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A STRATEGIC OVERVIEW OF MARICULTURE DEVELOPMENT IN CANADA: CURRENT STATUS AND FUTURE DIRECTIONS

by

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ABSTRACT

Based on a long history of fisheries research and resource enhancement, and with an increasing consumer demand for quality fish products, the last decade has heralded a rapid expansion of mariculture in Canada. The potential for the expansion of mariculture in Canada is significant; however, the development of this industry has been relatively constrained. Adverse natural environmental conditions and the ready availability of fish from the traditional fisheries have often hampered the progress of mariculture development.

The last decade of development is described from both Atlantic and Pacific coast perspectives and an overview of the issues, technological advances and the emerging strategies governing future mariculture development in Canada is presented.

Introduction

Canada has been blessed with extensive marine coastlines on both Atlantic and Pacific Oceans (as well as the Arctic Ocean), a wide assortment of endemic aquatic species of economic potential, a solid history and involvement in fisheries research and development, a well established fishery industry and ready access to major fish markets. These attributes all bode well for mariculture in Canada but why has mariculture been so slow to develop? It is only during the last decade, the 1980's, that Canadian mariculture has begun to assert itself as a significant factor in the Canadian fisheries sector. Perhaps one of the main reasons for the slow development of aquaculture has been the ready availability and predominance of traditional commercial fisheries in meeting market demand. The extension of the Atlantic Canada offshore economic zone to 200 miles in 1978 resulted in expectations of enhanced harvests from traditional fisheries; mariculture did not receive much attention during these times of plenty.

The 1990's marks a new era with the dawning of mariculture as a priority development opportunity on both Atlantic and Pacific coasts. Salmon farming has demonstrated even to the severest of critics that mariculture can be a major economic factor. In Atlantic Canada, aquaculture is proving to be a means for providing employment and diversifying effort from the traditional fisheries where serious crises now exist in the groundfish fisheries (cod, haddock, halibut). Now, even among commercial fishermen, there is a strong interest in the culture of marine fish in addition to salmon. On the Pacific coast, the rapid expansion of salmon farming of several species such as chinook, coho and Atlantic has steadily grown, despite major restructuring of the industry and a shifting towards Atlantics in the mix of species produced.

The shellfish culture industry, although longer established than commercial finfish mariculture, has maintained steady growth, but has not progressed to the same extent as the finfish sector. Natural environmental constraints to the growth of shellfish mariculture, from sanitation related closures of harvesting areas to toxic algal blooms, have limited the development of shellfish culture on both coasts.

This paper will focus on the development of Canadian mariculture industry and the regulatory framework that governs it. The issues of environment impacts, product quality, markets and strategies related to research and development will be discussed. Some of the future directions of mariculture in Canada will also be presented.

An Overview of Aquaculture Development in Canada

The culture of aquatic species has a long tradition in Canada. There were trout hatcheries before Confederation in 1867 and, shortly thereafter, salmon hatcheries for stream enhancement purposes were established. Research on oyster biology and culture was supported in the 1930's and a hatchery was established at Ellerslie, Prince Edward Island (P.E.I.) to augment natural spatfall.

With the exception of commercial trout hatcheries and pond culture, mainly in Central Canada, the major finfish activities in Canada were the federal salmon enhancement programs and the supporting network of hatcheries on both east and west coasts. However, since 1937, the provinces of the west coast and central Canada have developed an extensive system of trout hatcheries. Fisheries research in support of these programs and biological research on fisheries resources, in general, by the Fisheries Research Board of Canada, and later the Science sector of the Canadian Department of Fisheries and Oceans (DFO), provided a strong scientific basis in support of Canadian mariculture. The provinces have also supported development of fish hatcheries and aquaculture in general.

In Atlantic Canada, trials to culture and grow-out salmon in marine cages were initiated in the late 1960's on Prince Edward Island; in Nova Scotia, near Arichat, Cape Breton and Peggy's Cove, near Halifax, and in St. Andrews, New Brunswick in the early 1970's. These experiments were not successful due to lethal winter water temperatures. A shore-based facility was established in the late 1960's at Lake Charlotte, near Halifax, but went bankrupt a few years later as a result of too little production at too high a cost.

The trigger for the rapid development of Canadian mariculture came with the success of salmon cage culture in Norway and the application of this technology to Canadian waters.

In Atlantic Canada, this occurred in 1978 with a successful pilot sea cage experiment near Deer Island, New Brunswick on the Bay of Fundy. The high tidal action and oceanic circulation allowed for acceptable winter water temperatures for the overwintering of Atlantic salmon. With the proof that it was feasible, a number of the natural benefits of the area came into play:

(1) the ready availability of Atlantic salmon seedstock, initially from a federal hatchery producing salmon smolts for public enhancement, soon to be replaced by commercial smolt production facilities;

(2) the local presence of, and access to, scientific and technical expertise;

(3) an assistance program to enable local citizens to own, operate and develop a salmon farm;

(4) close access to major markets in the USA and Central Canada; and

(5) close attention paid at the onset to good husbandry practices and rigid measures imposed for fish health protection.

Today, the finfish mariculture industry of New Brunswick is producing 12,000mt from 63 sites and valued at $100 million (Cdn.).

On the Pacific coast, in British Columbia, commercial marine fish culture was present in the late 1960's. It was, however, a very different type of operation. There were less than 10 sites and they were generally small, each with less than 200mt production. At that time, the industry focused on production of pan size (3/4 to 1 lb.) coho salmon for the restaurant trade. During the 1980's, the industry grew to approximately 140 sites producing about 12,000 tonnes. Concurrently, there was a shift to production of larger (2 kg or larger) chinook salmon. Starting in the late 1980's, Atlantic salmon also became part of west coast production. In 1988, Atlantics were approximately 1% (80 tonnes) of total salmon production (6,590 tonnes). It is expected that in 1992, Atlantic salmon constituted approximately 37% of approximately 20,000 tonnes (worth an estimated $110 million) marketed. Chinook salmon constituted 54% of that production (Kenny 1993). The price differential between Atlantic salmon and chinook salmon has been the chief factor in the move from production of Pacific salmon on this coast.

The protected coastline, water temperature regimes and the ready availability of native Pacific seedstock, particularly chinook and coho, were natural ingredients for a successful industry. The British Columbia salmon culture industry now constitutes the major mariculture activity in Canada. The growth of salmon mariculture in Canada is show in Figure 1.

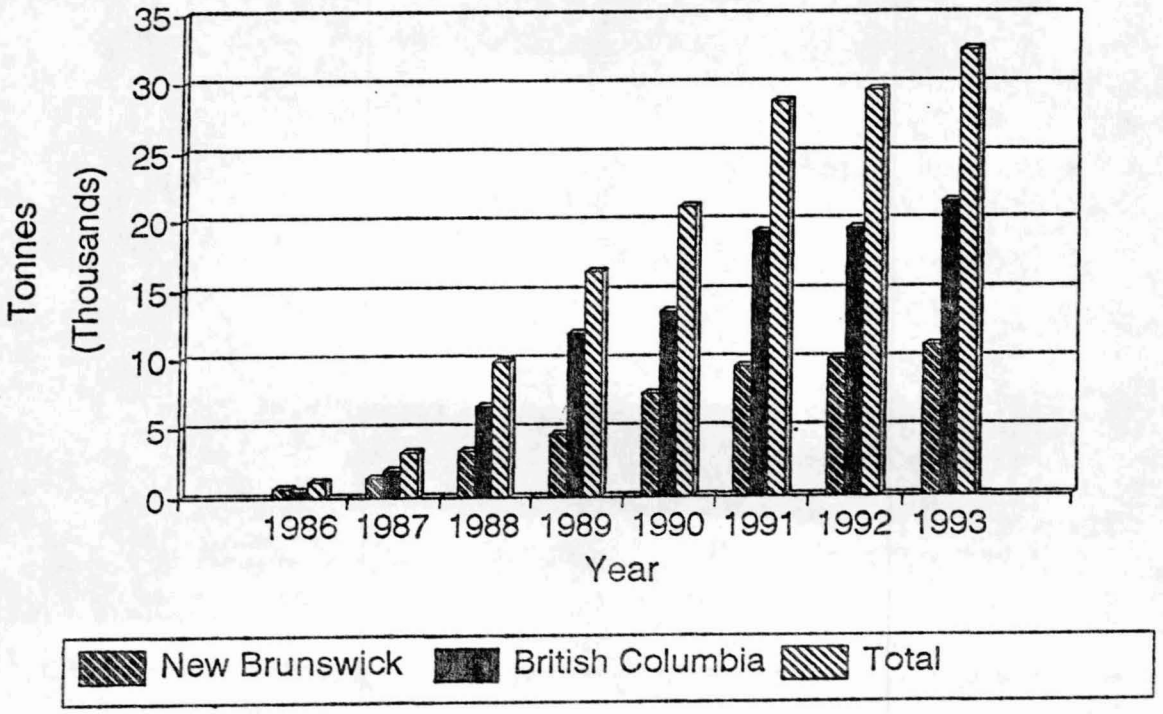

Figure 1. Salmon mariculture production in Canada (source: Kenney, 1993)

Much of the progress of aquaculture development in Canada can be traced from a meeting held in Winnipeg, Manitoba in 1973 when the lead fish culture researchers met to review the status, opportunities and potential for aquaculture in Canada. At that time, the total estimated production was 6,000 mt, worth $12 million (MacCrimmon, Stewart and Brett, 1974). This level of production did not change in the decade that followed. Rainbow trout and oyster production predominated.

Early in its development industry, researchers and government recognized the need for a vehicle for information transfer and a body to lobby for industry concerns. In 1983, the first Aquaculture Conference was convened in St. Andrews, New Brunswick, to assess the economic potential of aquaculture in Canada with invited presentations on such topics as research, development, regulations, legal implications, etc. (Pritchard 1984). This meeting was also the starting point of the Aquaculture Association of Canada, the main organization for all aquaculturists in the country. Identification of research needs for the industry and who will do the research is an evolving and iterative process. In 1984, the Science Council of Canada undertook a review of the requirements in support of the aquaculture industry. (Science Council of Canada, 1986).

When the industry started to develop rapidly in the mid 1980's, it identified a need for a co-ordinated approach to licensing aquaculture. Between federal, provincial and local governments, a aquaculturist was required to have an array of permits before starting operations and the wait to acquire a site lease could be a year or more. These uncertain conditions made it difficult to acquire or maintain funding for new aquaculture operations.

In 1985, the Canadian Minister of Fisheries and Oceans and the Provincial Ministers of Fisheries met to discuss aquaculture and the various constraints on its development because of overlapping responsibilities within the federal/provincial areas of jurisdiction. The major outcome of these meetings was the agreement that there would be "one stop shopping" for anyone wishing to have a lease or licence to conduct aquaculture. Over the next few years, a Memorandum of Agreement (MOU) on Aquaculture was developed for each province which outlined, the general working arrangements in which the two levels of government would work and co-operate in the development and management of aquaculture. These agreements were signed and put in place between 1986 and 1989.

In 1987, the Parliament of Canada, through its Committee on Fisheries and Oceans, undertook a comprehensive review of aquaculture in Canada and delivered this report to the House of Commons in 1988. These recommendations led to the Department of Fisheries and Oceans releasing their policy document on aquaculture in 1990, entitled "A Strategy for Aquaculture in Canada: Cultivating the Future". This document identified the continuing role of the federal department in aquaculture in such areas as research and development, product safety, environmental protection, marketing and statistics.

One of the positive spin-offs of this strategy was the support for the creation of a "Canadian Aquaculture Producers Council" (CAPC) which involves aquaculture producer association representatives from across the country. CAPC is a means of expressing industry concerns on policy, regulations and other issues of importance to the economic well being of their industry. For example, a recent CAPC initiative involves a project to review the R&D in support of aquaculture, to identify the key short, mid and long-term needs of the industry and to formulate a mechanism whereby the industry can influence the planning, priorities and funding of R&D conducted by governments, private research agencies and academia on behalf of the industry.

Some of the provinces have their own research programs which make significant contributions in support of industry. For example, British Columbia has maintained since 1988 an ongoing program of studies into the interactions between aquaculture activities and the environment (Black, 1990). In a recent ICES review of projects, these studies represented the second largest group of studies on these interactions in Europe and North America (ICES, 1992).

In September 1992, a national meeting was convened in Montreal, Quebec which involved representatives of industry, federal and provincial agencies with involvement in aquaculture and universities. This meeting, called the Canadian Aquaculture Planning Forum (CAPF) specifically addressed several topics in its Workshops, covering the environment, research and development, product safety and marketing. In the concluding plenary session, 42 recommendations were endorsed and many of them are now being implemented. The CAPF is to be convened on an annual basis.

Most recently, in response to the rapidly increasing pace of aquaculture development in Canada, the Deputy Minister of Fisheries and Oceans has commissioned the preparation of a new aquaculture strategy. As the Department is the lead federal agency responsible for aquaculture, the Deputy Minister states that "it is important that DFO recognize the aquaculture industry as a key client group... (and that the Department)... can play a catalytic role to encourage the growth and development of this emerging sector of the Canadian fishery".

Today, in Canada, fish culture is being practised in every province; mariculture is the predominant element with British Columbia and New Brunswick the production leaders based primarily on salmon. For shellfish, British Columbia and Prince Edward Island are the leaders with oyster and mussel the major products. There is also active research and commercialization trials on a broad array of other finfish and shellfish species. How to facilitate and support these developments in a co-ordinated and orderly regulatory framework in order to resolve the many social, economic and political issues that undoubtedly arise in the creation of a major new industry is the immediate challenge to all Canadian aquaculturists.

The Regulatory Framework

The culture of aquatic species in Canada falls squarely between the responsibilities of the Government of Canada and those of the provinces. When mariculture was in its infancy, up to the 1960's, the demand for site leases and licences for operations was principally focused on shellfish harvesting areas, and these were administered (by agreement) by the Federal Department of Fisheries and Oceans (DFO). In Canada, DFO is responsible for the management of the fisheries resource although specific administrative arrangements have been made to certain provinces to assume some of this authority. This is the general pattern, for example, with the management of the freshwater fisheries in such provinces as Ontario, Quebec, the prairie provinces and British Columbia. Generally, the management of anadromous and marine species has remained a direct federal responsibility.

The federal responsibilities for the national management of "fish" and the provincial responsibilities for property, industry, training and education, consumer safety, etc., within their boundaries, meant that aquaculture quickly became embroiled in a quagmire of regulatory "red tape", hardly conducive to the orderly development of a new industry. The signing of federal/provincial agreements or Memoranda of Understanding (MOU's) clarified the basic procedures required of aquaculturists and the areas of prime responsibilities of both levels of government. In all provinces, with the exception of Prince

Edward Island, the province takes the lead in the administration of issuing site permits. All agencies with valid regulatory involvement provide formal comment to the licensing authority. In some provinces, such as Nova Scotia, a formal public meeting must be called before a site is leased. In most other provinces, only a formal public announcement is required during the site review process; with public reactions taken into account before a mariculture site is approved. These decisions are generally made by the Provincial Minister of Fisheries who is also responsible for aquaculture.

In addition to taking the lead role in approving mariculture leases and providing licences of operation, the provinces within the authority of their respective Aquaculture Act legislation also assume the key roles of co-ordinating industry development, providing marketing assistance, extension services, training and education, and maintaining commercial statistics. In general, Provincial Fisheries Departments consult with other provincial agencies, such as Environment, Municipal Affairs, Natural Resources, etc., on aquaculture applications.

There are a number of areas where there is clear joint federal/provincial involvement such as (1) environmental impacts; (2) fish health protection; (3) industry development assistance; (4) product safety; and (5) resolving resource user conflicts (traditional fisheries, navigation, shore owners, etc.) in the coastal zone.

Federally, the Department of Fisheries and Oceans, with its own regulatory and development responsibilities, and its lead co-ordinative role with other federal agencies, has a significant influence on the development of aquaculture in Canada. At its Ottawa headquarters, a newly created Aquaculture Policy and Planning Division is playing a key role in shaping aquaculture policy, both within the Department, with other federal agencies and with industry. The principal contact with the provinces is through the Departments' Regional offices. Each DFO region is headed by a Regional Director-General and each region has appointed a Regional Aquaculture Co-ordinator to address the specific aquaculture issues falling within that particular administrative area. There are six (6) DFO regions in Canada, as follows:

	DFO Region	Province(s)		Comment
1.	Pacific	British Columbia	-	includes Yukon Territory
2.	Central and Western	Ontario, Manitoba, Saskatchewan, Alberta	-	includes Northwest Territories
3.	Quebec	Quebec		-
4.	Newfoundland	Newfoundland	-	and Labrador
5.	Gulf	New Brunswick (NE) and Nova Scotia (NE) and Prince Edward Island	-	management of fisheries in southern Gulf of St. Lawrence
6.	Scotia-Fundy	New Brunswick (SW) and Nova Scotia (SW and E)	-	management of fisheries in Bay of Fundy and on Scotian Shelf.

DFO administers the national Fish Health Protection Regulations, promulgated in 1976, which principally focus on preventing and controlling the introduction and spread of fish diseases on an interprovincial and international basis. These regulations and the associated manual of compliance which outlines diagnostic procedures and requirements for such activities as hatchery certifications and quarantine, are currently under revision. DFO "Local Fish Health Officers" administer these regulations from their laboratory bases in each Region, in close collaboration with provincial fish health veterinarians.

The introduction and transfer of fish also falls within the federal regulations. Each DFO region has an "Introductions and Transfers Committee" which overviews this issue and recommends on the providing of permits. A national meeting to develop policy on this matter was recently convened in Ottawa and a new national policy is soon to be released. The Canadian position takes into account the ICES Code of Practice on Introductions.

The health and safety of fisheries products, which are marketed interprovincially or internationally, are subject to DFO's Fish Inspection Act. The special issues related to product quality of salmon culture, such as medicated feeds, pigments, therapeutant residue levels, packaging and labelling, grade standards, have resulted in new initiatives in response to these requirements. The presence of algal toxins has required enhanced monitoring and inspection of shellfish production in affected areas to meet consumer safety standards. In Canada, the Department of National Health and Welfare and the Department of Agriculture are responsible for chemical criteria to be applied for seafood products and fish feeds, respectively.

In eastern Canada, the siting of a new aquaculture operation imposes itself on existing users of the coastal zone and traditional fisheries are generally implicated. DFO carries out site evaluations and consults with traditional fishermen on site suitability from their perspective. DFO also has a legislated mandate for fish habitat protection and, hence, considers the potential environmental consequences of a new site or the expansion of an existing site. DFO provides its comments to the provincial licensing authority. In British Columbia, site inspections are generally carried out by the province and DFO expresses any concerns by means of the interagency referral system. As the industry continues to develop and expand, these issues become more tenuous and political.

Another federal regulation relates to whether or not there is undue interference with navigation. Under the Navigable Waters Protection Act, the Canadian Coast Guard reviews all mariculture site applications and grant "exemptions" to those applications that meet the criteria of non-interference with navigation.

The Federal Environment Department has the responsibility for the classification of shellfish growing areas under a list of categories such as *open, conditionally open, open for depuration* or *closed* for harvesting. Mariculture sites will not be allocated in known "closed" shellfish areas. As coastal zone use increases, the potential areas for shellfish culture are reduced. This Department is also responsible for ocean dumping and this avenue has been used to dispose of mortalities from salmon farms due to winterkill or other causes. Land based waste management (i.e., composting) techniques are becoming mandatory in must jurisdictions with ocean dumping only permitted under exceptional circumstances.

Provincial jurisdiction in Canada includes the leasing of land use rights to aquaculture operations and the regulation of business activities within each province. With the exception of Prince Edward Island, aquaculture site and operational licensing is carried out by the provinces. The process for

authorizing a site permit involves an extensive procedure of consultations and evaluation. This process, which has been described in detail elsewhere (Black, 1991; Black and Truscott, 1993), incorporates input from a wide variety of coastal zone users as well as regulatory agencies prior to site approval. In British Columbia, after a site is licensed, annual monitoring of production and site development is carried out by two provincial agencies, the Ministry of Agriculture, Fisheries and Food, and the Ministry of Environment, Lands and Parks.

The processing of aquaculture products and their sale, wholesale or retail, is provincially regulated; however, all products destined for out-of-province must meet federal inspection standards.

Research and Development

Fisheries research on those species involved in Canadian mariculture has a long tradition and started well in advance of industry development. For example, research on the biology of Atlantic salmon originally required for stock assessment and enhancement purposes provided a good knowledge base for the eventual use of this species in mariculture. This is similar for Pacific salmon, oysters and scallop. In the case of lobster, the necessary culture biology is available; however, the "economics" of lobster mariculture does not warrant its commercialization.

Research on fish diseases and parasites, pathology, nutrition, ecological studies in coastal embayments, growth and reproductive physiology and marine algal toxins, etc., had all been underway well in advance of the advent of commercial aquaculture in the early 1980's in Canada.

The focus of Canadian mariculture research in the last decade has become increasingly focused on providing a scientific basis for culture practices which would reduce the cost of production and on aquaculture interactions with the environment. For finfish, essentially salmon, this involved applied research on improved diet formulations and nutritional requirements for different life stages; understanding the factors controlling sexual maturation; disease diagnosis, prevention and control; genetic selection and broodstock development; and culture system design and improved husbandry techniques. The objective of this research, whether conducted in government laboratory or private research facility, was to transfer the technology to industry to improve productivity and international competitiveness.

Since the early stages of rapid development of the salmon farming industry in the mid 1980's, potential interactions with the environment have been a major concern of the public and regulatory agencies in Canada (Gillespie 1986). As a result of these concerns, a large number of studies have been conducted. In a recent report surveying studies on environmental interactions within the ICES countries, the only country which reported more of this type of studies than Canada was Norway which produces over 4 times the amount of salmon produced in Canada (ICES 1992).

The mariculture industry has undertaken a rapidly expanding program of research on its own behalf. There are a number of government agencies that will contribute a share of the funding in support of industry "market driven" research. These projects often times involve proprietary research, the results are only made available to the specific company conducting the research. This usually involves only the larger companies and those that are more vertically integrated (e.g., have hatchery, grow-out facilities and processing capacity). The smaller companies and individual growers have to

rely on the information provided in the open literature and by their associations. Many research studies are carried out by producer associations on topics of concern to their membership. This approach has been successfully used by the two major Canadian mariculture producer associations, the British Columbia Salmon Growers' Association and the New Brunswick Salmon Growers' Association. Research projects ranging from husbandry improvements, waste management, and predation control to packaging, transportation, marketing and other infrastructure needs have been supported.

In Atlantic Canada, each of the provinces has an agreement with the federal government to support fisheries development. These agreements, known as "Co-operation Agreements" are cost-shared between the two levels of government. They usually have 5-year terms, and include an aquaculture component. The use of this program was instrumental in the early assistance to individual growers in the Bay of Fundy industry. Today, in New Brunswick, this program supports research projects on finfish, shellfish and environmental studies, as well as to help fund extension services. These "Co-operation Agreement" activities have greatly assisted the development of mariculture in all Atlantic provinces. New agreements are in preparation. For example, in New Brunswick, the main thrust will be the support of research and development of new species for commercial culture with five finfish (Arctic char, striped bass, halibut, haddock and winter flounder), and five shellfish (giant scallop, Bay scallop, quahaug, soft-shell clam and surf clam) species being identified. In Nova Scotia, considerable research will be focused on coastal environmental assessments to determine areas for development, support for the application of new and innovative culture technologies, and assistance to improve salmonid and European oyster production. In Newfoundland, the emphasis has been placed on the culture of marine fish, in addition to scallop and salmonids. Prince Edward Island is the major producer of cultured mussels and recent attention has been focused on quality control and marketing. The increasing recognition of toxic algal blooms has called for enhanced monitoring and the development and application of premarket product testing protocols.

In 1985, under the auspices of the Canada/New Brunswick Co-operation Agreement, an experimental farm was established in the Bay of Fundy to demonstrate to all growers, or potential growers, how to farm fish in sea cages. At the same time, it would carry out commercial scale trials leading to improved cost effective husbandry practices of benefit to the entire industry. This experiment is known as the Atlantic Salmon Demonstration and Development Farm (ASDDF) and since 1989, it has been directly managed by the New Brunswick Salmon Growers' Association. The site consists of a shore-based office, laboratory and 27 sea cages of various design. There is a broad spectrum of tests underway on such topics as comparative feeding techniques and feeding regimes, diet formulations, cage densities, therapeutant residual withdrawal rates, antifoulants maturation control. Most importantly, the ASDDF serves as the marine holding site for the pedigreed broodstock developed by the nearby Salmon Genetics Research Program at the specialized hatchery facilities of the Atlantic Salmon Federation. The Federation, in addition to conducting research on the genetics questions of wild/cultured salmon interactions, disease resistance and polyploidy, serves as the primary breeder for the Bay of Fundy industry. Using Saint John River stock, strains have been selected over three generations for characteristics of improved culture performance. Ten "multiplier" commercial growers receive improved progeny for egg production purposes.

With proceeds from the sale of experimental fish, the NBSGA reinvests in research trials at their experimental site or contributes to other research projects addressing their priority concerns. Some of these projects are on marketing, "fast tracking" of the registration of therapeutants not legally available in Canada for aquaculture, and studies on disease prevention and control.

British Columbia's research activities are extensive and have been mentioned earlier. What is perhaps not apparent is the institutional derivation of these studies. Typically in British Columbia, aquaculture research is initiated by either the federal government, the provincial government or universities. The federal government has focused its research activities on diseases, the development of new culture technologies and evaluation of new species for culture; the province has focused on developing new information on aquaculture/environment interaction and transferring research findings to industry; and academia has been involved with training the next generation of aquaculturists and has not focused on any one area of scientific research.

Industry has played a key role in helping to define new research initiatives. Initially, this was done by industry organizations such as the British Columbia Shellfish Growers' Association. However, in the last few years, an umbrella organization, the British Columbia Aquaculture Research and Development Corporation (B.C.A.R.D.), has been created by industry to facilitate outlining and priorizing the industries research needs and passing these on to the universities and government agencies.

Environmental Planning for Mariculture

The environmental issues facing Atlantic and Pacific aquaculturists have many common features; however, from the perspective of grow-out conditions and the candidacy of mariculture species of commercial potential, there are marked differences. On both coasts, research has been conducted on the ecological impacts of salmon farming on the marine environment, and on documenting the interactions between scale of production, nature of ocean bathometry and circulation, cage separation distance, proximity to traditional fishery fixed gear, navigational patterns and fish migration routes. An improved understanding of the real and perceived impacts of salmon aquaculture on other commercial fisheries resources, and the need for factual scientific information on these questions are increasing in demand. Opposition to new site approvals without local environmental or resource information being available is becoming a major problem. Governments have a key role in both conducting and supporting environmental studies related to mariculture production and development areas. Of particular importance are the sensitive topics of impacts of drug residues, diseases and parasites affecting wild fish, the risk to wildstock by sea cage "escapees", the impact of predator control devices such as seal scarers, on migrating wild species (e.g., Pacific salmon, Atlantic herring), and the effectiveness of waste management techniques.

In Atlantic Canada, the environmental issues are quite distinct for finfish and shellfish mariculture operations. The first and foremost problem governing all marine finfish culture is whether the winter water temperatures will permit overwintering. Last winter (1993), certain sections in the Bay of Fundy salmon growing area experienced lethal temperature with over 100,000 fish being killed. Sites had to be repositioned. In Nova Scotia, environmental studies have revealed that winter temperatures in the Annapolis Basin might permit satisfactory grow-out conditions. Some under ice grow-out of salmonids in the Bras d'Or Lakes of Cape Breton, Nova Scotia has also been demonstrated. Under ice grow-out has also been successfully demonstrated in Newfoundland; however, the cost effectiveness of this strategy, in comparison with surface sea cage culture, is questionable.

Even if new Atlantic coastal areas are found which do not experience lethal winter water temperatures, winter conditions are generally harsh and finfish grow-out is difficult even in protected locations.

The main environmental problem for Atlantic shellfish mariculture is toxic algal events, paralytic shellfish poisoning (PSP), domoic acid, diuretic shellfish poisoning (DSP) and other yet to be identified algal borne toxins. A phycotoxin monitoring program is operated by DFO in major shellfish growing areas and preharvest monitoring is carried out at some Nova Scotian and P.E.I. mussel producer sites in affected areas.

There is considerable interest in the culture of the giant sea scallop; however, the various grow-out techniques for "meats" only scallop production, including the use of ear hanging, have not proven to be economic. Nova Scotia sea scallop mariculture is currently based on marketing whole scallop products. Because of the algal toxin concerns, government-producer quality assurance protocols are put in place to ensure individual lots of whole scallop are tested for the presence of toxins before placed in the marketplace.

On the Pacific coast, the environmental conditions for mariculture are generally more beguine. Low water temperatures are not the concern; in fact, the warmer marine conditions are more conducive to algal blooms which have caused serious problems to salmon aquaculturists in such areas as Sechelt Inlet. Toxic algal blooms of Heterosigma akashiwo have been responsible for 80-90% of cultured fish lost to algal events in British Columbia (Black, et al., 1991, Black 1991). Nontoxic blooms have also killed cage held fish and caused substantial mortalities. New sea cage production has generally been shifted to more exposed locations to avoid these blooms.

The Pacific coast tends to have more deep fiord-like inlets with sills at their entrance in comparison to the Atlantic coast. The reduced oceanic circulation under these circumstances is more likely to lead to detrital build-up under the sea cages. In general, west coast environmental conditions are not as harsh as the north Atlantic Canadian coast and more conducive to finfish culture.

As mariculture develops on both Canadian coasts, new sites are receiving increased scrutiny from environmental groups, other users of the marine coastline and the public-at-large. Perceptions on the potential harmful effects of mariculture tends to dominate the agenda and governments directly involved with the leasing and licensing of new sites are being asked to provide factual background information on existing environment conditions, on the presence of other commercial species in the site area and on possible interactions. The public is seeking assurance that the needs of other uses (i.e., fisheries, navigation, recreation, etc.) and users, such as shoreline property owners, are protected.

In Atlantic Canada, a serious conflict arose between commercial fishermen and aquaculturists for five salmon culture sites in the Annapolis Basin, Nova Scotia. Even though the sites were "experimental" in scale, that is each site consisted of a single cage holding 15,000 fish to test the grow-out conditions and assess the potential impact on the local environment, mass public meetings and political involvement caused whole the development to be deferred. A few months later, in Jeddore, Nova Scotia, a shellfish lease was denied, based on the strong protest received at a public meeting. In New Brunswick, the continuing expansion of salmon farms in the Bay of Fundy is receiving increased scrutiny from environmentalists as well as from herring weir fishermen who are concerned that the presence of salmon in cages interferes with the migration and swimming patterns of young herring in proximity to their fixed gear. Interestingly, many of the salmon farmers in the area were once herring fishermen and now speak effectively on behalf of the mariculture industry. In Newfoundland, the mussel culture industry is required to allow lobster fishermen to place their traps in and about the mariculture lease as a condition of their permit.

An environmental monitoring program is in place in British Columbia and considerable attention has been paid to studying the changes salmon culture operations make on the surrounding physical, chemical and biological marine environment. Sedimentation impacts have been observed to be limited to a 30m perimeter around the farms with significant impacts on benthos only directly beneath the pens. Recovery after cage removal or relocation has been demonstrated to be relatively rapid.

The loss of farmed salmon to seal predation is becoming a significant production loss and the use of acoustic control measures is raising concern with fishermen who feel it has an adverse effect on the migration of wild salmon.

The farmed-wild salmon interaction issue is a major environmental concern in British Columbia and an emerging issue of importance in Atlantic Canada as evidenced by the recent initiatives of the North Atlantic Salmon Commission (NASCO). Although Atlantic salmon are not thought to interbreed with native west coast species, the extent of the interaction would depend on the number of escaped fish. There are three areas of concern related to this issue of salmon interactions:

(1) genetic and the question of domestication of wild stocks by escapees;

(2) ecological, including competition of escaped salmon on feed sources and spawning areas; and

(3) the transfer of diseases between farmed and wild stocks.

This latter issue is more likely a problem for fish farmers, given the predominance of wild populations.

Markets, Production and Forecasts

Mariculture in Canada is largely based on salmon from the Provinces of British Columbia and New Brunswick. Canada currently ranks as the fourth largest salmon farming country; in 1992, this represented almost 29,500 mt, valued at over $200 million Canadian, and 9% of the total world production of farmed salmon.

The New Brunswick finfish industry is based solely on Atlantic salmon production at 62 sites (45 companies) and supplied by 13 hatcheries producing just over 3 million smolts. Production in 1992 was 10,000 mt of which 74% was exported to the U.S.A.; the remainder was sold domestically, mainly to Ontario and Quebec.

The British Columbia industry produced 19,500 mt of farmed salmon of which 60% (11,800 mt) was Chinook, 36% was Atlantic (7,200 mt) and the remainder, 500 mt was Coho. The industry has undergone a major restructuring in which the 125 sites, operated by 55 companies in 1991, have been reduced to 99 sites and 20 companies in 1992. Eighty percent of British Columbia farmed salmon production is produced by seven companies. Smolt production in 1992 from British Columbia's 18 hatcheries was 4.5 million Atlantic, 3.1 million chinook and 0.8 million coho.

On the west coast, Atlantic salmon has been shown to reach greater weights in a shorter time in seawater than Chinook. In addition, they can tolerate higher stocking densities and are less susceptible to disease than Chinook. Because of the stronger prices for Atlantic salmon, and that they have a higher dressed yield per fish than Chinook, British Columbia growers are

shifting production to Atlantics as smolts become available. The major market is also U.S.A. where 76% (15,600 mt) of the production is exported. Nine percent is exported to Japan and the remaining 15% (or 2,925 mt) is marketed in Canada.

Atlantic salmon is the dominant fresh salmon species imported by the U.S.A. With Chinook production in British Columbia being highly seasonal and declining, the major challenge for Canadian salmon farmers is meeting the competition from Chilean salmon on U.S.A. markets. The doubling of Chilean imports to the U.S.A. between 1991 (6,700 mt) and 1992 (13,000 mt) gained significant ground on Canadian salmon exports to the U.S.A.of 18,200 mt (in 1992). The competition for the U.S.A. market between Canada and Chile will be the dominant marketing issue for Canadian producers during the next decade.

Canadian salmon mariculture owes much of its success to the proximity to U.S.A. markets. Initiatives are underway by the salmon growers associations on both coasts to define and plan their marketing and promotional strategies with greater precision. There have been geographic assessments conducted as to the destination of Canadian produced farmed salmon. The primary markets for Canadian salmon on the east and west coasts of U.S.A. consist of populations of 64.2 and 38.2 million, respectively, and this represents about 40% of the total American population. The use of generic marketing strategies has been successfully employed by many food commodity sectors to stabilize prices and to encourage increased consumption. Statistics showing the decline in seafood consumption in the U.S.A. since 1987 (16.2 lbs. to 14.9 lbs. in 1991) runs contrary to the increasing preference for seafood as determined by consumer research surveys. Price sensitivity analysis has shown that retail sales of salmon are more sensitive to price levels than the restaurant trade. Perhaps the most encouraging trend is the increase in American salmon consumption in comparison to other seafoods, as well as on a per capita consumption basis.

Canada has a strong foothold in the U.S.A. market and this is expected to increase in response to generic marketing and promotion initiatives by the industry on both coasts. The point of sale (POS) public relations program of the British Columbia Farmed Salmon Institute is focused on specific U.S. retail and food service sectors. Marketing programs such as this are becoming priority for Canadian producers to maintain and improve their competitive position in their prime marketplace, the U.S.A. as well as in other international markets.

The marketing of Canadian cultured shellfish production has tended to follow the trading patterns established for many years for oysters on the east and west coasts. Mussel growers, particularly on Prince Edward Island, have shown regional leadership in co-ordinating local production and focusing its product on specific markets, principally in the northeastern U.S.A. and central Canada. Atlantic mussel growers are currently working towards an Atlantic-wide mussel marketing organization which would involve all growers in the four Atlantic provinces. The fledgling sea scallop culture industry is primarily marketing its production domestically although, in future, the objective will be to service markets in the northeast U.S.A. The limited shelf life of the "whole scallop", the main product currently being produced, will present problems for the producers. With the application of improved scallop culture grow-out technologies and reduced cost of production, adductor muscle "meats" only cultured sea scallop production should be feasible. In Nova Scotia, a major scallop mariculture operation based on "meats only" is soon to start using new earhanging attachment technology.

Canada is at present a small player in an industry which markets globally as such it will continue to be a price taker rather than a price setter in the market place. Our highest production, salmon, has only captured 9% of the world cultured salmon market. To radically change this would require a massive increase in our production and flooding the market with product. In the early 1990's Norway had massive increases in production and the market responded by dropping the price it was willing to pay for farmed salmon. The result of this drop in price was numerous bankruptcies in salmon farming world wide but particularly so in the low equity companies of the Canadian west coast industry. Clearly competition through increased production is not a strategy for the future of Canadian aquaculture.

The production cost structure of Canadian aquaculture industries also imposes limitations on our strategies for the future. For example, Canada's principle competitor for farmed salmon has been Chile. With similar environmental conditions and abundant coastline this country is likely to be able to produce most of the species the Canadian industry can. However, its labour and feed costs are a fraction of those the Canadian industry has to pay. Clearly competition using the same technologies and traditional aquaculture species is unlikely to be an effective development strategy.

To support higher cost of production in Canada, industry will have "high grade the market" (target our sale on only the highest value products). In today's market this is likely to mean Canada will have to have demonstrateably better quality product than its competitors and be the first to put new products on the market. These new products are likely value added products (products whose value is increased through additional processing or specialised packaging). This means that Canada will have to look for its future by being the first to invent and implement new technologies and be able to identify and capture niche marketing opportunities. Here, Canada has a significant edge in the market place. Its highly educated work force and technologically advanced society are ideal for adopting this strategy - a strategy which has proven successful in other countries such as Germany.

Future Directions for Mariculture in Canada

Mariculture has developed in Canada in the shadow of a prosperous and expansive harvest fishery on both the Atlantic and Pacific coasts. Traditional fisheries interests have dominated the political agenda in this sector and the pace of mariculture development in Canada has suffered accordingly. Despite this, the value of aquaculture production has increased from $12.1 million in 1983 to an estimated $259 million in 1993. The potential of aquaculture, marine and freshwater, is great and the success of salmon farming in British Columbia and New Brunswick have demonstrated the extent of the socio-economic benefit.

Today, Canada is facing a dramatic downturn in the Atlantic fishery and is having to provide costly assistance to many communities and displaced fishermen in Newfoundland and the other Maritime provinces. This major upheaval in traditional fisheries is bringing an increased interest in mariculture as an alternative source of economic activity for rural coastal communities. Fishermen are becoming interested, most for the first time, in mariculture. Much of the interest in finfish culture is not with salmonids, rather the marine species they are more accustomed to handling such as cod, haddock, winter flounder and halibut, as well as sea scallop and mussels. This attention is placing demands on the scientific community (DFO, the provinces, universities, private research institutions) to provide the needed culture technologies. In Canada, there are currently 12 finfish and 8 shellfish

species under study, nearing commercialization, or being produced (Stewart and Cook, 1992). Governments are most sensitive to community based expressions of interest in mariculture and are now developing new programs to encourage and assist mariculture.

At the same time, mariculture has rapidly become an international industry, with reduced costs of production, access to markets and market share, and international competitiveness becoming the factors that determine the success or failure of the business. Canada is already a major exporter of fish products; however, the entrance of mariculture into this mainstream presents new marketing requirements - many that have yet to be addressed.

For Canada to develop its vast mariculture areas and become a world leader in mariculture production, it will first have to recognize officially that aquaculture is a major component of the fisheries sector. With this, a number of requirements must be addressed as summarized below:

1. Better Knowledge of the Coastal Environment

   As mariculture receives the development support and the political attention of federal and provincial governments, the competition for space and use of finite coastal areas will increase. Public concerns on the use of coastal waters and, in particular, the proprietal requirements of fish farming, are increasingly considered to interfere with traditional uses of the "common property" resource. In short, the "new kid on the block", the aquaculturist, is being challenged by the more established users to justify his right to develop.

   There is a need for enhanced coastal planning initiatives, involving all users, and based on environmental studies and resource surveys so that decision making is not only based on user interests and public perceptions but on an environmental data base as well. The need for baseline information, estimates of holding and/or carrying capacities and coastal assessments should be prerequisites for development. Once mariculture sites have been established, environmental parameters should be appropriately monitored to ensure pre-established environmental quality standards are maintained. Communication of environmental information to the public is an essential step in developing a balanced public perception of the effect of aquaculture and other users on the marine environment.

   The need for more environmental and resource information in present and future mariculture production areas, the development of increasingly comprehensive geographic information system (GIS) methodologies to integrate the information from these areas and methods to assess quantitatively the impacts and interactions of mariculture will remain a major topic as the Canadian industry develops into the next decade.

   Proper coastal resource planning will also help identify and formally acknowledge coastal areas where aquaculture, after a complete evaluation of benefits and costs, is a preferred resource use. This allows industry to plan its future development on the basis of a minimum amount of production area which will be available to it and allows government to plan apriori infrastructural support for the intended mix of coastal zone uses.

2. Developing a Regulatory Regime for Mariculture

Given the unique jurisdictional divisions in Canada between federal and provincial responsibilities, much has been achieved over the past decade to harmonize governmental actions on mariculture (i.e., the federal/provincial Memoranda of Understanding). In the future, attention must be paid to address the constraints to aquaculture contained in the regulations under the Canada Fisheries Act which are dedicated exclusively for the conservation and protection of wild fisheries resources and the management of the harvest fisheries. Examples would include addressing such issues as: (1) the imposition of minimum size limits for capture fisheries to ensure harvesting occurs after reproductive size has been attained. This regulation currently applies to culture operations where this should not be a constraint; (2) the required use of tags for all cultured Canadian Atlantic salmon marketed to safeguard wild stocks and deter the illegal harvest of wild salmon; (3) the restrictions placed on the use of broodstock for culture purposes; (4) the application of fish health regulations as an aquaculture measure, not solely as a means of protecting wildstock.

Steps to co-ordinate the regulatory climate, both national and international, on such topics as the use of therapeutants, pigments and grade standards must also be taken. In addition, the standards used for the classification of shellfish harvesting areas require review as many of the current provisions adversely affect mariculture development. For taxation purposes, fish farmers wish to be classified with land farmers to obtain similar advantages of using their "crops" for collateral and insurance purposes. These are but a few of the regulatory provisions that must be refined to meet the specific interests of the aquaculture industry.

3. Institutional Support for Aquaculture

The expansion of commercial aquaculture in Canada was the result of a market which created demand for the industry and the institutional and technical support which facilitated the industry's development. This development, however, was achieved within an evolving regulatory atmosphere and, lately, within the context of a broader planning activity (e.g., Black, 1991; Black and Truscott, 1993). It is the institutional and technical support for the development of the mariculture industry and the strategic planning to identify its future needs that must now be addressed.

As our understanding of the requirements of production technologies evolves and the science and technology in support of mariculture becomes more complex, there will be an increasing need for highly trained staff and scientists to assist industry solve technical impediments to its future growth. To meet this need during the last decade, universities and colleges on both coasts are developing training programs and degree level programs. In British Columbia, Malaspina College and Simon Fraser University have aquaculture programs underway and the University of British Columbia and the University of Victoria provide several aquaculture courses. In the Atlantic provinces, the New Brunswick Community College in St. Andrews and Holland College in Prince Edward Island have diploma programs in Aquaculture. The Universities of New Brunswick, Prince Edward Island (Atlantic Veterinary College), Memorial University (Newfoundland) and Dalhousie University (Nova Scotia) also offer courses in aquaculture.

4. Commitment, Co-ordination and more focus for R&D

Industry, academia, and government play complementary roles in developing aquaculture research priorities. These roles however are different and it is important that the priorities of no one group wholly dominate the direction taken in research for aquaculture. Each group, by the very nature of its mandate, will have different priorities and different time frames determining its priorities. Industry, to survive on a year to year basis, must focus most of its attention on research to solve the immediate problems in being profitable. Government and academic research can afford to have a more distant time horizon and can deal more effectively with research to reassure the public about environmental and public safety concerns or to address the longer term scientific issues. Lose the proper balance of these needs in R&D and ultimately the industry's ability to survive in the global marketplace will be sacrificed.

The Canadian aquaculture industry has recently identified research in the areas of nutrition, fish health, reproduction, engineering and management as areas of prime importance. The resultant research is considered to have a direct effect on the unit cost of production and subsequent competitiveness of the product in the global market. The industry considers its research priorities in the content of its need to keep labour, feed, processing, transport costs to a minimum, mortality rates low, operating at optimum production capacities and producing highest quality products on a consistent basis.

As the industry develops, it will become more important to clarify the respective roles of government and industry research. It is clear that government research will continue to focus on its needs for information on interactions between cultured and wild species, the environment, the use of chemicals and issues of product safety and longer term biological research and development issues. The industry will primarily focus its research efforts to meet their immediate needs on husbandry improvement technologies, feeds and feeding strategies, broodstock development, disease diagnosis and control, and applied biotechnology. The funding of university research is becoming more project (than process) oriented and will be increasingly involved in research of direct relevance to industry. The future trend in government funding is clearly focused on industry lead, market driven research.

There is a need to co-ordinate the R&D effort more effectively and one suggestion is that a "National Aquaculture Industry R&D Board" be established which would overview the funding of aquaculture research and recommend on its direction. By this mechanism, it is proposed that government support for research would be assessed by the Board, with Regional committees, and hence, be more responsive to industry needs. This initiative would also include a cataloguing of all R&D projects and providing a technology information system. This and other mechanisms to improve the effectiveness of aquaculture R&D are under active review. Already, in British Columbia and New Brunswick, there are government/industry committees in place to co-ordinate R&D efforts in support of aquaculture. Any new national plans would have to take these existing structures into account.

One major requirement of the scientific community will be to conduct research in support of the culture of new species of economic potential. The need to diversify from traditional cultured species, such as salmonids and oyster is clear. Canada has a wide range of endemic, high value, cold water species to select from and this is a key direction for

future research. In addition, there is the need to diversify from the existing production of fresh whole fish or shellfish to value added or products aimed at special market niches such as those required for the fast food "industry".

In the highly competitive market environment described earlier, it is clear that solving the same problems using the same approach used in other countries will, at best, only slightly increase industry competitiveness. To make the largest competitive gains for the industry some research support must be directed towards innovative approaches. For example, most aquaculture countries support research into defining fish diseases and creating new therapeutants to control these diseases. Some researchers have taken the novel approach of assuming that disease in cultured fish is principally caused by the stress of the environment the fish live in and are attempting to define how to minimize those stresses. If successful, not only will they reduce industries financial losses due to disease, but they will also reduce the cost of production by reducing the need to buy antibiotics.

5. The Problem of Supply and Markets

With the possible exception of Canada's more established salmonid (salmon and trout), oyster and mussel culture industries, markets are not the constraint, it is the lack of production. Many fish farmers cannot yet produce, at a commercial scale, sufficient product to maintain the continuity of supply that the established fish markets demand. At the present time, this is the critical constraint for the development of Canadian aquaculture. High start-up costs, the long lead time until the first product can reach the market, the lack of investor confidence and venture capital, the strain of limited working capital at the beginning, and a stringent regulatory regime under which to operate, all contribute to the problems. Many of the pioneers who have surmounted the above and related problems are becoming very successful. This success, however, has not come easily.

To expand traditional cultured salmon markets and to maintain newly developed markets Canada will have to initiate and rapidly act on up-to-date market analysis identifying niche market opportunities and new value added products. This will require development of a flexible and rapid-to-change processing industry in support of aquaculture. With the present decline of the traditional fisheries, some of these changes are now being initiated in an attempt by the processing industry to utilize wild caught fish species previously underutilized.

Canada has the distinct advantage of having a vast market at its doorstep. This proximity facilitates market research and promotion and, most importantly, involves lower costs for transportation. Focusing Canadian mariculture production to meet specific markets, maintaining high standards of product quality, diversifying its product lines in relation to consumer preferences, and promoting the overall health benefits of seafood, is the future path for Canadian mariculture.

Conclusion

This Regional assessment of Canadian mariculture has provided a brief history of the development of the industry. The future direction of mariculture development in Canada will depend on how well Canadian aquaculturists are able to use their cold water marine environments and develop the many endemic species of economic potential. That development will also be enhanced or constrained by the role government plays in industry development. In the decade between 1983-1993, the value of Canadian aquaculture increased twenty fold. This growth is expected to continue, especially in light of the current downturn in traditional fisheries and the research and development initiatives now being sponsored by national and provincial governments, and by industry in support of mariculture.

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