decisions, taking into account all environmental participants and their inputs and needs, makes its initiation not only worthwhile, but essential for realistic coastal zone management. Much of the data that would be needed on coastal topography, hydrography (tides, currents, temperatures, salinity, etc.), sediments, oceanographic influences, biota, human populations and existing environmental uses is already on file and mainly needs to be drawn together and organized, as in the LENKA system, along county lines and amalgamated at the provincial level. A considerable number of local scientists already familiar with the existing data have long been interested in pursuing just such a scheme. In fact, a substantial amount of work has been initiated as described in a report(16) that tabulated some of the geographic, oceanographic and hydrological parameters for 141 coastal embayments in the former Scotia-Fundy Region and southern Gulf of St. Lawrence. Thus, a significant part of the overall job is done in that much of the physical data for the Maritime Provinces area is already organized into a useful data base.

In summary, the task would be largely one of consolidating information already in existence in files, disparate data bases and various published reports, to make it available in a form that permits its ready use by applicants for use of space in the coastal environment (land and/or aquatic areas), regulators and the general public. The basic organization of the data should relate to individual bays, inlets, fjords, immediately adjacent land areas, and freshwater contributions with amalgamation primarily at the county level and, in a final step, at the provincial level. As there will be a continuing need to absorb new material and concepts, the system must be made flexible enough to be updated regularly. From the Norwegian experience it would appear that the initial work could be accomplished best by creating an intergovernmental corporate body for a definite short term (e.g., 3-year period) charged with preparation of the required comprehensive environmental data bases in a form suitable for integrated coastal zone management.

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# Sedimentary Changes at a Bay of Fundy Salmon Farm Associated with Site Fallowing

*D. J. Wildish, H. M. Akagi and N. Hamilton*

Sediments at a salmon farm fallowed in August 1997 were monitored by geochemical and benthic macrofaunal techniques over a 200-d period. Geochemical results suggested the existence of organic enrichment hot-spots, tens of metres in size, which persisted for 12 mo after fish removal. Sulfide levels in sediment core samples, in and near hot-spots, suggested that the rate of recovery from hypoxia/anoxia deep in the sediments was slower than at the surface. Macrofaunal sampling 9 mo after fish removal was used to classify the farm site by the classical criteria of organic enrichment. Both this and recently proposed geochemical criteria show that the farm examined is oxic (= transitory) with respect to the organic enrichment index.

## Introduction

Infectious salmon anaemia, ISA, was discovered in the Bay of Fundy salmon mariculture industry in 1996. The infectious agent, first recognized in Norway, was a virus that, until 1998, did not have a vaccine. The initial strategy to limit the spread of the disease was to slaughter salmon at ISA-infected farms to prevent further spread of the disease. Because of the potentially serious economic consequences of ISA, numerous changes in Bay of Fundy management practices were instituted. The rationale for these changes derived from epidemiological studies in other countries that assessed cause-effect factors in disease spread.[1-3]

One management change was site fallowing of ISA-infected farms. Fallowing involved the complete removal of fish, nets and wooden cages, although tubular frame plastic or metal cages were left in the water following sterilization by steam cleaning. The objective was to disrupt the life cycle of the virus and possible vectors of it, such as sea lice, *Lepeophtheirus salmonis* and *Caligulus elongatus*, by removing all contact with host fish for up to 2 yr.

We took advantage of one site fallowing within the Bay of Fundy industry to study the recovery of sediments throughout the lease area during a 200-d period. The objectives were to document sediment recovery by geochemical methods and to assess the site for organic enrichment impacts based on classical macrofaunal distribution methods as reviewed by Pearson and Rosenberg.[4] Another objective was to compare the classical macrofaunal distribution results with a recently proposed new organic enrichment index based on geochemical measures.[5]

## Methods

The farm chosen was in the L'Etang inlet, an area with the highest density of salmon farms throughout the Bay of Fundy industry. The farm investigated (Fig. 1) was abandoned in August 1997. Our observations began on 28 May 1998 (for macrofauna) and on 4 July 1998 (for geochemistry). The geochemical observations were repeated on six occasions, terminating on 12 January 1999. In the following spring the site was re-occupied and salmon smolts were re-introduced.

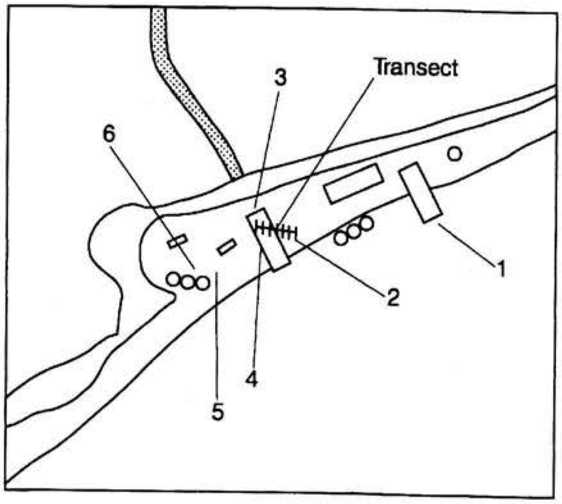


**Figure 1. Map showing the position of macrofaunal sampling stations (1-6) and transect stations in L'Etang inlet. The three rectangular structures represent groups of empty steel cages.**

A permanent transect was established for sediment geochemical sampling with a leadline as shown in Figure 1. The seven permanent sampling stations along the leadline were spaced at 10-m intervals. The transect originated just outside the cage footprint (#1) and proceeded diagonally to terminate at the cage array centre (#7). For each sampling occasion the SCUBA diver followed the protocol described in Wildish et al.,[6] obtaining cores of 6-10 cm depth and with an undisturbed sediment-water interface. Core tubes were 50 cm long and 5 cm diameter. Holes were drilled at 2-cm depth intervals so that a cut-off 5-cc plastic syringe just fit into the hole. Each hole was covered with duct tape, which was removed at sampling to allow insertion of the syringe. The sediment obtained allowed at least 3 depth samples to be analyzed for each core. Redox (Eh) was measured at the surface and total sulfide at the first three depths: 0-2, 2-4 and 4-6 cm in the sediment. Subsampling and geochemical determinations were as described in Wildish et al.[6] with redox measurements made with an Orion platinum electrode connected to a battery-operated ion meter. The results are expressed in mV relative to the normal hydrogen electrode. Total sulfides were measured with a silver/silver sulfide half-cell electrode and reference electrode, calibrated with a known solution of sodium sulfide. Samples for determination of total sulfide were measured after 5 cc of sediment was added to an anti-oxidant buffer solution.

A battery-operated continuous temperature recorder (StowAway Tidbit, Bourne, MA) was placed just under the sediment surface at the first transect station. It was periodically retrieved and the results downloaded to a laptop computer.

Benthic macrofaunal sampling was undertaken on one occasion at the six stations shown in Figure 1. Three replicate grab samples were taken at each station with a Hunter-Simpson grab of 0.1 $m^2$ sampling area. Sampling characteristics of this grab are given in Wildish[7] and grab fullness estimates recorded as follows: 1 = < one-third full, 3 = completely full and 2 = between 1 and 3. Three subsamples from the surface sediment, 0-2 cm depth, were removed in a cut-off syringe for analyses of total sulfides. The sediment was then sieved on deck using a seawater hose and sieve stand, in which the finest mesh was 1 $mm^2$. Samples were preserved in 5% formalin in seawater and returned to the laboratory for storage. The identity of macrofauna to the lowest possible taxon and counts of individuals in each taxon was made by the Atlantic Reference Center of the Huntsman Marine Science Center, St. Andrews, NB.

Analysis of the sediment geochemical results was by non-parametric statistics because of the lack of normality in distribution of Eh and total sulfide. A Mann-Whitney U test[8] was used to test the null hypothesis that two independent samples were drawn from the same population with the same median value.

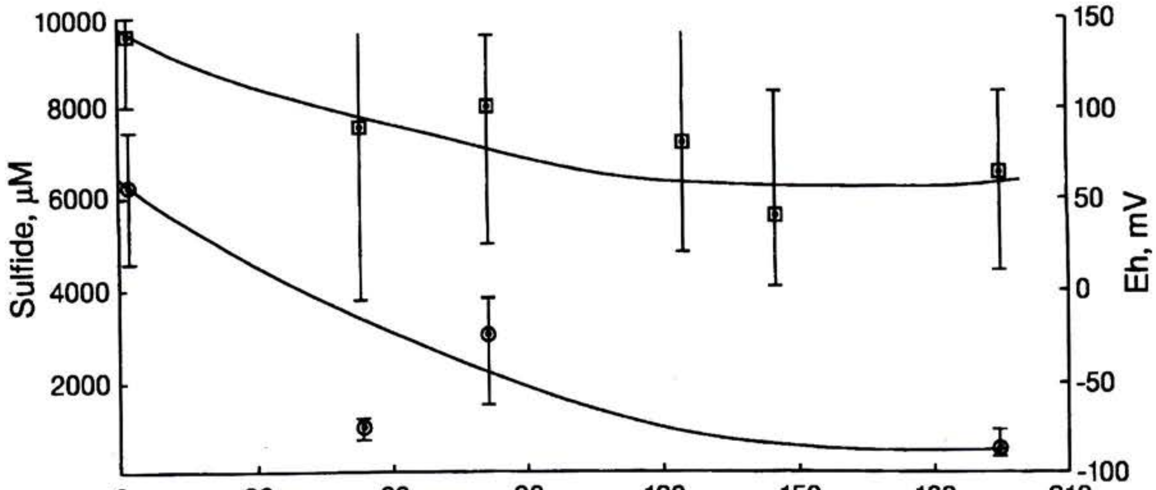


**Figure 2. Total sulfide ($S^=$, µM, circles) and redox (Eh, mV, squares) as means and range of least impacted transect stations in surface (0-2 cm) sediments.**

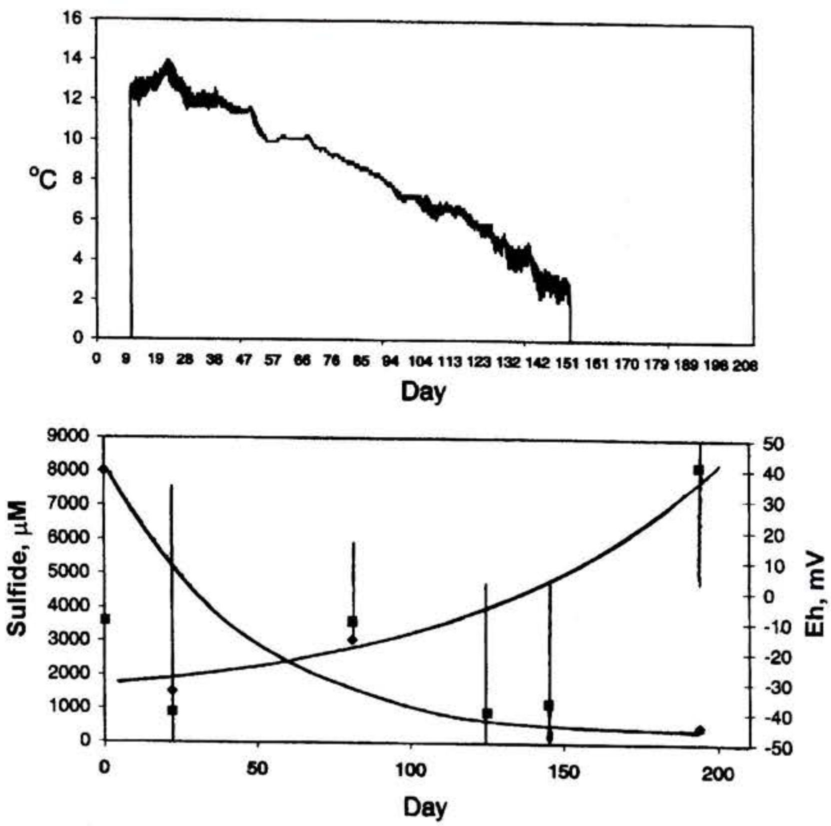


**Figure 3. Upper panel, surface sedimentary transect temperature; lower panel, total sulfide ($S^=$, μM, diamonds) and redox (Eh, mV, squares) as means and range of most impacted transect stations in surface (0-2 cm) sediments.**

The macrofaunal data were arranged in a two-way matrix of species by number of individuals in each taxon and analysed by the PRIMER computer programs package (Plymouth Routines in Multivariate Ecological Research, v. 4.0). Two standard diversity indices were calculated: Shannon–Wiener and Simpson. We also calculated the linear slope relationship based on the number of new species in each grab replicate and the natural logarithm of the accumulated number of individuals,(9) starting at replicate #1 and proceeding sequentially to replicate #18.

## Results

Inspection of geochemical data in surface transect samples shows that they are grouped as follows: "least impacted", inclusive of stations 1-4; "most impacted", the remaining stations 5-7. The medians and range of geochemical variables are shown during sea-

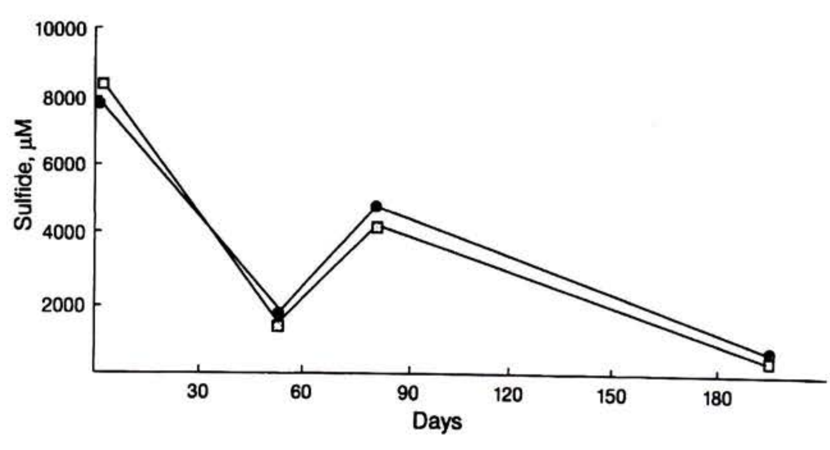


**Figure 4. Total sulfide as μM as means of all transect stations at 2-4 cm (circles) and 4-6 cm (squares) depths in sediments.**

**Table 1. Initial and final geochemical depth profiles at transect stations. Eh as mV relative to the normal hydrogen electrode, total sulfide as $S^{=}$, µM.**

| Date | Sediment depth (cm) | Stations | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | | 2 | | 3 | | 4 | | 5 | | 6 | | 7 | |
| | | Eh | S= | Eh | S= | Eh | S= | Eh | S= | Eh | S= | Eh | S= | Eh | S= |
| 2/7/98 | 0-2 | +16 | 2 500 | +176 | 7 100 | -196 | 1 000 | +184 | 5 600 | -80 | 6 000 | +36 | 7 400 | +25 | 6 300 |
| | 2-4 | 0 | 7 300 | | 7 700 | | 6 100 | | 10 000 | | 9 100 | | 8 300 | | 8 700 |
| | 4-6 | | 8 100 | | - | | 7 600 | | 7 500 | | 9 500 | | 7 200 | | 11 000 |
| 12/1/99 | 0-2 | +15 | 710 | +46 | 230 | +77 | 120 | +107 | 240 | +71 | 110 | -0.2 | 160 | +42 | 270 |
| | 2-4 | | 810 | | 440 | | 870 | | 590 | | 660 | | 610 | | 430 |
| | 4-6 | | 1 000 | | 980 | | 12 000 | | 650 | | 810 | | 820 | | 560 |

**Table 2. Benthic macrofaunal and total sulfide data at a fallowed fish farm in L'Etang inlet on 28 May 1999.**

| Station | Grab fullness index | Sulfide µM | Species per replicate grab | Individuals per replicate grab | Shannon Index | Simpson Index |
|---|---|---|---|---|---|---|
| 1A | 1 | 410 | 38 | 127 | 3.33 | 0.044 |
| 1B | 1 | 610 | 30 | 120 | 2.55 | 0.140 |
| 1C | 1 | 610 | 26 | 211 | 2.14 | 0.204 |
| 2A | 2 | 2700 | 40 | 889 | 1.67 | 0.408 |
| 2B | 2 | 1700 | 19 | 59 | 1.99 | 0.293 |
| 2C | 2 | 800 | 25 | 262 | 1.91 | 0.247 |
| 3A | 1 | 900 | 58 | 337 | 3.38 | 0.058 |
| 3B | 2 | 860 | 28 | 125 | 2.70 | 0.117 |
| 3C | 1 | 950 | 30 | 398 | 2.07 | 0.247 |
| 4A | 2 | 1000 | 34 | 274 | 1.80 | 0.408 |
| 4B | 2 | 1100 | 27 | 140 | 2.35 | 0.170 |
| 4C | 2 | 1200 | 28 | 174 | 2.41 | 0.160 |
| 5A | 3 | 880 | 55 | 323 | 3.17 | 0.074 |
| 5B | 3 | 350 | 34 | 192 | 2.75 | 0.105 |
| 5C | 3 | 700 | 16 | 102 | 1.92 | 0.270 |
| 6A | 3 | 660 | 19 | 134 | 1.85 | 0.266 |
| 6B | 3 | 530 | 22 | 252 | 2.04 | 0.227 |
| 6C | 3 | 1000 | 22 | 132 | 2.45 | 0.117 |

sonal sampling spanning a 200-d period. For the least impacted stations (Fig. 2), both Eh and sulfide decline throughout the period. For the most impacted stations (Fig. 3), Eh values are lower and in the negative range. Eh and sulfides are inversely related for most impacted stations, just as they are under farms still receiving faecal and waste food on a daily basis. Also shown in Figure 3 is the continuous record of surface

**Table 3. Dominant macrofaunal species by abundance at a fallowed salmon farm, based on 18 grab replicates and 6 stations.**

| Taxa | Total number sampled | Number of stations occupied | Number of replicates occupied |
|---|---|---|---|
| Nematoda | 1069 | 6 | 18 |
| *Modiolus modiolus* | 751 | 6 | 14 |
| *Nephthys incisa* | 430 | 6 | 18 |
| Oligochaeta | 225 | 6 | 17 |
| *Euchone incolor* | 130 | 5 | 15 |
| *Pholoe tecta* | 112 | 6 | 17 |
| *Prionospio steenstrupi* | 108 | 6 | 18 |
| *Thyasira flexuosa* | 96 | 2 | 4 |
| *Mytilus edulis* | 76 | 2 | 4 |
| *Cossura longocirrata* | 75 | 6 | 11 |

sedimentary temperature. Notable features are a tidal signature (difficult to see at the scale shown) of a range of ~1.5°C and a decrease to ~2°C by the time the record is discontinued.

Seasonal geochemistry at the two sub-surface depths are shown for all transect stations in Figure 4. Notable features are an increase of sulfide levels with depth and a decrease of sulfide at all depths over time. Sulfide levels at all stations were lower by the end of the study (Table 1). Median values for sulfide at all depths in Table 1 is significantly lower at the end than at the beginning of measurements. Thus, $U_1 = 20.5$ and $U_2 = 399.5$, with $N = 41$, hence the normal deviate, d, can be used and $D = 4.94$, $P<0.001$. This means that $H_1$ can be accepted, that the initial values of sulfide do not have the same median and parental distribution as the final ones.

None of the six macrofaunal stations sampled were situated directly under the cage footprint, although stations 1-4 were close (Fig. 1). The results obtained are summarized in Table 2, inclusive of an estimate of grab fullness. Grabs were only partially filled at stations 1-4 because harder sediments were present there, in contrast to 5 and 6, where soft, silt/clay sediments predominated. High numbers of species (range 16-58) and individuals (range 59-889) per replicate are reflected in the diversity indices shown in Table 2. The sulfide content of surface sediments ranged from 350 to 2700 µM (Table 2), with a median for all replicates of 870 µM.

For all 18 replicates sampled, a total of 4261 individual macrofauna were found. This sample contained 115 different taxa, most identified to species (Appendix 1). We calculated the relationship between the number of new species, S arithmetic, on accumulated abundance, N logarithmic. The regression constants for our data are: $S = 18.69 \ln(N) - 44.4$, $N = 18$, $r^2 = 0.93$, $P<0.01$.

The dominant macrofauna (Table 3), defined as the top ten taxa with the highest abundance inclusive of all 18 grab replicates, consist of a mixture of organic enrichment indicator and keystone dominant species. The former include *Nephthys incisa*, oligochaetes, *Prionospio steenstrupi*, *Thyasira flexuosa* and *Mytilus edulis*,[4] and the latter, *Modiolus modiolus*. Shown in Table 3 are the number of stations and replicates occupied by each taxon. This indicates the type of distribution; thus, nematodes are present in all 18 replicate samples, indicating uniform distribution, whereas the blue mussel, *Mytilus edulis*, is contagiously distributed.

## Discussion

Spatial organic enrichment gradients of the order of tens of centimetres were recognized in field studies of surface sediments.[5] In the present study we identified

**Table 4. Classification along organic enrichment gradients based on microbial, macrofaunal and geochemical criteria.**

| Criteria | Category | | | | Reference |
|---|---|---|---|---|---|
| Microbial | Normal | Oxic | Hypoxic | Anoxic | Poole et al.[10] |
| Macrofaunal | Normal | Transitory | Polluted | Grossly polluted | Pearson and Rosenberg[4] |
| Geochemical | | | | | Wildish et al.[5] |
| Eh, $mV_{NHE}$ | >+100 | 0-100 | -100-0 | < -100 | |
| $S^=$, µM | < 300 | 300-1300 | 1300-6000 | > 6000 | |

organic enrichment impacts of the order of tens of metres. This is consistent with a severe effect near the centre of the steel cage array, which persisted with negative redox and sulfide > 6000 μM, for ~12 mo after cessation of salmon feeding. During the fall and winter, surface sediments rapidly lost sulfide until, by January 1999, sulfide = 500 μM and Eh = +40mV. Thus, the worst hot-spots of organic enrichment at this site return to oxic conditions in about 1 yr. Conditions deeper within the sediment take longer to recover, as indicated by the increases of sulfide concentrations with depth in the core samples.

Some possible reasons for recovery in the absence of fresh inputs of fish faeces and waste food include: physical re-suspension/sorting of sediments by tidal and wind/wave activity and macrofaunal mixing and transport of oxygenated seawater in burrows to deeper layers of sediments. Both of these processes are influenced by temperature. In addition, the details of seasonal pelagic-benthic coupling for the local area are poorly known (e.g., when is phytodetritus in significant amounts oxidized within the sediments?). This issue is germane to the seasonal patterns which are of significance when interpreting practical monitoring data based on sediment geochemistry.[6]

Considering now the question: How does the macrofaunal abundance data collected by this study fit with the organic enrichment macrofaunal data reviewed by Pearson and Rosenberg?[4] The latter work includes: generalized macrofaunal species, biomass, and abundance curves in relation to an organic enrichment gradient (see their Fig. 2); a regional list of species which are indicators of organic enrichment (see their Table 1c, inclusive of western north Atlantic indicator species); and an organic enrichment classification based on the macrofauna present (see their Fig. 15). The classification of Pearson and Rosenberg[4] corresponds to one independently devised by Poole et al.[10] that is based primarily on microbial communities in sediments (Table 4).

The fallowed salmon farm sediments support dominant macrofauna (Table 3) recognized by Pearson and Rosenberg[4] as enrichment indicators. The macrofauna thrive in enriched conditions where dissolved oxygen is available and toxic substances produced by anaerobic microorganisms are negligible. Also present are typical transitory genera of Pearson and Rosenberg,[4] e.g., *Thyasira, Pholoe, Chaetozone* and *Pectenaria* (Table 3 and Appendix 1).The salmon farm macrofauna classify as transitory by the method of Pearson and Rosenberg.[4]

Based on the sediment geochemical limits proposed by Wildish et al.,[5] which corresponds to the two earlier organic enrichment classifications of Table 4, the sulfide results (Table 2) classify the macrofaunal stations examined throughout the lease as oxic (= transitory). This concordance between macrofaunal and geochemical variables is evidence of the utility of both methods. At the salmon farm, either method signifies a recovering benthic community, which is taking advantage of nutrients remaining from the earlier farming activity.

We conclude that the simpler and more cost-effective sediment geochemical method provides definition of the sedimentary organic enrichment gradient, comparable to the classical macrofaunal species:abundance analysis. Further studies are required to determine whether the concordance found in this study is a universal feature when used in divergent habitats and organic enrichment conditions.

*We thank the salmon grower for allowing us to sample within his lease, the captain and crew of Pandalaus III, Mr. J. Hunt of Fundy Diving for skilful help in field sampling, and the Atlantic Reference Center for identifying and counting the macrofauna.*

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**Appendix 1. Taxonomic list for a fallowed fish farm lease area in L'Etang inlet, Bay of Fundy, sampled on 28 May 1998. Abundance is the total number of individuals collected per 1.8 m$^2$ grab sampling area.**

| Taxa | Abundance | Taxa | Abundance |
|---|---|---|---|
| *Suberites ficus* (Johnston, 1842) | 1 | *Cossura longocirrata* (Webster and Benedict, 1887) | 75 |
| *Peachia parasitica* (Agassiz, 1859) | 3 | *Galathowenia oculata* (Zachs, 1922) | 3 |
| Nemertea (juveniles) | 14 | *Pectinaria hyperborea* (Malmgren, 1866) | 16 |
| *Micrura* sp. | 12 | *Ampharete lindstroemi* (Malmgren, 1867) | 65 |
| Nematoda | 1069 | *Anobothrus gracilis* (Malmgren, 1866) | 19 |
| Polychaeta (pieces) | 18 | *Polycirrus* sp. | 4 |
| *Harmothoe imbricata* (Linnaeus, 1767) | 64 | *Polycirrus eximus (Grube, 1855)* | 1 |
| *Hartmania moorei* (Pettibone, 1955) | 1 | *Polycirrus medusa* (Leidy, 1855) | 31 |
| *Eusthenelais limicola* (Ehlers, 1864) | 1 | *Neoamphitrite figulus* (Dalyell, 1835) | 3 |
| *Pholoe* sp. | 12 | *Terebellides stroemi* (Sars, 1835) | 45 |
| *Pholoe minuta* (Fabricius, 1780) | 16 | *Trichobranchus glacialis* (Malmgren,1866) | 2 |
| *Pholoe tecta* (Stimpson, 1854) | 112 | *Apistobranchus typicus* (Webster and Benedict, 1887) | 1 |
| *Eteone longa* (Fabricius, 1780) | 45 | *Pherusa affinis* (Leidy, 1855) | 2 |
| *Paranaitis speciosa* (Webster, 1789) | 1 | *Pherusa plumosa* (O. F. Müller, 1776) | 6 |
| *Phyllodoce mucosa* (Oersted, 1843) | 31 | *Brada villosa* (Rathke, 1843) | 1 |
| *Phyllodoce maculata* (Linnaeus, 1767) | 2 | *Diplocirrus hirsutus* (Hansen, 1879) | 4 |
| *Eulalia viridis* (Linnaeus, 1767) | 1 | *Potamilla neglecta* (Sars, 1851) | 3 |
| *Microphthalmus aberrans* (Webster and Benedict, 1887) | 24 | *Euchone incolor* (Hartman, 1965) | 130 |
| *Exogone verugera* (Claparède, 1868) | 4 | Oligochaeta | 225 |
| *Ehlersia cornuta* (Rathke, 1843) | 5 | *Polinices* sp. | 3 |
| *Sphaerosyllis* sp. | 4 | *Frigidoalvania pelagica* (Stimpson, 1851) | 5 |
| *Nereis virens* (Sars, 1835) | 2 | *Astryis zonalis* (Gould, 1848) | 13 |
| *Nereis zonata* (Malmgren, 1867) | 3 | *Buccinum undatum* (Linnaeus, 1758) | 3 |
| *Aglaophamus neotenus* (Noyes, 1980) | 55 | *Colus pygmaeus* (Gould, 1841) | 1 |
| *Nephtys incisa* (Malmgren, 1866) | 430 | *Nassarius trivittatus* (Say, 1822) | 9 |
| *Goniada maculata* (Oersted, 1843) | 1 | *Curitotoma incisula* (Verrill, 1822) | 1 |
| *Ophelina acuminata* (Oersted, 1843) | 12 | *Cylichna alba* (Brown, 1827) | 16 |
| *Capitella capitata* (Fabricius, 1870) | 52 | *Flabellina* sp. | 1 |
| *Mediomastus ambiseta* (Hartman, 1947) | 50 | *Diaphana minuta* (Brown, 1827) | 1 |

**Appendix 1 (cont'd) Taxonomic list for a fallowed fish farm lease area in L'Etang inlet, Bay of Fundy, sampled on 28 May 1998. Abundance is the total number of individuals collected per 1.8 m² grab sampling area.**

| Taxa | Abundance | Taxa | Abundance |
|---|---|---|---|
| *Maldane sarsi* (Malmgren, 1865) | 1 | *Nucula proxima* (Say, 1822) | 14 |
| *Praxillella praetermissa* (Malmgren, 1865) | 3 | *Nucula tenuis* (Montagu, 1908) | 4 |
| *Rhodine gracilor* (Tauber, 1879) | 8 | *Yoldia sapotilla* (Gould, 1841) | 5 |
| *Sternaspis scutata* (Renier, 1807) | 10 | *Mytilus edulis* (Linnaeus, 1758) | 76 |
| *Aricidea* sp. | 51 | *Modiolus modiolus* (Linnaeus, 1767) | 751 |
| *Aricidea quadrilobata* (Webster and Benedict, 1887) | 1 | *Placopecten magellanicus* (Gmelin, 1791) | 9 |
| *Paraonis fulgens* (Levinsen, 1884) | 2 | *Astarte undata* (Gould, 1841) | 3 |
| *Levensinea gracilis* (Tauber, 1879) | 2 | *Cyclocardia borealis* (Conrad, 1831) | 35 |
| Spionidae | 4 | *Hiatella arctica* (Linnaeus, 1767) | 21 |
| *Polydora* sp. | 6 | *Mya arenaria* (Linnaeus, 1758) | 4 |
| *Prionospio steenstrupi* (Malmgren, 1867) | 108 | *Mya truncata* (Linnaeus, 1758) | 1 |
| *Spiophanes bombyx* (Claparède, 1870) | 34 | *Periploma fragile* (Totten, 1835) | 11 |
| *Lumbrineris* sp. | 5 | *Thyasira flexuosa* (Montagu, 1803) | 96 |
| *Lumbrineris fragilis* (O.F. Müller, 1776) | 5 | *Phoxichilidium femoratum* (Rathke, 1799) | 9 |
| *Lumbrineris impatiens* (Claparede, 1868) | 13 | *Pycnogonum littorale* (Strom, 1762) | 2 |
| *Ninoe nigripes* (Verrill, 1873) | 29 | Ostracoda | 8 |
| *Leitoscoloplos robustus* (Verrill, 1873) | 25 | *Eudorella* sp. | 3 |
| *Cirratulus cirratus* (O.F. Müller, 1776) | 41 | *Diastylis* sp. | 1 |
| *Tharyx* sp. | 40 | *Diastylis sculpta* G.O. (Sars, 1871) | 14 |
| *Chaetozone setosa* (Malmgren, 1867) | 9 | *Edotea montosa* (Stimpson, 1873) | 1 |
| *Limnoria lignorum* (Rathke,1799) | 3 | *Ptilanthura tenuis* (Harger, 1878) | 9 |
| Amphipoda | 1 | *Pagurus arcuatus (Squires, 1964)* | 1 |
| *Argissa hamatipes* (Norman) | 1 | *Cancer borealis* (Stimpson, 1859) | 1 |
| *Photis macrocoxa* (Shoemaker, 1945) | 1 | *Asterias vulgaris* (rubens) (Linnaeus, 1758) | 1 |
| *Monoculodes tesselatus* Schneider | 4 | *Strongylocentrotus droebachiensis* (O.F. Müller, 1776) | 5 |
| *Phoxocephalus holbolli* (Kroyer, 1842) | 4 | *Cucumaria frondosa* (Gunnerus, 1770) | 1 |
| *Harpinia propinqua* (Sars, 1895) | 8 | *Ciona intestinalis* (Linnaeus, 1767) | 4 |
| *Maera danae* (Stimpson, 1853) | 6 | *Macrozoarces americanus* (Schneider, 1801) | 1 |
| *Phascolion strombi* (Montagu, 1804) | 1 | | |

# Calendar

## conferences, workshops, courses and trade shows

• **Larvi 2001,** 3-6 September 2001, Ghent University, Belgium. The aim is to bring researchers together to evaluate recent progress, identify problem areas and stimulate future cooperation in research and industrial production of freshwater as well as marine fish and shellfish larvae. Information: Artemia Reference Center, Ghent University, Rozier 44, B-9000 Ghent, Belgium (tel +32-9-2643754, fax +32-9- 2644 193, e-mail larvi@rug.ac.be, website: http://www. rug.ac.be /larvi/).

• **International Commemorative Symposium: 70th Anniversary of the Japanese Fisheries Society,** 1-5 October 2001, Yokohama, Japan. Many of the topics weill deal with aquaculture. Information: Dr. Toshiaki Ohshima (tel +81 3 5463 0613, e-mail symp70yr@tokyo-u-fish.ac.jp, website http://www.symp70yr.or.jp).

• **8th Aliia HELEXPO, International Exhibition of Fisheries, Aquaculture and Relevant Equipment,** 1-4 November 2001. For information contact the Secretariat of ALIIA at tel +31 292 201 or by fax at +31 291 551.

• **2nd International Conference on Marine Ornamentals**, 27 November - December 1 2001, Wyndham Palace Resort and Spa, Walt Disney World® Resort, Lake Buena Vista, Florida. The aquarium hobby is second only to photography in popularity in the United States, and is rapidly becoming popular in many countries worldwide. The long-term goal is to develop culture protocols that can be used by industry to continue the growth of an important economic activity, while at the same time reduce harvest pressure from worldwide reef ecosystems. Contact: Dr. James C. Cato, Director, Florida Sea Grant College Program, University of Florida, State University System of Florida, PO Box 110400, Gainesville, FL 32611-0400 (tel 352 392-5870, fax 352 392-5113, e-mail: jcc@gnv.ifas.ufl.edu, website: http://www.ifas.ufl.edu/~conferweb/MO/).

• **Fish International 2002, 8th international trade fair for fish and seafood,** "The Quality Exhibition", 14-17 February 2002m Bremen Fair Center, Germany. For information, contact MGH by e-mail at info@ fishinternational.de or check the website www.fishinternational.com

• **Aquaculture America 2002,** 27-30 January 2002, Town and Country Hotel, San Diego. The US National Annual Conference and Exposition of the US Chapter of the World Aquaculture Society, the National Aquaculture Association, and the US Aquaculture Suppliers Association. Contact: World Aquaculture 2002, Conference Manager, 2423 Fallbrook Place, Escondido, CA 92027 USA (tel +1 760 432 4270, fax +1 760 432 4275, e-mail: worldaqua@aol.com).

• **10th International Congress of Parasitology,** 4-10 August 2002, Vancouver Conference and Exhibition Centre, Vancouver, British Columbia, Canada. Sponsored by the Canadian Society of Zoologists (Parasitology Section) and the American Society of Parasitologists. Program: plenary sessions, invited lectures and submitted posters and oral presentations. Tentative sessions: immunology, molecular biology, morphology and ultrastructure, biochemistry and physiology, systematics and evolution, ecology and epidemiology. Information: Conference Secretariat, Venue West Conference Services Ltd., #645-375 Water Street, Vancouver, BC (tel 604 681-5226, fax 604 681 2503, e-mail congress@venuewest.com, website http://www. Venuewest.com).

• **World Aquaculture 2002,** May 2002, Beijing International Conference Centre, China. Information: Director of Conferences (tel +1 760 432 4270, fax +1 760 432 4275, e-mail: worldaqua@aol.com).

• **Aquaculture Canada 2002, 19th annual meeting of the Aquaculture Association of Canada,** 17-20 September 2002, Delta Prince Edward, Charlottetown, PEI. Theme: *Finding Solutions, Creating Sustainable Wealth.* Co-hosted by the PEI Aquaculture Alliance and the PEI Department of Fisheries, Aquaculture and Environment.

• **Aquaculture America 2003**, February 2003, Commonwealth Convention Center, Louisville, Kentucky. Information: Director of Conferences (tel +1 760 432 4270, fax +1 760 432 4275, e-mail: worldaqua@aol.com).

• **Aquaculture 2004,** 29 February - 4 March 2004, Honolulu, Hawii.