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of the
Aquaculture Association of Canada

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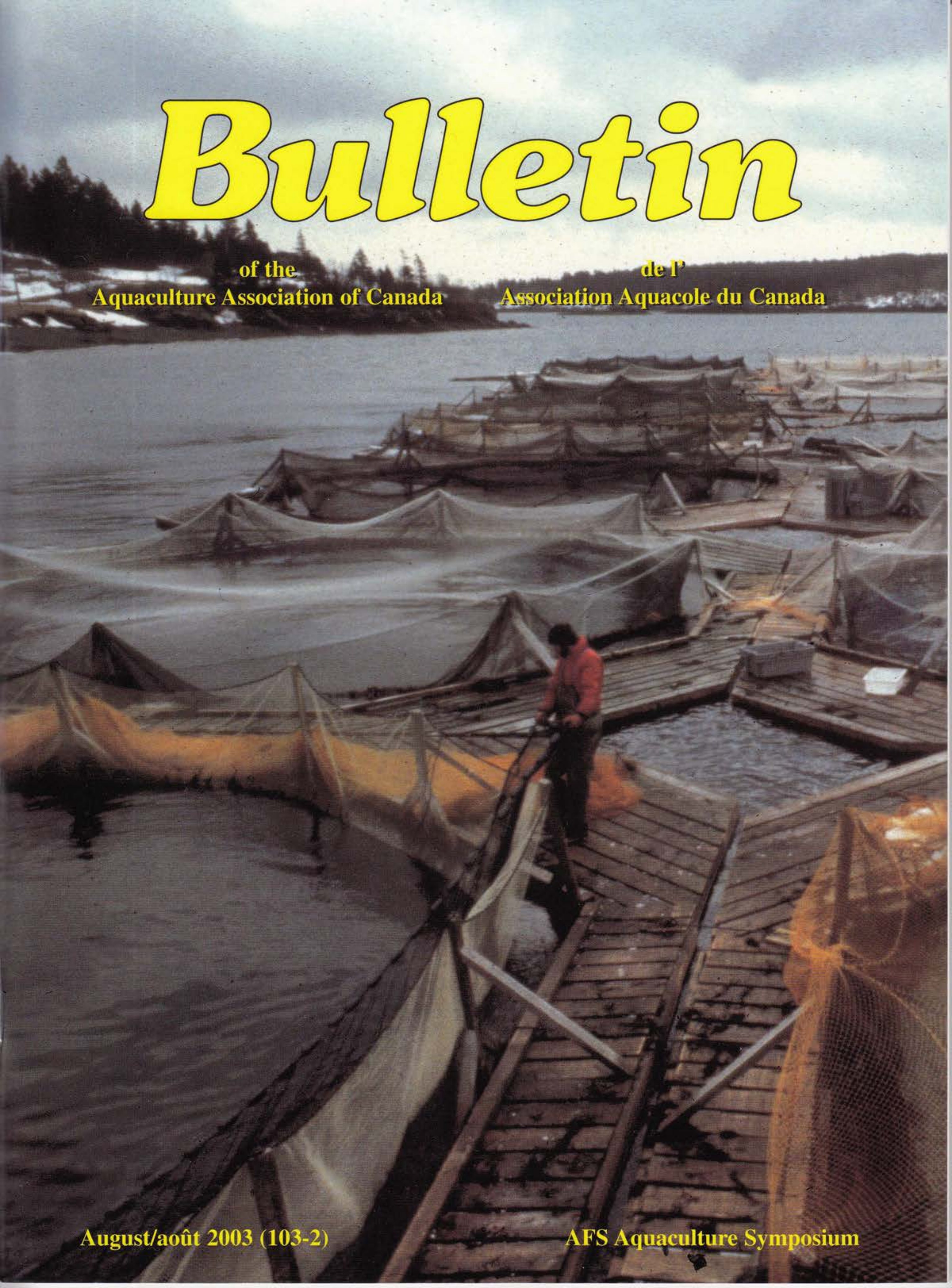

August/août 2003 (103-2)

AFS Aquaculture Symposium

VIEW FROM HERE

Time for a change?

I found myself re-living the past during the discussions at the BC Shellfish Growers Association recently. The outcome of this experience was (again) the realization that nothing much has changed over the last 20 years in aquaculture development in Canada. **I know it is time for a change.**

The current crisis in the BC shellfish industry—declining prices—is one with which most other aquaculture sectors are, unfortunately, familiar. And I do not mean just reduced profitability. I mean prices so low that business viability and personal livelihoods are threatened. How do we always arrive at this point? The general scenario, that of production-driven industry development, plays out as follows.

Aquaculture development provides the promise of jobs, economic revitalization for coastal communities and First Nations, and export revenues—things that are almost irresistible to governments. Aqua-business start-ups are encouraged, tenures are made available and the industry begins. Initial profitability leads to increased growth through re-investment and the positive profile attracts new start-ups. During the ramp-up phase, producers are on a "high", selling all their product, making money and growing their businesses. Governments are enthusiastic, jobs are created, the industry grows and targets are met. Everyone is oblivious to the tidal wave of increased production about to crash over them. Nobody considers marketing until it is too late.

Production-driven industries fail because production inevitably exceeds market demand and prices crash. The downward cycle in prices accelerates as profits diminish and weak businesses become price-takers to meet their bank payments to survive (if only for the short-term). Any producer reading this article can relate to this scenario. By the time the wave crashes it is too late for many producers and industry consolidation is inevitable. I find myself wanting to ask who is responsible for this scenario—which has been repeated time and again across Canada—when I should be asking how we can change things to facilitate profitable aqua-businesses? The answer is quite simple. We need an integrated approach to industry development that involves both production and marketing.

Being a veteran of the above scenario, with the scars to prove it, my opening statement in lectures to aquaculture students is "If you cannot profitably sell it, then why grow it?" Implicit in the profitability of an aquaculture industry are success in both production and marketing. In today's paradigm we are relatively good, and improving, at addressing production-oriented research questions. We have AquaNet, we are developing new research centres, and we are focussing on research to improve our competitive advantage. We are, unfortunately, not

Production-driven industries fail because production inevitably exceeds market demand and prices crash.

good at supporting or undertaking equally important research to address marketing and food production issues. We must increase awareness that marketing and market research is just as essential to success as is production. We must educate both government and industry that we ignore marketing at our peril. **Selling** is what you do when demand for the product exceeds production (selling is easy). **Marketing** must be done before the supply and demand lines meet (marketing takes time and effort).

Everyone is familiar with the phrase "information is power." Canadian aquaculture producers supply food to the global marketplace. To survive and thrive we need global market information. Should we produce fresh or frozen product? Is value-added the way to go? What form should the product take—value-added fresh, or frozen? And most importantly, what are our competitors doing, and what are our competitive and comparative advantages? A competitive advantage may be, for example, that our waters support faster growth. A comparative advantage may be that the market is right next door so transportation costs are less than that of our competitor. The competitive advantage would be decreased if the competitor begins a selective breeding program that increases growth rates. The comparative advantage would be impacted if the competitor moves to value-added and/or frozen products that reduce the cost of shipping. How then should an industry or a company position itself? What product forms are advantageous and what research do we need to support these product forms? The answer to these questions is that we cannot successfully position ourselves unless we have full knowledge of our competitors and the marketplace.

How are we going to obtain this information? In by-gone days, before aquaculture development, the federal Department of Fisheries and Oceans (DFO) had a marketing and economics branch that provided information services. The Department had several technology development stations across the country that addressed food development issues and technology innovation. DFO recognized that fish, once caught, are food and therefore must be transformed into what the market demands. These service areas were eliminated when DFO re-focused its mandate on conservation and protection of the wild resource. Where in Canada do these services currently reside? Can we get access to them? Is our federal lead agency equipped for such a vital mission?

I will end with a quote from Peter Drucker, noted economist and Nobel Laureate, that was highlighted in the recent report from the Office of the Commissioner for Aquaculture Development (OCAD)— "Aquaculture, not the internet, represents the most promising investment opportunity of the 21st century". My view is that unless Canada realigns its agencies and mandates and provides adequate resources to address both aquaculture production and marketing, our country's ranking in global seafood production will continue to decline, and I will re-submit this story in another 10 years.

... unless Canada realigns its agencies and mandates and provides adequate resources to address both aquaculture production and marketing, our country's ranking in global seafood production will continue to decline...

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Front cover: Wood-frame "Malloch" cages on a Lime Kiln Bay salmon farm in the mid 1980s. These cages are the original hexagonal design developed by John Malloch and used by the pioneer salmon farmers in the Fundy Isles region of the Bay of Fundy. Photo by P.W.G. (Bill) McMullon, St. Andrews, NB.

Comptes Rendus: Introduction

"L'aquaculture: un complément aux pêches et une solution alternative à leur déclin"

L'aquaculture connaît un essor important depuis plusieurs années. Elle est destinée à occuper une part de plus en plus de la production mondiale de poissons et fruits de mer. Malgré cet avenir prometteur, l'aquaculture est en butte à des problèmes importants. Sa complexité croissante réclame une saine gestion de son développement, tout en utilisant les technologies les plus performantes à la production des espèces ciblées.

Afin de susciter des échanges sur l'aquaculture, le symposium « L'aquaculture : Un complément aux pêches et une alternative à leur déclin » a été organisée lors de la réunion annuelle de l'American Fisheries Society ayant lieu du 10 au 14 août 2003 dans la ville de Québec. C'était une occasion privilégiée de sensibiliser la communauté des pêches, prépondérante dans les symposiums de l'AFS et de l'aquaculture sur la complémentarité de leur utilisation des ressources aquatiques et de faire connaître les derniers développements dans la recherche.

Les membres du comité organisateur, provenant des organismes gouvernementaux fédéraux et provinciaux, des universités et des représentants de l'industrie, ont élaboré un programme touchant aux aspects d'actualité dans l'industrie. Les conférenciers invités ont présenté des modèles de réussite en aquaculture appliqués ici et ailleurs dans le monde. Des discussions (plénières) sur les interactions entre les pêcheries et l'aquaculture ont suscité un vif échange parmi les participants.

Les conférences du symposium ont ainsi été divisées en trois volets. Les aspects socio-économiques de l'aquaculture et leurs incidences sur les communautés côtières représentaient la première problématique abordée. Il existe une résistance aux changements dans plusieurs communautés côtières de la part des pêcheurs traditionnels qui peuvent voir les aquaculteurs comme des rivaux. Pourtant, plus souvent qu'autrement, ces deux activités sont complémentaires. L'aquaculture sert de façon importante à l'ensemencement. Elle peut assurer un arrivage stable de matière première aux usines de transformation de produits marins et en faciliter la survie au bénéfice des pêcheurs traditionnels. Elle permet aussi d'alléger la pression sur des stocks qui s'épuisent en proposant un substitut de nature équivalente.

Le deuxième volet traitait des technologies et des défis au développement de l'aquaculture en climat froid. Les défis et contraintes du climat, de la géographie et de la biologie ont une influence sur la sélection des espèces. Il y a beaucoup de progrès et de possibilités d'innovations dans les techniques de production, tels que les systèmes de recirculation ou des nouvelles structures pour l'élevage en mer. L'optimisation de la croissance et de nutrition doit être développée en fonction des glaces qui recouvrent le golfe du Saint-Laurent pendant une partie de l'année. Les nouveaux débouchés au niveau d'applications biomédicales pour les espèces qui ont de bons potentiels de croissance sont aussi à considérer.

Le troisième volet portait sur les interactions de l'aquaculture sur l'environnement aquatique, la capacité de support et l'impact de l'environnement sur l'aquaculture. Au niveau environnemental, l'aquaculture est souvent pointée du doigt comme une industrie très polluante, qui détruit les habitats fauniques, qui propage maladies et parasites et qui consomme plus de poissons en intrant qu'elle en produit finalement. Les risques associés à des fuites de poissons dans les milieux naturels causent eux aussi une forte appréhension du public.

Les conférences de ce symposium ont donc pu présenter l'aquaculture comme une industrie légitime en pleine expansion s'assurant du respect de l'environnement.

— ***Simona Motnikar***
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Introduction

"Aquaculture: A Complement to Fisheries and an Alternative to their Decline"

Aquaculture is an industry that has greatly expanded in the past several years and is expected to produce a growing proportion of the total world fish and other seafood supply. Despite this promising future, the industry is facing significant problems. The growing complexity of aquaculture requires a sound development strategy. It is critical that the best available technologies be adopted for the production of species selected for culture.

In order to promote an open exchange on aquaculture, the symposium "Aquaculture: A Complement to Fisheries and an Alternative to their Decline", was organized during the American Fisheries Society (AFS) annual meeting, held from August 10^{th} to 14^{th}, 2003 in Quebec City. It was a wonderful opportunity for those interested in aquaculture to interact with the fishery participants—who predominate at the AFS meetings—on the complementarity of the use of aquatic resources. This occasion also permitted the presentation of the most recent aquaculture research developments.

The members of the symposium steering committee, representing federal and provincial governments, universities, and the aquaculture industry, put together a program based on current issues of importance to the industry. Invited speakers presented aquaculture success stories from Canada and abroad. A discussion period on the subject of interactions between fisheries and aquaculture provoked a lively exchange among the participants.

The symposium presentations were divided into three sections. The sociological and economic aspects of the industry and their effect on coastal communities comprised the theme of the first section. Some coastal communities have raised concerns about their perception of aquaculture as a rival of the traditional fisheries and, yet, these two activities more often than not complement each other. Aquaculture, for example, plays an important part in fisheries restocking programs. Aquaculture can also provide a stable supply of raw material for processing plants and thus ensure their survival to the added benefit of traditional fishermen. In proposing aquaculture as an equivalent and viable substitute for the traditional fishery, pressure on disappearing fish stocks can also be alleviated.

The second section of the symposium centered on the developmental and technological challenges to aquaculture imposed by the Nordic climate in Quebec. Climatic, geographic and biological challenges and constraints influence the species that can be cultured in this area. There has been a lot of progress and many innovative possibilities exist in production techniques appropriate for our climate, such as the use of recirculation systems or ocean culture equipment. Growth and nutrition of cultured species must be optimized, while keeping in mind the ice cover that is present in the Gulf of Saint Lawrence for several months of the year. Emerging biomedical applications for products from species with excellent growth potential was also considered.

The third section dealt with the interactions of aquaculture with the aquatic environment, including carrying capacity and the impact of the environment on aquaculture. Furthermore, from the environmental perspective, aquaculture is often identified as a polluting industry that destroys aquatic habitats, propagates diseases and parasites, and requires the use of more fish for production than it ends up producing. The risks associated with the escape of fish into the natural environment also raise strong public apprehensions.

Throughout this symposium aquaculture was presented as a legitimate industry, and one that is expanding worldwide. This does not, however, preclude the need to ensure respect for the environment.

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Special thanks to the American Fisheries Society (AFS) for including the Aquaculture Symposium in their 133rd annual meeting

AFS provided the infrastructure, technical support and overall organization which insured a successful and productive event

Opening Address

by the Aquaculture Coordinator,

Quebec Ministry of Agriculture, Fisheries and Food

A few months ago I accepted the invitation to open this symposium on aquaculture as an alternative to dwindling fisheries resources. I must say that I have only been focussing on Quebec aquaculture for three years and I am still uncertain as to what must be done and how this economic activity can grow and develop in a sustainable manner in Quebec. My thoughts and reactions may seem naive to some of the many experts in fisheries management, fish genetics, and environmental engineering here in the room. However, they are what I keep in mind when giving advice and as I make daily decisions within my Ministry.

Three themes will be explored during the symposium opening here today:

- Aquaculture as a way to revitalise coastal communities;
- The technology and challenges facing the development of aquaculture in cold climates; and
- The interactions between aquaculture and the environment.

These themes are of crucial interest to the development of aquaculture in Quebec. As for me, I will touch on these themes only indirectly and my little speech could be entitled: "Is there room for aquaculture in Quebec? Although the answer is "yes" it must be qualified by the questions: What kind of room and at what price?

Quebec has two distinct types of aquaculture. First, there is land-based fish farming which has been taking shape for a century. It is essentially a means of meeting the fish stocking needs of the sport and recreational fishing industries. Today, the production value of this activity represents around $15 million to some 150 family businesses. Over 60% of their production is used for stocking. In many ways, this private stocking industry is unique. Indeed, in many countries, the task of restocking water bodies is the responsibility of government agencies. For nearly three years now, these private entrepreneurs have been battling the imposition of new phosphorus emission standards that they deem are too harsh. Their association has proposed a voluntary approach to reaching the emission reduction goals (40% reduction in phosphorus emissions over a period of 10 years in exchange for acceptance of current production levels for all but a few firms that are extreme cases). For the last year, their proposal has collided with legislation designed with repression in mind and with the coercive vision of some environment managers. This has occurred despite the fact that the administration does not have the resources needed to impose its vision. The current situation is paradoxical in that legislation designed to protect the environment is preventing industry leaders from promoting sustainable development within their own industry.

Today, a new threat appears to be looming on the horizon as theories such as genetic purity of wild fish populations are applied in the field, coupled with consideration for the idea that aquatic environments are closed systems impermeable to external influences. I have intentionally used the terms *genetic purity* and *closed systems* rather than genetic heritage and comprehensive ecosystems. It seems to me that this rigid view of natural resource conservation should be examined in the light of the concepts of biosphere evolution and the role that the human species must play, both consciously and unconsciously. I am surprised to see how certain theories that I would qualify as Malthusian are rapidly translated into practical applications by government organisations that have conservation as their mandates, without first having been widely discussed with the stakeholders most affected by these applications.

Today, fish farmers hope that the support provided by their service industry to outfitters and fish pond owners will keep them from being annihilated by the indifference of a largely urban population. Of course, if the farms were to eventually disappear, it would temporarily solve the phosphorus waste problem experienced by the strongest and best organised lobby groups—such as the city-dwellers who own ever-larger, increasingly expensive cottages on the shores of the most readily accessible lakes. It is also these urbanites, less and less aware of how nature is used directly to produce their daily food supply, who are willing to support conservation movements opposed to any means of human intervention in the environment designed to foster biomass production for food purposes.

What role does development play in the concept of sustainable development as defended by many so-called ecological groups in the Occident? I believe that many of them see this role as being played outside their own backyard, in those countries where the issue of daily food is a painful physical reality and sustainability a luxury.

... fish farmers hope that the support provided by their industry to outfitters and fish pond owners will keep them from being annihilated by the indifference of a largely urban population.

The survival of aquaculture primarily directed towards stocking merits our full attention. We hope to benefit from all the technological and genetic advances to re-establish and develop in a sustainable manner a small industry that contributes modestly, but effectively, with many other Quebec food producers, to maintaining a rural way of life that a growing number of urbanites relentlessly seek. I hope that your discussions on the issues of genetics and ecosystem conservation during this conference will take us a step further towards determining just to what extent humans can act on the physical and biological environment of which they themselves are components in order to increase fish farming production.

This century-old land-based type of aquaculture that first developed as a service to land-use planners is not our only concern. In Quebec, efforts to develop aquaculture in coastal maritime zones are now almost a quarter-century old. A handful of promoters supported by a few researchers have been developing methods to farm mussels and scallops for over 20 years. In the late 1980s, a wave (a very small one) of attempts to farm salmon in cages crashed against climatic conditions and a rapid drop in North American market prices brought on by improved productivity in regions with greater competitive advantages—such as New Brunswick, to name only our nearest competitor.

Today, commercial mussel and scallop production in Quebec is less than 900 tonnes of production for over 10,000 km of coastline. This production, valued at a million dollars, would be considered inconsequential in any other developed country with such a long coastline. That being said, over 70% of the coastline lies along James Bay, Hudson Bay and Ungava Bay, north of the 53rd parallel. Only 2,500 km lie on the Gulf of St. Lawrence. Given the available technologies, very little of the coast offers the shelter, water depth, and access needed to foster the development of aquaculture activities. As well, winter ice drifting all along the coast from January to March is not to be overlooked.

Keeping in mind the framework for reflection established for this symposium, I will focus my next comments on efforts to develop juvenile scallop seeding on specific fishing grounds. Indeed, over 10 years ago, fishers and biologists in the Magdalen Islands decided to explore a bottom-seeding approach for traditional fishing grounds. They were inspired by what was being done in Japan, but they ran up against unreceptive legislation and an administration that was reticent to the idea of bottom-seeding in support of a commercial fishery that would be managed by the fishers themselves. Given these constraints, today the work is done under the direction of a private enterprise, owned by the most motivated fishers, who have leases to over 5,000 hectares of seabed. It is surprising to see that the lack of flexibility in fishing legislation led to the privatization of a public domain and efforts to regenerate wild populations. Today, we can question ourselves about the risks taken by a private-sector group—risks that I believe the community would have been better able to assume. Once again, I hope that the presentations and discussions during this colloquium will help shed additional light on the subject, and let us know whether the path we are taking is the right one.

In addition to these efforts to consolidate mussel production and scallop seeding, we continue to pursue and encourage efforts to diversify mariculture in Quebec, focussing on the oyster, softshell clam and cage grow-out of brook char.

These efforts are being closely scrutinised by both professional and amateur environmentalists who want to protect fish habitat. The fortunate owners of ocean shorefront properties examine aquaculture activities with a magnifying glass. Fish farmers are also monitored by binocular-wielding recreational sport professionals and their clients, including kayakists, sail boarders, sail and motor yachters, and other personal watercraft enthusiasts. The efforts of farmers are fought energetically by commercial crab, cod and lobster fishers, to name only a few groups. All these users of near inshore waters have shown themselves to be relentless defenders of nature, but their concern is limited to the potential effect of aquaculture. The weekend sailors had no problem presenting a project to enlarge a marina and commercial fishers demanded that cuts to the crab quota be cancelled. And, without cracking a smile, representatives of the fishing industry have expressed concern that cultured mussels will eat too many lobster larvae!

And, without cracking a smile, representatives of the fishing industry have expressed concern that cultured mussels will eat too many lobster larvae!

Protection of the aquatic environment, protection of fish habitat, conservation of the genetic heritage and biodiversity have become the leitmotiv of all those who use the coastal environment, and who do not want to share their playground with the new kid on the block. I fear that all too often government administrators, who are subjected to all these pressures, take the easy way out as well by invoking a well-known cautionary principle in its simplest form "*do nothing, don't make waves*".

As for brook char grow-out in open waters, for two years now an applied research consortium, admittedly awkward in managing their program, has attempted to implement an 8-month grow-out of 24,000 brook char in Gaspé Bay. There are still no cages in the water nor are there any char being reared in cages. Thanks to requirements pertaining to navigation, and wildlife and fish habitat protection imposed by regulating agencies at various levels of government there soon will not be anything we do not know about the Gaspé Bay ecosystem. But we still know nothing about the profitability of cage grow-out of brook char and the risk involved should commercial development take place.

Two Magdalen Island residents who are oyster farming promoters have had the painful experience of attempting to develop this production activity on a shoestring in an area valued by many nature lovers and the tourism industry as a unique environment that should be preserved. In one case, the aquaculture plan encroaches on the horned grebe wildlife refuge, an area that represents 72% of all wildlife refuges in Quebec (although the Magdalen Islands represent merely a tiny portion of Quebec territory). While the horned grebe population on the Islands is at risk, this bird is doing just fine elsewhere in Canada. As for the other oyster farming project, the 3 hectares requested were too close to the only rainbow smelt spawning ground on the Magdalen Islands. While this spawning ground is unique to the 200 km^2 Islands area, it is far from being the only one in the southern Gulf of St. Lawrence.

These examples illustrate the challenges faced by those who are trying to develop aquaculture in Quebec. "Given these conditions, why go on?" you may ask.

Why? Because what alternatives are there for the economies of rural and coastal regions affected by drastically declining fisheries resources, improved productivity in the forest industry and the depletion of mineral deposits? Emigration to urban centres or providing services to tourists 3 months of the year? I believe that the residents of these regions deserve better, and at least as much attention as the wildlife that surrounds them.

Admittedly, aquaculture—like growing crops and raising animals—will permanently modify the environment in which it takes place. But I am convinced that it can take place and that it can be developed in a reasonable manner without compromising the future of all ecosystems within these regions—ecosystems that have already been shaped in many ways through human intervention.

Thank you for your attention and enjoy the symposium.

— Jean-Paul Lussiaà-Berdou
Aquaculture Coordinator
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The Relative Contributions and Ecological Impacts of Aquaculture and Capture Fisheries

James H. Tidwell and Geoff L. Allan

Historically, the oceans were considered limitless and thought to harbor enough fish to feed an ever-increasing human population. However, the demands of population growth, particularly in poorer countries, now far outstrips the sustainable yield of the seas. At the same time as fishing has become more industrialized, and wild fish stocks increasingly depleted, aquaculture production—fish and shellfish farming—has grown rapidly to address the shortfalls in capture fisheries. With this rapid growth, aquaculture has come under intense scrutiny and criticism as environmentalists fear that it could cause significant environmental problems and further impact wild species that are already over exploited. Indeed, both capture fisheries and aquaculture have environmental costs, all human activities of significant scale do, but it is necessary to fairly evaluate and compare the ecological and economic impact of both. In fact, a thorough analysis shows that the ecological threat of aquaculture is much lower than continuing to supply the majority of fish protein from wild capture owing to aquaculture's greater control over production, harvest, processing and transport, which results in less wastage and reduced energy demands.

Fish is a vital source of food for people. Fish is man's most important single source of high quality animal protein and provides approximately 16% of the animal protein consumed by the world's population.[5] It is a particularly important protein source in regions where high-quality protein from livestock is relatively scarce—fish supplies less than 10% of animal protein consumed in North America and Europe, but 17% in Africa, 26% in Asia and 22% in China.[8] The Food and Agriculture Organization of the United Nations (FAO) estimates that about 1 billion people world-wide rely on fish as their primary source of animal protein.[8]

Fish also has substantial social and economic importance. Over 36 million people are employed directly through fishing and aquaculture,[8] and as many as 200 million people derive direct and indirect income from fish.[10] The FAO estimates the value of fish traded internationally to be US$51 billion per annum.[8] Consumption of food fish is increasing, having risen from 40 million tonnes in 1970 to 86 million tonnes in 1998,[8] and is expected to reach 110 million tonnes by 2010.[6] Increases in per capita consumption account for only a small portion of the increase in total demand. It is the growing human population in many countries in Asia, Africa, and South America that is primarily responsible for this steadily increasing demand for food fish. These statistics illustrate that a consistent source of fish is essential for the nutritional and financial health of a large segment of the world's population.

Today, fish is the only important food source that is still primarily gathered from the wild rather than farmed—with marine capture historically accounting for more than 80% of the world's fish supply. Total landings from marine fisheries increased approximately five-fold in the 40-year period from 1950 to 1990.[14] More recently, however, capture fisheries have not been able to keep pace with growing demand, and many marine fisheries have already been over-fished. From 1990 to 1997, fish consumption increased by 31% while the supply from marine capture fisheries increased only 9%.[6] This has intensified the pressure on the harvesters, which has translated into increased pressures on, and over-fishing of, many commercial fisheries. Nearly half of the known ocean fisheries are completely exploited[6] and 70% are in need of urgent management.[15]

As fisheries become depleted and fish get harder to catch, many fishermen and governments have responded with increased investment in equipment and technology to fish longer, harder, and farther away from their home ports. These efforts have resulted in what is essentially an "arms race" within the marine fishing industry, both in the addition of greater numbers of people and ships but also in better technologies.[15] Radio and satellite navigation allow fishermen to better locate fishing grounds, while new fish-aggregating devices intensify the harvests. These changes put immense pressure on fish stocks and leave fewer regions out of reach so that fish can reproduce unmolested. This decreases the reproductive capacities of fisheries, thus exacerbating the effects of over-harvesting. Indeed, capture fisheries have advanced to the point where newly discovered fish populations can be put under severe stress more quickly than regulators can collect needed biological data and impose catch limitations. Based on the current assessment of overexploitation of many fish stocks, and overcapacity and overcapitalisation of many fishing fleets, Mace[14] concluded that many capture fisheries would probably not be commercially viable without significant government subsidies. However, the private and public investment in increased infrastructure creates a financial inertia that makes it more difficult to reduce the pressure on fisheries.[20]

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Consumer tastes and demand in the First World have largely contributed to the problem. Increasing demand for top predators, such as swordfish or tuna, has put severe pressure on existing stocks. The average size of fish caught for some species has dropped until there is now a significant need to impose minimum size limits, or capture moratoria, to allow these and other species to reach reproductive age and size before being removed from the population. The hunt for certain species also affects non-target species through their inadvertent capture, known as "by-catch". Long-line fishing for swordfish and other billfishes may significantly diminish the populations of many shark species, which are known to have slow reproductive rates and thereby slow recovery rates.

Trawling technologies also capture a large amount of by-catch, known as "trash fish". Alverson et al.[2] estimated that ocean fishing results in about 28.7 million tonnes of by-catch annually, most of which is simply discarded. These figures are likely low estimates of total wastage, as by-catch figures are often under-reported, and statistics do not include fish lost to spoilage, undetected mortality under the surface, and ghost fishing through lost equipment that continues to catch fish.[2] For certain shrimp species, the by-catch is often composed of a high percentage of juveniles of commercially important species, compounding the impact on both present and future fisheries production. Nance and Scott-Denton,[16] when analyzing a 5-yr survey of trawling operations in the Gulf of Mexico, found that only 16% of the total catch was commercially valuable shrimp, while 68% of the catch was unintended by-catch, mostly juvenile finfish. In some areas of the Gulf of Mexico, it is estimated that for every 1 kg of shrimp harvested, 10 kg of other species are caught and discarded. High profile examples of by-catch conflicts, such as the capture of sea turtles by shrimp trawls and of dolphins by purse-seines targeting tuna, have drawn severe criticism by environmental groups and consumers. But it is consumer demand that has fueled this conflict, as tuna and shrimp are the top two seafood demand categories in the developed countries.

Humankind also places severe indirect strains on ocean fisheries. The World Resources Institute reported that about 51% of the world's coasts are at high or moderate risk of degradation.[6,23] Since approximately 90% of the marine capture fisheries depend on coastal habitats for young fish to develop, direct and indirect losses of nursery habitat and negative impacts on water quality have devastating impacts on commercial fisheries.

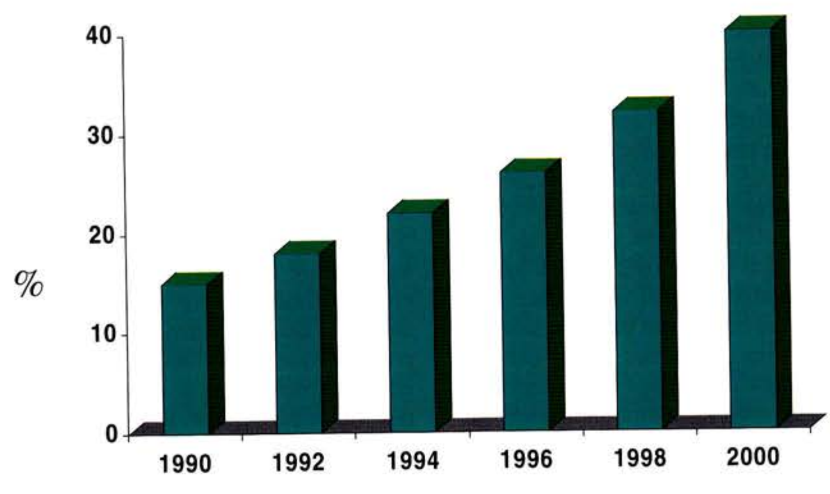
To meet the ever-increasing demand for fish, aquaculture has expanded very rapidly and is now the fastest growing food producing industry in the world. The proportion of the total fish supply produced by aquaculture increases yearly. By the year 2030 it is estimated that over half of the fish[7] consumed by the world's people will be produced by aquaculture (Fig. 1). Total aquaculture production increased from 10 million tonnes of fish in 1984 to 38 million tonnes in 1998,[8] and a growth rate of 11% per year has aquaculture on a pace to surpass beef production by 2010. Not only is the total amount of fish being produced important, but also how and where it is produced is important. While 80% of cattle is raised in industrialized nations, fish farming has been growing almost six times faster in developing countries than in developed countries. The FAO states that "As an inexpensive source of a highly nutritious animal protein, aquaculture has become an important factor for improving food security, raising nutritional standards, and alleviating poverty, particularly in the world's poorest countries." Indeed, in those areas where the need is greatest, the contribution of fish and shrimp farming is expected to increase. For instance, the FAO estimates that small-scale aquaculture production in Africa will significantly increase by 2010; in fact, fish and shrimp production in Africa has already grown by about 400% between 1984 (37,000 tonnes) and 1998 (189,000 tonnes).

Rapid growth of aquaculture has led, in some cases, to environmental problems and conflicts over limited resources. One problem widely publicized by non-government organizations and environmental groups has been losses of mangrove forests.[18] Mangroves are extremely productive coastal ecosystems and their decline has indeed been extensive—as much as 55-60% of the original forests have already been lost. However, most of that loss is due to clearing for rice production, grazing, urban development, fuel, construction materials, wood pulp, and tourism; conversion to shrimp farms accounts for less than 10% of the decrease.[3] In fact, the vast majority of new shrimp pond construction does not affect mangroves because these areas have proven to not be well suited for shrimp production due to acid soils and high construction costs. Mangrove buffer zones now are protected in many new shrimp farm developments, and replanting has become common.

"Biological pollution" is a term that has been used to describe the potential of introduced species on natural populations. Its recent usage has primarily been in the context of Atlantic salmon *(Salmo salar)*,[18] the main salmon species reared artificially. Total aquaculture harvest of this fish in 1999 was about 800,000 tonnes or about 2.7% of total world aquaculture production.[7] Over 94% of the world's Atlantic salmon adults are in aquaculture production facilities and 6% in the wild.[11] Recently the vast literature on the potential impacts of Atlantic salmon from aquaculture sites on wild salmonid populations were comprehensively reviewed and analyzed by Gross.[11] The author reported that along with potential negative genetic and ecological effects, Atlantic salmon aquaculture does offer some benefits for wild populations, but these benefits are often overlooked. In developed countries there has been a significant shift in consumer preference from wild Atlantic salmon, and other wild salmonid species, to farmed Atlantic salmon. Increased availability has decreased prices, resulting in decreasing harvest pressure on wild stock. Gross's conclusions were that aquaculture is not the root cause of the current poor state of wild salmonid fisheries and conservation. The author reported that there are two primary causes—mismanaged capture fisheries and habitat destruction—of wide-scale extirpations, depletions, and loss of biodiversity in both Atlantic and Pacific salmonids, and this occurred long before commercial salmon aquaculture appeared in the 1970s.

Recent criticism has also centered on the use of fishmeal in aquaculture diets. Naylor et al.[18] reported that aquaculture is "a contributing factor to the collapse of fisheries stocks world-wide." The authors further state that with aquaculture expansion, "ever increasing amounts of small pelagic fish would be caught for use in aquaculture feeds to expand the total supply of commercially valuable fish." However, in truth, fishmeal production has changed very little over the past 20 years. Adele Crispold (pers. commun.) from the FAO explains that market forces have simply reallocated the use of a fixed amount of fishmeal, but have not actually changed the total amount of pelagic fish harvested or fishmeal produced. The percentage of total fishmeal production used for aquaculture feeds has indeed increased from 10% in 1988 to 35% in 1998.

Figure 1
Percentage of Total World Seafood Supplied by Aquaculture



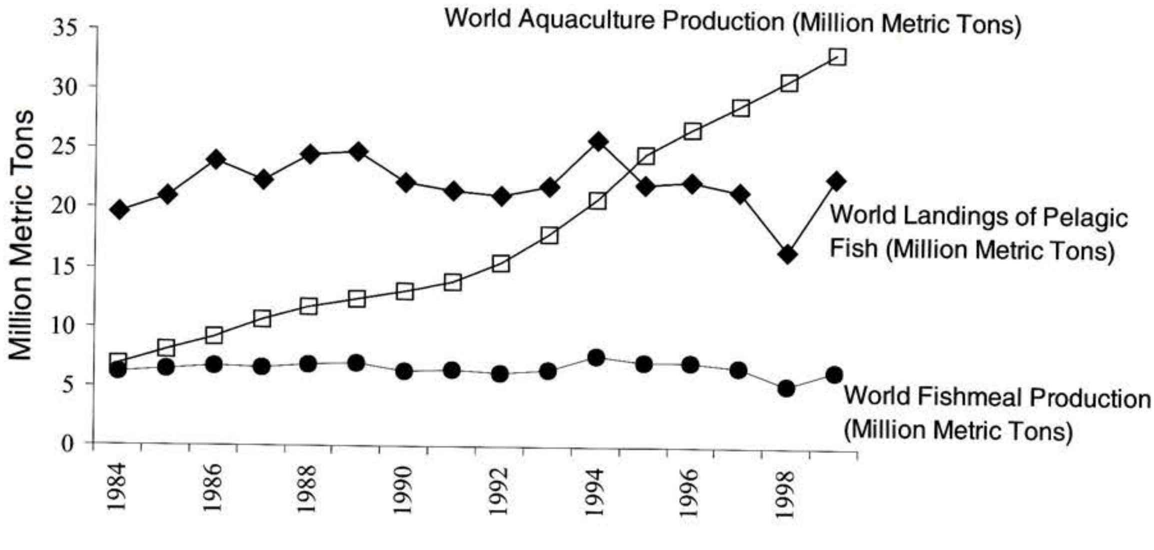


Figure 2

Relationship between aquaculture production, pelagic fish landings, and fishmeal production from 1984-2000 based on FAO data. There is no statistical relationship between production of fish meal and aquaculture production (P value > 0.82).

However, the large majority of fish meal is still used in livestock feeds and for fertilizers. The actual amount of fish harvested to produce fishmeal has remained relatively constant at about 30 million tonnes per year.[6] A statistical analysis of FAO data over the past 15 years indicates that there is no statistical relationship ($P > 0.80$) between aquaculture production, harvest rates for pelagic fishes, or fishmeal production (Fig. 2). A shift in fishmeal use toward aquaculture may actually represent an environmentally friendly use of this resource, as fish are more efficient feed converters than the primary users, terrestrial livestock.

Naylor et al.[18] also proposed that certain types of fish, particularly salmon and shrimp, are actually net consumers of fish, requiring as much as 3 kg of fish in their feed to produce 1 kg of farmed fish. Overall, these species represent a relatively small proportion of total aquaculture production (Fig. 3). Furthermore, to evaluate these values fairly, they must be compared to these products if sourced from wild harvests. Forster[9] points out that, based on classic values of energy flows, 10 kg of forage fish are required to produce 1 kg of a carnivore—such as Atlantic salmon—in the wild. If by-catch values are taken into account, at least another 5 kg of fish can be added to the equation. Based on these considerations, even if farmed salmon or shrimp do utilize 3 kg of fish to produce 1 kg of weight gain, this would actually represent a significant ecological advantage compared to 10-15 kg of forage fish and by-catch involved in the growth and capture of 1 kg of wild salmon or shrimp. Also, when considered *in toto*, aquaculture is a huge net producer, generating 3.5 to 4.0 kg of food fish for each kilogram of pelagic fish (live weight) used in fish meal production (Fig. 4).

Importantly, the efficiency of aquaculture production will improve further. As an industry, aquaculture is still in its relative infancy, thus knowledge of the nutritional requirements of most fish species is rather limited compared to poultry and other livestock. Naylor et al.[18] noted that livestock feeds on average "contain only 2-3% fishmeal." However, twenty years ago, fishmeal was also the preferred source of protein for poultry feeds, just as is the case for some aquaculture species today. Reduced reliance on fishmeal for poultry feeds came as a result of nutrition research, particularly the quantification of requirements for individual amino acids and energy needs as well as the rigorous evaluation of alternative ingredients. The search for alternative ingredients is already a research priority for aquaculture for exactly the same reason: the desire to minimize feed costs. In channel catfish diets, the proportion of fishmeal in the feed has decreased from 8-10% in 1990 to less than 3% currently, based on an improved knowledge of their nutritional requirements.[19] This species is also a net producer, returning 6-7 kg of fish production for each kilogram of pelagic fish (live weight) used in feeds. Several other species can also be successfully fed with similarly low contents of fishmeal.[1] Other factors caused by the relative immaturity of the industry will also greatly benefit from continuing research efforts. In salmon production, the introduction of vaccines has reduced the amount of antibiotics used per kilogram of salmon cultured by over 97%.[13]

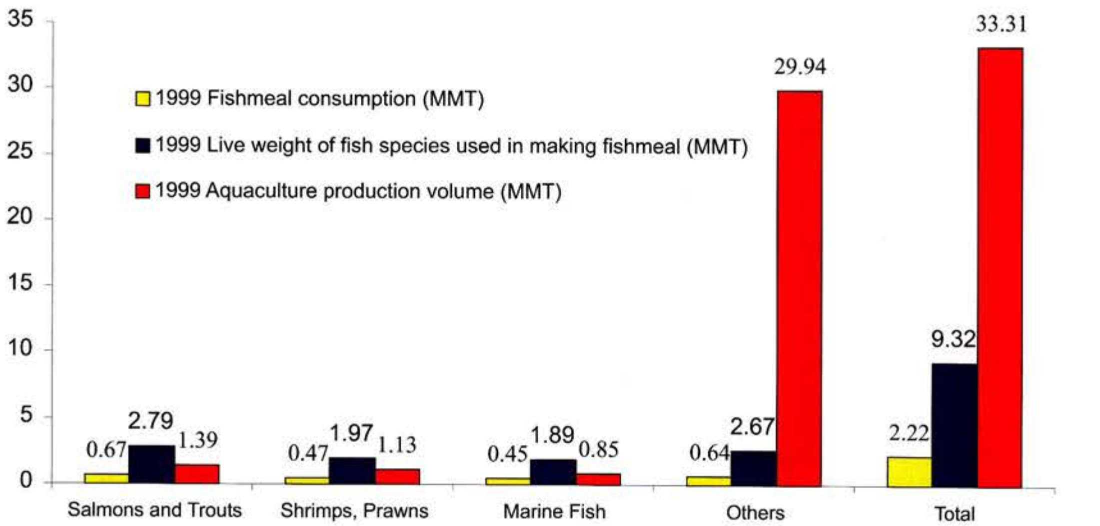
If aquaculture development is unfairly impeded, the increasing deficit between wild harvest rates and total demand for fish will actually increase the pressure to capture more fish from the wild and further devastate stocks of many marine fish species.

Increased use of animal by-product meals to decrease aquaculture's use of fishmeal has also been proposed.[21] Due to concerns over BSE ("mad cow disease") such rendered products are available at relatively low costs. While their use in other ruminants is of great concern, the evolutionary distance between ruminants and cold blooded fish and crustaceans could possibly provide a safe outlet and use for these products.[22] However, significant research would be required to ensure consumer safety.

In an earlier paper, Naylor et al.[17] concluded that, due to a reliance on fishmeal, aquaculture of these species is being subsidized by the marine ecosystem. However, all human food production is eventually "subsidized" by aquatic or terrestrial ecosystems. The production of some aquaculture species is indeed partially fueled by primary and secondary productivity within the marine system, but fish caught in the oceans have been *entirely* subsidized by the marine ecosystem. Even the "cultural species" identified by Naylor et al.[18] as net producers, such as carps, tilapia, and catfish, do not actually convert food to flesh with higher efficiency than other species such as salmon or shrimp. They are, in fact, only "subsidized" by different ecosystems—the freshwater ecosystem in the form of natural food items or terrestrial ecosystems through the production of feed ingredients, such as corn or soybean, each of which has its own ecological costs. Prudent and proper use of fishmeal under certain situations may actually be advantageous for the environment. Due to its extremely high nutritional quality, i.e. the proper balance of amino acids and

Figure 3

Relationships between fishmeal consumed, calculated live weights of pelagic fish used, and weight of aquaculture products produced.



fatty acids, and extremely high digestibility, the use of some fishmeal in the diet can reduce waste production in the culture system compared with completely plant-based diets.

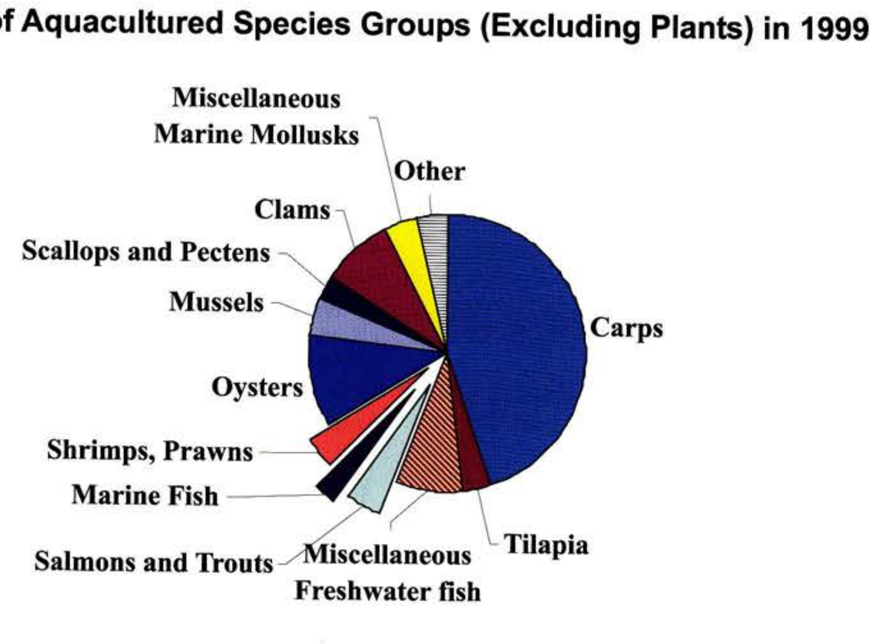
The demand for fishmeal could potentially be met by improved use of by-catch from wild capture fisheries.[12] The amount of by-catch killed and discarded annually is estimated to be between 18-40 million tonnes[5]—approximately the total amount of fish currently harvested for fishmeal production (30 million tonnes). There is also a significant amount of fish currently wasted due to the intentional discarding of part of the catch. This occurs when fishermen wish to save limited quotas at times when prices are low or when they practice "high grading"—discarding smaller fish of low value to create capacity for species that achieve a higher price on the market.[6] For some capture fisheries, as much as 40% of the total catch is discarded. In aquaculture there is much more control over production, harvest, processing and distribution,[12] and these practices seldom occur.

Figure 4

The proportion of total aquaculture production accounted for by different taxonomic groups.

Capture fisheries and aquaculture should not be considered in isolation. In certain areas some supposedly "wild harvest" fisheries are actually highly dependent on an aquaculture phase to produce young fish that are necessary to maintain current capture rates. In Alaska, for instance, aquaculture is basically "outlawed." However, without the aquaculture production of seedstock, Alaska's wild-harvest salmon and oyster industries could not supply a fraction of the total production currently generated. According to Coates,[4] the divisions between aquaculture and capture fisheries will rapidly fade and, in many regions, have already gone. In fact, the best hope of providing fish to meet future demands will likely be co-ordinated partnerships of aquaculture, managed wild fisheries, and wise protection and management of coastal zones and ecosystems.

Studies that do not weigh the relative costs and impacts of the different sources of fish are overly simplistic and not constructive. Skewed conclusions can cause negative public opinion that could impede environmentally responsible aquaculture and its ability to supply the projected 35 million tonnes of aquatic foods needed to meet the difference between demand and capture.[8] Unfounded negative media coverage could further stifle aquaculture development in rural and low-income areas where its potential impact is greatest. In a recent report, FAO[8] stated that "irrespective of whether inaccurate information is generated deliberately to promote a specific cause, or inadvertently through ignorance, it can have a major impact on public



opinion and policy making that may not be in the best interest of either the sustainable use of fisheries resources or the conservation of aquatic ecosystems."

There are not too few fish—there are too many people. If agriculture had not developed to increase the production of terrestrial livestock, we would never have been able to support the current human population. A similar juncture has been reached or passed in fish supplies. Although per capita consumption has not increased substantially, population growth has increased to the point that capture fisheries alone can fill only two-thirds of the current demand for fish. Thus almost all future demand will have to be met by aquaculture. According to the FAO,[8] "there do not seem to be any insurmountable obstacles to the continued growth of aquaculture." Both aquaculture and capture fisheries cause environmental impacts, which can be substantially reduced through further research and improved management. However, if aquaculture is unfairly assigned a negative label through unbalanced ecological assessments, its potential contributions to present and future food securities could be severely compromised. This could be especially devastating in regions where high-quality protein is needed most. If aquaculture development is unfairly impeded the increasing deficit between wild harvest rates and total demand for fish will actually increase the pressure to capture more fish from the wild and further devastate stocks of many marine fish species. These consequences on both human and fish populations would seem to go against the stated intentions and missions of many of the groups currently attacking aquaculture.

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Complementarity between Aquaculture and Small-scale Fishing: Bay of Brest Scallop Case

Jean Boncoeur, Frédérique Alban and Jean-Claude Dao

In the midst of the 20th century, the Bay of Brest (France) had an important scallop fishery. Following a collapse of the stock in the 1960s a recovery plan was set up that included a restocking program. After a trial-and-error period, this program made a significant move towards economic sustainability in the 1990s. Due to the production of juveniles in a hatchery-nursery, but also to the harvest regime of part of the adults, scalloping in the Bay of Brest may now be considered as half-way between fishing and aquaculture. After describing the program, the paper analyses its results, and the way it is perceived by fishers.

Au milieu du siècle dernier, la rade de Brest (France) était une importante pêcherie de coquille St-Jacques. Suite à l'effondrement du stock dans les années 60, un plan de restauration a été mis en oeuvre, comprenant un programme de repeuplement. Après une période de tâtonnements, ce programme semble en voie d'atteindre son équilibre économique dans les années 90. La production de naissain en écloserie, mais aussi le régime d'exploitation d'une partie des animaux adultes, font aujourd'hui de la récolte de la coquille St-Jacques en rade de Brest une activité située à mi-chemin entre la pêche et l'aquaculture. Après avoir décrit le programme, la communication analyse ses résultats et la façon dont il est perçu par les pêcheurs.

Introduction

Marine aquaculture in France is dominated by shellfish farming, an activity with an estimated output of 315 million euros in 2001, compared with the value of 1,069 million euros landed by the French fishing industry during the same year.[1] Except for some shellfish farmers who do small-scale fishing as a side-activity, relations between the two industries are limited. They are organised on the basis of separate institutions, usually employ different categories of manpower and concentrate on different species. Due to environmental and economic factors, most saltwater finfish farming products in France are imported, and are regarded as direct or indirect competitors by the fishers. Not surprisingly, representatives of the French fishing industry did not warmly welcome recent proposals from the European Commission to redeploy fishers towards aquaculture.[2]

However, aquaculture may be of help to fishers facing a problem with the resource. This paper is devoted to the scallop fishery in the Bay of Brest, Western Brittany, France (Fig.1), where a type of aquaculture was developed by local fishers during the last two decades as an attempt to help the fishery recover, not as an alternative to fishing. As a result, scalloping in the bay may now be considered as an activity halfway between aquaculture and fishing, an unusual situation in the context of French marine fisheries.

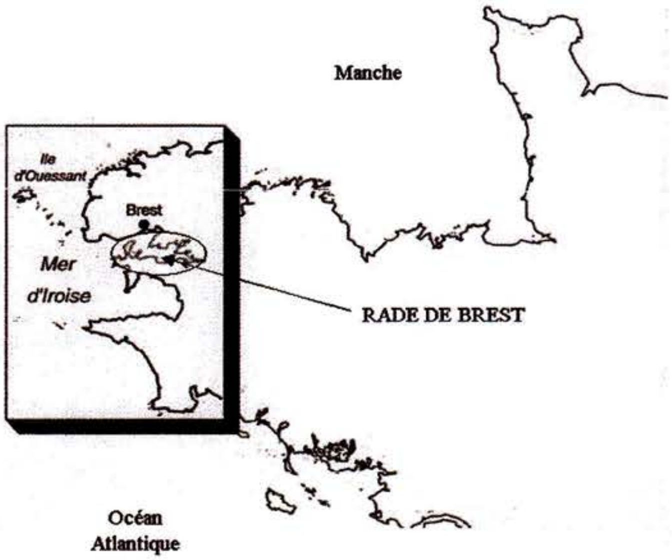
During the 1990s, several papers have presented the biological and technical aspects of the restocking program of the common scallop in the Bay of Brest,[3-7] and a few others have discussed its economic and institutional aspects.[8-10] Since that time however, there have been significant changes in the program and new information is available from a field survey of fishers.[11]

After describing the rationale for the program and its main characteristics, we analyse the results, with a focus on the economic consequences. The perception of the program by fishers is also considered.

The Scallop Restocking Program of the Bay of Brest

Shellfish dredging in the Bay of Brest is a seasonal activity, taking place in winter. Nowadays, the bulk of catches relies on two species: the common scallop (*Pecten maximus*) and the warty venus (*Venus verrucosa*). During the years 1999 to 2003, the estimated average yearly landings were 318 tonnes for

Figure 1. Western Brittany and the Bay of Brest (France)



common scallop and 145 tonnes for warty venus. The value of these landings (around 2 million euros) represents approximately 4% of the total landed value of the two species at the national level. The fleet is composed of some 60 boats, all under 12 m long, that are usually owned by their skipper and have one or two persons onboard. After the dredging season, most of these boats leave the bay to catch finfish or crustaceans or to harvest seaweed.

The Bay of Brest shellfish fishery is managed on the basis of a limited entry license system, with gear, time and space restrictions. In practice, the main authority in charge of this management is the local fisheries committee of Nord-Finistère, under the supervision of the regional fisheries committee of Brittany and state administration. The most salient characteristic of the fishery is the existence of an aquaculture-based restocking program for the common scallop.

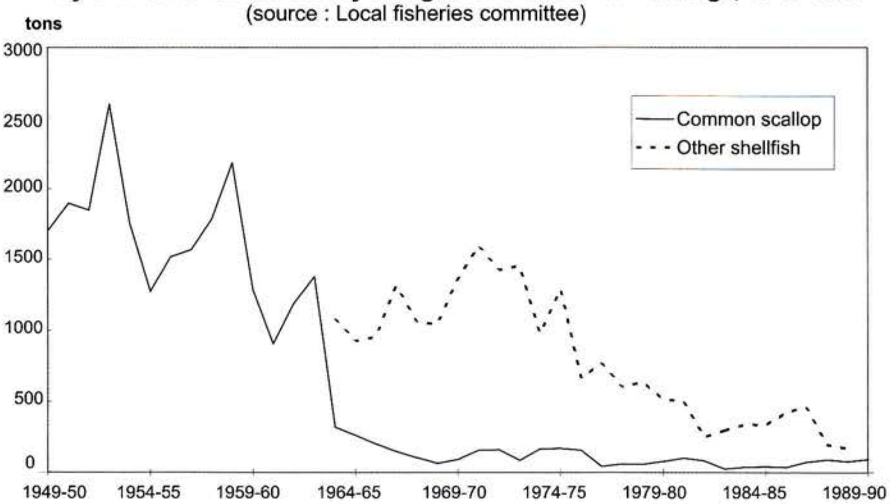
Rationale for the program

Although the importance of the fishery may now be considered marginal, that was not the case half a century ago. The bay supported one of the main common scallop fisheries in Europe, with average landings around 1,800 tonnes per year, harvested by some 260 boats and 840 fishers.(12) The mechanisation of the fleet after World War II resulted in a rapid increase in fishing effort, which was soon followed by a drop in landings. This trend was dramatically accelerated by an exceptionally cold winter in 1962-63 which caused high mortality of scallops, specially among juveniles. As a result, landings fell to 320 tonnes in 1963-64 and the natural stock has never recovered.(13) Landings of common scallops continued to decline, reaching a level close to zero at the beginning of the 1980s (Fig. 2).

Fishers first reacted to this collapse by transferring their fishing effort to other shellfish, but some also developed a part-time oyster-farming activity. This adaptation initially gave good results. In 1970-71 the total landings of warty venus, oysters (harvested on natural beds), and variegated and queen scallops reached 1,600 tonnes. Oyster farming, a new activity in the area, rapidly increased in the 1960s and reached a peak of 5,236 tonnes in 1973.(14) But the respite was short. Landings of warty venus started to decline in the 1960s, and almost disappeared in the 1970s.

Figure 2

Bay of Brest shellfish fishery : long term evolution of landings, 1949-1990
(source : Local fisheries committee)



A similar trend affected the variegated scallop a decade later. *Ostrea edulis* was nearly eradicated from the bay by outbreaks of parasites in 1973 and 1980.

During the 1980s, shellfish dredging in the Bay of Brest almost seemed to be extinct. The local fisheries committee attempted to rescue the fishery by two complementary means:[12] a limited entry license system (1985), and an aquaculture-based restocking program for common scallop that was officially launched in 1983.

Main features of the program

During the 1970s, various restocking experiments took place in the bay, based on collecting naturally produced juveniles.[15] Unsatisfactory results led to the decision—in the early 1980s—to produce larvae in a hatchery. The philosophy of the stocking program also changed over time. Initially, it was aimed at restoring the spawning stock biomass (SSB), in order to boost natural recruitment. But, as no significant relation between SSB and recruitment was found for *Pecten maximus*,[16] the program was re-oriented towards a so-called "sowing-recatching" strategy, aimed at circumventing the barrier of high mortality of juveniles during the first year.[8] To this end, an original operational chain was developed (Fig. 3).

Once cultured juveniles have reached the size of 3 cm, they are sown in the bay using one of two methods: extensive sowing on natural scallop beds, and intensive sowing in a marine reserve where dredging is prohibited for several seasons (usually 3). Imitating the principle of crop rotation in agriculture, intensive sowing is normally done in a different place each year, to allow an annual harvest each year. Five reserve sites have been selected, representing a total surface of 5.5 km^2. In practice, the rotation system is not regular, and the share of cultured juveniles sown in reserve sites varies between years. Globally, over the 1990s, it was about 60%.

The two sowing methods result in two different harvesting systems. In the case of extensive sowing on natural beds, aquaculture juveniles get mixed with natural ones and, after recruitment, both are fished in the same way. In the case of intensive sowing, reserve sites are only open to fishing by a decision of the local fisheries committee, which sets a TAC (total allowable catch), and distributes it equally among licensed boats under the form of non-transferable individual quotas (IQ).

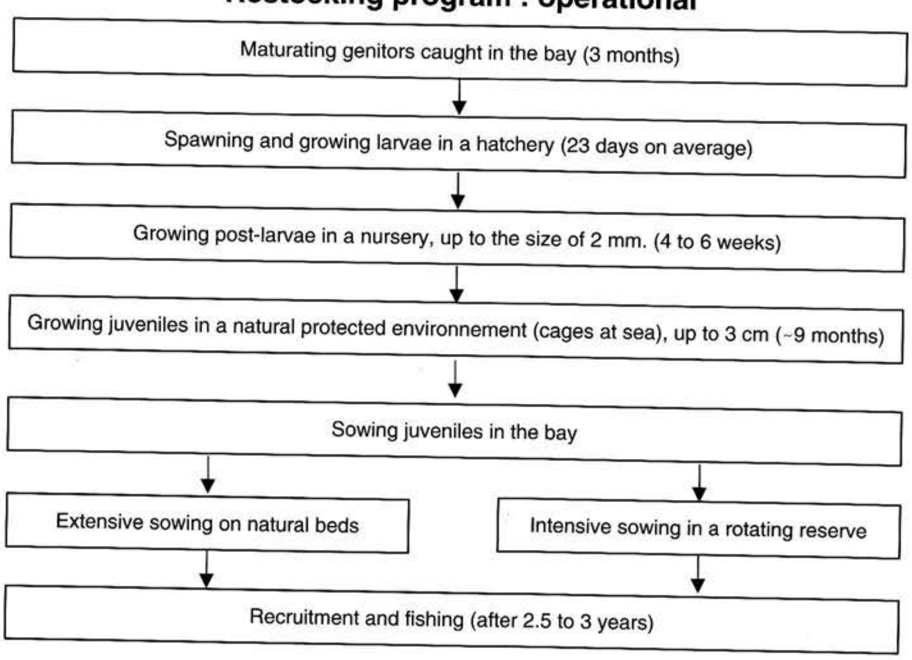
The reserve mechanism was first introduced as a technical experiment. However, it soon came to play a highly "political" role in the management of the fishery.

Results of the Program

In this section, we consider the technical and finan-

Figure 3

Restocking program : operational



cial results of the program, and provide an assessment of its economic impact and the way it is regarded by fishers.

Technical and financial performance

During the first 12 years of the program, the output of aquaculture juveniles was too low and uneven to provide significant support to the fishery. As a result, consideration was given to stopping the program in the mid-1990s. But the latter part of the decade was marked by a significant improvement in performance. Technically, a better mastering of the process and some additional investment were followed by a

Figure 4

Yearly sowing of common scallop juveniles on natural beds and inside the reserve, 1990-2000 (million individuals). Source : Tinduff Hatchery-Nursery

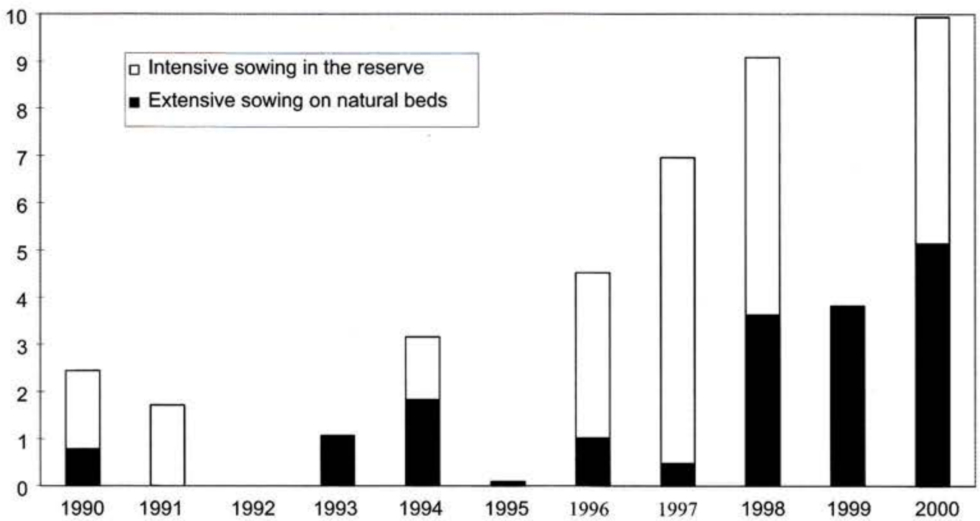


Figure 5

Landings of common scallops in the Bay of Brest, according to origin (tons)
Source : local fisheries committee

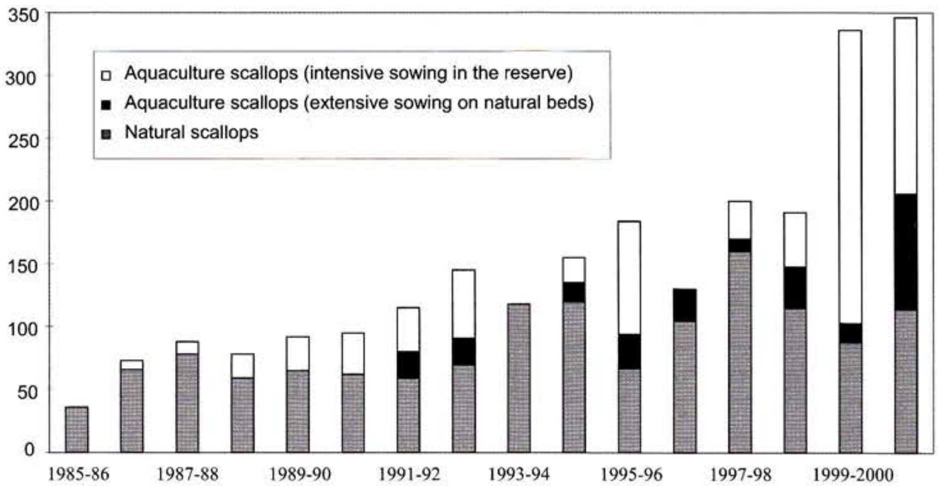
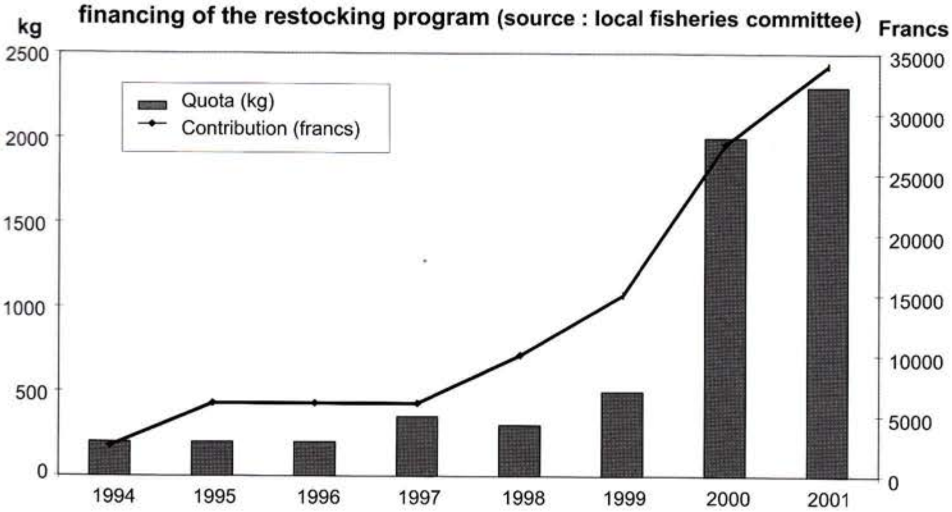


Figure 6

Individual catch quota on the rotating reserve and individual contribution to the financing of the restocking program (source : local fisheries committee)



take-off in the production of juveniles, which allowed annual sowings in the bay to jump from 2 million individuals at the beginning of the decade to nearly 10 million in 2000 (Fig. 4). This was followed by a significant increase in landings, which rose from 50 tonnes during the 1980s to an average 320 tonnes during the 1999-2003 period, a level not reached since 1963 (Fig. 5). A major part of this increase is due to cultured scallops, which can be identified by the stress ring sowing induces on their shell.

The greater availability of aquaculture scallops in the rotating reserve allowed the yearly IQ distributed to fishers to increase from 200 kg in 1994 to 2,300 kg per boat in 2001. This "quota policy" was used as an incentive for fishers to accept paying for the program. This was a critical requirement for its survival. Although the program was initially funded mainly by public money, it was admitted that, after an experimental phase, it would have to be financed by the fishers. Therefore, in the mid-1990s, the local fisheries committee had to persuade fishers to pay for the program at a level high enough to ensure cost-recovery, a challenge that was considered difficult.[9]

The solution adopted was to include a uniform financial contribution to the program in the cost of the license paid each year by fishers. This cost is traditionally quite low in France, and so was the initial additional contribution. The committee increased the required contribution in parallel with the increase in the annual IQ on the reserve (Fig. 6). The increase was rapid indeed, soaring from 76 euros in 1994 to 5,200 euros in 2001. It was accepted by fishers because the parallel rise in the IQ generated revenue high enough to balance the additional license cost. As a result, the decrease in public subsidies during the second part of the 1990s was overcome (Fig. 7) and by the end of the decade the operating costs of the program were fully covered by the fishers.

Figure 7

Tinduff Hatchery-Nursery: operating costs and subsidies, 1995-2000

(Source : Association l'Ecloserie du Tinduff, book keeping data)

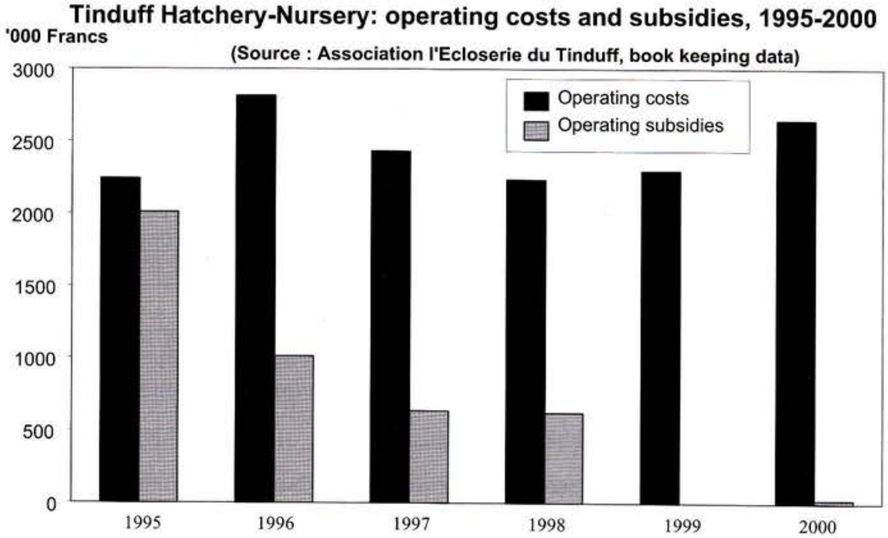


Table 1. Estimated contribution of the program to the economic performance of the fleet

	Reference level (2000-2001)	Contribution of intensive sowing in the rotating reserve		Contribution of extensive sowing on natural beds		Total contribution of the program	
Yearly values	*	absolute *	relative **	absolute *	relative **	absolute *	relative **
Global turnover of the fleet	5,671	619	11%	407	7%	1026	18%
Landing taxes	93	25	27%	16	17%	41	44%
Net sales	5,578	594	11%	391	7%	985	18%
Variable costs (except wages)	875	6	1%	0	0%	6	1%
Wage costs							
Skippers net imputed wages	1,398	176	13%	116	8%	292	21%
Cash wage costs	1,343	95	7%	62	5%	157	12%
Total	2,741	271	10%	178	6%	449	16%
Operating cost of the program	342	205	60%	137	40%	342	100%
Full equity profit	719	112	16%	75	10%	187	26%
Net activity income of skippers-owners	1,701	288	17%	191	11%	479	28%

* '000 euros. ** % of reference level. Source : Alban et al. [11].

Contribution to the Economic Performance of the Fleet

The consequences of the program on the profitability of the boats and fisher's income have been assessed in a field survey conducted in 2000-2001.[11] A total of 48 skippers were interviewed and the survey covered all their fishing activities. .

The assessment method consisted of building a scenario with no program and comparing it to the actual situation. The scenario relied on a few simple assumptions such as constant fishing effort (except for the reserve), CPUEs proportional to stock biomass, lack of impact on natural recruitment and lack of price effects, which were considered not unrealistic in the case under survey. The main results are presented in Table 1. According to the simulation, the program contributes to more than 25% of the profitability of the total fleet, as well as total skippers-owners activity incomes (this result takes into account the cost borne by fishers for the financing of the program).

The main part of this contribution comes from the rotating reserve system, which alone contributes to more than 15% of the boat's profitability and the income of the skipper-owners. This result is non negligible, considering the fact that harvesting the reserve represents less than 1% of the total yearly fishing time of the fleet.

Opinions of Fishers

The survey provided an opportunity to investigate the opinions of fishers on the fishery, its management system and the restocking program. The results are summarised in Tables 2, 3 and 4.

A large majority of skippers regard shellfish dredging in the bay as critical to the economic sustainability

Table 2. Skippers' opinions concerning the Bay of Brest shellfish fishery*

• Boat economic sustainability requires shellfish dredging in the bay	84%
• Common scallop is critical to the sustainability of the bay shellfish fishery	71%
• I am confident in the future concerning shellfish dredging in the bay	75%

* Frequencies of answers agreeing with the stated opinion. Source : Alban et al. [11].

of their boat. This opinion is consistent with the fact that, in many cases, this activity provides half of the revenue of the boats, but requires no more than 10% of its fishing time. A majority of skippers also declared that the common scallop was a critical species to the bay shellfish fishery, and that they were confident in its future (an opinion probably influenced by the upward trend of the fishery during the years preceding the survey).

According to the survey, however, fishers are not fully satisfied with the management system of the fishery. A major stake concerning this management is the transparency of landings, which the local fisheries committee has attempted to improve by forcing fishers to have their landed shellfish weighed in the Brest fish auction market. Only one fisher out of five interviewed considered this goal had been achieved. A way to improve landings transparency is to reduce the number of authorised landing places, but only a few fishers support this idea. This unsolved question may explain why only a minority of skippers favour generalising the IQ system to the whole fishery.

The restocking program was considered a technical success by 3 out of 4 fishers, and 80% declared they were satisfied with the dual sowing system. The principle of cost recovery was accepted by a majority of fishers, but with some restrictions by 40%. Many fishers think the program should be partly funded by public money, because the fishery has suffered from deteriorating environmental conditions (such as water pollution due to intensive farming around the bay) for which they hold no responsibility. The principle of a uniform financial contribution to the program included in the yearly license cost is accepted by 3 out of 4 fishers, despite the fact that all boats do not fish the same quantity of scallops. The explanation is twofold: i) fishers regard the uniform yearly IQ on the reserve as the counterpart of the uniform license cost; and ii) they are reluctant to accept financial contributions based on individual catches because they are skeptical about the trasnparency of information on landings.

Conclusion

The scallop restocking program of the Bay of Brest was an attempt to rescue a badly depleted fishery. After a period of trial-and-error, it resulted in a two-fold relationship between aquaculture and fishing: i) aquaculture provides a large part of the juveniles that are later harvested by fishers; and ii) the rotating re-

Table 3. Skippers' opinions concerning the management system of the fishery*

• Compulsory weighting of landings in the Brest fish auction market creates**	
– more transparency	19%
– additional constraints for fishers	33%
– a simplification of marketing operations	40%
– better marketing opportunities	12%
• There should be only one authorised landing place in the bay	23%
• Access to the resource should rely mainly	
– on effort control (present system)	58%
– on output control (generalisation of the IQ system)	33%

* Frequencies of answers agreeing with the stated opinion. ** Possibility of multiple answers. Source : Alban et al. [11].

Table 4. Skippers' opinions concerning the restocking program *

• The program is a technical success		75%
• The present dual system for juvenile sowing (natural beds + reserve) is satisfying		81%
• I agree with the principle of self-financing of the program	– fully	56%
	– partly	42%
• I agree with the principle of a contribution based on a uniform lump sum for all boats		75%

* Frequencies of answers agreeing with the stated opinion. Source : Alban et al. [11]

serve system creates harvesting conditions that can be considered halfway between fishing and aquaculture.

After two decades, the technical results of the program show a late but substantial take-off. On the economic side, cost-recovery has been reached (at least for operational costs) and cultured scallops now provide a significant part of fisher's incomes. The managers of the fishery demonstrated a high capacity for innovation and pragmatism, including dealing with institutional and psychological barriers. The IQ policy was notably critical in the acceptance by the fishers of the principle of cost-recovery.

However, the present financial scheme is questionable for two reasons: i) it is disproportional (payments are uniform, but the benefits generated by the program vary according to individual catches) ; and ii) it does not generate a long-term committment from the fishers to the program and therefore leaves the door open to short-term opportunistic behaviours (fishers may be tempted to take a license only when the ratio of the IQ to the license cost is high enough).

As regards to fisher's attitudes, a remarkable change concerning cost-recovery occurred in recent years. However, the field survey indicates there is still some ambivalence concerning, notably, the sensitive question of transparency of landings.

Finally, it must be stressed that the recent recovery of the fishery and the original equilibrium created between aquaculture and fishing are still fragile. Important factors of uncertainty remain, among which are the environmental conditions of the bay due to high and multiform anthropic pressure.

This paper uses results of a survey realised for the local fisheries of North Finistère, and of the EC funded VALFEZ research project (QLK5-CT1999 -1271). The authors are grateful to J.P. Carval for its documentary help.

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An Overview of Coordinated Local Aquaculture Management Systems (CLAMS) in Ireland

Helen Cooper

Ireland's bays and inshore waters are a primary natural resource. Their utilisation for the sustainable development of aquaculture requires a dynamic and evolving management system. The logical management approach is a locally based and all embracing system designed to maximize production and environmental management through the integration of production goals with minimal conflict with other resource users.

The Irish aquaculture industry has led the way in the development of such a unique and progressive approach to bay/inshore waters management. The industry has grown from initial developments in the 1970s to one that is now a significant contributor to the Irish national economy. There are 3 core species reared—Atlantic salmon, mussels and oysters—and other species of both shellfish and finfish are at a pre-commercial stage.

In Ireland's National Development Plan 2000-2006, the aim by the close of the programme in 2008 is for the aquaculture industry to reach a production of 95,000 tonnes with a first sale value of €175 million. It is essential that these increases are achieved in a sustainable manner and it is as a result of this that the harmonisation and integration of substantial aquaculture development into the coastal zone through coordinated local aquaculture management has been placed as a pillar in the strategic policy of the national development plan.

Ireland's inshore waters are a shared resource and any long-term development in a shared resource must be undertaken in a sustainable manner. Throughout the 1990s two state agencies, BIM (Bord Iascaigh Mhara) and Marine Institute had, at the request of both the aquaculture industry and the licensing authorities, helped resolve a number of aquaculture licensing issues. As with any conflict resolution situation, the groups and individuals involved had a range of opinions from two or more sides of the issue. Each of these situations tended to be dealt with on a case-by-case basis with very little input at the local level as to how aquaculture should be developed.

A structured local system was required, one that was proactive rather than reactive. It was with this in mind that in 1998, the CLAMS (coordinated local aquaculture management system) initiative was commenced. It is important to make the point at this stage that whilst it is two State agencies that have the responsibility of implementing CLAMS, the process does not have any licensing or regulatory role.

Because CLAMS is designed to treat each bay as a separate entity the process involves drawing up a plan for each area. The plan involves a long consultative process with many interested parties and is designed to provide clear and concise information on the specific area concerned. The final document includes a detailed description of the bay in terms of physical characteristics, history, aquaculture operations, future potential and problems.

As there are a number of existing industry codes of practice already in place these are incorporated into the plan and are applied to the specific circumstances within the plan area. All other resource users and activities within the bay are described and included in the plan, and this depth of knowledge of the other stakeholders is utilised in the establishment of a local communication network, which then feeds into a national communication network.

How does the CLAMS process work?

A series of preliminary meetings are held with individual producers in a defined area/bay, which facilitates the explanation of the CLAMS process and allows for the identification of common issues. From these individual meetings an agenda for an initial CLAMS meeting is drafted. At the initial meeting the CLAMS group is formed and a liaison officer appointed—either a BIM or Marine Institute regional development officer. Whilst the liaison officer is responsible for the drafting of the CLAMS plan there are two key tasks that are undertaken by the officer as part of that plan The first is the formulation of a work programme that aims to address pertinent issues in the bay. The second key task is that of contacting all the relevant stakeholders in the bay. This is achieved by drawing up a list of consultees to allow them to have a say on the aquaculture production in the bay.

Whilst all stakeholders are given the opportunity to comment on the aquaculture industry in the bay, no consultee can stop the process. This is one of the key points within the CLAMS process. However all views are brought to the CLAMS group for discussion and are included in the document within a dedicated section. Then where the group feels that it is possible and reasonable, these issues will be included in the overall management plan. In summary, the final CLAMS document contains the following information: baseline information, relevant industry codes of practice, a development plan, management issues and consultee issues.

CLAMS is a unique initiative in that it provides a mechanism not only for aquaculture producers in a specific bay to deal with common issues together, but it also provides an opportunity for all stakeholders to comment on the aquaculture in the bay.

Once the plan is finalised it is officially launched, but more importantly it is adopted by the local authorities and placed in public places for reference. However, this is where the real work for the group begins. The CLAMS process is designed to be a working system and not a document on a shelf. It is the task of the liaison officer to ensure that the work programme outlined in the document is implemented.

As of 2003, there are 9 CLAMS documents and associated work programmes being implemented around the coast. Eight others are at various points along the process chain.

Whilst a large amount of work has been undertaken by the Irish aquaculture industry under the aegis of CLAMS, is it blinkered in its approach? Ireland is a member state of the European Union and as such both the industry and the State are all too aware there is always a bigger picture. In fact, in this case there are two bigger pictures, Integrated Coastal Zone Management (ICZM) and the Strategy for the Sustainable Development of European Aquaculture.

Integrated coastal zone management is obviously not just an issue for the European Union, but one that is affecting all marine resource users globally. In May 2002, the European Council published a recommendation for all member states to develop national strategies for ICZM. These strategies are due to be submitted to the EU by 2006 and the strategies have to show that all stakeholders have been involved in the development of the strategy. As the Irish aquaculture industry begins to come together as cohesive groups under CLAMS, it will mean that as stakeholders they will not be ignored and will allow for a "sea looking back at the land" viewpoint to be taken into account instead of the usual one which is that of the land looking out to sea.

In October of 2002 the European Union published *The Strategy for the Sustainable Development of European Aquaculture*. This document states that 'the Commission recognised the importance of aquaculture' and 'the necessity to develop a strategy for the development of the sector'. The document goes into detail as to how this aim can be achieved, but there is one particular area of relevance to the implementation of CLAMS in the Irish industry, that of governance. The document emphasises the importance of stakeholder participation and also encourages the industry to make more use of self-regulation and voluntary agreements. To this end, it is the intention of both the industry and the relevant State agencies to introduce the CLAMS process to all areas of aquaculture production; it can be considered that the Irish aquaculture industry is moving towards this specific objective under the Strategy for Sustainable Development.

CLAMS is a unique initiative in that it provides a mechanism not only for all aquaculture producers in a specific bay to deal with common issues together but it also provides an opportunity for all stakeholders to comment on the aquaculture in the bay. This communication network is vital if aquaculture in Ireland is to continue to grow in a sustainable manner.

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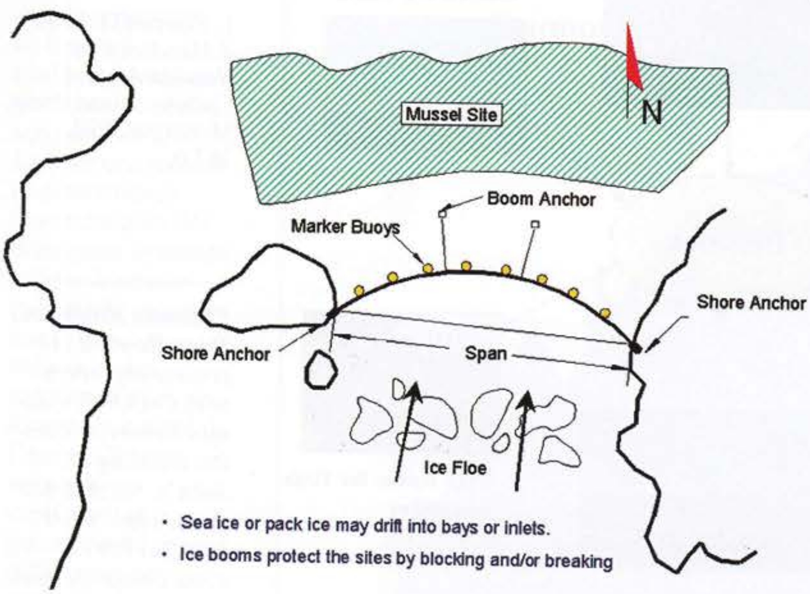
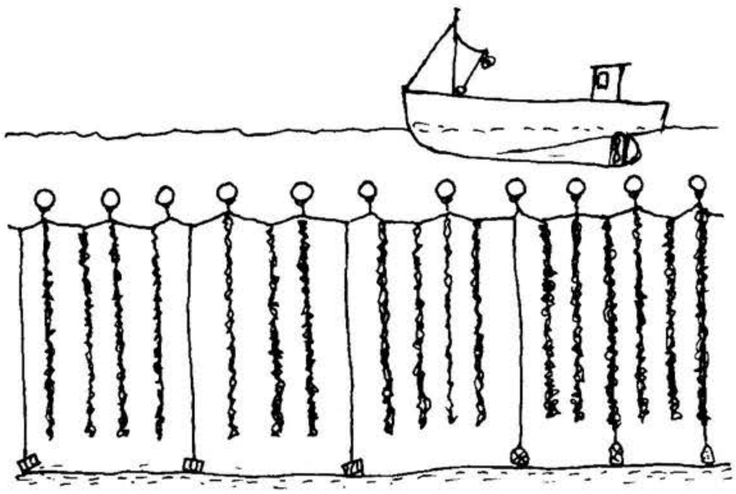
Aquaculture in Northern Regions: Ice Risk, Management and Protection

Freeman Ralph and Dean Rowsell

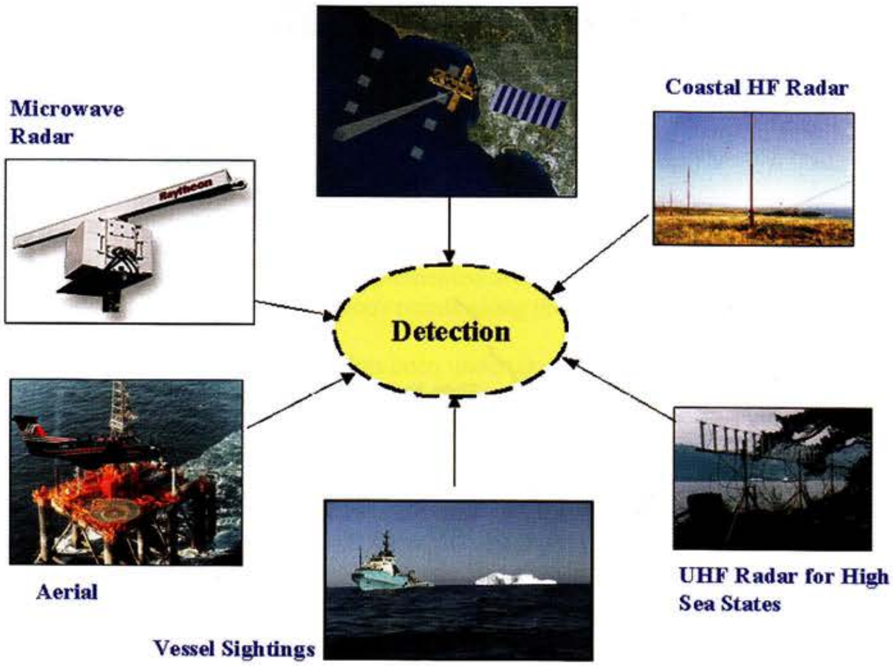
Aquaculture in Newfoundland and Labrador, as well as Atlantic Canada, is an expanding industry with the potential to extend operations into offshore regions. Aquaculture developments on the east and northeast coast of Newfoundland and Labrador, both onshore and offshore, must consider presence of sea-ice and icebergs. Sea-ice typically poses a risk to aquaculture systems at or near the surface and icebergs pose a threat to systems both on the surface and submerged (depending on location and depth). The risk of ice related damage to aquaculture systems can be reduced through the utilization ice tolerant and/or protection systems. For near-shore applications, i.e. mussel farms, ice booms can be used to prevent ice from drifting near the site. Submerged technology can be utilized to avoid contact from sea-ice or icebergs for both



Sea-ice protection of an aquaculture site



Submerged mussel line technology (Scarratt [1])



Ice detection technologies

near-shore and offshore applications. Ice management may also be used to minimise the risk. Various ice detection methods such as aerial reconnaissance, marine radar and satellite imagery can be used to monitor ice movement and identify potential threats. Active measures can then be taken such as pushing or breaking up the sea-ice with a vessel. Icebergs can be managed using a range of towing or deflection methods. Before establishing an aquaculture system offshore, historical data should be used to calculate the rates of sea-ice and/or iceberg occurrence and optimal regions identified based on the results.

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Les systèmes de recirculation en pisciculture: état de l'art et perspectives

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Les contraintes environnementales et réglementaires poussent de plus en plus de pisciculteurs à utiliser les systèmes d'élevage en recirculation, qui par ailleurs cadrent particulièrement bien avec les recommandations de l'Union Européenne pour le développement d'une aquaculture durable. Ces systèmes de production ont été initialement développés d'une part aux Pays-Bas pour le grossissement d'espèces d'eau douce et d'autre part en France pour la production d'alevins de poissons marins. Ils sont maintenant de plus en plus utilisés en Europe quelque soit la salinité et la phase d'élevage. Des unités industrielles produisent actuellement de quelques dizaines de tonnes à quelques centaines de tonnes de poisson par an. La comparaison des caractéristiques bio-techniques des principaux systèmes utilisés à échelle industrielle, montre que (1) les exigences des espèces élevées vis à vis de la qualité de l'eau et (2) leur métabolisme expliquent en grande partie les différences entre systèmes. Les performances technico-économiques d'un pilote industriel seront présentées et les voies d'amélioration seront discutées à la lumière des recherches en cours.

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Use of Ecosystems Science in Ecological Aquaculture

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In the 21st century, aquaculture developers will need to spend as much time on technological advances coming to the field as they do in designing ecological approaches that clearly exhibit stewardship of the environment and coastal societies. The degraded state of aquatic ecosystems worldwide, combined with public concerns about adding new sources of pollution to already overburdened aquatic ecosystems require: a) comprehensive planning for aquaculture in the future of sustainable fisheries, b) integration of aquaculture into plans for restoration of coastal ecosystems and the future of coastal communities, and c) increased market development of environmentally (and socially) certified commodities. An alternative model called "ecological aquaculture" is needed to develop clear, unambiguous linkages between aquaculture, the environment and society, and promote the complementary roles of aquaculture in contributing to environmental sustainability, rehabilitation and enhancement to a highly concerned, increasingly educated and involved public. Ecological aquaculture brings not only the technical aspects of ecological methods and systems ecology to aquaculture, but incorporates principles of social ecology, and concerns for these wider social, economic and environmental contexts. New aquaculture operations must plan at the outset to: 1) become an integral part of a community and a region, 2) plan for social development by working with leaders to provide inputs and recycle wastes, 3) create a diversity of unprocessed and value-added products, and provide local market access, and 4) plan for job creation and environmental enhancement on local and regional scales.

The Importance of Fishery Products to a Crowded, Protein-Hungry Planet

Fishing is the largest extractive use of wildlife in the world.(1) The coastal economies of all nations are dependent on fishery products and fisheries are a source of employment for about 200 million people. In 1999, the total value of world fishery production was US$125 billion.(2)

World production of fish, crustaceans, mollusks and plants reached 142 million metric tons in 2001. Capture fisheries accounted for 66% of the total, producing 93.7 million tons, of which inland capture was 8.7 million tons. Aquaculture production, including plants, was 48.4 million tons.(2) Marine and freshwater fish are also an increasingly important recreational resource, both for active users such as anglers and for passive users such as tourists, sports divers and nature-lovers.

Fishery products are the primary source of protein for some 950 million people worldwide and represent an important part of the diet of many more, especially for the poor.(1) Fish contribute more animal protein for human consumption than beef and poultry combined. Fish is the primary source of omega-3 fatty acids in the human diet. Omega-3 fatty acids are critical nutrients for normal brain and eye development of infants, and have preventative roles in a number of human illnesses, such as cardiovascular disease, lupus, and depression and other mental illnesses.(3)

In less than 50 years, the world's average per capita consumption of fish has almost doubled. In response, reported production of fish for direct human consumption doubled between 1950 and 1970, but has stabilized since then at an average of 9 to 10 kg of fish per capita. Fish consumption per person is expected to continue to rise, with a likely range for demand of 150 to 160 million tons, or between 19 and 20 kg per person in 2030.(1)

Global increases in consumption of food fish are projected to take place predominantly in the developing countries, especially in Asia, where populations are growing and higher incomes are allowing purchase of high value fisheries items for the first time by many people. Due to the exploding world population, however, demands for fishery products are greater than supplies, resulting in unemployment, price fluctuations, and grotesque market and regulatory inefficiencies.

About two-thirds of the world's major marine fisheries are fully exploited, overexploited, or depleted.[2] About 30% of the world's fisheries catch are discarded. Global fisheries lose an estimated US$50 million per year which are made up by ineffective government subsidies.[4] There is a growing trend—one that will only increase in the future—of shortages in wild fishery resources, price increases, and of replacement of wild fish by cultured fish in generic "white fish markets". But unless we change our current practices, there will have to be *per capita* declines in the use of fish and other marine products.

... coastal urbanization and gentrification threaten the future of traditional coastal communities that form the heart and soul of a "working coast".

There is a real and present danger that the accelerating demands for high protein foods could drive not only additional failures of fisheries but also lead to massive losses of biodiversity and the complete dismantling of aquatic ecosystems.[5] In addition, coastal urbanization and gentrification threaten the future of traditional coastal communities that form the heart and soul of a "working coast". It is urgent to undertake the necessary planning needed to ensure the sustainability of *both* nature and millions of coastal peoples.

We cannot catch more fish from the sea. But the world can turn to farming the waters—not just hunting them—and rapidly accelerate the promise of aquaculture and ferment a "blue revolution". But this blue revolution cannot be a modern clone of the "green revolution" which required greater petrochemical inputs and toxic chemicals to sustain higher levels of production at the expense of both nature and society. Aquaculture's blue revolution needs to be an "evolution"—not a "revolution"—which incorporates modern, 21st century, knowledge-based processes to pioneer the development of sustainable, socially and ecologically integrated aquaculture systems that are planned systems and processes which have *positive* impacts on both natural and social ecosystems.[6]

The Need to Rapidly Evolve Ecological Aquaculture

Aquaculture is growing rapidly, but its most rapid period of growth still lies ahead. According to the FAO,[2] farming now represents some 27% of the world production of fish, crustaceans and shellfish versus just 4% in 1970. In Europe, just 12% of fishery products are produced by aquaculture, but more than 50% of seabream comes from aquaculture. Worldwide, about 95% of Atlantic salmon now originates from farms.

Several reasons account for the rise of aquaculture. First, the variability of fisheries and the rise of overexploitation have resulted in aquaculture products garnering additional market shares by guaranteeing regular supplies and uniform quality. Secondly, increased population growth and income levels in Asia have increased demands for fishery products. In the industrial countries, fish is regarded as healthy food, but it is in the developing countries where demand is increasing rapidly.

The rapid growth of highly productive, feedlot-type, intensive aquaculture systems growing carnivorous fish in net pens located in open waters have garnered the bulk of critical concern. In comparison to terrestrial agro-ecosystems, the productivity of these systems is impressive. A Norwegian salmon farm of just 0.1 ha produces 600-700 tons, corresponding to a herd of 50,000 sheep and lambs. In 2000, Norway produced about 470,000 tons of fish on just 73 km of a total coastline of greater than 21,000 km. Norwegian terrestrial meat production was just 259,000 tons in 2000.[7]

However, the rapid growth of highly productive, feedlot-type intensive aquaculture has raised a number of concerns about the sustainability of current production models, and the future roles and responsibilities of these new aquaculture industries in coastal societies, both ecologically and socially.

An alternative model of aquaculture development—called "ecological aquaculture"—is needed which develops clear, unambiguous linkages between aquaculture, the environment and society, and promotes the complementary roles of aquaculture in contributing to environmental sustainability, rehabilitation and enhancement to a highly concerned, increasingly educated and involved public.[6] Ecological aquaculture, a "new" field of applied environmental scholarship—actually it's an ancient field—needs to emerge throughout the world to assist aquaculture's rapid transition to social and environmental sustainability. In the 21st century, aquaculture developers will need to spend as much time on technological advances coming to the field as they do in designing ecological approaches to development that recognize and plan to be a part of human-dominated ecosystems, with an increasing level of user conflicts. The degraded state of aquatic ecosystems worldwide, combined with public concerns about adding any new sources of pollution to already overburdened aquatic ecosystems require:

- more comprehensive planning for aquaculture at many different scales,
- integration of aquaculture into plans for the restoration of coastal ecosystems and the future of coastal communities, and
- increased market development of environmentally (and socially) certified commodities.

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The Use of Ecosystems Science to Investigate Aquaculture

Ensuring that accelerated aquaculture development be done in an ecological manner is much more than a simple technological exercise—it is an exercise in multi-disciplinary, multi-institutional environmental scholarship. Millions of people whose lives depend upon harvesting marine resources from fishing and farming require that we devise a planned system that *includes* them, and ensures their future. Behavioral changes will be required that can be accomplished through social investments, strategic subsidies, and market mechanisms that facilitate change in consumer behaviors. Jamieson[8] believes the most effective strategy for sustainability is not technological, but solutions "located in their source: humans, their behavior, and their institutions". In this regard, development of ecological aquaculture is essentially a conscious exercise in social engineering.

One major stumbling block is the lack of rigorous, comprehensive, multi-disciplinary scientific analyses of aquaculture which would define in a more holistic manner the ecological framework for analysis, impacts on the production "chain", and critically important resource input/output and cost/benefit issues. The broader issue is that the future sustainability of both wild and farmed stocks depend upon many of the same marine and agricultural resources—from food to habitats. Although capture fisheries, aquaculture and terrestrial agriculture operations are researched, planned, and managed as if they were independent entities, they share concerns about environmental disruptions, genetic and habitat diversity, feeds, and the sustainability of protein meal/oils and industries, among other shared concerns.

The future challenge for planners—who clearly need to accelerate aquaculture development—is to plan for new production—not only technically, but also as community development— and consider the social ecology of aquaculture developments. To date, macro-economic factors have been the main controllers of aquaculture developments, with environmental and social costs externalized.[9] Proper planning for ecological aquaculture internalizes all of nature's and society's costs as part of an entire regional development activity that plans for the regional impacts of the entire "aquaculture production network" that connects aquatic seed and feed production centers and markets in order to maximize local social-economic multiplier effects.

Ecosystems science is the practical application of ecological theory to urgent societal issues needed for environmental management. It includes the scientific study of conservation and management of natural, human-dominated and man-made ecosystems, habitats, and species; restoration ecology and regenerative studies; urban and industrial ecology; and the role of ecological research in global and sustainability problems.

A new understanding of ecological systems has emerged[10,11] which is of great importance to the comprehensive study of complex systems such as aquaculture ecosystems. There is growing recognition that complex systems are: (a) hierarchical in nature; (b) have different properties and dynamics occurring at different scales of organization; and (c) have inherent uncertainties that require ecologists to incorporate and build in—not to exclude—uncertainty. The notion of hierarchy requires that a study of ecosystems first consider the types of systems and the ecological hierarchies (scales) that exist in order to determine the appropriate means of investigation.[12] For example, to understand a type of aquaculture ecosystem, studies of the natural and social ecology of the system at the species, community, ecosystem, and regional scales are required.

Applying the notion of complexity to aquaculture ecosystems suggests new roles for ecosystems science in the evolution over time towards sustainability of aquaculture ecosystems. An investigator must first take great care to ecologically classify the structure and functioning of the aquaculture system and scales of investigation necessary to deal with research issues in both a natural and social ecological context. A particular concern is the neglect of investigations on the social ecology of aquaculture ecosystems. As one example, ecology research on the natural ecology of aquaculture ecosystems in central Africa focused on group training in scientific production methods. Training courses were attended by village leaders who were men; social science research investigations, however, found that the actual managers of the pond aquaculture ecosystems were children.[13]

The challenge for researchers studying aquaculture ecosystems is to abandon the normal approach of hypothesis testing and analytical searching for the correct model for solving a problem. Instead we must develop a manner of investigation that uses a diversity of different perspectives and models, brings different players to the table, and synthesizes the different natural and social ecological methods together in order to achieve understanding. The values of various stakeholders and community members will play an essential role in the decision making process. The role of the scientists will be to inform the decision makers about the ecological options, the tradeoffs and uncertainties involved, and various strategies for influencing what happens. However, ecologists cannot predict with complete certainty what will happen in this situation, nor can they inform us about the "correct" way to proceed. Thus, the role of science in decision-making for sustainability changes from problem solver, in the sense of providing a solution for the situation, to the role of facilitating understanding about the bio-physical and social realities of the situation, and in so doing contributing to its resolution.[14]

Vital to establishing a framework for more comprehensive natural and social ecological analyses of aquaculture ecosystems is the recognition of three important guidelines that will help investigators determine aquaculture's hierarchies:

1. Aquaculture is not a uniform "industry" or a standard set of practices easy to classify, codify, label or regulate. It is very important to always define the structure, functions and hierarchical placement of an aquaculture system before addressing its social and environmental connections and impacts. Unfortunately, this simple point is not widely practiced by many "analysts" of the field. Indeed, analyses of "aquaculture" cannot be scientifically credible unless directed to the actual ecological structure and functional type of aquaculture ecosystem to which is being referred.
2. There are intimate—albeit largely unplanned—connections between capture fisheries, enhanced fisheries ("ranching"), and culture fisheries ("aquaculture"), and greater recognition is needed regarding the vital contribution of culture fisheries (aquaculture) and enhanced fisheries (ranching) to global fisheries production. FAO[2] reports that aquaculture is the fastest growing form of global food production, accounting for over 25% of total world fish production, and that aquaculture will provide most of the growth in world fisheries production over the next 50 years.
3. The success of aquaculture is dependent not only on its technical needs for hatcheries to produce seed, and feed mills to produce feeds, but also on markets, equipment, and the capacities and capabilities of the entire seafood infrastructure. Determinations of the costs and benefits of aquaculture require more comprehensive ecological analyses of the entire "aquaculture production network" (the "support network") for a particular aquaculture species.

.. aquaculture is the fastest growing form of global food production ...

Hierarchies of Aquaculture Ecosystems

There are at least four hierarchies important to the analysis of aquaculture ecosystems worldwide: system/species, functional, global/regional, and farm.

Systems/Species Hierarchies

Aquaculture is as diverse a field of endeavor as agriculture. There are a wide diversity of systems and species which can be classified in many different ways, from non-fed, photosynthetic, marine-agronomic-type operations; to publicly-funded aquaculture hatcheries for fisheries enhancement (Alaska salmon, oyster restoration); and intensive, feedlot-type industrial production systems in open waters. Worldwide, the most common type of aquaculture system remains the classic earthen ponds growing omnivorous fish species that were either produced in hatcheries or collected from the wild, and cultivated in ponds being fed supplemental feeds on an exact feeding schedule. Most of these pond systems are located in Asia, and are open systems having little or no capital investments in waste treatment facilities (but may be completely integrated operationally so that no aquaculture wastes are discharged).

The most important ecological classifications of aquaculture ecosystems are: (a) their location within or separate from the environment, (b) the levels of operational intensity (management, feeds, water flows, etc.), and (c) the level of system's integration. Table 1 captures the diversity of the systems and functions of aquaculture ecosystems. Table 2 is an attempt at developing a better classification system for these diverse aquaculture ecosystems.

Functional Hierarchies

Ecosystem science can examine in detail the functional hierarchies of

Table 1. Classification of Aquaculture Systems (from Costa-Pierce[15])

Types	Kinds & Levels
Stocking, Management and Economic Intensity Levels	Intensive; Semi-intensive; Extensive
Water Salinities	Freshwater; Brackish water; Seawater
Water Flow Characteristics	Running Water (Lotic); Standing Water with Flushing; Standing Water (Lentic)
Amount of On-site Water Treatment and Recirculation	Open, No Recirculation; Semi-closed, Partial Recirculation; Closed, Full Recirculation
Environmental Location	Indoor; Outdoor – Natural; Outdoor–Artificial
Feed Qualities	Complete; Supplemental; Natural
Feeding Strategies	Continuous; Scheduled; Natural
Species Stocking Strategies	Monoculture; Janitorial Polyculture; Polyculture
Species Temperature Tolerances	Eurythermal; Stenothermal; Coldwater; Warmwater
Species Salinity Tolerances	Euryhaline; Stenohaline; Marine (Mariculture); Brackish water
Species Natural Food Habits	Carnivorous; Omnivorous; Herbivorous; Opportunistic
Fry Sources	Hatcheries; Wild Capture of Broodstock; Natural
Level of Systems Integration	Stand Alone; Integrated
Unit Types	Raceways; Tanks and Cages (Floating, Fixed); Net Pens (Fixed); Rafts (Ropes, Nets); Ponds
Marketing Channels	Human Food (Local, Export); Sport, Recreation, Tourism

aquaculture ecosystems, especially the material, cash and nutrient flows.

For example, a major concern is that intensive aquaculture systems located in open waters add a new source of untreated aquatic pollution to already overburdened natural ecosystems. Not unexpectedly, aquaculture systems that have a high intensity of production, and discharge wastes with no treatment whatsoever to oligotrophic ecosystems have the greatest potential for nutrient impacts on the environment. The amount of dependence on the natural environment for waste assimilation—and the level of ecological subsidy provided—is directly related to the amount of on-site treatment of wastes that is per-

Table 2

A natural and social ecological classification of aquaculture ecosystems

Solar Aquaculture	Smallholder Aquaculture	Semi-Intensive Aquaculture	Intensive Aquaculture	Intensive Industrial Aquaculture
Natural foods	Low quality supplemental feeds, fertilizers	High quality supplemental feeds, fertilizers	Complete feeds	Complete, high protein feeds
Plants, shellfish, fish	Tilapia, carps, crustaceans	Crustaceans, fish	Marine fish, crustaceans	Marine fish, crustaceans
In nature, In large ponds	Ponds, Tanks	Ponds, Tanks	Tanks, Pens, Raceways	Tanks, Pens, Raceways
Families, small businesses	Families, small businesses	Families, small to medium-scale national businesses	Large, regional & national businesses	Multi-national corporations

formed. However, while super-intensive, flow-through aquaculture systems have potentially the highest nutrient impact on natural ecosystems, impacts from such systems can be insignificant if complete, on-site waste treatment occurs. Therefore, super-intensive aquaculture cannot always be assumed to have major nutrient impacts that impair natural aquatic ecosystem structure and functions. The place to start in these analyses are summaries of functional data on aquaculture ecosystems (such as that reviewed in Costa-Pierce[15]), which will allow ecologists to develop more rigorous simulation models that can be tested with empirical research on the nutrient impacts of floating cage and raft aquaculture, recirculating systems, and semi-intensive pond systems.

Social ecology analyses of aquaculture's functional hierarchies are also needed. For example, if aquaculture systems are located completely within natural environments (cages, rafts) and are not required to treat their wastes, the public is subsidizing the environmental costs of these operations at the level of: (a) the additional capital costs for complete waste treatment, (b) the operating costs for treatment facilities, and (c) the interest on loans received to purchase and operate waste treatment systems. These subsidies need to be compared with other available public policy options to sustain a working coast. In Norway, for example, aquaculture provides an estimated 3,500 direct jobs and 40,000 to 45,000 total jobs in support services, etc.[7] Many small, rural coastal communities are sustained by the taxes provided by these intensive operations. The issue for analysis is the weighing of the social and ecological costs/benefits of both environmental and social subsidies.

Global/Regional Hierarchies

There are intimate but little recognized and largely unplanned functional connections between capture fisheries, enhanced fisheries ("ranching"), and culture fisheries ("aquaculture") (Fig. 1). These connections are important to the future of global fisheries production, but are little recognized. In many nations, planning for aquaculture developments is not incorporated into the overall planning framework for sustainable fisheries and coastal zone management. For example, in the USA, the Magnuson-Stevens Fishery Conservation and Management Act (Magnuson Act), passed in 1976 and recently re-authorized, says little about the important positive impacts of aquaculture technologies in the restoration of capture fisheries, even though aquaculture expands the production of commercially valuable species.

Alaska is a textbook case of the need for more comprehensive planning for fisheries, aquaculture, and the future of coastal communities. Some time ago, Alaska made salmon aquaculture technically illegal, in order to protect its salmon fishery and its pristine marine environments (and with the unstated purpose of protecting its salmon markets?). But in actuality, Alaska is a salmon-aquaculture-powerhouse. The state has salmon hatcheries and nurseries and uses those fish to supplement wild stocks. For example, salmon hatcheries and nursery net pens in Prince William Sound have added millions of salmon to the some 10 million salmon harvested each year since the 1990s. Wertheimer et al.[16] found that these hatchery salmon did not displace the region's wild salmon stocks; rather, the hatchery salmon have added to the size of Alaska's salmon harvest. As a result, Alaska is awash in salmon, not only from the wild, but also from its aquaculture-enhanced salmon fishery. This additional production from its subsidized hatcheries has done little to improve the lives of Alaska's producers or consumers. According to The Anchorage Daily News, Alaska fishermen landed almost 75 million salmon in the summer of 2001, yet they received only US$216 million for them, less than half the revenue they earned 15 years before. A system's ecology approach that more comprehensively analyzed both fisheries and aquaculture of salmon—in the global context—would provide some useful scientific information to policy-makers (and taxpayers!).

Farm Hierarchies

Ecosystems science approaches are particularly valuable for analysis of aquaculture ecosystems at the farm level. Farms are managed agro-ecosystems with discernable production networks with numerous interconnections that supply inputs and outputs to the system using local or imported resources, and recycle or discharge wastes and materials, plus export products that have values whose economics and social ecology can also be mapped and analyzed.[17] Ecological analyses can lend insight into innovative methods that can be employed to close "leaky" loops of energy and materials that can potentially enhance/degrade natural ecosystems and increase/decrease profit. Aquaculture depends upon inputs from various food, processing and transportation industries and produces valuable waste waters, manures and fish wastes, all of which can be a vital part of an ecological system that can be planned and organized for community-based ecosystem rehabilitation, reclamation and enhancement—not degradation. Transitions to sustainable, ecological aquaculture will require a movement from the sewage treatment and assimilative concepts of waste management towards the concepts of input management and integrated waste treatment technologies.

At the farm level, ecosystems science can be used to identify suitable farmers, map land and water types and enterprise mixtures that are most likely to benefit from exposure to aquaculture as a new farm enterprise. Mapping also helps in identifying current

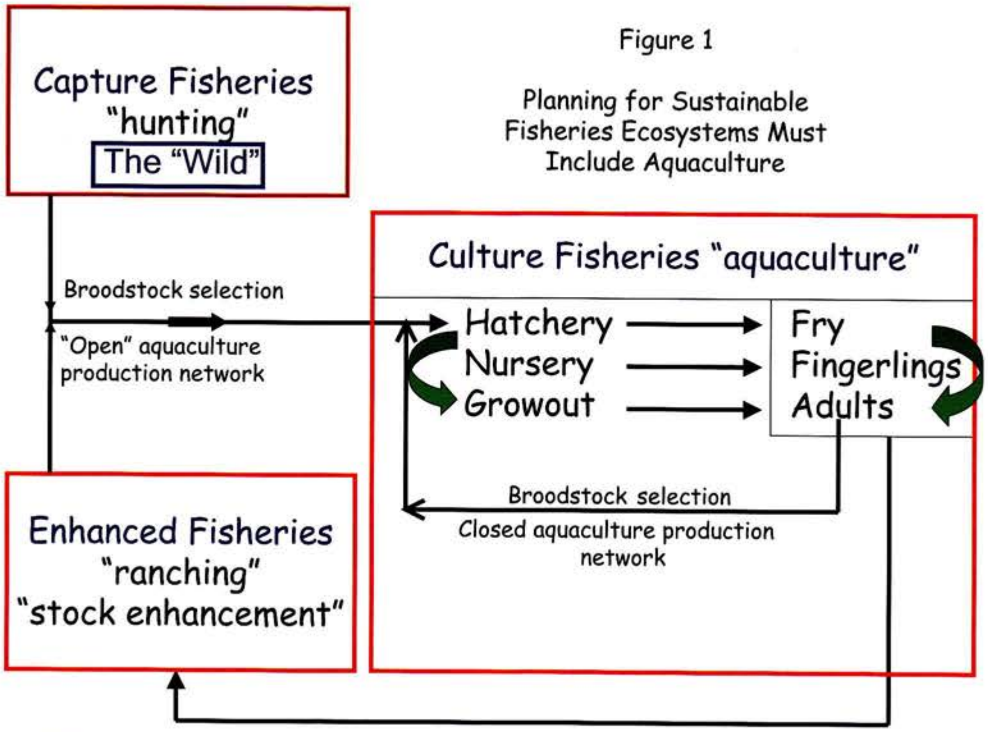


Figure 1

Planning for Sustainable Fisheries Ecosystems Must Include Aquaculture aquatic farmers who may benefit from technologies developed by researchers, extension agents, and interested farmer investigators. Researchers and extension workers have used ecological methods to identify where technological help might improve the overall farming/fishing ecosystems and how aquaculture may assist in enhancing the productivity and efficiency of resource flows.[17] Ecosystem analyses, pictorial modeling, and systems diagnosis of farmer's problems helps in the development of appropriate technologies, assists in developing a farmer/fisher-centered research agenda on agriculture/aquaculture experiment stations or research institutes, and facilities more rapid, efficient, and lower cost transfer of new information to farmers/fishers.[17]

Ecological Engineering of Aquaculture Ecosystems

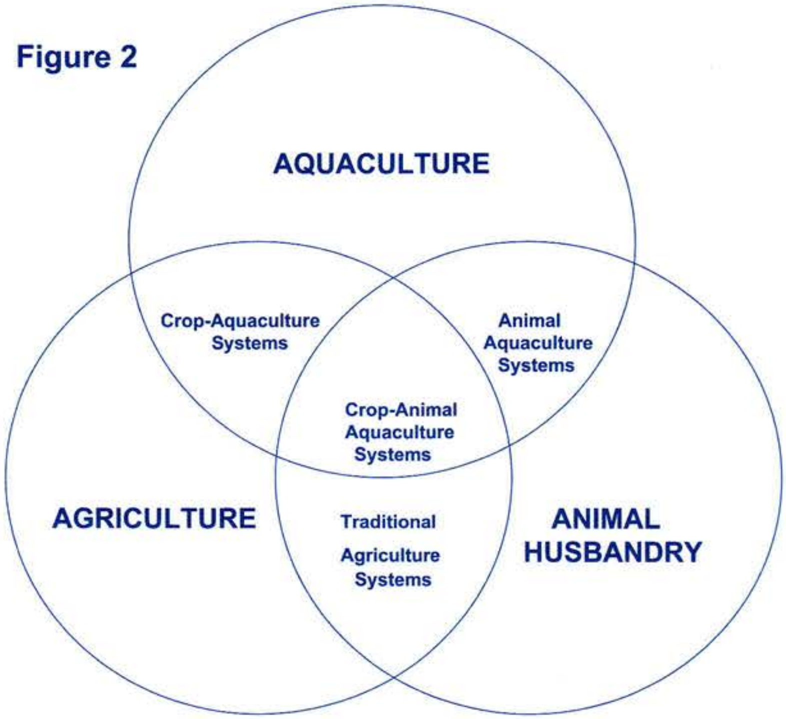
Given the diversity of aquaculture ecosystems, the possibilities for ecological engineering are numerous.[18] For example, the integration of aquaculture, agriculture and animal husbandry on small farms in Asia creates definable aquaculture ecosystem types (Fig. 2). These aquaculture ecosystems closely resemble natural ecosystems having their own structure, closely coupled nutrient recycling pathways, and ecological management strategies.[6] Such integrated systems provide the following advantages:

- **synergy, complementarity and adaptability:** "polyvalent" technologies are "market-driven"; in other words, technological change is market-driven. Witness the extraordinary technological adaptability of Chinese/Taiwanese farmers to market changes; they "flip" from species/systems rapidly in response to market changes, exhibiting an extraordinary "bank" of traditional knowledge.
- **drought-proofing:** efficient use in agriculture of warm, fertile irrigation waters from aquaculture.
- **waste-treatment capability:** ponds are "sunlit rumens"[19] processing low quality agricultural by-products into high quality aquatic proteins, and
- **restoration capability:** conversion of marginal lands to prime agricultural lands by managing long-term rotations and natural/social cycles between agriculture and aquaculture systems.

The Need for Ecosystems Science to Address the "Aquaculture Paradox"

Naylor et al.[20, 21] have raised questions whether aquaculture contributes to the depletion of world fisheries. This "aquaculture paradox" is nothing new, being recognized many years earlier by Schroeder[19] in a little publicized article that surprised few in the aquaculture science community at the time.

Figure 2



Schroeder found that a carp pond in Israel fed compound feeds with a fish meal content above 25% would actually *consume* fish, not be a net producer of fish.

Indeed, in the 1970s there were arguments being put forward that herbivores such as tilapia were similar to cattle grazers, feeding on plankton. Such arguments were debunked by simple calculations using known trophic level efficiencies, and further research on tilapias which showed them to be opportunistic, broad spectrum omnivores. Delivering tilapia to market that were reared solely on phytoplankton would take years! Thus, most tilapia farms today outside of the resource poor nations use commercial fertilizers and fish meal-based feeds to deliver a quality, healthy fish product in a remarkably short time.[22,23]

The validity of the Naylor et al. analyses have been questioned.[24] However, the broader issue raised by these authors is that both wild and farmed fish stocks depend upon many of the same marine and agricultural resources—from food to habitats—and that aquaculture's true impact must be examined—and planned for—much more comprehensively.

This is the real policy question vitally important for the future of the "blue revolution". Although capture fisheries, aquaculture and terrestrial agriculture operations are researched, planned, and managed as if they were independent entities, they share numerous common concerns about consumers, labeling, genetic and habitat diversity, feeds, the sustainability of fish meal/oil fisheries, and onwards. The green revolution took off without considering the knock-on impacts on the environment, society and economies. The blue revolution needs to be planned in a much more comprehensive manner. To examine the true impact of aquaculture on fisheries, for example, additional, more comprehensive and rigorous scientific analysis of fish meal and oil fisheries must be undertaken that includes all uses (agricultural and aquacultural). More detailed analyses of the fisheries of individual fish meal and oil species must be done. Lastly, more rigorous investigations of the social ecology of the aquaculture revolution need to be accomplished so that more transparent accounting for aquaculture's social subsidies are made. It is time for ecosystem ecologists and marine policy-makers to give more attention to the blue revolution!

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Exotic Species in Aquaculture

Fred Whoriskey

The culture of marine and freshwater organisms for human use is poised for phenomenal growth. This "Blue Revolution" can bring employment and other social and economic benefits, providing aquaculture is implemented in an environmentally and socially sustainable manner. However, definitions of what constitutes "sustainable" vary among stakeholder groups, and great tension develops when one group's "acceptable" practices are viewed as a threat by others. The use of exotic species or strains in aquaculture is controversial. With current technologies and practices, it is inevitable that cultured organisms will escape to the wild where they will begin to interact with native species. Spectacular damage has occurred in native ecosystems through the unintended release and colonization of exotic species. Non-native species introductions are now widely viewed as the second greatest threat to native biodiversity, behind habitat destruction. This has led to the adoption of international agreements and new government polices to control unintended introductions. The prevention of exotic species introductions is also becoming a major focus of non-governmental conservation groups. Aquaculture is both a source and a victim of non-native introductions. For all of these reasons, requests from the aquaculture industry to grow exotic species will be intensively scrutinized, and will remain controversial until the potential for impacts of escaped exotics can be controlled.

Introduction

Introduced species (I use the term 'exotic species' synonymously in this text) "are those that have been transported by human activities—intentionally or unintentionally—into a region in which they did not occur in historical time and are now reproducing in the wild".[4] The use of exotic species in aquaculture is controversial. Here I outline aspects of the issue, and explain some of the reasons for the concern. Present policy frameworks are examined to show how governments and society are viewing exotic species, and I present two case studies from Canada that look at the use of exotics in aquaculture. To close, I provide my sense of what all this means for aquaculture in the future.

The Issue

Humans have either deliberately or unintentionally introduced exotic species into geographical areas where they have not occurred before. The exotics can have significant direct or indirect impacts upon native species and the people who depend on them.[17] Direct impacts include predation and/or competition for which the native species have no defense, or as a vector of novel parasites or diseases for which the natives have no natural immunity. Indirect impacts may occur when the establishment of an exotic alters ecological community structure and functions. For example, native species that have no direct contact with the invader may find their food supply depressed because the invader's actions have altered food webs. In some parts of the world, up to 80% of the species considered as endangered are at risk due to the pressures of non-native species.[32]

There is concern that the establishment of an exotic in a region may lead to an "invasional meltdown", which is defined as a "... process by which a group of nonindigenous species facilitates one another's invasion in various ways, increasing the likelihood of survival and/or of ecological impact, and possibly the magnitude of impact. Thus, there is an accelerating accumulation of introduced species and effects...".[35] Hence the presence of an invader may facilitate the establishment of species with which it has co-evolved, leading to a rapid and potentially highly undesirable change in ecological community structure. While Simberloff and von Holle[35] found that the available information on biological invasions was too anecdotal to calculate the frequency of "invasional meltdown", recent work underlines that it is a real phenomena (e.g., Cohen and Carleton[5] and Levin et al.[21]).

While species can naturally disperse to new places, human interventions have exponentially accelerated the numbers moving, their rates of spread, the dispersal distances, and their impacts.[4,8] For example, Pimental et al.[32] reviewed the impacts of exotics upon the native flora and fauna in the USA. They calculated that due to human activities about 50,000 species of plants and animals have been introduced to the country, and that over the past 40 years the rates of introduction have greatly increased. About 400 of the 958 species listed as threatened or endangered under the Endangered Species Act are considered to be at risk primarily because of competition with and/or predation by nonindigenous species. The control costs, environmental damage and economic losses caused by introduced exotics in the US total at least $137 billion per year.

There is limited information on the economic impacts of exotic species introductions in Canada. In cases where a reasonable amount of data was available, MacIssac et al.[24] found that: 1) six species are presently costing agriculture $273 million per year for control, but that these costs could rise to as high as $5-14 billion in the future, 2) eight species are imposing costs and damages to forestry of $7.7 to $ 20 billion per year, and 3) damage from four coastal and aquatic invaders amounts to $300 to $ 776 million per year.

We are uncertain why in some cases invasions succeed, and in others they fail despite repeated opportunities for the exotic to establish itself. Carleton[4] likened the process to a game of roulette, where if an invader with the right characteristics is present in the right place at the right time, colonization is successful. Invasion success also depends on the biological traits of the invading organism. The characteristics that make a good invader include: high reproductive rates (or good juvenile survival), good dispersal mechanisms, broad tolerance to environmental conditions, flexible habitat requirements, a will to eat almost anything, good antipredator strategies, and an aggressive streak.[46]

In sum, exotic species introductions can pose serious ecological and economic dangers. Invading species are now widely considered to be the second most important threat to native biodiversity, behind habitat destruction.[2,36,39]

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Aquaculture and Exotic Species

Aquaculture has been both a vector and a victim of the spread of exotic species, and sometimes both at the same time.

Naylor et al.[30] reviewed the role of aquaculture in the spread of exotic species, particularly in the United States. They concluded that globally aquaculture has become a leading vector of aquatic invasive species. In the case of the United States, they found aquaculturists reared over 100 different species of aquatic plants and animals, and most of them were not native to their farm site. To give another example, in the southern United States and in other southern locations, exotic tilapia are extensively cultured. Many have escaped from commercial aquaculture sites (and other places, too) and established self-sustaining populations, leading Costa Pierce and Riedel[7] to conclude: "We contend that saline tolerant tilapiine fishes constitute a major threat to the fish communities of the world's estuaries."

Aquaculture itself has suffered from the impacts of exotic species introductions. For example, the exotic European shore crab (a.k.a. the green crab *Carcinus maenas*) was originally introduced to east coast North America in the early 1800s.[4] It has spread widely, and extended its distribution to mussel farming areas of Prince Edward Island in 1995,[9] where its predation does great damage. A single green crab can consume up to 36 mussels a day.[31] Mussel growers are now bracing themselves for the arrival of the Asian shore crab (*Hemigrapsus sanguineus*), which was first reported from the east coast of North America in 1994.[26] It has been displacing the green crab as it extends its distribution northwards, and may soon invade blue mussel culture areas.[38] Mussel culture is also reeling from the impacts of the clubbed tunicate (*Styela clava*), which arrived in Prince Edward Island in 1998 and whose massive fouling of mussel lines has severely impacted production.[9] As a final example, the infectious salmon anemia virus, which has had devastating impacts on the Atlantic salmon farming industry in Europe and North America, may have been moved across the ocean (which continent was the donor and which was the recipient is uncertain) by the inter-continental transfer of exotic salmonids.[20]

In an interesting recent incident, salmon farming is at the same time both a vector and potential victim of an exotic's spread. Controversy has erupted among Tasmanian salmon farmers over the Australian federal government's decision to allow the importation of uncooked salmon from Norway. Recently, carcasses from Norway bearing live sea lice arrived at an Australian fish market. Sea lice are a major pest in many salmon farming areas, but do not naturally occur in the Southern Hemisphere.[18]

Cage Culture of Exotic Salmonids in Canada: Reciprocal Transplants

Wild salmonids are a mainstay of both commercial and sport fisheries in Canada.[34] Pacific salmon support a commercial fishery worth hundreds of millions of dollars per year.[6] Recreational anglers paid out $6.7 billion in 2000, the year for which the most recent figures are available,[10] much of it for catching salmonids (e.g., Whoriskey and Glebe[47]).

The commercial culture of salmonids in sea cages started in the 1970s and has since become a multibillion dollar a year global business. Production of Atlantic salmon (*Salmo salar)* topped 1.1. million mt in 2001,[16] with much of it occurring in areas outside of the species native range (e.g., Gajarado and Laikre[12]). Smaller quantities of other salmonids are also grown in sea cages, including the rainbow trout (known also as steelhead, *Oncorhynchus mykiss*), which in North America is native to watersheds west of the Rocky Mountains.[34]

The escape of cultured salmonids to the wild, and their interaction with wild salmonids, is a source of great concern. A primary worry is the interbreeding (genetic introgression) of cultured fish with wild conspecifics. The potential for the introduction of exotic competitors to native wild salmonid areas is a second major source of alarm.

In Canada, at least two native salmonids have been moved outside of their natural range for culture in sea cages. The two that are supporting major industries are the Atlantic salmon, which have been moved to the country's west coast, and the rainbow trout, which have been moved to the east coast. Both species have similar life cycles, with reproduction and a juvenile phase in fresh water, and extensive ocean feeding migrations.[34] Experimental work has shown that in the juvenile phase, the two species will compete for food and space.[11,41] Both species have been escaping from sea cages in regions outside of their natural range.

Atlantic salmon on Canada's West Coast

The Atlantic salmon was introduced to the British Columbia sea cage industry in 1984, because it was a more desirable market fish, and because the knowledge about its culture was more extensive and some found the species adapted better to the cage environment.

Prior to the development of the sea cage industry, attempts were made to introduce the Atlantic salmon to the Pacific region for sport fishing reasons. Over 8.6 million Atlantic salmon (Miramichi River origin) were placed in more than 60 lakes and streams in British Columbia, and none resulted in the establishment of a self-sustaining population.[13] Waknitz et al.[44] reported that more than 130 attempts to colonize Atlantic salmon in 32 states of the USA failed.

Because of the British Columbia colonization failure, and the generally poor colonization success of the Atlantic salmon compared to other salmonids when the species is introduced outside of its natural range, some have concluded that the escapes of Atlantic salmon from sea cage sites will not pose a long term threat to Pacific salmon on the West Coast.[13,29,44] However, under the right conditions, the Atlantic salmon can be a very successful invader. A number of range extension attempts within the species indigenous geographic area have been spectacular successes.[28,46]

Escapes of Atlantic salmon on the West Coast of Canada have become very controversial, as contrary to expectations the species has been found out at sea as distant from B.C. culture sites as Alaska, and subsequently multiple year classes of juveniles were detected in rivers in the province.[40,42,43] Volpe[43] traced the evolution of government's position on the escapes of Atlantic salmon and their subsequent entry and spawning in rivers. He reported that these positions evolved through the following stances:

- Escapes are very rare.
- Escapes are inevitable but they won't survive in the wild.
- Some Atlantic salmon may survive but will not ascend freshwater rivers.
- Some adult Atlantic salmon are likely to be found in freshwater rivers but can't spawn.
- Spawning is likely to occur but progeny will not be competitively viable.

The present position is:

- Multiple year classes of juvenile Atlantic salmon in some rivers do not pose a threat to native populations.

These position shifts, adopted successively as the predecessor positions crumbled in the face of conflicting evidence, have left a large fraction of the public very uneasy about the assertion that the Atlantic salmon does not pose a danger to Pacific salmon species. One significant change between the time period in which deliberate introductions of Atlantic salmon failed, and the present, is a major downturn in the population status of Pacific salmonids, especially the rainbow trout.[14,19,22,45] Conditions may be far more favorable for colonization now than in the past.

Rainbow trout on Canada's East Coast

Rainbow trout were originally stocked to parts of Newfoundland in the late 1800s and early 1900s, and a small number of self-sustaining populations were established in the southeast of the Province. Most were freshwater resident, but a few had anadromous components to their life cycle.[33]

While Atlantic salmon culture dominates the east coast sea cage industry, rainbow trout are being or have been cultured primarily in the Bay d'Espoir region of Newfoundland and in the Bras d'Or lakes region of Nova Scotia. The relatively low salinity water conditions in these two areas favored the use of the brackish-tolerant rainbows. For a variety of reasons, the culture of rainbow trout in the Bras d'Or region failed, with the last fish being removed from their cages in September 2002.

There was concern right from the start of the industry about the possible impacts of escapes of rainbow trout upon native wild Atlantic salmon populations, especially if the species was to establish self-sustaining populations as it has so successfully done elsewhere.[23] In Newfoundland, rainbow trout were only observed in the areas where known introductions had occurred up until the mid 1970s, at which time the marine and estuarine culture of the species began. Subsequently, rainbow trout began to be captured in geographically dispersed areas, and at an increasing frequency.[33]

Newfoundland growers were for a time restricted to the use of sterile (triploid) rainbows. However, triploid fish have a number of deficiencies that at present make them poor performers in cage culture.[1] Growers were permitted to shift to all-female diploid rainbows on the grounds that with no males around, if the fish escape, reproduction in the wild could not occur. In addition, a sonic tracking experiment was conducted in the Bay d'Espoir region found that experimentally "escaped" rainbows remained in the vicinity of the cages for a period of months.[3] Thus there was a general sense that the risks posed to native salmonids by culturing rainbow trout in Newfoundland were minimal. By contrast, Nova Scotia permitted the use of diploid rainbows of both sexes.

Rainbow trout have escaped from cage sites in both regions, although the actual numbers are unknown. I have managed to compile reports of 401,000 rainbows getting loose in these regions since 1990. In a sure sign of trouble, in 1999 Canada's Department of Fisheries and Oceans implemented a year round, no bag limit, recreational fishery for the escaped rainbows in the Newfoundland cage culture region. And disturbing reports began to surface of the capture of rainbow trout far from the culture region in the Atlantic salmon rivers of Newfoundland's west coast.

The present (and at times very nasty) debate about aquaculture is really about reconciling the benefits and costs of the activity, on the way to the social license.

In response to the unease generated by these reports, Mullins and Porter[27] surveyed Trout River on Newfoundland's West Coast, and found rainbow trout ranging from 1.8 kg down to fry size, including mature individuals of both sexes. They concluded that the evidence "…suggests that rainbow trout have successfully reproduced in Trout River for several years and have established a small population.", and indicated that they were hearing reports of captures of rainbows by anglers in the mouths of other Newfoundland west coast rivers. While the source of the fish cannot be documented unequivocally, escaped farmed fish are the primary suspect. Mullins and Porter[27] speculated that the original colonists came from the Nova Scotia growing sites, because the all-female lines in use in Newfoundland would not have males available for mating. However, it is also plausible that escaped Newfoundland females could have met up on the province's west coast with either escaped males from Nova Scotia, or perhaps stray males from other areas where the species is now established and has access to the sea.

Mullins and Porter[27] stressed that the wild Atlantic salmon population in Trout River was depressed, which could have been a major factor favoring the colonization of rainbows.

The Policy Framework

Because of the impacts and costs of exotic species introductions, the issue is now receiving high-level policy attention in many countries. Indeed, Naylor et al.[30] concluded that the absence of strong policies in many countries to regulate the use of exotic species increased the risks posed by their culture.

International attention was focused on the issue of exotics by the signing of the Convention on Biological Diversity at the Rio de Janeiro Earth Summit in 1992. Among other things, the document committed signatories to the conservation of biodiversity, and to its sustainable use, The Convention specifically addresses introductions of exotic species. Article 8 (h) states:

Alien species *Each contracting party shall, as far* *as possible and as appropriate: (h) Prevent the introduction of, control or eradicate those alien species which threaten ecosystems, habitats or species;*[37]

Signatories to the Convention must implement programs in support of this article.

Many jurisdictions proceed with caution when considering permitting activities that could result in the introduction of an exotic species. For example, Maine's Aquaculture Strategy calls for the development of regulatory procedures that would control when and where exotics could be introduced.[25] These would follow the ICES Code of Practice for Introductions and Transfers of Biological Organisms.[15] Canada is presently updating its own code for Introductions and Transfers of Organisms. The codes, however, call for a risk assessment approach, but do not specify what levels of risk are acceptable and under what circumstances an introduction or an activity should not proceed.

Conservation organizations are also developing policy around the use of exotic species in aquaculture. The Atlantic Salmon Federation in 1999 adopted an aquaculture policy that contained the clause: *"ASF opposes the use of exotic species in culture facilities from which any escapees are probable and supports the use of local strains of native species."*

In a newly released Aquaculture Position Paper, the World Wildlife Fund[49] highlighted the risks posed by "the introduction of exotic fish and shellfish species that escape and compete with, infect, or prey on, native species..." and in one of 11 recommended best-practice methodologies stated: *"Exotic species and races should be farmed in closed systems where the potential for escapes can be largely eliminated."*

The significance of the policy of these non- governmental organizations (NGO's) lies in their willingness to take the issue to governments and the public at large to attempt to get government to adopt similar policy. Those who proceed with aquaculture practices that are in opposition to the positions will be subjected to intense scrutiny, and possibly criticism in the media. The negative attention is not good for business.

Conclusion and Recommendations

Canada's Aquaculture Commissioner, Mr. Yves Bastien, frequently speaks of aquaculture's quest for a "social license". Aquaculture has brought big social and economic benefits to Canada, but it has also brought environmental and social impacts. The present (and at times very nasty) debate about aquaculture is really about reconciling the benefits and costs of the

Bonnie Beney with a rainbow trout caught in the Magaguadavic River, New Brunswick, Canada

activity, on the way to the social license.

... the HAACP approach should make it possible to significantly and cost-effectively reduce escapement.

For the reasons I have outlined, exotic species introductions have become and will justifiably remain a major public concern, and there are additional worries that go beyond the relatively straight forward cases I have provided. For example, the use of foreign (European) strains of Atlantic salmon in New Brunswick's sea cage industry is presently prohibited to protect the genetic integrity of wild salmon stocks from farm escapees, but the industry remains interested in them, and the illegal presence of these strains has been detected in a New Brunswick river.[48] Pressure is also building to authorize the use of transgenic salmon in the Atlantic salmon farming industry. To many, transgenics are the "mother of all exotic species issues".

Proposed or actual uses of exotic species in aquaculture are going to be closely monitored, and resolution of the issues surrounding them will play a major part in determining whether or not aquaculture's social license is obtained. While avoiding the culture of exotics altogether is one solution, it is probably facile and naïve to assume this will happen in a dynamic global economy. However, there are a number of other steps that can be taken that will help restore public confidence, and aid the development of workable solutions.

First off, we need to be more humble in the face of the "best available science". The contrary-to-expectation, reciprocal discovery of exotic, spawning, escaped farm rainbow trout and Atlantic salmon on Canada's East and West Coasts respectively, suggest that the "best available science" used to make the decision to proceed may have been dated. Environmental conditions had changed in the period since the science was done. If this had been recognized from the start, and a series of monitoring programs and new mitigation studies put in place that proceeded in parallel with the authorization for the use of the exotics, then there would have been few if any nasty surprises. Government would not have been trapped tap-dancing its way through successive policy positions, with its public credibility declining with each new stance.

Cost-effective containment strategies also need to be developed. Genetic containment through the use of sterile individuals in aquaculture would allay many of the public concerns about growing exotic species. While triploidy seems the most promising method for the large-scale sterilization of fish, there are major technical problems that need to be worked out before it becomes commercially viable.[1] We are not at this time sufficiently supporting the research work necessary to resolve these problems, or to develop alternate methods of sterilization.

Physical containment can also be improved. In theory, a land-based culture facility should give growers the control necessary to reduce escapement to practically zero. However, the viability of land-based facilities will very much depend on the prices obtainable for the species being cultured. This suggests that the strategy for use of exotics in land-based systems would be to culture species that generate a high-price product. There are limited possibilities for this.

Containment can also be improved at existing sea cage sites. In a first-of-its-kind approach, Maine Atlantic salmon growers developed a Hazard Assessment Critical Control Point (HAACP) approach to minimizing escapees, in partnership with a number of non-governmental organizations (including the Atlantic Salmon Federation and Trout Unlimited). By identifying the most probable points for problems (escapes) to occur during a production cycle, and adopting a pre-emptive, preventative plan, the HAACP approach should make it possible to significantly and cost-effectively reduce escapement. The system is now being implemented broadly across the Maine industry.

We are still a long way from resolving the present concerns about the culture of exotic species in aquaculture. Their use will remain controversial until effective solutions are found.

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Abstracts of Contributed Papers and Posters

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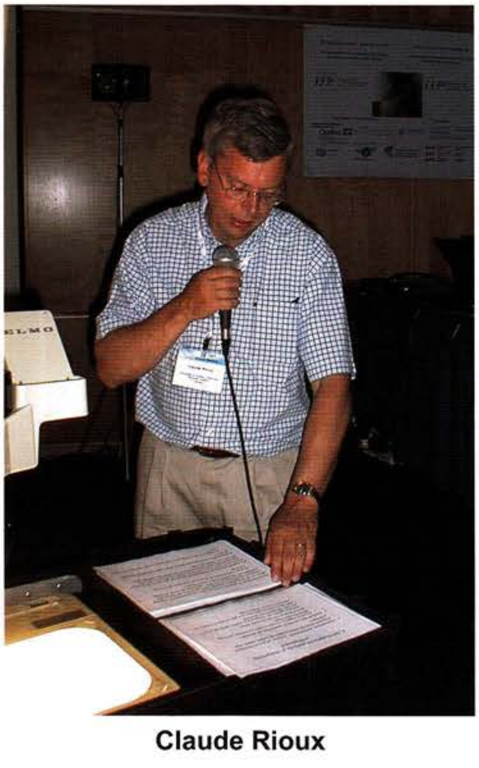
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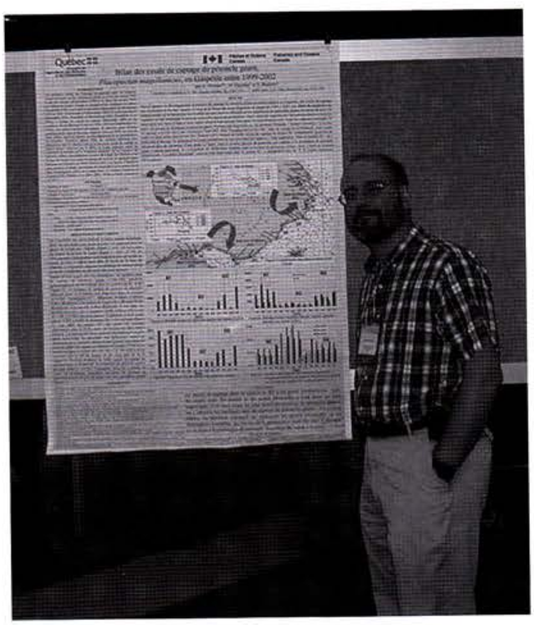
Section 3—Interaction between aquaculture and the environment



Benoit Thomas

Communauté de pêcheurs et aquaculture: Apprentissage mutuel et capital social dans une collectivité rurale côtière du détroit de Northumberland

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Les pêcheurs côtiers de la communauté de Botsford sont des pêcheurs polyvalents. La construction du Pont de la Confédération d'une longueur de 13 kilomètres qui relie les provinces du Nouveau-Brunswick et de l'Île du Prince-Édouard a affecté une partie de leur territoire de pêche. Ces derniers ont alors regroupé les ports de pêche les plus affectés autour d'un projet d'ensemencement de naissains du pétoncle puis dans un projet d'élevage et de croissance du pétoncle dans des cages. Des compensations de Ressources Humaines Canada jusqu'en 2001 ainsi qu'un prêt de l'APÉCA à compter de 2001 furent consentis afin de contribuer au projet. Pêches et Océans Canada a aussi fourni un appui scientifique au projet. Selon un questionnaire distribué auprès de 37 pêcheurs à l'hiver et au printemps 2002 et un groupe de discussion administré à l'automne 2002, ainsi que des entrevues auprès d'informateurs clés, tous reconnaissent avoir appris à divers niveaux tant sur la biologie du pétoncle, que sur le rôle des associations et des agences gouvernementales en terme de soutien aux organisations de pêcheurs. Nous voulons discuter ici tant des apprentissages individuels ou organisationnels que du capital social nécessaire à la mise en place et au fonctionnement de ce projet.

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Gestion et prévention des conflits d'usage en aquaculture marine

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Le développement de la mariculture se traduit par l'introduction d'un nouvel usage dans un milieu déjà utilisé. Il modifie les droits des acteurs déjà présents. Cette modification est susceptible de s'accompagner d'une nouvelle répartition de la richesse, ce qui peut être la source de conflit d'usage. Comme une partie non négligeable de la valeur créée par le milieu marin est non-marchande, cette valeur est souvent diffuse et implicite. Il devient difficile d'évaluer par des méthodes classiques la valeur des usages perdus ou diminués et, éventuellement, de les compenser. Il en découle la nécessité de trouver des nouvelles formes institutionnelles de gestion qui pourraient faire ressortir les valeurs d'usage en se fondant sur les droits affectés par l'aquaculture. L'objectif de cette communication sera de faire le lien entre la modification des droits d'usage, les valeurs d'usage affectées par cette modification et la gestion de ces changements. Quelques enseignements tirés de l'observation de la situation aux Îles-de- la-Madeleine ainsi qu'une revue de la littérature sur quelques cas européens permettent de mettre en évidence le besoin d'une approche basée sur la concertation et la gestion partagée afin de favoriser le développement de la mariculture.

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Développement d'un modèle d'étalonnage dans l'industrie québécoise de production de moules bleues

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Les marchés sont ouverts et aucune entreprise aquacole ne peut compter sur un marché «réservé». Dans le cas des moules bleues, par exemple, les détaillants québécois peuvent s'approvisionner auprès des entrepreneurs des Maritimes. La possibilité pour les entreprises maricoles de se comparer aux entreprises de leur secteur constitue une activité importante en vue de concurrencer les meilleures firmes sur le marché. Les entreprises les plus performantes sur le plan des coûts de production, de la gestion technologie et du management financier pourront se maintenir sur le marché. Un modèle d'étalonnage dans l'élevage des moules bleues peut être un outil utile. L'étalonnage peut se faire sur plusieurs dimensions de l'entreprise. Compte tenu de la taille des entreprises et du niveau de développement du secteur mytilicole, le modèle développé se concentre sur deux fonctions principales : le processus technique et la fonction financière. Le système d'indicateurs doit répondre à plusieurs caractéristiques. Parmi celles-ci, la pertinence, la simplicité, la qualité de l'information et la précision sont les plus importantes. Des indicateurs techniques et financiers ont été élaborés à partir de la littérature et raffinés avec la participation des producteurs québécois. Les données des producteurs ont été structurées dans une base de données qui permet de faire des calculs de ratios techniques et financiers. Plus d'une quarantaine d'indicateurs peuvent être calculés. L'information obtenue permet de comparer les entreprises entre elles, de suivre l'évolution dans le temps, de comparer une firme spécifique avec la moyenne du secteur ou encore avec la plus performante. Les indicateurs montrent que la production québécoise doit déployer des efforts importants pour améliorer sa rentabilité. Le développement ultérieur de l'outil permettra d'intégrer des producteurs d'autres régions du monde.

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Une approche intégrée pour la sélection des zones propices au développement d'élevages de poissons en cage marine dans la baie de Gaspé : prise en considération des aspects environnementaux, techniques et sociaux

Eric Tamigneaux, Karen Lord, Marie-Lyne Larrivée, Giovanni Castro et Laurent Millot[1]

Même si de nombreuses piscicultures terrestres produisent des salmonidés, il n'existe aucune ferme d'élevage de poissons en mer au Québec. En 1999, les organismes gouvernementaux en charge du développement de l'aquaculture ont lancé un programme expérimental d'élevage d'omble de fontaine en cage marine dans la baie de Gaspé. Le programme est destiné à vérifier (1) s'il est possible de mettre au point des ancrages et des

cages capables de résister aux conditions de mer de la baie, (2) s'il est possible de contrôler ou de minimiser les impacts de ce type d'élevage sur l'environnement, (3) si ce type d'élevage est rentable, et (4) s'il peut se faire dans le respect des autres usagers de la zone côtière. L'étude des conditions océanographiques de la baie, une modélisation des courants et des vagues, un portrait de la biochimie des sédiments et de la faune benthique, l'identification des pathogènes des salmonidés sauvages, des consultations avec les groupes de pêcheurs et des activités de communication avec le public ont précédé l'installation de la cage expérimentale. Le programme a su profiter de l'analyse des bonnes et mauvaises expériences vécues ailleurs pour adopter une approche précautionneuse qui permettra un développement prudent et responsable de l'aquaculture marine.

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Faisabilité technico-économique de la dépuration de myes *(Mya arenaria)* en milieu naturel, Québec, Canada

Laurent Girault, Karine Berger, Jean-Claude Hallé et Marie-Lyne Larrivée[1]

Ce projet a été mené pour permettre l'exploitation des bancs coquilliers du sud de la Gaspésie contaminés par les coliformes fécaux. Des myes ont été cueillies dans le barachois de Port-Daniel et immergées dans un site maricole. Des échantillons de myes ont été prélevés régulièrement (Jours 0-14) pour dénombrer les coliformes présents dans la chair et pour tester l'efficacité de différents contenants de dépuration placés à 5 et 10 mètres de profondeur. Une décontamination rapide a été observée dans toutes les conditions testées. Le choix définitif d'un contenant et d'une profondeur dépendra néanmoins de la durée de reparcage retenue. La faible mortalité des myes (3%) est un résultat encourageant, mais la baisse du rendement en chair rend préférable un reparcage de courte durée (= 6 jours). D'après l'analyse économique, cette durée de reparcage serait rentable pour un mariculteur qui possède déjà l'équipement et les infrastructures de base. Ce projet aura permis à l'ACIA de réviser ses exigences quant à la validation d'un protocole de reparcage de courte durée : le mariculteur aura toujours l'obligation de faire la preuve de l'efficacité de la dépuration sur des organismes fortement contaminés (20 lots > 230 c.f./100 g). Cependant, cette démonstration pourra désormais être réalisée pendant la commercialisation du produit.

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L'aquaculture et les technologies d'enseignement à distance : comment utiliser l'Internet et les systèmes de vidéoconférence pour répondre adéquatement aux besoins de formation de l'industrie maricole dans les régions éloignées

Eric Tamigneaux,[1]*Marie-Hélène Fournier,*[1] *Renée McInnis,*[1]
Jacynthe Marquis,[1]*Eric Dea*[1] *et Guy-Pascal Weiner* [2]

Avec leur économie axée sur l'exploitation des ressources marines, une population relativement dispersée et un faible taux de scolarisation, le profil des régions maritimes de l'Est du Canada reste un peu à part. Malgré la demande croissante pour une main-d'œuvre toujours mieux formée, les programmes de formation et de perfectionnement professionnel sont souvent peu variés et difficiles d'accès. À cela s'ajoute un exode accéléré des jeunes générations vers les centres urbains. Tout ceci constitue parfois un obstacle au développement des entreprises axées sur des technologies non conventionnelles, comme c'est le cas de la mariculture. La formation à distance et les nouvelles technologies de la communication peuvent contribuer à résoudre ces difficultés en livrant « à domicile » une formation très spécialisée s'appuyant sur les ressources offertes par la vidéoconférence et par l'Internet. Cependant, pour que cette approche soit un succès, il est nécessaire d'adapter à la fois les méthodes et le contenu de l'enseignement aux particularités de la clientèle des régions éloignées et aux besoins réels de l'industrie aquicole. Pour relever le défi jusqu'au bout, il faudra apporter des solutions innovatrices axées sur l'acquisition équilibrée de compétences théoriques aussi bien que pratiques.

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SECTION 2: TECHNOLOGY AND CHALLENGES TO AQUACULTURE DEVELOPMENT IN COLD CLIMATES

Approach to the selection of species for the diversification of mariculture in Quebec: Comparison of methods

N. R. Le François [1]

Concerns about the overexploitation of wild aquatic resources, the slow recovery of fisheries and the need to encourage the diversification of the mariculture industry of the province of Quebec (Canada) provide a strong incentive to determine the potential of a wide selection of marine and anadromous fish and marine invertebrates for cold-water mariculture. The method we developed for species selection has three approaches. The first selection method is qualified as integrative. Starting from a list of 47 species that potentially are of commercial interest, a biotechnical review is conducted. Technical sheets for each species are produced and selection criteria developed for the three approaches to aquaculture development (complete production cycle (egg to egg), on-growing, and stock enhancement). Species are ranked according to their degree of suitability for the given biological parameters. This comparative approach provides a valuable tool to assess the potential of a species for aquaculture and should be done prior to efforts to domesticate the species. The second selection method used is more systematic and includes the comparison of a large-number of species for which there is little information on their culture potential. The third selection method is market-oriented and is conducted on a small-number of species for which there was a lack of economic information. We recommend that the sequence of analyses be in this order: 1) systematic 2) integrative and 3) market oriented. The presentation ended with a discussion of S.W.O.T. analysis, a useful tool for the evaluation of R&D or eco-

nomical progress. Technical and financial risk assessment analysis can benefit from the comparative approach and the information gathered during the analyses.

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Biomolecule extraction within an aquaculture production cycle: Possibilities of stabilization and/or increase of benefits

N. R. Le François [1] et P. U. Blier [2]

The profit margins of most commercial aquaculture operations based exclusively on flesh production are highly vulnerable to fluctuations in market prices and feed, labour and/or energy costs. These factors can reasonably be considered as obstacles to the sustained emergence of cold-water mariculture initiatives in Québec. Furthermore, under our climate, profit margins are generally small due to environmental constraints such as temperature (extensive ice-coverage, longer production cycles). The extraction of high-value biomolecules within an aquaculture production cycle, and their commercialization, could stabilize and potentially increase financial returns and stimulate the growth of this promising economic sector (marine resources-mariculture-biotechnologies).

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Biological adaptations to cold water: Negative or positive traits for aquaculture?

Céline Audet [1] and Yvan Lambert [2]

Hardy species, that are well adapted to natural cold water conditions, have been considered for diversification of aquaculture in cold water areas. These species have developed different types of physiological adaptations that allow them to survive, grow, and reproduce in harsh environments. Even though such traits increase fitness under natural environmental conditions, they could be undesirable for aquaculture production. Our studies on juvenile winter flounder from natural populations of the St. Lawrence estuary offer a good example of how specific adaptations to the environment must be understood and modulated if specific strains are to be used for aquaculture production. In this case, feral juveniles captured from the field and raised under natural environmental conditions naturally stop eating in mid-November and fast until March. Increased temperature or photoperiod did not inhibit the winter fast and dramatically decreased fish condition before feeding resumed at the end of winter. These results raise a number of questions, including: Is this trait inherited? Is it specific to the strain or does it result from the exposure to specific environmental conditions in early stages? Will it be observed in juveniles produced in aquaculture hatcheries? All these questions have to be addressed, whether juvenile production is oriented toward food production or toward enhancement of wild populations.

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Résultats des ensemencements de pétoncles géants juvéniles réalisés en 1996 et 1998 au large des Îles-de-la-Madeleine (Québec, Canada)

D. Hébert,[1] M. Nadeau,[2] S. Vigneau[1] et M. Giguère[3]

À l'automne 1996 et au printemps 1998, un total de 6,4 millions de pétoncles juvéniles a été ensemencé au large des Îles-de-la-Madeleine sur deux sites distincts. Des pétoncles marqués ont été mélangés à travers les semences afin d'estimer les taux de retour au moment de la pêche. En 2001 et 2002, une vingtaine de pétoncliers ont pêché un total de 38 t de muscles sur les deux sites. Bien que les sites ensemencés aient été pêchés intensivement, très peu de pétoncles marqués ont été retrouvés. Ces derniers ont toutefois été récupérés sur les zones ensemencées, suggérant une dispersion limitée des pétoncles d'élevage. D'autres sources d'informations permettent de déduire que les pétoncles ensemencés occuperaient une plus grande proportion dans les débarquements que ce qu'indiquent le taux de recapture des pétoncles marqués. Plusieurs scénarios de calculs, basés sur la structure de taille des pétoncles débarqués ont été analysés. Les taux de retour estimés à partir de ces scénarios varient de 4% à 16 %. Bien qu'imprécis, ces résultats sont encourageants, compte-tenu des faibles quantités de pétoncles ensemencés. Les taux de survie sur le fond sont également difficiles à évaluer étant donné l'imprécision des méthodes d'évaluation du taux d'exploitation. L'identification de méthodes permettant d'évaluer les taux de retour et d'exploitation plus précises est nécessaire.

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Comparaison de cinq techniques d'élevage de pétoncles géants (*Placopecten magellanicus*), dans la baie de Gaspé, Québec, Canada

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Des pétoncles juvéniles ont été importés des Îles-de-la-Madeleine, en juin et en octobre 2001. Ils ont été immergés en baie de Gaspé dans cinq types de dispositifs : paniers pyramidaux, boucles d'oreilles, cages Savoury, lanternes Wang-Joncas, tables à huîtres. Les taux de croissance, les mortalités et plusieurs variables environnementales seront suivis pour chaque profondeur, chaque dispositif et chaque saison de transfert, jusqu'en 2004. Des analyses biochimiques compléteront les mesures de terrain.

Les mortalités sont élevées chez les pétoncles transférés au printemps. Ces pertes sont majoritairement attribuables aux stress combinés du transfert et de la ponte. Les mortalités étaient plus proches des valeurs normales après le transfert d'automne. Les taux de

croissance sont comparables à ceux observés ailleurs au Québec. Ils sont similaires pour les boucles d'oreilles, les paniers pyramidaux et les cages Savoury, mais ils sont inférieurs pour les tables à huîtres et les lanternes Wang-Joncas. L'effet de la profondeur est plus marqué sur le rendement en chair, qui est meilleur en surface, que sur le taux de croissance.

Le havre de Gaspé présentant d'importantes variations inter-annuelles des paramètres environnementaux, les suivis ultérieurs seront utiles pour préciser les conditions de régime moyen et les conditions extrêmes afin d'optimiser la stratégie d'élevage en conséquence.

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Le taux de récupération de pétoncles géants après un an de grossissement sur les capteurs est-il associé à la grandeur de maille des sacs et au substrat utilisé pour la fabrication du capteur?

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Des ensemencements commerciaux de pétoncles géants (*Placopecten magellanicus*) sont réalisés aux Îles-de-la-Madeleine (Québec, Canada) depuis 2000. Les pétoncles utilisés pour ces ensemencements sont captés en milieu naturel et laissés en grossissement dans les capteurs sur les sites de captage pendant un an. Durant l'année de grossissement sur les capteurs, les pertes de pétoncles sont importantes et peuvent être supérieures à 70% du nombre capté. Deux séries d'essais ont été réalisées en 2001 afin de vérifier si la grandeur de maille des sacs et le type de substrat utilisé pour la fabrication des capteurs pouvaient réduire ces pertes. Chaque essai comparait différentes combinaisons de sacs et de substrat. L'évaluation de la performance du capteur se faisait principalement en fonction du nombre de pétoncles vivants récupérés après 1 an. L'analyse préliminaire des résultats indique que les taux de récupération varient entre 11,1% et 36,5% dépendant de la grandeur des mailles des sacs utilisés. Le meilleur taux étant obtenu avec des sacs dont la maille à 2 mm. La deuxième série d'essais indique que le substrat rigide semble donner de meilleurs résultats avec un taux de récupération de 24,1% comparé à 12,7% pour le substrat souple.

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Élevage de moules en mer aux Îles-de-la-Madeleine: défis, contraintes et avantages

François Bourque et Bruno Myrand[1]

Aux Iles-de-la-Madeleine, la mytiliculture est pratiquée dans des lagunes qui fournissent des sites abrités des vents et recouverts d'un épais couvert de glace stable en hiver. La production actuelle est d'environ 300 tonnes par an. Il ne reste plus d'espace disponible pour une expansion de l'industrie. Le développement futur devra passer par l'élevage en milieu ouvert qui offre des conditions bien différentes : sites peu abrités situés à distance des côtes et présence de glaces dérivantes. Ainsi, la présence des banquises de glace nécessite que les structures d'élevage n'approchent pas à plus de 12 m de la surface. L'élevage en mer devrait aussi permettre d'obtenir des moules de qualité supérieure toute l'année en raison d'une ponte limitée. Un projet a été initié en 2002 pour déterminer les paramètres de production en milieu ouvert aux Îles. Le site expérimental a une profondeur de 19 m et est localisé à un endroit permettant de minimiser les conflits d'usage. Les compositions faunique et géochimique initiales du site ont été établies afin de documenter si cette activité avait éventuellement des impacts. Les premiers résultats de croissance sont comparables à ceux obtenus en lagune. Le captage de naissain a été observé sur toute la colonne d'eau. Le projet se poursuivra jusqu'en 2006.

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Optimization of seawater adaptability of triploid 0^+ brook charr *(Salvelinus fontinalis)* using experimental diets prior to transfer to estuarine conditions

Simon Lamarre[1] *et Nathalie R. Le François*[2]

Ice coverage in our northern climate severely challenges the utilization of sea cages for year-round fish production. One solution to this problem is to stock fish in cages in the early spring and harvest them at a commercial size in late fall, avoiding winter ice conditions and low temperatures. However, direct transfer of brook charr to seawater results in high mortality if the fish are triploids and weigh less than 50 g. We propose that the use of experimental osmo-enhancer feeds one month prior to direct transfer to seawater may optimise fish survival after transfer. Three experimental moist feeds were produced that contained 1) 3% betaine, 2) 10% NaCl, or 3) 3% betaine and 10% NaCl. These feeds were tested against a control moist feed that was not supplemented. Fish given the three experimental feeds had significantly improved survival compared to the control fish (85% vs 70% survival for experimental and control groups, respectively). No alterations in growth or condition index (K) were observed among treatments. Compared to the control group, gill Na^+K^+ATPase activity on transfer day was improved by 1.41 times by betain and 1.93 and 1.94 times by NaCl and betaine + NaCl, respectively. Ion balance, osmolarity and cortisol analysis of blood plasma reinforce the assumption that the effects of feed supplements on Na^+K^+ATPase activity are responsible for the improved performance of experimental groups. The possibility that the use of these feeds prolongs the "window of introduction" for this species should be evaluated in the near future.

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Enrichment experiments during first feeding of winter flounder larvae (*Pseudopleuronectes americanus*): Lipid and fatty acid composition

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We compared different rotifer enrichments that varied in terms of protein and lipid contents as well as in their DHA:EPA ratio to see how they could influence growth and development of winter flounder larvae. Rotifers (*Brachionus plicatilis*) were used at first feeding, i.e. from mouth opening until larvae reached a length of 5.5 mm. At 5.5 mm, larvae were fed brine shrimp (*Artemia salina*) and a miroencap- sulated diet until metamorphosis. A detailed analysis of lipid and fatty acid composition was done both on food (enriched rotifers) and winter flounder larvae. Lipid classes, TAG:ST and DHA:EPA ratios are used as biological indicators of larval condition.

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Répartition des pathogènes de différentes population naturelles de moules du Québec

Sonia Belvin,[1] Benoît Thomas,[2] et Sharon McGladdery[3]

Afin d'éviter ou de restreindre la prolifération des maladies chez les populations québécoises de moules, il est primordiale d'avoir une connaissance approfondie de l'état de santé des populations. Cette étude a permis d'élaborer le profil de distribution des pathogènes dans trois régions maritimes du Québec, soit la Gaspésie, la Côte-Nord et les Îles-de-la-Madeleine. Le cilié *Ancistrum mytili* est le plus fréquemment rencontrés avec des prévalences de 21,7 à 35,8%. Tous les pathogènes recensés entre 1999 et 2001, au printemps et à l'automne, sont communs à l'Atlantique canadien et n'ont été associés à aucun épisode de mortalité massive dans les eaux marines de l'est du pays. Par contre, en raison des variations spatiales et temporelles, il est recommandé de faire le suivi de santé annuel des populations exploitées ainsi qu'un examen histopathologique pour chaque population concernée préalablement à des opérations de transfert.

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Antifreeze protein synthesis in two wolffish species (*Anarhichas lupus* and *A. Minor*): Production pattern and applications

Mariève Desjardins,[1] *Nathalie R. Le François,*[1,2] *Garth L. Fletcher*[3] *and Pierre U. Blier*[1]

Atlantic and spotted wolffish (*Anarhichas lupus* and *A. minor*) are marine fish species identified as being good candidates for the diversification of Québec's mariculture industry. The Atlantic wolffish produces antifreeze proteins (AFP) to protect itself from the seasonal threat of freezing in shallow coastal regions. AFP have a high market value that could translate to added income for a mariculture operation. The production pattern of AFP in these species has been documented. To evaluate the potential of extracting such high-value biomolecules from wolffish, plasmatic AFP antifreeze activities (freezing point depression) and concentrations have been evaluated monthly on groups of fish held at two experimental temperature regimes: normal seasonal or fixed at 10°C. The results show that the Atlantic wolffish is a good year-round producer of AFP, whereas the spotted wolffish does not produce plasmatic AFP. Season (temperature and photoperiod) has a clear effect on the parameters studied, with winter values being much higher than those at other times of the year. AFP production seems to increase with fish size (comparison was done between adults and juveniles). Individual annual profiles of AFP production showed intra-species variability, potentially leading to genetic selection for this desirable trait.

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SECTION 3: INTERACTION BETWEEN AQUACULTURE AND THE ENVIRONMENT

Sterile (triploid) salmon: Addressing the interactions of cultured and wild fish

Tillmann J. Benfey, Stephanie Ratelle and Robyn A. O'Keefe[1]

The escape of exotic and/or domesticated fish and their subsequent interactions with wild populations is an issue of concern often raised with the Canadian salmon farming industry. Such potential interactions can be genetic, through interbreeding, or ecological, through displacement. Genetic interactions can be eliminated through the use of female triploid fish, which are functionally sterile and easily produced. However, very little is known about the behaviour of such fish, should they escape into the wild. We first examined this question with tank experiments, and found that triploid salmon parr do not differ from dip-

loids in their feeding response (number of pellets consumed and weight gain) when reared either separated by ploidy or in competition. We then examined the interactions between triploid and diploid salmon parr in semi-natural rearing channels and again found no difference between ploidies in either growth or displacement. This suggests that the ecological impacts of juvenile farmed salmon on wild populations will not be affected by ploidy.

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Influence of phytase addition to plant protein-based diets to rainbow trout

G. W. Vandenberg, S. L. Scott, V. Dallaire et J. de la Nöue[1]

Digestibility and feeding studies were performed to investigate the effects of adding phytase to a plant protein-based diet fed to rainbow trout. Plant protein-based diets were formulated to be isonitrogenous, isolipidic and isoenergetic to a high nutrient-dense, control diet. To the basal plant protein diet was added 3000 FTU phytase$\cdot$kg^{-1} phytase. An additional control group included the addition of monosodium phosphate to the plant protein diet to NRC requirements. For the digestibility studies, each diet was fed to triplicate groups of fish. For the feeding study, the above diets were fed to triplicate tanks of rainbow trout for 56 days.

The fish meal control diet had a higher ($P<0.05$) ADC for a number of macro and micronutrients and promoted higher growth rate, feed efficiency, and tissue ash and P versus the plant protein-based diet. However supplementation of plant protein-based diet with microbial phytase significantly improved the ADC's of energy, protein, ash, P and a number of macro- and micro-minerals. Fish growth, feed efficiency as well as retention of P and N were also significantly increased ($P<0.05$) with microbial phytase. Microbial phytase can increase the digestibility and bioavailability nutrients from plant protein-based diets, resulting in increased growth performance and reduced P excretion.

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Treatment of fish farm effluent using constructed wetlands and steel slag

A. Boumecied, M. Kharoune, Y. Comeau, and Y. Boulanger[1]

A pilot system to treat sludge silo supernatant has been installed at a fish farm in St. Damien, Quebec. It became operational in May 2003. The supernatant is easy to intercept and although the volume is low, it can contain a significant portion of total solids, phosphates, ammonia and oxygen demand. Treating the supernatant should improve the overall quality of the fish farm effluent. The system consists of two series of horizontal subsurface flow constructed wetlands followed by beds of electric-arc-furnace (EAF) steel slag. The wetlands contain an aerated section for enhanced degradation of organic matter and nitrification, and the EAF slag has been shown to effectively retain inorganic phosphates. Bench scale tests with a sludge-based simulated supernatant show that similar aerated wetlands have the potential for up to 95% reduction in COD and suspended solids, with 0.5 mg NH_4-N/ L in the effluent. Column tests with EAF steel slag have produced effluent phosphate concentrations of less than 0.1 mg PO_4-P/L. Different loading rates and modes of operation will be tested, as well as the effects of field conditions such as weather. Ease of operation and integration into the fish farm will be considered.

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Effect of population size structure in stocking experiments of bivalves

M. Fréchette,[1] *J.-F. Dumais*[2] *et M. Alunno-Bruscia*[3]

Stocking experiments imply deliberate choices about initial population density within treatment levels, but also about initial population size structure within treatments. Experimental individuals are either chosen randomly among available spat or selected on the basis of size. The effect of either case on stocking experiments is unknown. We addressed the issue by modelling a mussel stocking experiment with high and low variance in initial size of individuals. With low variance in size, density-dependent yield was lower than with high variance in size and there was no mortality. Thus stocking experiments may yield biased estimates with respect to actual commercial culture situations if initial size structure in experiments is different from that used in commercial culture. We reviewed all bivalve experiments published in Volumes 1 through 207 of *Aquaculture*. We found that less than 50% of papers reported appropriate information about size structure. Less than 25% of experiments used size structures similar to those in commercial culture. Therefore the importance of population size structure has been overlooked in many cases and a large proportion of stocking experiments may have reported biased appreciation of density-dependent patterns because of the use of inappropriate initial size structure.

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Hydrodynamic studies for finfish aquaculture developments in Baie de Gaspé

Vladimir Koutitonsky[1]

Site selection for fish farms in inshore areas requires a detailed knowledge of ambient hydrodynamic conditions. On one hand, flushing by strong currents will mitigate the impacts of organic loads on benthic ecosystems, while on the other hand, strong currents may cause mechanical damage to the fish cages, introducing a new fish species into the environment. This study reports on a circulation experiment undertaken in Baie de Gaspé, Gulf of St. Lawrence whose objective was to suggest an appropriate site to locate cages for the development of brook charr aquaculture. Stratification, tides, winds and currents are described and a 3-D circulation model is used to examine currents in the bay. The dispersion of a dissolved substance (organic matter) injected at several sites in the bay is then examined using a 3-D advection-dispersion model. Results point to a region where organic matter from the cages will disperse towards the Gulf. This would occur under predominant winds. A wave refraction model is used to compute orbital wave velocities and results from all models are eventually combined to select an appropriate region for the fish cages.

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Using a box model to predict the growth of cultured mussels as a function of mussel density and lease size

C. Bacher,[1] S. Robert,[2] P. Garen,[1] S. Bougrier[1] and E. Pallas[1]

Longline culture is expanding in Pertuis Breton (France) as an alternative way of rearing mussel *Mytilus edulis* compared to the traditional 'bouchot' method. We combined an ecophysiology model of *M. edulis* and a box model in order to simulate the growth of mussels reared in longlines and the appropriate size and mussel density for the cultivated area. We computed food transport in the longline area using outputs from a hydrodynamical model. Simulations were carried out for different mussel densities and lease sizes to assess their effects on mussel growth. The model demonstrated that actual mussel density and lease size had a minor impact on flows of particulate organic matter and phytoplankon and would not decrease food concentration in other cultivated areas. If lease size and mussel density were increased, they would have a minor effect on mussel growth, which shows the potential of the longlines technique in Pertuis Breton. Based on our simulations, a three-fold multiplication of either mussel density or lease size would therefore be a conservative recommendation for managers willing to increase mussel production without having deleterious effect on growth.

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Evaluation of ozone for improving water quality and increasing market value of fish in recirculating aquaculture systems

Kelley Baltzer,[1] Graham Gagnon[2] and Peter Tyedmers[1]

Ozone (O_3) is a powerful oxidant and is becoming popular in various aquaculture systems for disinfection and improving water quality by oxidation of inorganic and/or organic compounds. However, the use of ozone in marine-based aquaculture systems has been limited because of the lack of quantitative as well as qualitative design and performance information on O_3 for recirculating systems. This study investigated the application of ozonation to enhance process water quality in a land-based, recirculating Atlantic halibut aquaculture facility. A field-scale monitoring program was conducted to compare and examine the water quality for two full-scale modules that incorporated ozone into their design and one control module. The results showed a reduction of 15% total organic carbon (TOC) could be achieved for the modules with ozone generators installed. In addition, very favourable results were observed for the removal of nitrate, colour and suspended solids in

recirculation systems using ozone, as compared to those that did not use ozone. The reduction in colour and organic material should improve the overall health as well as the value of the halibut. It is therefore expected that the marginal costs per kilogram of marketable fish would be less than the marginal benefits that result from improved fish quality.

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Impacts of clam *(Mya arenaria)* harvesting with an hydraulic rake in Îles-de-la-Madeleine, Canada

Lise Chevarie,[1] Bruno Myrand,[2] Lizon Provencher[3] et Philippe Archambault[3]

A important natural bed of clams *(Mya arenaria)* with a population estimated to be 265 million (≥ 14 mm) is located in Havre-aux-Basques lagoon in Îles-de-la-Madeleine. A local producer needed a reliable source of clams and wanted to supply his needs from this site. An hydraulic rake is used for harvesting. However, before Fisheries and Oceans Canada will issue a license, they require that an impact study be conducted to demonstrate the hydraulic rake will not be destructive to benthic species. The impacts of spring, summer and fall clam harvests were studied over a 14-month period. Two harvest methods were studied: complete harvesting and strip harvesting. The impacts were minimal. After harvesting, no significant difference was found in the size of the population and no species was threatened. Even the small diminution of clams from harvesting was imperceptible over a 2-month period.

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Bilan des essais de captage du pétoncle géant, *Placopecten magellanicus,* en Gaspésie entre 1999-2002

B. Thomas,[1] M. Giguère[2] et S. Brulotte[2]

Des essais de captage de pétoncles géants ont été réalisés en milieu naturel à 14 sites répartis le long de la Péninsule entre Miguasha et Gaspé de 1999 à 2001. Au début de septembre de chaque année, quelques semaines après la ponte, quatre (4) séries de trois (3) capteurs ont été immergées à environ seize (16) mètres de profondeur à chacun des 14 sites. Deux séries de capteurs ont été relevées environ trois (3) mois après leur mise à l'eau et deux autres séries à l'été suivant; soit après 10 mois d'immersion. Seuls les capteurs immergés 10 mois ont permis de distinguer le pétoncle géant, *Placopecten magellanicus*, du pétoncle d'Islande, *Chlamys islandica*. Le succès de captage a été très élevé aux extrémités Ouest (BT: Baie Tracadigache) et Est (BG: Baie de Gaspé) de la Péninsule, mais faible entre ces deux pôles dans la baie des Chaleurs (BC). Malgré un faible succès de captage, le secteur BC pourrait comporter de bons sites d'élevage; la croissance moyenne journalière du naissain dans les capteurs y étant supérieure à celle des autres sites. Dans le secteur BT, le nombre moyen de pétoncles par capteur et la proportion de pétoncle géant ont été supérieurs, mais les variations annuelles y ont été plus grandes. Des différences notables entre le nombre de pétoncles ont été observées après 3 mois et 10 mois d'immersion. Ces différences s'expliqueraient par des pertes hivernales de naissain de plus de 75 % dans le secteur BT par rapport à environ 20 % dans les autres secteurs.

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Premiere in Canada: Deep-Layer Purification of Blue Mussels from the Baie de Gaspé

M-H. Deschamps [1] et M. Roussy [2]

The Baie de Gaspé has great potential for mussel culture but its growing waters are slightly contaminated by residential wastewater even though there is a sanitation plant. Therefore, the Canadian Shellfish Sanitation Program (CSSP) only allows harvesting of shellfish that will undergo a controlled purification treatment. Unfortunately, no commercial mussel depuration facilities exist in Canada. Following a technology-transfer tour organized with mollusc specialists in the United Kingdom (UK), we have adapted and tested the bulk bin depuration system for mussels developed in the UK and approved by the Food Standard Agency. Its operation simply involves depurating mussels in deep water using standard insulated tanks. We tested the system using mussels 65-cm thick. Water flowing at a rate of 10.56 L h^{-1} kg^{-1} was required to maintain minimal dissolved oxygen levels for temperatures ranging between 3° and 15 °C. Oxygen consumption increased exponentially with water temperatures. Mussel filtering activity was easily visible. Survival rates were nearly 100 %. These results satisfied the CSSP specifications. On this basis, the implementation of a pilot depuration plant in autumn 2002 has been authorized. For the first time in Canada, 30 000 kg of depurated mussel has been sold on the market.

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Working toward sustainable freshwater aquaculture in Ontario

N. Ali,[1] Cal Wenghofer,[2]
and other members of the Ontario Sustainable Aquaculture Working Group [3]

In July 1999 Environment Canada's Ontario Region initiated an industry-government-academia working group (co-chaired by Fisheries and Oceans Ontario- Great Lakes Area (DFO-OGLA)) to examine and develop scientifically-based approaches for environmentally sustainable freshwater aquaculture in Ontario. Over the last three years the group supported several projects geared towards development and testing of approaches for

preserving water quality and fish habitat in the vicinity of aquaculture operations. In addition to the specific projects supported by the group, members feel that the group provides a forum for useful discussion among industry, academia and government on aquaculture issues. To date, most of the projects have involved cage aquaculture operations. The poster provided progress reports on four of the projects supported to date. These are: Fish Manure Collector, Low Pollution Feed Development, Development of Practical Monitoring Techniques for Cage Aquaculture, and Experimental Fallowing Procedure.

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3. Names and affiliations of other members: MTM Aqua- culture (Mike Meeker), Aqua Cage Fisheries (Gordon Cole), Cold Water Fisheries (Tom Horne), Moose Mountain Fisheries (Gary Saville), North Wind Fisheries (Dan Glofcheskie), Ontario Aquaculture Association (Jim Taylor), Ontario Ministries of Natural Resources (Mark Muschett), Agriculture (Steve Naylor), and Environment (Mary Thorburn), University of Guelph (Richard Moccia), and Office of the Commissioner for Aquaculture Development (Eric Gilbert).

Validation d'indicateurs biologiques permettant d'évaluer la qualité nutritionnelle des sites d'élevage de la moule bleue

Simon Cartier,[1] *Jocelyne Pellerin,*[1] *Éric Tamigneaux,*[2]
Laurent Girault[2] *et Michel Fournier*[3]

L'hépatopancréas des moules prend rapidement du poids au printemps, lorsque la nourriture est abondante. Si cette relation, confirmée par des tests en microcosmes, pouvait être quantifiée, la mesure de la croissance annuelle de cet organe constituerait un indicateur biologique simple, rapide et peu onéreux, permettant d'évaluer directement le potentiel mytilicole et la capacité de support d'un site, en termes de performance nutritionnelle des moules et de prévision de leur croissance commerciale.

Afin d'établir cette relation, en fonction des caractéristiques environnementales du milieu, nous avons transféré en mai 2002 des moules juvéniles depuis Gaspé vers Gaspé (témoins) et trois autres sites présentant des conditions environnementales variées. Les moules transférées et du naissain indigène ont été échantillonnés aux deux semaines, de mai à novembre, pour mesurer les paramètres suivants : taille et poids des moules et des organes (hépatopancréas, gonade, manteau); réserves énergétiques (lipides, glycogène, protéines); maturation sexuelle; capacité immunitaire. La température de l'eau et les concentrations en phytoplancton étaient suivies sur chaque site.

Les résultats de 2002, ont démontré une influence importante du cycle reproducteur sur l'indice hépato-somatique et sur l'activité phagocytaire des hémocytes masquant ainsi l'effet des paramètres environnementaux.

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Évaluation des capacités et des conditions d'enlèvement continu du phosphore dissous par les scories d'aciéries

C. Lospied, M. Kharoune, R. Chapuis et Y. Comeau[1]

Dans le cadre de nos travaux de recherche sur le développement d'un procédé de déphosphatation des effluents piscicoles qui soit efficace et économique pour l'industrie piscicole québécoise, il a été démontré que les scories d'aciéries présentaient un fort potentiel d'enlèvement du phosphore. L'objectif principal de cette étude est d'évaluer la capacité de déphosphatation des scories d'aciéries de type "haut fourneau" (HF) et de type "four à arc électrique" (F'). Des essais en colonnes alimentées en continu ont été réalisés durant 450 jours avec un effluent artificiel contenant du KH_2PO_4. Les résultats indiquent que la capacité de déphosphatation est fonction de la concentration en phosphore de l'affluent et du type de scories testé. Les scories F' sont plus efficaces que les scories HF et ce, quelle que soit la concentration en phosphore utilisée. Les capacités optimales de déphosphatation des scories F' et HF sont respectivement de 6,5 et de 2,5 mg P/g de scories, respectivement. Durant la période d'expérimentation et dans toutes les conditions testées, il n'y a eu aucun relargage de métaux lourds. Ces résultats montrent clairement que les scories d'aciéries de type F' et HF présentent un fort potentiel d'utilisation comme matériaux de déphosphatation des effluents piscicoles.

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Evaluation of the impact of mussel culture on the sedimentary habitat: A multidisciplinary approach

G. Tita,[1] *J.-F. Crémer,* [2]*G. Desrosiers* [3] *and B. Long* [2]

A multidisciplinary approach was employed to study the effects of mussel farming on the sedimentary habitat. A culture site in the Great Entry Lagoon of the Magdalen Islands (Quebec, Canada) was selected for this purpose and compared to two control sites in the same lagoon. Sediment cores were collected for both sediment and faunal analyses. Axial tomodensitometry (ATD) was used for characterizing sediment 3D structures through imagery treatment. Organic matter vertical profiles observed through ATD showed temporal patterns suggesting sedimentation rates 50% higher at the aquaculture site compared to the control sites. Organic matter remineralization in the deeper sediment layers appeared to be substantially reduced beneath the mussel lines compared to the control sites. Mussel farming activity had a negative effect on the benthic meiofauna abundance, which was reduced by 70%. This may partially explain the reduced organic matter remineralization. No impact was detected on the macrofaunal communities. The mussel farming activity did not affect biodiversity in terms of species richness, Shannon's index and equitability.

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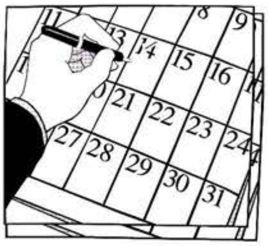
3. SMER-UQAR, 300 allée des Ursulines, Rimouski, QC G5L 3A1



Calendar

conferences, workshops, courses and trade shows

- **4th World Fisheries Congress**, 2-6 May 2004, Vancouver, BC, Canada. Information: Gary Carmichael (tel 604 688-9655, fax 604 685- 3521, e-mail fish2004@advance-group.com or carmichael_gary@yahoo.com, website www.worldfisheries2004.org.

- **New Marine Frontier Conference & Trade Show — Shellfish,** 14-16 May 2004, Port Hardy, BC, Canada. The Port Hardy & District Chamber of Commerce is hosting this conference on shellfish aquaculture development. Information: Port Hardy & District Chamber of Commerce (tel 250 949- 7622, e-mail phccmgr@ cablerocket.com).

- **Aquaculture International 2004,** 19-21 May 2004, Glasgow, Scotland. Information: e-mail sue.hill@ informa.com; website www.heighway.com

- **Atlantic Aquaculture Exposition, Conference and Fair,** 9-12 June 2004, St. Andrews, NB, Canada. Trade show produced by Master Promotions Ltd., PO Box 565, Saint John, NB (tel 506 658-0018, e-mail show@nbnet.nb.ca, website www. masterpromotions.ca).

- **Gadoid Mariculture: Development and Future Challenges,** 13-16 June 2004, Bergen, Norway. Symposium dedicated to the cultivation of gadoids (cod, haddock, pollock and hake). Website: http://www.ices.dk/iceswork/symposia.asp?topic=2004 or contact Dr. E. Trippel by e-mail at trippele@mar.dfo-mpo.gc.ca.

- **5th International Conference on Recirculating Aquaculture,** 22-25 July 2004. Hotel Roanoke and Conference Center, Roanoke, Virginia, USA. Information: Ms. T. Rakestraw (tel. 540 231-6805, fax 540 231-9293, e-mail aqua@vt.edu, website http://www.conted.vt.edu/aquaculture/).

- **US Trout Farmers 50th Conference and Trade Show,** 16-18 September 2004, Twin Falls, Idaho, USA. Information: e-mail ustfa@intrepid.net; tel Mary Lee at 304 728-2167.

- **Australasian Aquaculture 2004,** 26-29 September 2004, Sydney Covention Centre, Sydney, Australia. Information: John Cooksey, Director of Conferences (tel 760 432 4270, e-mail worldaqua@ aol.com, website www.was. org).

- **2004 Aquaculture Pacific Exchange Conference and Exhibition,** 30 Sept - 1 Oct 2004, Campbell River, BC, Canada. 100-booth trade show and 2-day conference. Master Promotions Ltd., PO Box 565, Saint John, NB (tel 506 658-0018, fax 506 658-0750, e-mail speacock@masterpromotions.ca, website www.masterpromotions.ca).

- **Aquaculture Canada^OM 2004,** 17-20 October, Fairmont Le Château Frontenac, Quebec City. Annual meeting of the Aquaculture Association of Canada. General information: e-mail aac@mar.dfo-mpo.gc.ca, tel 506 529-4766.. Program information: e-mail cyr@mi.mun.ca. Website: www.aquacultureassociation.ca.

- **7th International Marine Environmental Modeling Seminar,** 19-21 October 2004, Washington, DC USA. Topic: Environmental modeling for coastal North American waters: Impact assessment, resource management and mitigation. Deadline for submission of papers: 31 March. Information: http://www.sintef.no/imems2004/.

- **Aquaculture Europe 2004,** 20-23 October 2004. Barcelona, Spain. Information: website eas@ aquaculture.cc, fax +32 59 321005, e-mail ae2004@aquaculture.cc.

- **7th International Conference on Shellfish Restoration,** 7-20 November 2004, Charleston, South Carolina, USA Opportunity to discuss approaches to restore ecosystems through habitat quality assessment and restoration; stock enhancement; and habitat remediation. Information: e-mail elaine.knight@scseagrant.org, website scseagrant.org.

- **XIth International Conference on Harmful Algae,** 15-19 November 2004, Cape Town, South Africa. Abstracts due 31 May. Information: www.botant.uwc.ac/za/pssa.