Bulletin

of the
Aquaculture Association of Canada

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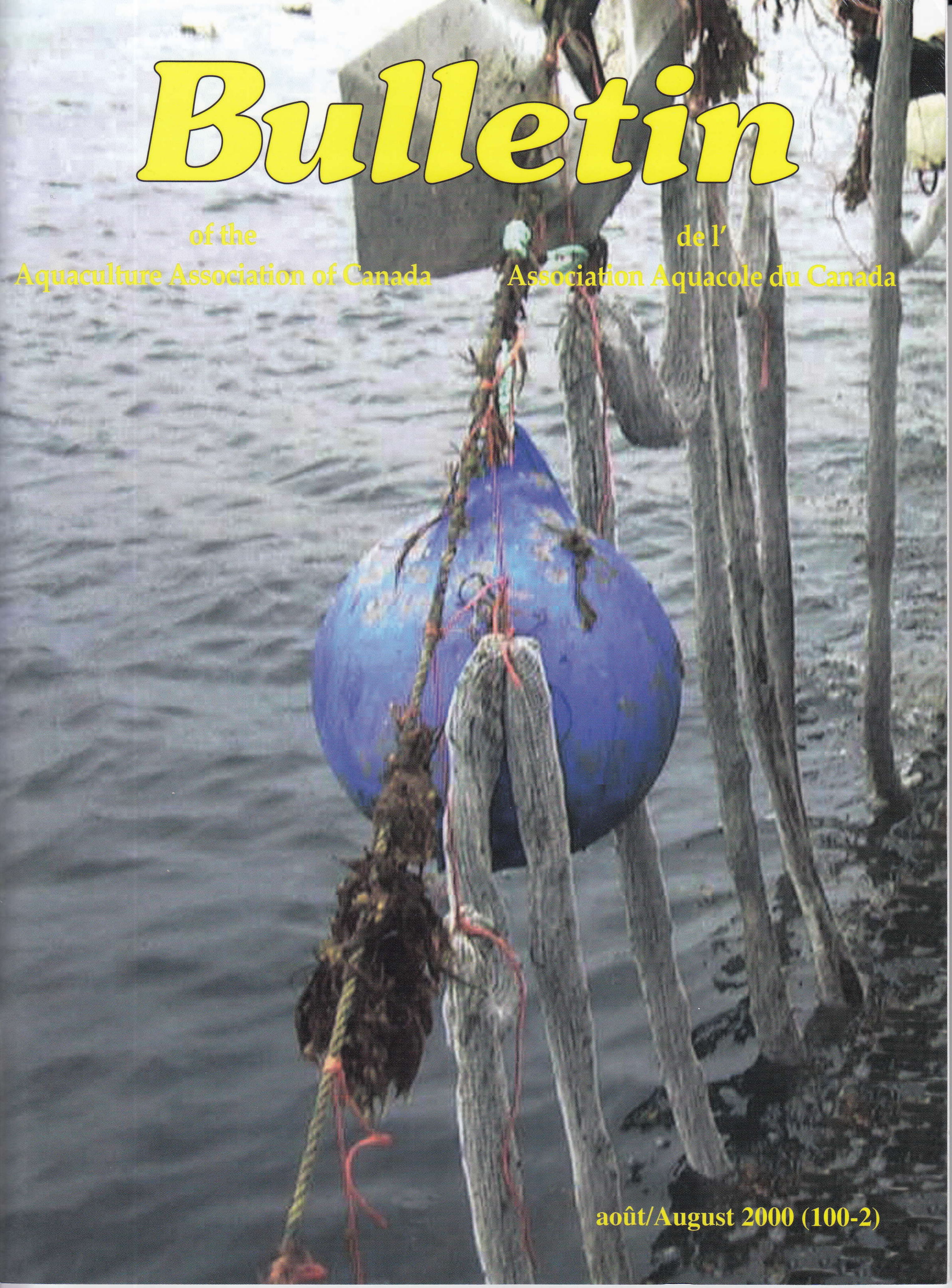

août/August 2000 (100-2)

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Cover: Many mussel growers in Canada are using a continuous socking system based on a method developed in New Zealand that uses a biodegradable cotton sock with a "fuzzy" rope in the center. The cotton sock falls off within a few weeks, leaving behind the mussels growing on the rope. The cover photo shows a filled sock tied to the head rope. [Atkinson & Bower Ltd. photo]

Contents

Oceanography and Shellfish Production: A Bio-Physical Synthesis using a Simple Model

Michael Dowd

The relationship between oceanographic processes and shellfish production is examined using a box model framework. Variations in the food field (suspended particulate matter or SPM) are considered as a function of three processes: tidal flushing, internal net production, and filtration activity of the shellfish population. A simple linear ordinary differential equation provides the basis for predicting SPM levels over time. A single parameter is used to describe the effect of each of the three processes. This box model is applied to Tracadie Bay, a shallow tidal lagoon on the north shore of Prince Edward Island with extensive mussel aquaculture development. Simple calculations and numerical experiments are carried out in order to assess and understand the dependence of SPM levels on variations in the total shellfish biomass. Spatial differences in SPM levels and the interaction between sub-regions of the bay are emphasized. The implications for shellfish growth and carrying capacity are examined and discussed.

Introduction

Shellfish aquaculture production depends on the surrounding oceanographic environment. Increased development in the coastal zone has resulted in the need for information on the interaction of cultured bivalve species and their environment. Filter-feeding bivalves obtain their food supply from the suspended particulate matter (SPM) in the surrounding water volume. This SPM is delivered to the bivalve through its transport by water movement and turbulent mixing. SPM levels (and composition) are primary factors in the overall energy budget and scope for growth of bivalves (e.g., Griffiths and Griffiths[1]).

The spatial distribution of SPM within a coastal region depends on water circulation and local sources and sinks. Circulation results from the fluid- and thermo-dynamic properties of seawater interacting with the geometry of the area under consideration and forcing due to tides, wind and freshwater. The spatial distribution of the SPM field is set by the interaction of this circulation field with localized processes causing SPM changes. In coastal environments, these include processes such as flushing with adjacent ocean waters, phytoplankton growth, decay of macrophyte detritus, land runoff and re-suspension of bottom sediments. A major sink of SPM in areas of intense shellfish culture is the particle clearance of the water volume brought about by the filtration activity of large numbers of bivalves.

In this note, we examine the role of oceanography and simple models in assessing shellfish-environment interaction. The emphasis is on quantifying SPM dynamics within a bay and applying these results to shellfish production. No attempt is made to consider the bioenergetics of the shellfish population (e.g., Dowd[2]). Instead, inferences on shellfish growth and carrying capacity are made based on predicted food levels (an approach taken with studies such as Chapelle et al.[3]). SPM levels are determined using a simple box model which includes the interaction of tidal flushing, internal net production and bivalve filtration. A multiple box model is applied to a shallow tidal lagoon (Tracadie Bay, PEI, Canada) in order to examine the processes contributing to spatial differences in shellfish growth and carrying capacity in the bay.

Model

A box model is a framework for describing changes in quantities of interest, or state variables, for a specific geographic region (i.e., the box). It has two main features: (i) it describes processes affecting the level of the state variable *within a box*, and (ii) it describes the flow of state variables *between boxes.* With reference to the latter feature, the geographical boundaries of boxes are chosen such that state variables are distributed homogeneously within the region under consideration (small spatial gradients). This box modeling framework provides a means to parameterize the

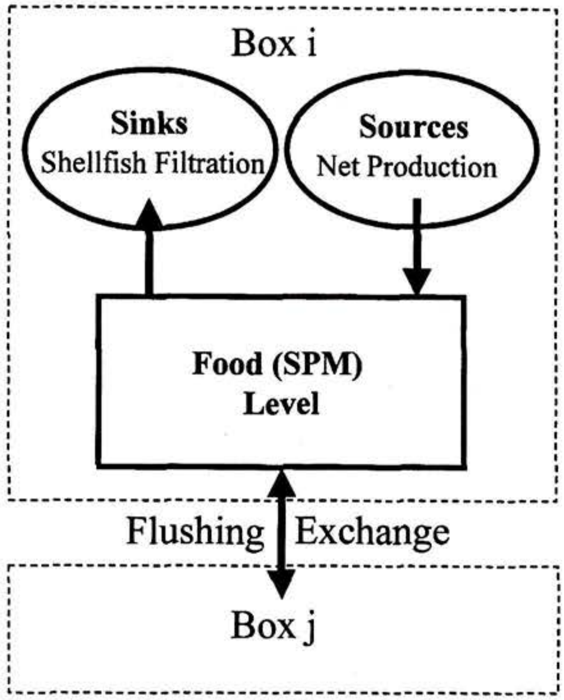

Figure 1. Conceptual picture of the box model. The state variable is the level of suspended particulate matter (SPM). Within the given box (Box i), SPM is increased by sources terms due to internal net production (assumed positive) and decreased by filtration of the water mass by the shellfish population. SPM is also increased or decreased by exchange with the adjacent box (Box j).

complex effects of water circulation and mixing and is used as the basis for more complex models of shellfish aquaculture ecosystems(e.g., Dowd,[2] Chapelle et al.,[3] Raillard and Ménesguen[4]).

A conceptual picture of the box model is given in Figure 1. The state variable of interest is the SPM level. Within a box, SPM is affected by processes such as primary production, re-suspension, and land runoff. This internal production is considered to be a net source term. Sink terms reduce SPM levels and are considered for our purposes to be due only to the depletion of SPM from the water volume due to the filtration activity of bivalves (note that other sinks could be absorbed in the internal *net* production). SPM in the box under consideration (box i) is exchanged with the adjacent box (box j), thereby changing SPM levels in both boxes and providing for interaction between regions.

The governing equation for SPM in box i is

$$\frac{d}{dt}[SPM]_i = K([SPM]_j - [SPM]_i) + (\alpha - \beta)[SPM]_i$$

where t is time, K is an exchange coefficient, α is the rate of internal net production and β represents the rate of SPM depletion via shellfish filtration. $[SPM]_i$ is the SPM concentration in the box i, while the j subscript refers to box j. The left-hand-side of the equation represents the time rate of change of SPM in box i. The first term of the right-hand-side is an exchange, or flushing, term and is equal to the difference in the SPM concentration between the two boxes scaled by an exchange coefficient (a gradient-flux relation which requires $K > 0$ to be physically realistic). The second term on the right-hand-side represents increases or decreases in SPM levels resulting from the balance between the sources and sinks of SPM. To be properly posed, this equation requires specifying the initial ($t=0$) values for SPM, as well as the SPM level in the adjacent box.

This equation presented above is perhaps the most simple mathematical representation of the system under consideration: the model is linear in the state variable, and the processes governing exchange, net production and filtration are each collapsed into a single parameter. The solution (integration) of the above equation yields the time evolution of SPM,

$$[SPM]_i(t) = \frac{K[SPM]_j}{K-(\alpha-\beta)} + \ldots$$

$$\left([SPM]_i(0) - \frac{K[SPM]_j}{K-(\alpha-\beta)}\right)\exp\{-(K-(\alpha-\beta))t\}$$

where $[SPM]_i(0)$ is the concentration of SPM at time zero. To ensure $[SPM]_i>0$ for all t requires that $K>(\alpha-\beta)$. The steady state value of SPM is

$$\overline{[SPM]_i} = \frac{[SPM]_j}{1-(\alpha-\beta)/K}$$

which indicates that the equilibrium SPM is a function of the outside value scaled by a simple ratio of the parameters. That is, if $1 > (\alpha - \beta)/K > 0$ (internal net production dominates over filtration) then SPM levels are enhanced relative to the adjacent box. If $(\alpha - \beta)/K < 0$ then SPM levels are reduced relative to the adjacent box. The (e-folding) time scale for equilibration of the system to its steady state value is $(K - (\alpha - \beta))^{-1}$.

In order to represent spatial variations in SPM over a region, multiple boxes must be combined together. In the context of the above, this means posing additional ordinary differential equations to represent SPM levels in other boxes (e.g., box j) and coupling these equations through the exchange terms. In this manner, SPM levels in the various boxes will co-evolve as the model is integrated forward in time. Note that while analytic solutions are still possible (it is, after all, still a linear system) they are less instructive. In what follows, we carry out numerical experiments with a multiple box model to explore spatial differences in SPM between regions in a tidal embayment and assess their implication for shellfish growth and carrying capacity.

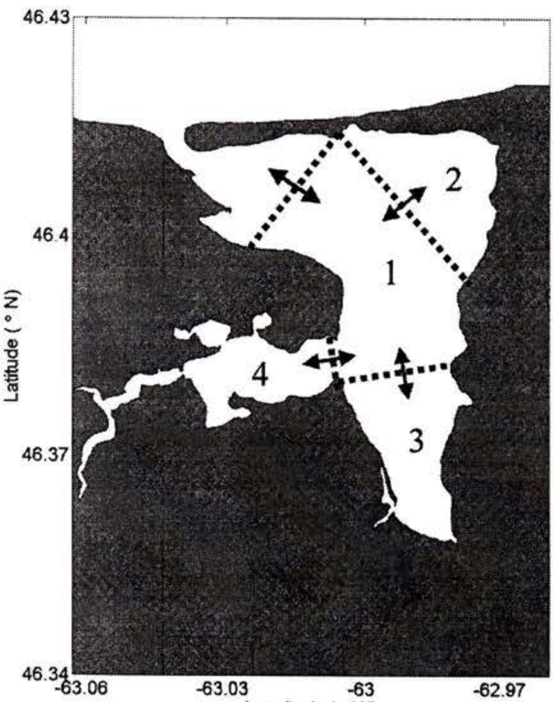

Figure 2. Map of Tracadie Bay and geometry of the box model. The boxes are designated by the labels 1-4 and their boundaries are given by the dashed lines. Two way arrows designate exchange between adjacent regions.

Application

The box model was applied to Tracadie Bay, PEI, Canada (shown in Fig. 2). This bay is a shallow (~5 m), nearly enclosed tidal embayment on the north shore of PEI. It is notable for its extensive mussel aquaculture development. The majority of the bay is covered by active leases and the total mussel biomass is estimated to be of order 10^6 kg wet weight (this quantity was determined from both production figures and the areal coverage of leases). Concerns have been raised about reductions in shellfish growth and the approach to, or exceedance of, the carrying capacity of the bay. There is also interest in the ecosystem effects of mussel culture from the perspective of coastal eutrophication.[5]

As an preliminary step, we examine the relative roles of mussel filtration, internal net production and tidal flushing in Tracadie Bay. Assume that (i) mussel biomass in Tracadie Bay is $1(10^6)$ kg wet weight, (ii) a representative mussel filtration rate of 1 litre per hour per individual mussel (e.g., Griffiths and Griffiths[1]), and (iii) there are 80 mussels per kg wet weight.[6] This implies that mussels are capable of filtering a volume of water equal to the tidal prism in ~2 days, and one equal to the total volume of the bay in ~10 days. As a proxy measure of internal production we note that a maximum light limited doubling time for phytoplankton growth is ~2 days for a shallow coastal embayment. A simple tidal prism calculation yields a flushing time scale of ~5 days. The important point is that the time scales for the processes of tidal re-supply of food, mussel clearance of the water volume, and regeneration of the algal standing stock are all of the same order of magnitude. The conclusion is that these elements play comparable roles in overall SPM dynamics and that the framework for the box model, as postulated in the previous section, is a justifiable one.

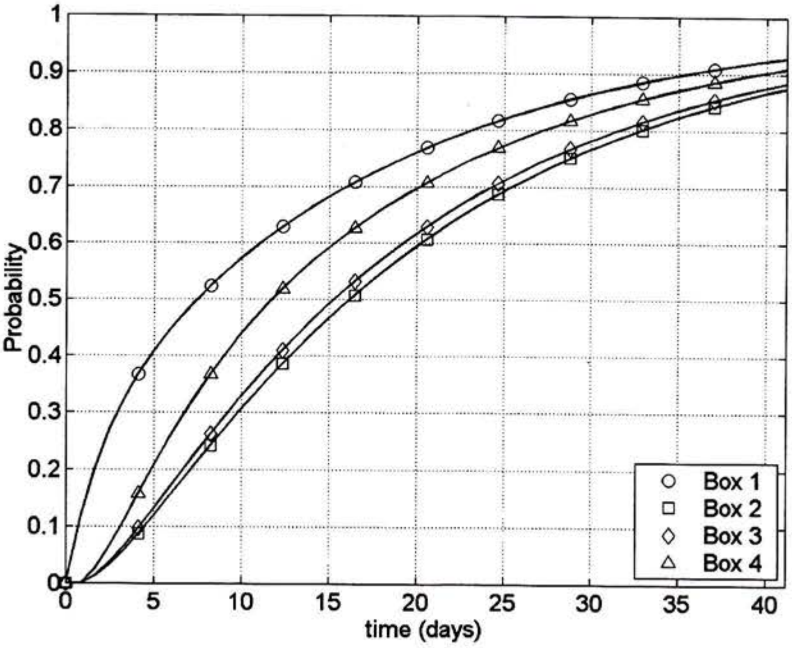

Figure 3. Probability of a particle exchanging with the outside open ocean as a function of time. The 4 curves each represent the exchange probability for a particle starting in the designated box.

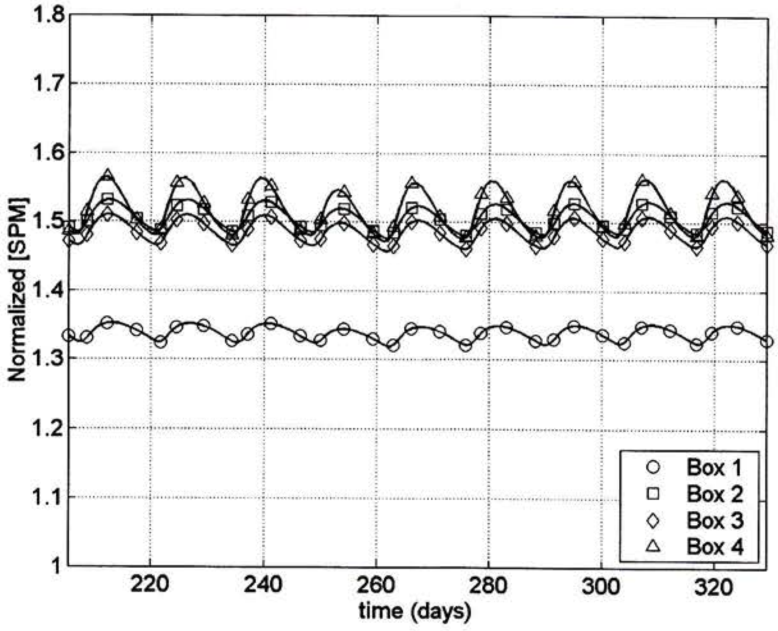

Figure 4. SPM levels for each of the four boxes in a system with positive net internal production only (see text). SPM level has been normalized to its outside concentration (i.e., a value of one is the outside concentration). The time series is shown after the system has reached a periodic steady state. The oscillations in the curves corresponds to the variations in the tidal amplitude and period (exchange coefficients).

Tracadie Bay has been divided into 4 spatial boxes (Fig. 2). The geographic boundaries of these boxes were based on observational and modeling studies of the tidal circulation of the bay. The 4 exchange coefficients were determined by the volumetric exchange of the tides given the box model geometry and assuming complete mixing within the box (a 2D generalization of the modified tidal prism method).(7) The tidal regime in Tracadie is dominated by diurnal tides (0_1,K_1) with a lesser contribution from the semi-diurnal lunar tide (M_2). For the purposes of this study, this complex tidal regime was reduced to a set of tidally averaged exchange coefficients. A Markov chain representation of the box model was also used to facilitate the calculations of various probabilistic quantities given below.

Results

Flushing rates were first examined by computing the probability that a particle, starting in a given box, exchanges with the outside and is thereby removed from the system (Fig. 3). Using an exchange probability of 0.5 to define a flushing time scale, we obtain flushing times of 7, 16, 15, and 12 days for boxes 1-4, respectively. Box 1 is in direct contact with the outside and is flushed most rapidly. Boxes 2-4 are more slowly flushed since particles must transit through box 1. Otherwise, the variability in their flushing rates is a function of the ratio of the tidal prism to the total volume for that box.

We next consider a system with internal net production of SPM only, and no mussels present (i.e., $\beta = 0$ in all boxes, $\alpha > 0$ with α equal in boxes 1-3 but slightly elevated in box 4 to mimic its high productivity). Figure 4 shows the resulting steady state SPM levels. The ~14-day periodicity is due to the cyclical variations in tidal height and tidal period from the 'beating' of the 0_1 and K_1 tides. The results show that, as expected, positive internal net production enhances SPM levels within the bay. A steady-state balance is achieved between this production and its dilution with outside waters. The well-flushed box 1 exhibits a 35% increase in SPM levels over the ambient outside concentration. The other, more poorly flushed, boxes show increases of between 50-55% above ambient. The implication for shellfish production is that at low mussel biomass (i.e., where the assumption of $\beta = 0$ is valid), individual growth rates will be enhanced in the poorer flushed regions of the bay.

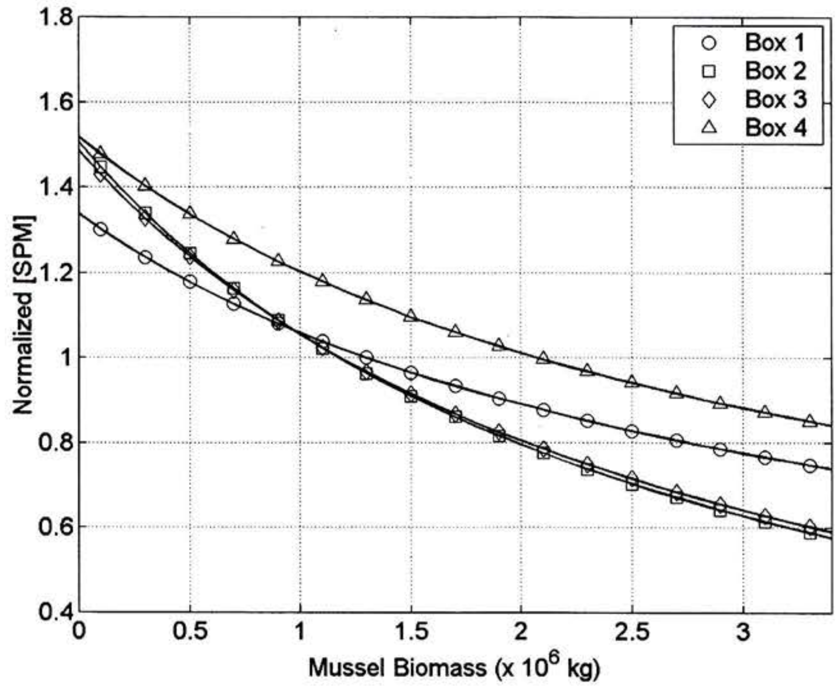

Figure 5. Normalized SPM level (as in Fig. 4) versus mussel biomass. The four curves are based on the mean of steady-state value of SPM for a given mussel biomass. The mussel biomass is a bay-wide value and distributed amongst boxes 1-3 with no mussels in box 4 (see text).

Table 1. A conceptual view of the potential for individual mussel growth in a system with positive net internal production. The discriminating variables are poor vs. well flushed areas, as well as low vs. high levels of mussel biomass. A greater number of the diamond symbols (♦) corresponds to an increased potential for growth of an individual mussel.

	Low Mussel Biomass	High Mussel Biomass
Poorly-Flushed Region	♦♦♦♦♦	♦♦
Well-Flushed Region	♦♦♦♦	♦♦♦

To link this system to shellfish growth and carrying capacity we now introduce mussels into the system. Varying the β parameter corresponds to increasing the mussel biomass since it represents the rate at which SPM levels are decreased through the action of bivalve filtration. β was determined using the volumetric clearance rate due to mussel filtration per unit biomass (0.5 liters/hr/individual), the volume of the box, and the total biomass of mussels.

To reflect the situation in Tracadie Bay, we consider the case where there are no mussels in box 4 (Winter Bay is a spat collection area). In the remaining boxes, the bay-wide total mussel biomass is varied over the range 0-3(10^6) kg wet weight. This biomass is distributed amongst the regions according to their relative volume (constant stocking density). Figure 5 shows the results from this calculation for the 4 regions of the bay. The general exponential decline in SPM concentration with increasing mussel biomass is evident for all regions. The SPM values for 0 kg biomass correspond to the mean of the steady-state levels shown in Figure 4. Box 4 exhibits higher SPM levels than the other regions due to its lack of mussels and high internal SPM production. At biomass levels < 0.8(10^6) kg the poorly flushed boxes 2 and 3 show enhanced levels of SPM over box 1. In contrast, at biomass levels > 0.8(10^6) kg, the levels of SPM in the well-flushed box 1 exceeds those in boxes 2 and 3.

Finally, we examine the interaction between regions in terms of the ultimate fate of a particle in the system. Specifically, we address the question: if a particle starts in a designated box and stays in the system, what is the probability that it is consumed in that box, or in any other box? Figure 6 shows the results from this calculation (recall that there are no mussels in box 4 and therefore the probability of being consumed in that box is zero). We see that if a particle starts in box 1 it has a nearly 60% chance of being consumed in that

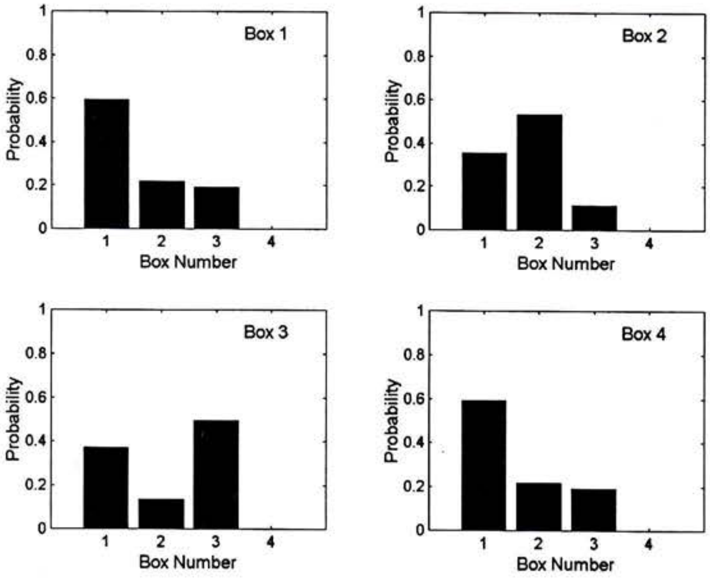

Figure 6. Probability that a particle which stays in the system is consumed in boxes 1-4 given that it starts in the box designated in the upper right hand corner of each panel. Note that since there are no mussels in box 4, the probability of being consumed there is zero.

box and 20% chance of being consumed in either box 2 or 3. If a particle starts in box 2 or 3 it has a 50% chance of being consumed there; if the particle is consumed in another box, box 1 is the most likely consumption area. For particles starting in box 4, there is a 60% chance they will be consumed in box 1. Box 1 acts as the dominant grazing sink for SPM due to its central location.

The general implication of our idealized box model system are qualitatively summarized in Table 1. First, consider the case of low shellfish biomass (e.g., $<0.5(10^6)$ kg in Figure 5). SPM levels are set mainly as a balance between internal SPM production, and exchange, with bivalve filtration playing a relatively minor role. Positive net internal production leads to higher levels of SPM in poorly flushed regions and consequently there is a very high capacity for individual mussel growth. With increased flushing rates, SPM levels are lowered and individual growth potential is reduced. Next, consider the case of high shellfish biomass (e.g., $>1.5(10^6)$ kg in Figure 5). SPM levels are set as a balance between bivalve filtration and exchange. The overall food level is reduced as compared to the low biomass case and therefore individual mussel growth is also correspondingly lower. Another difference from the low biomass case is that well flushed regions now have a greater individual growth potential than for poorly flushed regions due to enhanced tidal resupply of SPM.

Summary and Conclusions

We have investigated the relation between oceanography and shellfish production by examining their respective roles in setting food (SPM) levels. The control of SPM levels in a region was viewed as a balance amongst tidal flushing, internal net production (e.g. phytoplankton growth, land runoff, re-suspension) and particle clearance through the action of bivalve filtration. This is quantified in simple box model framework. This box model was applied to Tracadie Bay, PEI which was divided into 4 spatial boxes based on the tidal circulation. Numerical experiments were carried out to examine the SPM dynamics and their implications for shellfish growth and carrying capacity.

Our application has stressed the need to consider the bay system as a whole and recognize and quantify within-bay differences. These sub-regions interact with one another through water movement and are further influenced by the adjacent open ocean. Internal processes and bivalve filtration activity influence food levels and therefore shellfish growth and production potential. A primary purpose of our box model is to provide for a simple accounting of these processes and predict spatial differences between regions. Applying these ideas to the food field allows us to understand and quantitatively assess the role of oceanographic processes in the aquaculture ecosystem. Validation of these predictions with field data will provide the next step in this work.

The box model used here is a highly idealized description of the bio-physical processes taking place in the real shellfish ecosystem. As such, it proves useful as a very basic description and a first cut at understanding and quantifying the interactions between the oceanographic environment and the shellfish population. The model also provides the basis for much more complex shellfish aquaculture-ecosystem models,[2,4] but avoids the complex, nonlinear equations that are required for shellfish energetics and other processes. The advantage of the simple model is that a fairly complete understanding of the system behaviour is available (e.g., analytic solutions), unlike for the more complex ecosystem models. It is felt that the identification of simple, tractable and robust models are an important step in understanding mass and energy flows in aquaculture ecosystems, and for making the link between the environment and shellfish growth and production.

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Shellfish Health Protection Regulations in Canada

Susan M. Bower and Sharon E. McGladdery

Canada has economically significant shellfish aquaculture, commercial and recreational industries. As Canadian shellfish aquaculture continues to develop, there is increasing demand for acquisition of stocks that demonstrate optimal culture characteristics and for transfer of seed from distant producers. However, transplantation comes with an increased risk of accidental introduction or spread of infectious agents, as occurred in other countries where live transplants were linked to significant disease-related losses. In Canada, shellfish health is currently protected under the Fisheries (General) Regulations (VIII) Section 56(b), through an introductions and transfers risk assessment process (which also includes ecological and genetic risk evaluations) that is managed by a committee of federal and provincial representatives in each province. However, shellfish health certification is not a regulatory requirement. The proposed regulatory objective is to reduce the risk of introduction or spread of shellfish disease agents, which could threaten wild and cultured shellfish resources, while still providing opportunities to transfer live shellfish for production, enhancement or maintenance prior to sale. Regulations will also provide protection for both exporter (defense against subsequent disease outbreak accusations) and the importer (assurance of disease-free stocks) as well as facilitating access to international markets, which are developing import restrictions based on shellfish disease concerns. The proposed Shellfish Health Protection Regulations (SHPR) also address the issue of compensation for eradication and foster a unified interpretation across Canada. In October 1998, a technical committee of industry and government representatives from across Canada took on the challenge of reviewing and refining draft regulations. The reviewed draft should be ready for public comment/scrutiny in the near future.

Introduction

The value of the shellfish industry in Canada is continually increasing and much of the increase is attributed to aquaculture. This increasing value and corresponding large investments in shellfish aquaculture could be jeopardised if adequate disease prevention measures do not prevail. The health of most cultured organisms in Canada is protected by a regulatory approach. For example, the health of terrestrial species is monitored and controls administered by Agriculture Canada. Salmon health issues are addressed through the Fish Health Protection Regulations and these regulations are currently undergoing revision to incorporate other species of fish. However, there are currently no regulations in place to protect the health of shellfish in Canada. The following discussion will address this issue by first presenting examples of infectious diseases that have impacted oyster production in Canada. Then, examples of the severe consequences that inadvertent introduction of infectious pathogens has had for shellfish culture in other countries will be described. Next, the current system of shellfish health protection in Canada and the developing international requirements will be summarised. Finally, advantages of implementing the proposed Shellfish Health Protection Regulations (SHPR) will be listed and discussed.

Examples of Harsh Consequences Associated with Inadvertent Pathogen Introductions

Currently, the shellfish industry in Canada is fortunate in not having to contend with any debilitating infectious diseases. In the past, however, commercial stocks of oysters on both coasts have experienced disease outbreaks of concern to production.

On the East Coast of Canada, Malpeque disease took its toll on eastern oysters (*Crassostrea virginica*) during the early 1900s. It is believed that Malpeque disease was introduced into oysters in Malpeque Bay, PEI, between 1910 and 1915 with oysters transplanted from southern New England. Previously unexposed oyster populations demonstrated up to 90% mortality, but survivors showed apparent resistance to the disease. It took the disease some 30 years to spread and affect all stocks in the Gulf of St Lawrence. Low salinity appears to retard the disease; hence relict populations of oysters survive in upper estuaries of certain rivers.[1] The slow rate of spread and the fact that oysters in Bras d'Or Lake on Cape Breton Island are still free of the disease is attributed partly to deliberate attempts to contain the disease and partly to water circulation characteristics of the Gulf.[2] No epizootics associated with the disease have been reported since the 1950s (when the disease spread from Prince Edward Island to New Brunswick). Experimental transplants of "susceptible" stocks from disease-free populations on Cape Breton Island to Malpeque Bay, PEI, in the late 1960s and in 1994, resulted in 90% mortality within 24 months. Infected animals show gross signs of mantle regression, gaping, oedema and abscesses in the mantle (Fig. 1). Yellow-green scars were also observed on the inner surface of the shell. The agent causing this disease has yet to be clearly identified; however, it is highly infectious. Although oysters on Cape Breton Island are still susceptible to the disease, all other stocks are now resistant and the oyster industry has managed to survive despite initial losses and slow recovery from Malpeque disease.[1]

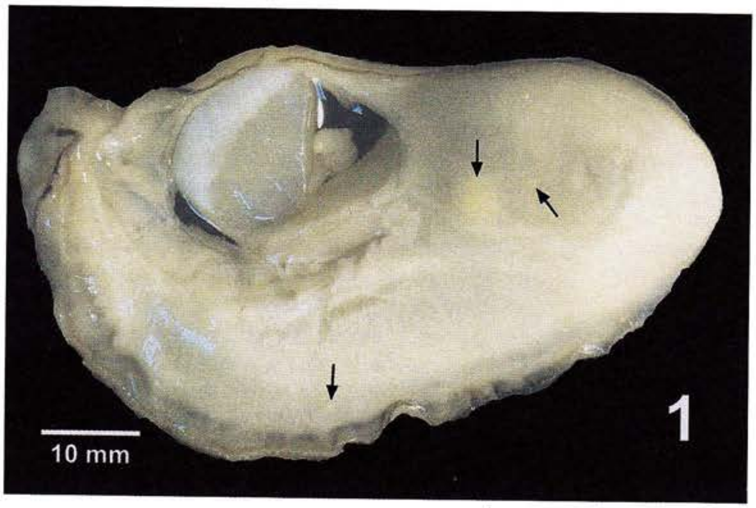

Figure 1. *Crassostrea virginica* removed from the shell and illustrating lesions (arrows) typical of Malpeque disease.

In British Columbia (BC), Denman Island disease made an appearance in the early 1960s in Henry Bay on Denman Island. In some years this disease has killed up to 53% of the old Pacific oysters (*Crassostrea gigas*) on low intertidal beds and surviving oysters have unsightly green pustules throughout the body (Fig. 2). The protozoan, *Mikrocytos mackini*, that causes this disease, appears to be ubiquitous throughout the Strait of Georgia and at a few locations on the west coast of Vancouver Island.[3,4] Nevertheless, the oyster culture industry has managed to successfully live with this pathogen. However, this may not be the case if *M. mackini* manages to become established further north. Laboratory studies indicate that *M. mackini* requires cool temperatures (about 10°C) for about 3 months before it is pathogenic to oysters.[5] These conditions are only met in southern British Columbia for a few months during the winter. In northern BC where temperatures are generally cooler, *M. mackini* may be more deadly than it is further south. *Mikrocytos mackini* is also pathogenic to all other species of oysters tested (eastern oysters, *C. virginica*; flat oysters, *Ostrea edulis*; and Olympia oysters, *Ostrea conchaphila*). Thus, inadvertent introduction of this pathogen to Atlantic Canada could also have severe consequences.

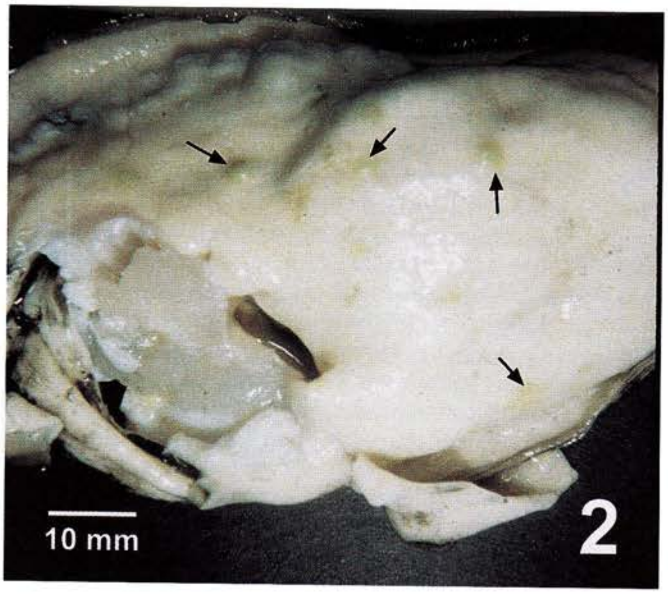

Figure 2. *Crassostrea gigas* removed from shell and illustrating lesions (arrows) observed during late stages of Denman Island disease caused by *Mikrocytos mackini*.

Other cultured species of shellfish in

other countries have not been as fortunate. For example, international transfers of penaeid shrimp that began nearly two decades ago and continues today within the shrimp-culture industry is reminiscent of international airline flight patterns.[6] In parallel with these transfers is the distribution of exotic shrimp viral diseases. At least half of the 12 known viral diseases of penaeids have been introduced to continents were they were previously not known. In conjunction with these accidental introductions were associated mortalities that adversely affected the profitability and often the success of shrimp farming ventures.

Oyster production in France between 1900 and 1993 has experienced several drastic reductions. Most of the major drops in production have been associated with infectious disease agents. [7] The most recent decline in production of flat oysters was directly caused by a protozoan pathogen (*Bonamia ostreae*) that was accidentally introduced with flat oyster broodstock imported from California.[8,9] Although flat oyster production has increased slightly in the last few years, this famous oyster of French cuisine is still difficult to find in the market place in France.

Additional information on diseases of shellfish is presented on our SeaLane Web Site at: http://www.pac.dfo-mpo.gc.ca/sci/sealane/aquac/pages/title.htm. We plan to update this web site as new information becomes available on shellfish diseases. This web site will serve as a data bank or source of information that can be used to assist in making decisions on the importation of shellfish.

International Requirements versus the Current System of Shellfish Health Protection

In addition to real concerns pertaining to inadvertent disease introductions, Canada has obligations to international organisations to which it belongs. Two examples with relevance to shellfish health issues are the Office International des Épizooties (OIE) and International Council for the Exploration of the Seas (ICES). The OIE, the World Animal Health Organisation, has set up an International Aquatic Animal Health Code to facilitate international trade in aquatic animals and products. This Code provides detailed definitions of minimum health guarantees to be required of trading partners in order to avoid the risk of spreading aquatic animal diseases. Within the Mariculture Committee of ICES, a Working Group on Pathology and Diseases of Marine Organisms (WGPDMO) convenes each year to compile and analyse aquatic animal disease information and formulate recommendations to ICES Member Countries. With both these international organisations, there is a requirement for conscientious reporting by member countries for the purpose of gathering information on the distribution of diseases of concern and making this information available to assist in minimising further spread of diseases.

More important than being a compliant member of international organisations is the vital aspect of international trade. The countries to which Canada exports commercially harvested wild and cultured shellfish products are increasingly becoming concerned about shellfish diseases. In fact, countries such as the United States, Australia and most European countries have disease control regulations for aquatic species and equivalent regulations are also under development for many Asian countries. Current trends indicate that shellfish products from a country without substantive evidence of active disease surveillance and corresponding reporting program could be excluded from some, if not all, international markets. Even if exclusion was a non-tariff trade barrier, the inability of a country to refute disease accusations will keep it from gaining access to desirable markets based on the strength of this accusation.

In Canada, shellfish health is currently protected under the Fisheries (General) Regulations (VIII) Section 56(b), through an introductions and transfers risk assessment process (which also includes ecological and genetic risk evaluations). Regional Introductions and Transfers Committees manage this process. However, unlike salmonids, shellfish health certification is not a regulatory requirement. Although the current system in Canada no doubt helps to curtail accidental shellfish disease introductions, without regulations to back up the efforts of the transplant committees, their effectiveness is limited. And equally, if not more importantly, the mandatory surveillance program and reporting systems that are likely to be imposed by international markets will not be fulfilled.

Advantages of the Proposed Shellfish Health Protection Regulations

Some of the advantages of instating the proposed SHPR are described below:

1. First and foremost, the proposed regulatory objective is to reduce the risk of introduction or spread of shellfish disease agents, which threaten wild and cultured shellfish resources, while still providing opportunities to transfer live shellfish for production, enhancement or maintenance prior to sale.
2. Certification resulting from the implementation of the regulations will protect (to the best of diagnostic capability) both the importer and the exporter. The importer will get some assurance that the stock proposed for transfer is free of disease and the exporter has a certification defence against a subsequent disease outbreak being blamed on the shipped stock. In addition, neighbouring producers and wild fisheries are exposed to less risk of expriencing considerable losses because of the activities of other facets

of the industry.

3. The regulations will make the current *ad hoc* process of deciding whether or not to import shellfish for culture better defined and more consistent across Canada. Tools to ensure consistent application include: a detailed Manual of Compliance; national co-ordination through the National Registrar for Diseases of Shellfish; national meetings (at least once per year) to address new concerns; maintenance of Quality Assurance/Quality Control standards in all laboratories conducting shellfish health certifications and training of qualified personnel to conduct health assessment assays. A transparent and consistent evaluation as provided under regulations would be to the benefit of all.
4. The regulations will require that the government establish a decision-making process based on risk assessment. Risk assessment may actually facilitate movements, while minimising adverse consequences on the environment.
5. A component of risk assessment includes a mandatory surveillance program and reporting system. The results of surveillance on the health/disease of wild and cultured stocks in combination with the zonation proposals, which are also a part of the proposed SHPR, should meet the health certification requirements of importing countries. Fulfilling these requirements will facilitate access to markets where restrictions are based on disease concerns.
6. The current draft of the regulations also includes mandatory reporting of a disease outbreak. In conjunction with this requirement will be government compensation in the event of eradication associated with an infectious disease emergency. As we can all appreciate, compensation can make a disaster more tolerable.

Conclusion

Without the voluntary compliance of the shellfish industry, legislation aimed at reducing risks and facilitating international trade is doomed to failure.[10] Because the system currently used in Canada has been effective to date, the proposed SHPR will incorporate current procedures to minimise administrative impact on all parties involved. For example, a "grandfather-like" clause would likely be implemented. This would involve documenting historic movements. Because there are no disease consequences to date attributable to these activities, it would be justifiable to allow these activities to continue. However, all new activities may be required to undergo scrutiny with respect to the SHPR, but assessments will have to be conducted in a timely fashion that is compatible with biological parameters. Also, procedures that maintain an adequate level of health protection while simplifying the process for applicants will be adopted. Essentially, national consistency, fairness and openness are recognised as key considerations for the development of workable SHPR. With the support of the aquaculture industry, the proposed legislation could prove to be a great asset.

In October 1998, a technical committee of industry and government representatives from across Canada took on the challenge of reviewing and refining the draft SHPR. This process has been stalled since early summer 1999 due to the temporary loss of a co-ordination position assigned to this project in Ottawa. Hopefully the project will get back on track before long. Once the draft has been fully reviewed and appropriate modifications made by the technical committee, the draft will be submitted for public scrutiny and comment.

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Susan M. Bower (Fisheries and Oceans Canada, Pacific Biological Station, Nanaimo, BC V9R 5K6, telephone 250-756-7077, fax 250-756-7053, e-mail BowerS@dfo-mpo.gc.ca) and Sharon E. McGladdery (Fisheries and Oceans Canada, Gulf Fisheries Centre, Moncton, NB E1C 9B6, telephone 506-851-2018, fax 506-851-2079, e-mail McgladderyS@dfo-mpo.gc.ca) conduct research on diseases of shellfish on the west and east coasts of Canada, respectively. Both were involved in preparing the original draft of the SHPR and are participate on the technical committee that is working towards the establishment of shellfish health protection regulations in Canada.

Shellfish Production on British Columbia's North Coast: An Industry in Transition

William A. Heath and Sheila Dobie

The North Coast area of British Columbia produces over $50 million in annual shellfish landings, representing more than 50% of the province's total commercial shellfishery harvest, including geoduck, razor clams, Dungeness crab, spot prawns, red sea urchins and sea cucumbers. In this biologically rich region, the farming of shellfish has not yet developed to a commercial scale, although there is considerable interest in it. A series of projects was initiated to explore the feasibility, training and planning issues around shellfish farming in this frontier region and to address other constraints, such as provision of marine biotoxin monitoring. In the current project, experimental trials with the Japanese scallop (*Patinopecten yessoensis*) were conducted at sites in the Queen Charlotte Islands/Haida Gwaii, starting in November 1997. At two off-bottom culture sites (Skidegate Inlet and Rennell Sound), favourable results for scallop growth (6-9 mm/month) and survival (over 90%) indicate that subsurface suspended culture is biologically feasible in these areas, but is not advisable in the more brackish Masset Inlet. Experimental growout of Pacific oysters (*Crassostrea gigas*) at a near-surface suspended (tray) culture site in Rennell Sound yielded favourable growth rates (up to 17.4 mm/month), but the issues of access (rough logging road), heavy biofouling (e.g., by the mussel, *Mytilus trossulus*) and settlement of sea stars will be significant factors to manage in any development of commercial shellfish culture. Additional regional constraints to commercial shellfish culture on the North Coast, such as community planning, growing-water classification, marine biotoxin monitoring, training, and transportation issues are being addressed through special projects and development of a strategy for regional shellfish development. Shellfisheries in this region will continue to be important, but in the near future shellfish farming may contribute to seafood industry diversification and sorely needed economic opportunities for north coastal communities in British Columbia.

Introduction

The North Coast region of British Columbia (BC) extends from the international boundary in southeastern Alaska to Cape Caution, and includes the Queen Charlotte Islands/Haida Gwaii (Fishery Statistical Areas 1-10; Fig. 1). It consists of a myriad of islands, inlets, bays and other coastal waterways that are prime habitat for shellfish or marine invertebrate resources. The area has a relatively small population (50 000 (est.) in 1999),[(1)] clustered in small cities and towns (e.g., Prince Rupert, Kitimat, Queen Charlotte City, Masset, Bella Bella) and numerous villages, many of them mainly First Nations' centres. The economy of the North Coast is primarily resource based, and was hard hit by the severe downturn during the late 1990s in the forestry and commercial fishing industry sectors. In 1995, North Coast commercial fishing landings were valued at $152 million, about 25% of the provincial total.[(2)] However, between 1995 and 1998, the landed value of Pacific salmon and herring catches in BC dropped 36% and 70%, respectively, a combined decline of over $93 million.[(3)]

Invertebrate Fisheries in BC's North Coast region

The North Coast region supports valuable invertebrate fisheries, such as those for Dungeness crab (*Cancer magister*), spot prawn (*Pandalus platyceros*), geoduck (*Panopea abrupta*), red sea urchin (*Strongylocentrotus franciscanus*), and the sea cucumber (*Parastichopus californicus*). Production and value from these North Coast fisheries rose rapidly from 1984 to the early 1990s (Fig. 2), reaching a combined annual value exceeding $55 million in 1995 and 1996.[3] More recently, value has declined about 12% with dropping prices for geoduck and prawns in Asian markets and changes to the management of the sea urchin fishery. Overall, the North Coast share of the total value of BC invertebrate fisheries has increased from about 20% in 1984 to more than 50% since 1992 (Fig. 3). Although the North Coast shellfisheries continue to be lucrative sources of fishery employment and income, many of the vessels and fishermen involved are currently from the south coast of the province, resulting in limited economic benefits to northern coastal communities.

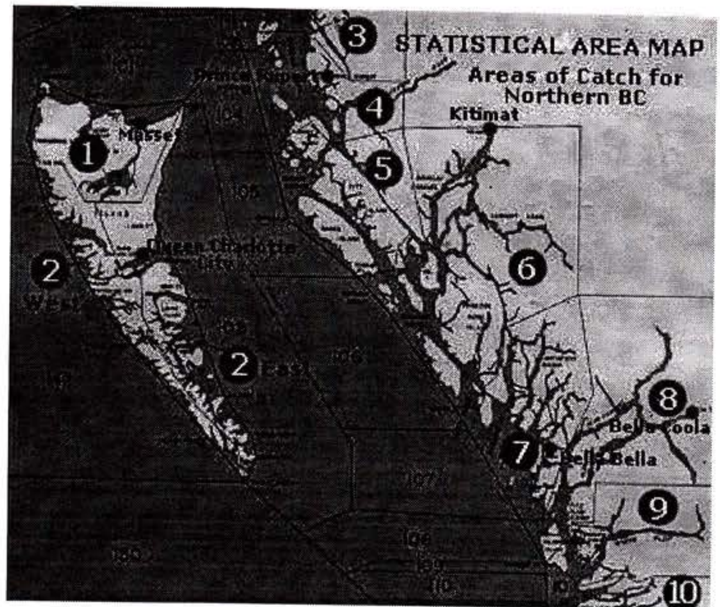

Figure 1. North Coast region of British Columbia, Canada, with Fishery Statistical Areas and larger coastal communities indicated (DFO area map).

North Coast Shellfish Culture Feasibility Projects

In order to identify new economic opportunities for hard-hit coastal communities near Prince Rupert and on the Queen Charlotte Islands/Haida Gwaii, projects were initiated to examine the feasibility of shellfish culture. Shellfish farming has a relatively long history in the south coast area of BC[4-6] and has more recently been developing in Alaskan coastal waters.[7,8] However, only the pioneering work of Dr. Dan Quayle in the 1960s on Pacific oyster string culture[4] describes experimental

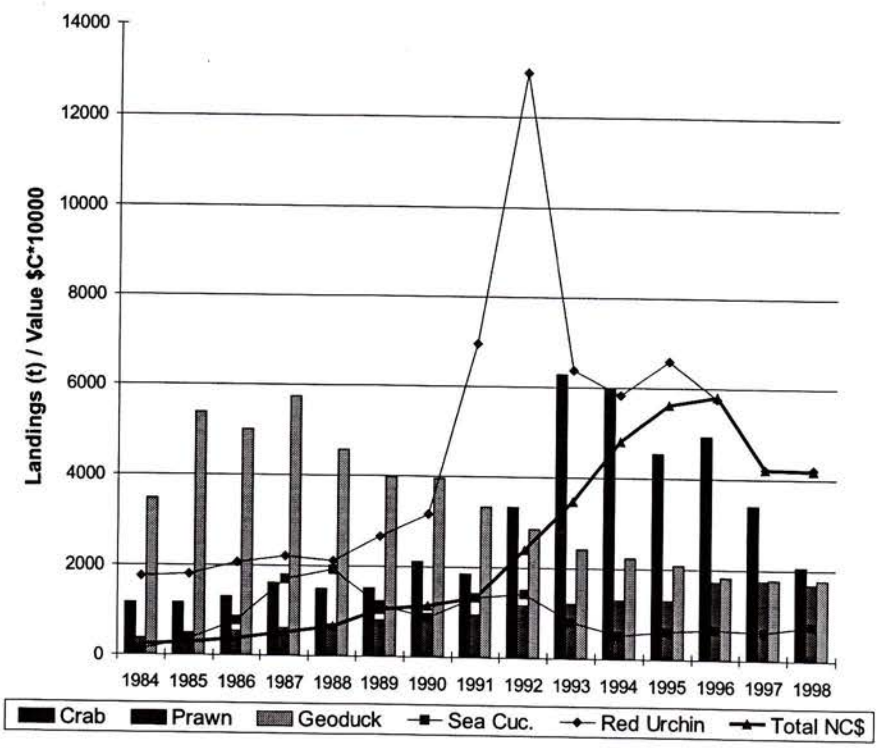

Figure 2. Fishery landings and total value for five major North Coast shellfishery species for 1984 to 1998. Based on DFO statistics; estimates only for 1997 and 1998.

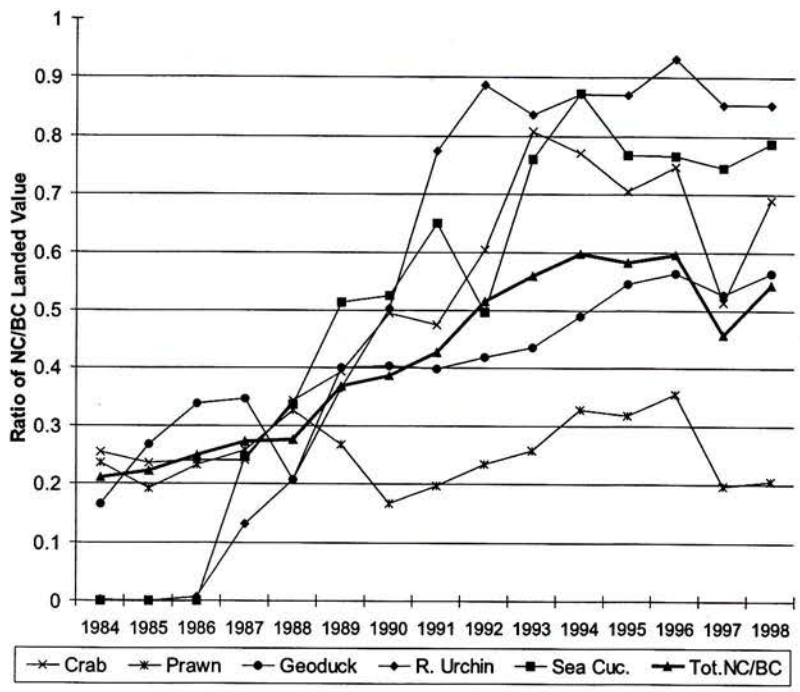

Figure 3. North Coast share of BC shellfisheries values for 5 major species and combined data for 1984-98. Based on DFO statistics; estimates only for 1997 and 1998.

studies of shellfish culture in the North Coast area of British Columbia. More recently, a baseline survey of the Queen Charlotte Islands area was completed for shellfish culture capability,[9] but grow-out trials for Japanese scallops and tray oysters to assess biological feasibility of culture from seed to market size were still needed.

Masset shellfish feasibility study

Masset is a village (population 1200) at the north end of Graham Island, on Dixon Entrance, that experienced major hits to its economic base in the 1990s. First, the Department of National Defense's Canadian Forces Station was decommissioned during 1995-1996 and soon after, the BC Packers Ltd. fish processing plant was closed following years of sharp declines in salmon harvests in the area. Only the local crab fishery remained as a significant resource base and it, too, is somewhat in decline with lower catches and more non-resident vessels fishing the resource. In 1996, the Village Council's Fishery Committee began a project with support from the Partners in Progress program of the Ministry of Agriculture, Fisheries and Food (MAFF) to assess the feasibility of shellfish culture in the northern Queen Charlotte Islands. Based on information from shellfish workshops and farm visits on BC's South Coast, the initial focus was placed on high-valued Japanese scallops (*Patinopecten yessoensis*), a species that prefers relatively low water temperatures and high salinities,[10] conditions that are frequently found in many North Coast locations. In November 1997, experimental suspended-culture trials were started at three sites (Skidegate Inlet, Rennell Sound and Masset Inlet; Fig. 4). A fourth site in McIntyre Bay, off Tow Hill, was also stocked with a smaller number of scallops in a bottom enclosure and off-bottom pearl net system.

Shared community shellfish pilot project (SCSPP)

In 1998, a more comprehensive shellfish development project for the North Coast was initiated, with coordination from the Seafood Development Office in Prince Rupert. The Shared Community Shellfish Pilot Project began village-by-village discussions with the Tsimshian First Nations, the community of Oona River and interests in Prince Rupert. This round of information meetings and discussions led to a commitment to a program of experimental trials to assess the feasibility of Pacific oyster and Japanese scallop culture and to provide training in culture methods. A total of 28 pilot sites were involved, including the four Masset Fishery Committee sites and several others nominated by proponents from Queen Charlotte City and Skidegate. To further the education and planning aspects, well-attended aquaculture conferences were held in Prince Rupert and Masset in 1998.

Methods

Experimental deployment systems

To culture *Patinopecten yessoensis* successfully, a deepwater, bottom-dwelling scallop, minimal motion of the culture apparatus is desirable.[10,11] For this small-scale experimental growout trial, the following mooring systems were used at the sites:

(a) ***Scallops:*** Subsurface float (rigid plastic trawl float, 25-cm diameter) at 14-m (46 ft) depth, above a series of 8 pearl nets (tied in linear fashion), linked by anchor line (13-mm Dacron rope) to 15-kg concrete anchor; connected by 27 m of 13-mm groundline to another 15-kg anchor, and finally by 25 m of 13-mm Dacron line to a surface marker float (commercial crab pot float; see diagram in Fig. 5A). This system presents minimal risk to navigation, while being relatively easy to sight and recover, yet is relatively inconspicuous or uninviting to those who might tamper with moored gear. Scallop seed (mean shell height of 21.1 mm) from Island Scallops Ltd. on Vancouver Island was shipped by air[12] before being stocked at a density of 16/net in 6-mm mesh pearl nets and deployed from the mooring system.

(b) ***Oysters:*** Surface float (crab float), 2-m line to stack of Dark Sea™ oyster trays, line to concrete anchor (15 kg; Fig 5B). Oyster seed (41.2 mm mean shell length) was initially placed at a density of 80/tray in a stack of 6 Dark Sea™ trays. Two more trays were added to the stack in September 1998 to reduce density to about 60/tray for the larger oysters.

Monitoring

At intervals of about 3 to 4 months, depending on weather conditions, the sites were visited by small boat. At each site, the mooring system was lifted aboard, 30 to 50 shellfish were randomly removed for counting and measuring by sliding calipers (shell height, ± 0.5 mm; Fig. 6). Observations were made on survival, fouling and gear condition. Predators (e.g., juvenile starfish among oysters) were removed if they posed a threat to shellfish survival. Nets were changed or trays cleaned of fouling if needed before re-deployment of mooring systems. Surface water temperature and salinity were measured by mercury thermometer and refractometer, respectively.

Results

Scallops

Growth

Growth profiles of *Patinopecten yessoensis* at the four sites (Fig. 7) indicate that growth occurred throughout the year at all sites, but was faster at the Skidegate Inlet and Rennell Sound sites than at Masset Inlet. The small sample of bottom cultured scallops at McIntyre Bay grew at a rate similar to the Skidegate group until July 1998, before lagging behind during the summer. Comparing the seasonal growth rates (Fig. 8; measured as mm/month), it is apparent that fastest growth occurred in summer (July-September at 6-9 mm/month) and autumn (September-December; at 6-7.5 mm/month.), with slower growth during winter (December-March; 1-4.5 mm/month) and spring (March-July; 3-5.5 mm/month). Surface water temperatures ranged from 8°C in winter and spring to 17°C in summer at Skidegate Inlet and Rennell Sound, and from 7° to 15°C at Masset Inlet for corresponding periods. Surface salinities remained high (29-34 ppt) at Skidegate Inlet and Rennell Sound sites, but were considerably lower (21-24 ppt) at the Masset Inlet site where the brackish water had a tea-like colour that reduces light penetration.

Survival

Survival was high at all stations, except when a couple of subsurface float malfunctions interfered with husbandry conditions. For example, at the Skidegate site, survival was 97% for the first full year of grow-out, until the subsurface float leaked and allowed several pearl nets to sink to the bottom, leading to high mortality, likely from suffocation. At the Rennell Sound site, survival and growth were negatively influenced following another partial failure of a subsurface float that was replaced by a surface float. Although this float was replaced by a new subsurface

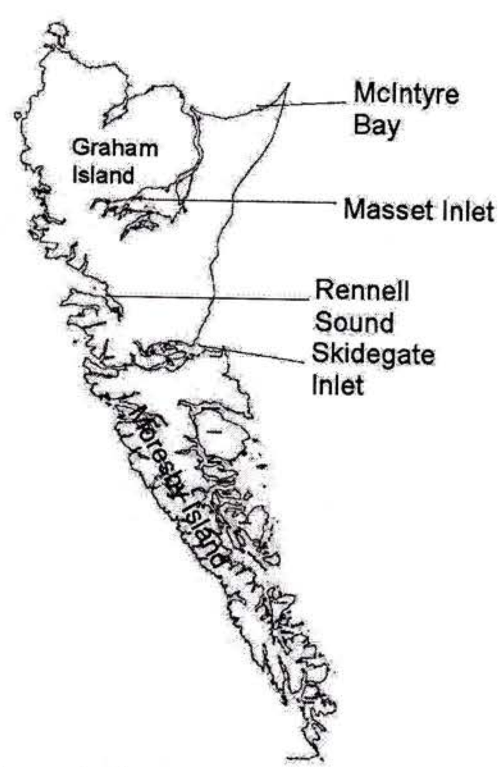

Figure 4. Locations of Queen Charlotte Islands/Haida Gwaii shellfish trial sites monitored by Masset Fishery Committee and BCMAFF.

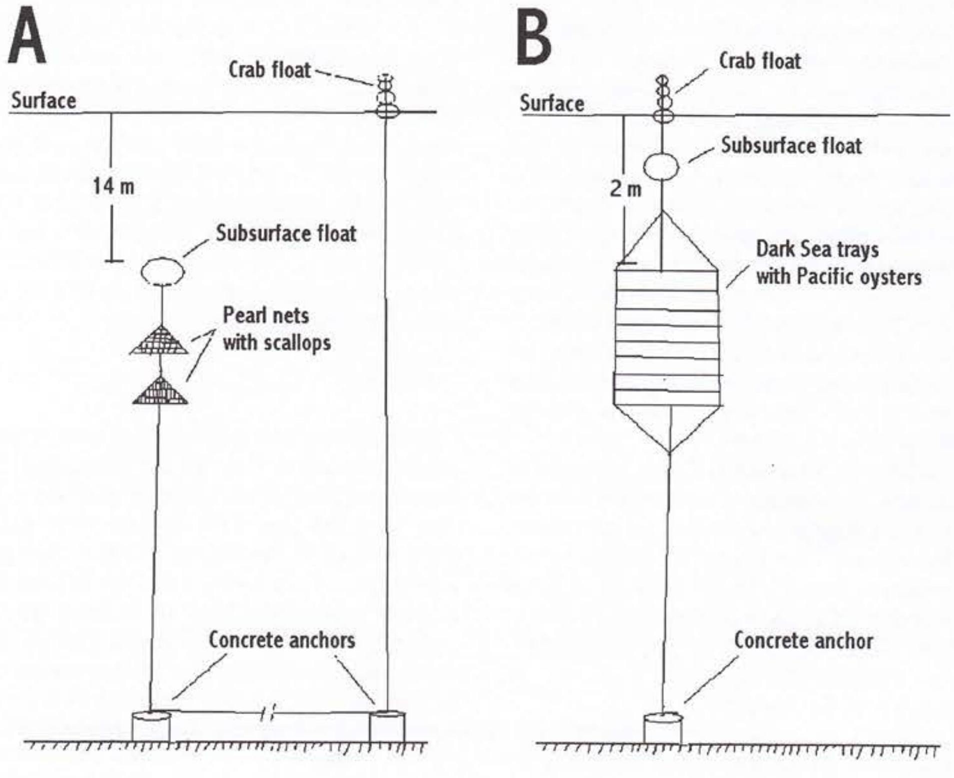

Figure 5. A. Experimental subsurface culture system for scallops at QCI/HG sites. B. Experimental suspended culture system for tray oysters at Rennell Sound site.

Figure 6. Measuring scallops during growth trials for suspended culture in pearl nets at sites in the Queen Charlotte Islands.

float at the next sampling time, the period of greater motion of pearl nets induced by the surface float led to a high incidence of biting or conchiolin that deformed the shells of about 50% of the scallops. About one-third of these recovered, but 29 of the more severely deformed scallops were culled from the group after one year of grow-out. In contrast, at the Masset Inlet site where there were no float problems, survival remained high (over 95%), even

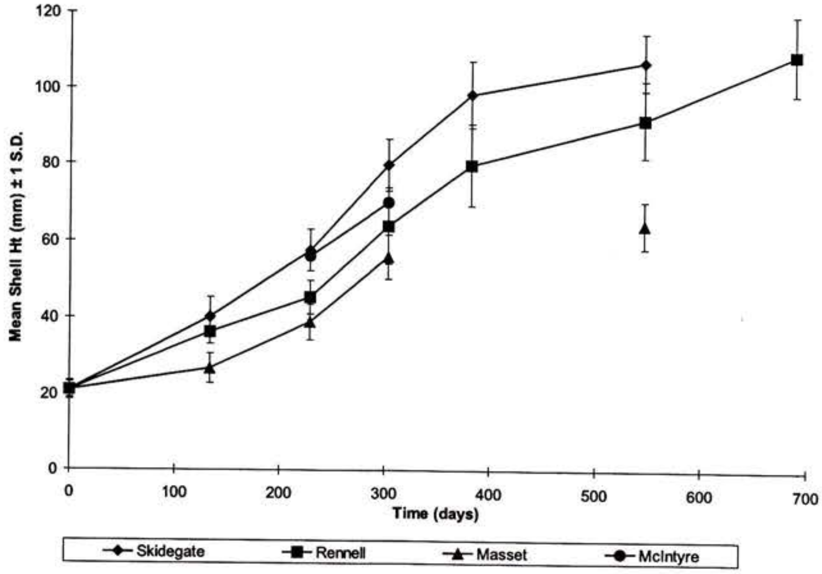

Figure 7. Growth profiles of scallops, *Patinopecten yessoensis,* at QCI/HG growout trial sites.

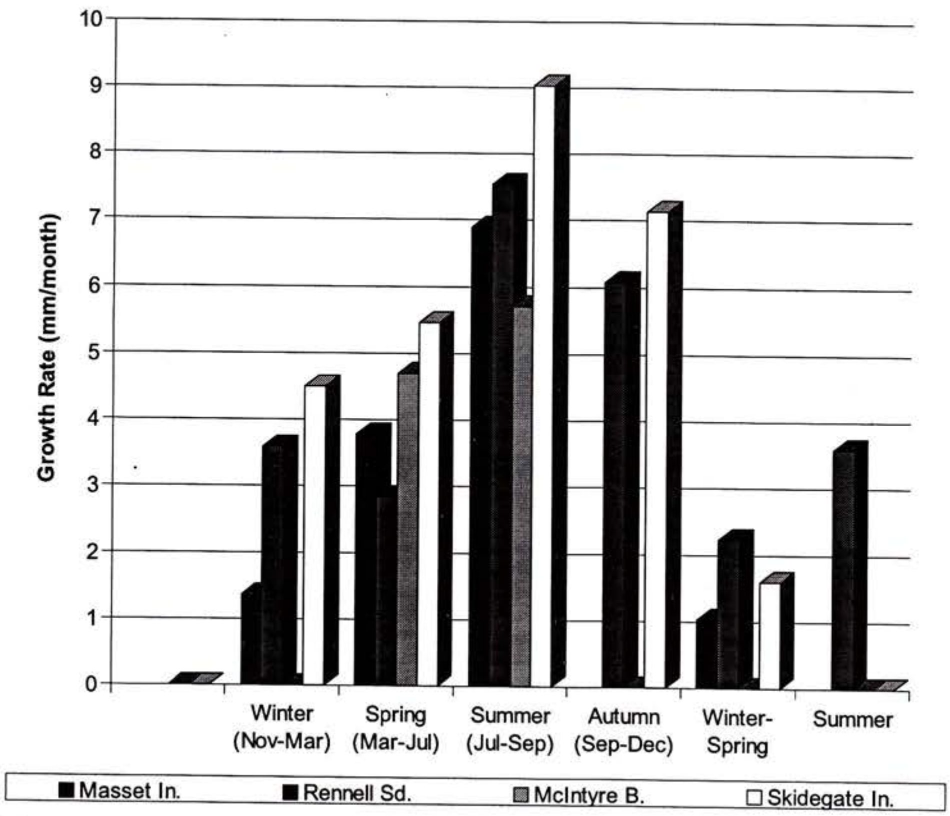

Figure 8. Monthly growth rates (mm/month) of *Patinopecten yessoensis* at QCI/HG sites, grouped by season.

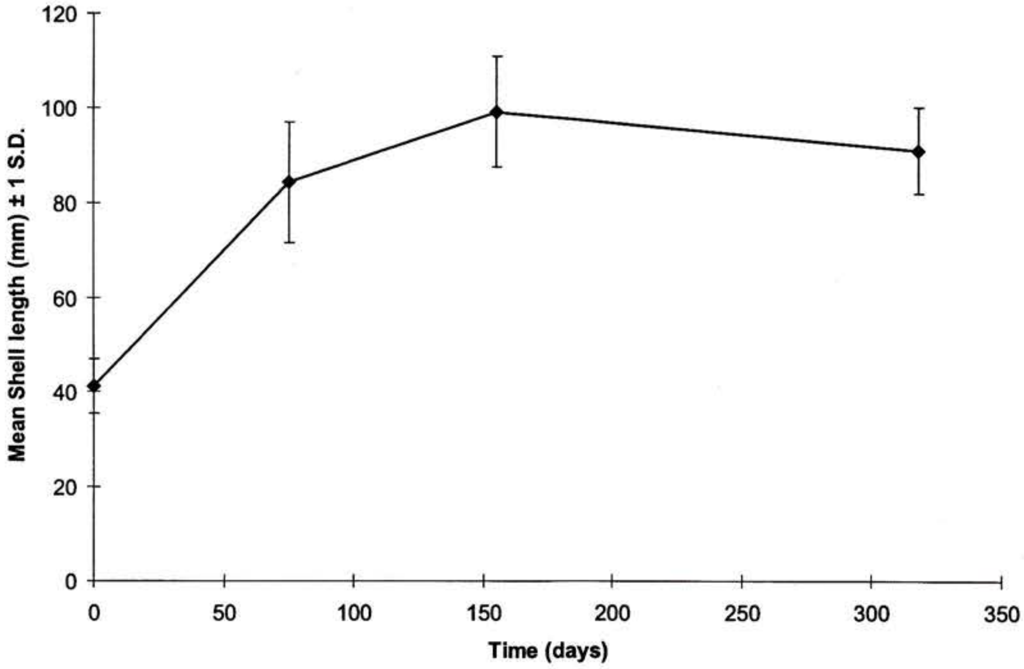

Figure 9. Growth profile of Pacific oysters, *Crassostrea gigas,* in suspended trays at the Rennell Sound site.

though lower salinities were experienced at that site.

Oysters

The Pacific oysters deployed in Rennell Sound in July 1998 (shell length of 41.2 ± 5.8 mm; mean ± 1 SD) grew at an average rate of 17.2 mm/month until mid-September, and continued to grow at 5.6 mm/month until December, by which time they had reached a marketable size of 99.2 ± 11.7 mm (Fig. 9). Survival was excellent (100%) until a few oysters were eaten by sea stars (*Pisaster ochraceus*) over winter. The starfish, which settled in summer, had consumed most of the mussel fouling from the summer period before getting large enough to start consuming oysters.

Discussion

Scallops

Oceanographic conditions conducive to the farming of the Japanese scallop in British Columbia are productive waters with cool temperatures[12] (8-16°C; reduced growth was observed above 12.5°C and mortalities increased above 16°C)[10] and relatively high, stable salinity (>28 ppt). In addition, a suitable site must be capable of providing conditions of minimal movement, or motion, of the culture apparatus, either through natural (geographic) protection from significant wave action and horizontal currents, or through proper installation and use of anchoring and subsurface longline systems.[10,13] In the absence of subsurface float failures, the experimental mooring systems used here appeared to provide very satisfactory conditions for scallops.

Surface conditions of water temperature and salinity are more prone to extremes (high or low temperature; low salinity) and represent the worst-case scenarios for handling this scallop species during monitoring, sorting or harvesting operations.[12] Based on the observations during monitoring, the physical conditions found at Skidegate Inlet and Rennell Sound sites appear to be highly favourable for rapid growth and good survival of *P. yessoensis*, as the results were very comparable to those of good sites on the west coast of Vancouver Island.[10] Although survival was also very good at the Masset Inlet site, growth was much slower, mainly during the winter and spring seasons, likely due to low available light for primary production in the brown, brackish waters of that area. The preliminary observations of good growth and survival of scallops in a bottom enclosure in McIntyre Bay were very encouraging, suggesting that further investigation of this approach to scallop culture may be worth pursuing in areas of McIntyre Bay that are not used for commercial crab fishing.

Oysters

For the Pacific oyster, *Crassostrea gigas*, growth and survival in suspended tray culture at Rennell Sound were very suitable for commercial culture, but the high level of biofouling, especially from mussels, and the high incidence of settled sea stars are potentially problematic. These factors would not be as serious for a subsurface scallop farm as the heavy fouling only extended to about 4 to 5 m, whereas the culture depth for scallops would be lower. In addition, however, access to the area via the long and rough logging road from Queen Charlotte City (or open water on the west coast) would be daunting on a regular basis for a commercial shellfish operation.

Conclusion

The most favourable area for shellfish culture of the ones studied here is Skidegate Inlet, due to its favourable range of temperature and salinity, excellent growth and survival of scallops, and relative ease of access from Sandspit or Queen Charlotte City. Although the eastern end of the Inlet appears at first glance to be exposed to storm waves from Hecate Strait, the area is actually relatively protected due to the shallow bar at the inlet entrance, that breaks up much of the force of the waves before they enter the inlet. Consequently, subsurface scallop culture is likely to be quite feasible in the eastern part, as well as in some of the inner areas of Skidegate Inlet. Further studies will help to identify other suitable shellfish culture sites for scallops, oysters and possibly other species.

Next steps

As shown here, experimental trials of shellfish growout in new areas will find data to support (or not) development on a commercial scale. For those individuals or groups interested in shellfish farming, this would ideally be a simple process of moving from the pilot to commercial scale, should the data show it to be viable. However, the North Coast communities looking at this opportunity are not finding it such a straight-forward transition. What is required is a level of community involvement in this business development, which is not a common mix of talents and inclinations (i.e. independent-minded entrepreneurs vs. a lengthy community process of relationship building).

Community process leads to new shellfish tenures

To be players in the development of a shellfish farming industry, the North Coast region has entered into the provincially-directed Shellfish Development Initiative (SDI). This process requires communities to undertake a planning process that includes the identification of suitable sites and recommendation of criteria for the use of these new shellfish tenures.[14] Fortunately, this group process was not a difficult one to begin. The North Coast shellfish farming interests have been meeting since January 1999 to discuss the pilot projects and the marine biotoxin issues of concern to the North Coast communities. Results of the Shared Community Shellfish Pilot Project (SCSPP) clearly demonstrated that shellfish, such as Pacific oysters and Japanese scallops, can be grown on the North Coast at comparable rates to the established south coast BC industry. This finding has now energized many of the coastal communities within the region to further investigate the economic benefits of shellfish mariculture.

Regional shellfish planning committee

The North Coast Regional Planning Committee for Shellfish Mariculture was established as a result of a project supported through the Rural Secretariat (Rural Partnership Program). This Regional Committee was also an out-growth of the network of original communities who participated in the SCSPP, sponsored by the BC Ministry of Fisheries (now MAFF). The following is the list of representation on the North Coast Regional Shellfish Planning Committee:

- Metlakatla Band Council
- Allied Tribes
- Metlakatla Development Corp.
- Northwest Maritime Institute
- Kitkatla Band Council
- Department of Fisheries and Oceans
- Lax Kw'laams Band Council
- Oona River Community
- Haisla Band Council
- Tsimshian Tribal Council
- Haisla Fisheries Commission
- Kitsumkalum Band Council
- Hartley Bay Band Council
- Skeena Watershed Stewardship Co-ord.
- Skeena-Queen Charlotte Regional District
- Kincolith Band Council
- North West Community College
- Northern Development Commission
- Community Futures Development Corporation of the Pacific Northwest (Community Futures)

Tasks and Actions of the Regional Committee:

1. A Regional Plan was completed in May 1999. Discussion from the committee revealed that this document will be an excellent tool assisting efforts to develop a shellfish farming industry and to keep interested parties informed and on track. It is being perceived as a "living document" with amendments to be made as the committee directs.
2. It also was identified that contact with the Canada-BC-First Nations' Treaty Process was required for the Committee to ensure its interests were being made clear to the Treaty table.
3. Regional projects that could contribute to the development of the industry guided in part by priorities identified in the Regional Plan: This has begun with an agreement between the Committee and MAFF to work in partnership on the Biophysical Capability Evaluation Survey for Shellfish Farming. The bulk of this work has been done under contract by Axys Consulting Ltd. However, portions of the funds have been made available to the Regional Committee for participation in the survey and for the winter component of the survey.
4. The lack of a system for regular biotoxin testing on the North Coast is a critical capacity issue for any shellfish industry. The initial start, with a few sampling stations and the involvement of a local laboratory, has now evolved to a stand-alone marine biotoxin program with its own dedicated co-ordinator, two years of funding, and a commitment from federal agencies to build a sustainable program.
5. Long-term directions of the Regional Committee are to further develop its internal structure and roles. Visioning of the representatives has formed the basis of a formal mission statement. Discussions have so far determined membership structure and boundaries, while formal policies for decision-making are currently in draft stage.

In summary, the Regional Planning Committee for Shellfish Mariculture has established itself as the regional entity for the North Coast that will participate in the decisions about the establishment of this industry, based on identified needs and wants from the various communities. From the basis of pilot studies such as described here that offer clear evidence that shellfish farming is feasible in the north, we move into our communities and educate them of the opportunity and what it could mean to the sustainable economy of the region. From this foundation comes a solid plan for a new industry, respecting other uses and values that need room or protection, and a committed group of local interested parties ready to make it happen.

The North Coast shellfish industry will continue to have a strong contribution from shellfisheries, but, in the future, shellfish mariculture will add new products for processing and marketing, and thus provide expanded opportunities for economic development and employment for North Coast communities in British Columbia.

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A New Approach to Shellfish Aquaculture Development in British Columbia: The Clayoquot Sound and Barkley Sound Shellfish Aquaculture Steering Committees

Josie Osborne

In recent years, west coast Vancouver Island (WCVI) native and non native communities have expressed interest in developing and diversifying local economies through shellfish aquaculture. This desire, coupled with the November 1998 announcement of the Province of British Columbia's intention to work with communities in accepting applications for new shellfish aquaculture tenures, resulted in the formation of the Barkley Sound and the Clayoquot Sound Shellfish Aquaculture Steering Committees. The BC Assets and Lands Corporation initially asked the steering committees (which are currently comprised of representatives from a broad range of interests) to accomplish three objectives: to determine suitable areas for shellfish aquaculture in local areas; to recommend rates of development for shellfish aquaculture in areas under the committees' operation; and to develop community-based criteria by which tenure applications will be adjudicated. In addition, both committees have extended their objectives to include supporting a locally developed oyster culture skills training program. The Clayoquot Sound Steering Committee is also exploring local shellfish processing opportunities. The opportunities and challenges these steering committees face in achieving their objectives are presented.

Introduction

Coastal communities in British Columbia (BC) have increasingly seen shellfish aquaculture as an environmentally-sustainable, economic development opportunity. Kingzett and Tillapaugh[1] describe the BC shellfish industry and recent initiatives. Shellfish aquaculture can provide a modest family income with comparatively (relative to other resource-based industries) little capital investment, training, or education. Growing shellfish markets offer new entrants opportunities for access to markets. Furthermore, many BC coastal communities are situated in or near prime shellfish growing areas with high water quality and reasonable access to the infrastructure required to process and market farmed shellfish products.

In BC, the shellfish aquaculture industry is regulated by two provincial agencies: the BC Assets and Lands Corporation (BCAL), a Crown corporation that manages Crown land and issues Crown foreshore tenures, and the Ministry of Agriculture, Fisheries, and Food (MAFF), which issues aquaculture licences and is responsible for enforcement and inspections. In 1994, the Province stopped accepting applications for new tenures or expansions to existing tenures on BC's south coast (Vancouver Island and the mainland south of Cape Caution), mostly due to limited resources for a large number of applications. This halt severely limited further development of the shellfish aquaculture industry in BC, and a 1997 report[2] on the economic potential of shellfish aquaculture in BC identified access to new sites as the most primary factor restricting BC shellfish production.

In November 1998, the Province announced that it would begin accepting applications for the expansion of existing shellfish farms and would soon begin accepting applications for new shellfish farms.[3] The Province also stated that it would work with local communities to determine the location and rate of development of the industry in their areas. The Province's Shellfish Development Initiative, coupled with the desire of the Clayoquot Sound Central Region Board (CRB) (a native/non native body that oversees land-use decisions in Clayoquot Sound) to discuss oyster culture expansion opportunities in Clayoquot Sound, resulted in a workshop on the future of oyster aquaculture in Clayoquot Sound in February 1999.[4] At this workshop, local representatives sent a strong message to the Province that (1) decision-making on shellfish leases should be locally based and (2) local benefits from oyster culture and processing should be ensured. Local First Nations and non First Nations representatives also expressed concern about the Province's timeline for accepting applications.

In this paper, I describe the formation of three shellfish aquaculture steering committees on the west coast of Vancouver Island, their areas of operation, and the groups and organizations that are currently represented on each committee. Next, I describe in detail the objectives of the Clayoquot Sound Shellfish Aquaculture Steering Committee (the Clayoquot committee) and the Barkley Sound Shellfish Aquaculture Steering Committee (the Barkley committee). Finally, I describe the challenges that the Clayoquot committee and the Barkley committee work with, as well as the opportunities for both shellfish aquaculture and for increased involvement of affected parties in decision-making around shellfish aquaculture on the west coast of Vancouver Island.

West Coast Vancouver Island Shellfish Aquaculture Committees

Clayoquot Sound Shellfish Aquaculture Steering Committee

The Clayoquot committee was established in April 1999, after the February 1999 oyster aquaculture workshop. The Clayoquot Sound CRB facilitates the operation of the Clayoquot committee and provides technical, facilitative, and financial assistance.

The Clayoquot committee operates in the Clayoquot Sound drainage area, which includes all foreshore from Cox Point in the Tofino area along the shoreline to Hesquiat Harbour, and includes the islands and inlets in Clayoquot Sound (Fig. 1). Protected areas, such as the Cleland Island ecological reserve, the Pacific Rim National Park Reserve, and provincial marine parks, are not available for shellfish aquaculture development and therefore are not included in the area of the Committee's operation. The Clayoquot Sound area includes the municipality of Tofino as well as the smaller centers of Esowista, Opitsat, Ahousat, and Hot Springs Cove.

The Clayoquot committee is currently comprised of representatives of a wide range of interests (all affecting shellfish aquaculture) including Ahousaht, Hesquiaht First Nation, Tla-o-qui-aht First Nations, the Nuu-chah-nulth Tribal Council Fisheries Program, the shellfish aquaculture industry, BC Ministry of Agriculture, Food and Fisheries (MAFF), BCAL, the Regional Aquatic Management Society, the Strawberry Island Research Society, Ma-Mook Development Corporation, the Alberni-Clayoquot Skills Centre, and the Area F/WCVI Clam Management Board.[5]

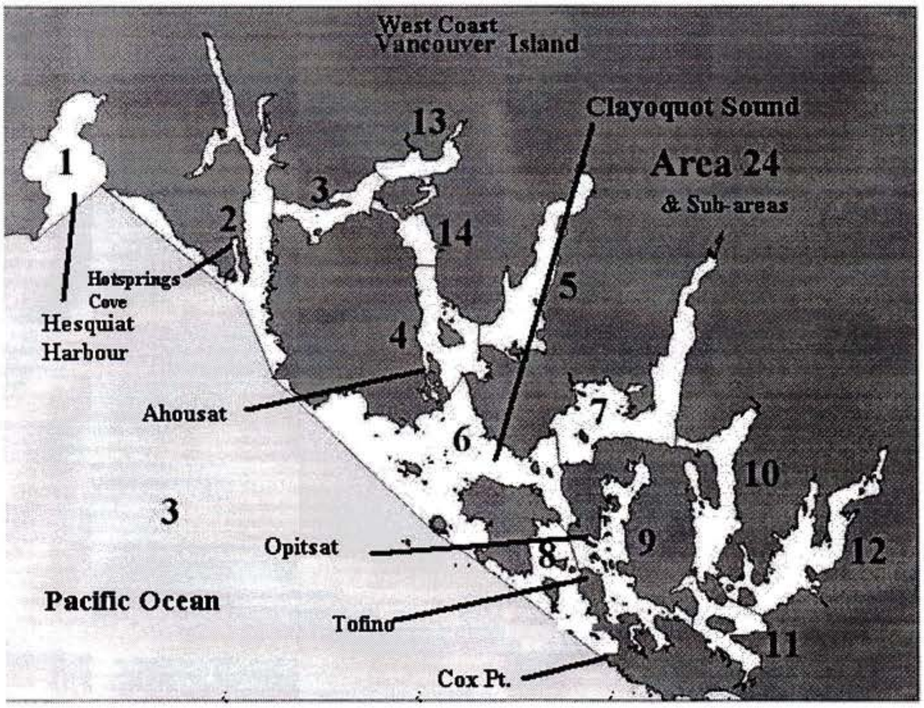

Figure 1. Map of Clayoquot Sound area on the West Coast of Vancouver Island (Fishery Statistical Area 24).

Barkley Sound Shellfish Aquaculture Steering Committee

The Barkley committee was established in June 1999 when the Regional Aquatic Management Society (RAMS), after participating in the formation of the Clayoquot committee, approached BCAL and offered to facilitate the shellfish initiative in the Barkley Sound region. RAMS (a native/non native society that supports negotiations between the Nuu-chah-nulth, BC, and Canadian governments for the establishment of a regional aquatic management board in Nuu-chah-nulth territory on the west coast of Vancouver Island) facilitates the operation of the Barkley committee and provides technical, facilitative, and financial assistance.

The Barkley committee operates in the Barkley Sound drainage area, which includes all foreshore from Amphitrite Point in the Ucluelet area along the shoreline to Cape Beale in the Bamfield area, and includes the islands in Barkley Sound (Fig. 2). Protected areas, such as the Broken Islands section of the Pacific Rim National Park Reserve, are not available for shellfish aquaculture development and therefore are not included in the area of the committee's operation. The Barkley Sound area includes the municipalities of Ucluelet, Port Alberni, and Bamfield, as well as the smaller centers of Ittatsoo (Ucluelet East), Kildonan, and Anacla (Pachena Bay).

The Barkley committee is currently comprised of representatives of a wide range of interests (all affecting shellfish aquaculture) including Barkley Sound First Nations (Ucluelet, Toquaht, Tseshaht, Uchucklesaht, Hupacasath, and Huu-ay-aht), the Nuu-chah-nulth Tribal Council Fisheries Program, the shellfish aquaculture industry, the BC Shellfish Growers Association, the Alberni Valley Sportfishing Association, MAFF, BCAL, RAMS, the Community Futures Development Corporation, the Alberni-Clayoquot Skills Centre, and the Area F/WCVI Clam Management Board.

Nootka/Kyuquot Shellfish Aquaculture Steering Committee

Although it is not discussed further in this paper, a third shellfish aquaculture steering committee has been established in the northern region of Nuu-chah-nulth territory. The Nootka/Kyuquot Shellfish Aquaculture Committee is facilitated by RAMS and has been formally in operation since February 2000, after public meetings in the northern region indicated interest in establishing a steering committee.

The Nootka/Kyuquot committee operates in the Nootka Sound, Esperanza Inlet, Kyuquot Sound, and Checleset Bay areas of northern west coast Vancouver Island. Protected areas such as provincial marine

Figure 2. Map of Barkley Sound area of the West Coast of Vancouver Island (Fishery Statistical Area 23).

parks, and the territory of the Ehattesaht First Nation (roughly Zeballos Inlet, Espinosa Inlet, Port Eliza, and the west coast of Vancouver Island between Yellow Bluff and Rugged Point) are not included in the Committee's area of operation.

The Nootka/Kyuquot committee is currently comprised of representatives of a wide range of interests (all affecting shellfish aquaculture) including Ka:'yu:'k't'h'/Che:k'tles7et'h'Nations, Nuchatlaht First Nation, Mowachaht/Muchalaht, the Nuu-chah-nulth Tribal Council Fisheries Program, the shellfish aquaculture industry, the BC Shellfish Growers Association, the Comox-Strathcona Regional District, municipal governments of Zeballos, Tahsis, and Gold River, MAFF, BCAL, the Area F/WCVI Clam Management Board. Both the Ehattesaht First Nation and the federal Department of Fisheries and Oceans are observing the committee's activities. RAMS facilitates the operation of the Nootka/Kyuquot Committee and provides technical, facilitative, and financial assistance.

Steering Committee Objectives

Steering committees were requested by BCAL to accomplish three objectives: (a) to develop suitability maps of their areas that detail acceptable and unacceptable portions of coastline for further shellfish aquaculture development, (b) to recommend a rate of development for shellfish aquaculture in the area under the committees' operation, and (c) to develop community-based criteria for the adjudication of geographically overlapping tenure applications and for ranking applications in cases where applications are received for a greater amount of area than the rate of development allows. These three objectives, and additional objectives the steering committees have undertaken, are described in detail below.

Suitability mapping

The first objective of the steering committees is to develop shellfish aquaculture "suitability maps". The purpose of these maps is to outline areas of coastline (in each committee's area of operation) that are suitable or not suitable for shellfish aquaculture. Suitable areas are those that do not conflict with other uses such as aboriginal uses, other foreshore leases (for forestry, finfish farming, etc.), or recreational uses. The term suitability is often confused with the term capability; capability is the biological and physical capacity of a particular foreshore or deepwater site to grow shellfish,[6-9] whereas suitability is an indicator of social values and objectives.

Suitability maps were initially developed in multi-stakeholder mapping exercises, where various representatives colour-coded areas on marine charts as suitable, maybe suitable, and not suitable for shellfish aquaculture development. Participants were asked to explain to the larger group why they had categorized coastline in the ways they did, and the charts were refined accordingly in group discussion.

The suitability information was then digitized and placed in a geographic information system (GIS) database. For further comment and input, the suitability maps were taken to local First Nations communities, to advertised public meetings, and to several interest groups that had not been present during the initial mapping. The suitability maps were then further refined. Finally, relevant local or regional planning information (e.g., the Barkley Sound Planning Strategy) was incorporated into the suitability maps (planning information was not available for all areas).

When BCAL issues a call for applications for new shellfish tenures in each committee's region, applicants will be directed to the suitability maps, which will be posted on the Internet and will be available at several office locations in the relevant region. Suitability maps are intended to be dynamic; the steering committees will periodically update them to ensure that applicants receive the most up-to-date information. Suitability maps do not indicate specific sites where applicants should or should not apply; rather they indicate broad areas that are suitable or not suitable for development.

Rate of development

The second objective of the steering committees is to recommend to BCAL a rate of development for shellfish aquaculture in each region (i.e., Clayoquot Sound and Barkley Sound). As part of its November 1998 announcement, the Province stated that they were committed to doubling the current land base under shellfish tenure within ten years, and provincial representatives have suggested that communities could consider a 10% increase in tenure land base per year in their area.

Steering committee members feel strongly that the rate of development must reflect both (1) the need to expand the industry to create industry stability and diversity as well as much-needed economic opportunities and (2) the need to proceed cautiously as the industry expands to ensure that local values and objectives are incorporated into the tenuring process. As of April 2000, neither the Clayoquot committee nor the Barkley committee have finalized the rate of development they will recommend for the first round of new applications, however they will both likely be greater than 10%. This is probably because the shellfish aquaculture industry is less developed on the west coast of Vancouver Island than in other parts of BC (the Province's suggestions were for province-wide development).

Criteria and community applications

The third objective that BCAL asked the steering committees to accomplish is the development of community-based criteria for the adjudication of overlapping tenure applications and for ranking applications in cases where applications are received for a greater amount of area than the rate of development allows. These criteria do not replace the provincial tenure application process. Instead they complement it by incorporating local values and objectives that the Province cannot incorporate into their process.

The steering committees have developed criteria relating to three main categories: (1) site development, (2) community, economic, and industry benefits, and (3) environmental integrity. There are two main purposes of these criteria: to adjudicate applications based on the values and objectives of local communities, First Nations, and shellfish growers and to inform prospective applicants of those values and objectives.

Criteria were developed through numerous meetings by eliciting values and objectives of local committee representatives (including First Nations, non native communities and local shellfish growers) then crafting criteria that reflect those values and objectives. For example, a local value is environmental integrity, and one objective based on this value is the minimization of adverse environmental impacts. Accordingly, criteria for on-site solid waste storage disposal and other environment-related practices were developed. Like the suitability maps, criteria were presented to First Nations and local communities, and suggested changes were ratified by the steering committees and incorporated into the criteria. Finally, community criteria have or will pass through the BC Attorney General's office to ensure that they do not fetter provincial ministers' discretion.

To accompany the criteria, scoring guides were also developed to ensure consistent adjudication of applications, which will be done by a multi-stakeholder community criteria review committee. Finally, a community application form was developed to accompany the BCAL application form. This community application asks prospective applicants for the information that committees require to apply their community criteria. It also directs applicants to local contacts for viewing suitability maps and discussing their questions or concerns.

It is important to note that community criteria, like the suitability maps, are intended to be dynamic. They will be changed and improved over time as the steering committees work with BCAL in shellfish aquaculture tenuring.

While BCAL has asked the steering committees to develop community criteria for the adjudication of geographically overlapping tenure applications and for ranking applications in cases where applications are received for a greater amount of area than the rate of development allows, both the Clayoquot committee and the Barkley committee would prefer to apply their criteria to all tenure applications. The committees believe this is the only way that all shellfish tenure applicants are oriented to the values and objectives of Clayoquot Sound and Barkley Sound communities. The committees will be working with BCAL and the Province to develop a mutually acceptable application process.

Locally-developed training programs and local processing opportunities

Development of the shellfish aquaculture industry on the west coast of Vancouver Island presents a real economic development opportunity for coastal native and non native communities. To better take advantage of this opportunity, steering committee members recognize the need to maximize community and industry benefits by maximizing the chances for success of individual shellfish industry participants and by developing local processing opportunities. (The nearest shellfish processors are on the east coast of Vancouver Island, a minimum three-hour boat ride and drive from most west coast communities).

Consequently, the Clayoquot committee has been developing an oyster aquaculture skills training program with local economic development corporations and skills-training centers. The focus of this program is to deliver skills training that is tailored to the needs of WCVI communities and increases an individual's chances of success in the shellfish industry, as either an owner/operator or an employee of a local farm. The Clayoquot committee is also pursuing funding for a feasibility study for local processing opportunities.

Challenges and Opportunities

The steering committees, similar to other groups or processes that involve a wide range of stakeholders each with specific interests, necessarily face challenges and opportunities. In the following sections, I briefly describe some of the challenges that the Clayoquot Sound and Barkley Sound Shellfish Aquaculture Steering Committees are facing and the unique opportunities that have been created.

First Nations treaties and interim measures

Nuu-chah-nulth First Nations are currently negotiating treaties with the governments of British Columbia and Canada. While these negotiations are completely separate from steering committees' activities, they do affect shellfish aquaculture because Nuu-chah-nulth First Nations are negotiating (with the Province of British Columbia) access to particular foreshore and deep-water sites for shellfish aquaculture development. As of April 2000, these negotiations were underway, and the resulting First Nations sites will be incorporated into the shellfish aquaculture suitability maps so prospective applicants are aware of their location.

Funding

For their successful operation, steering committees rely on meeting facilitators, meeting rooms, and clerical services for minute-taking and meeting notification. In times of ever-shrinking budgets, it can be a challenge to find necessary funding. BCAL, through Fisheries Renewal British Columbia (FsRBC; a Crown corporation that provides financial support for fisheries development and diversification), is providing financial support to the steering committees. This support allows community groups to develop local capacity and hire local people in the development of suitability maps, development rates, and community criteria. In addition to BCAL/FsRBC funding, both RAMS and the Clayoquot Sound CRB have provided considerable in-kind and cash support.

Relationship with the commercial wild clam fishery

A complex and contentious issue that WCVI shellfish resource users are facing is the reconciliation of clam aquaculture and commercial harvesting of wild intertidal clams (primarily manila clams), which occur on the same land base. Clam beaches on WCVI currently support over 300 licensed commercial clam harvesters[5] and several manila clam farms. In addition, clam beaches are dug by recreational diggers and by First Nations for food, social, and ceremonial resources. This issue is complicated by the multi-jurisdictional nature of clam habitat tenuring and clam fishery management in BC: the Province is responsible for tenuring Crown foreshore (i.e., it is the 'landlord' of Crown lands) while the federal Department of Fisheries and Oceans is responsible for wild clam fishery management, including the health of the intertidal clam resource. Currently, there are no comprehensive provincial or federal policies that permit reconciliation of the two, competing, uses. Local WCVI resource users (e.g., the Shellfish Aquaculture Steering Committees and the Area F Clam Management Board) are taking a proactive approach to this issue by offering to assist governments in the development of new policy by providing specific recommendations on how competing uses can be reconciled.[5]

Water quality and marine biotoxin monitoring

Water quality (e.g., fecal coliform contamination) is increasingly becoming a problem in specific areas on the WCVI. In addition, government budgets for paralytic shellfish poisoning (PSP) or marine biotoxin monitoring are being reduced and resource users, such as shellfish growers, are increasingly taking over the costs and responsibilities for monitoring. Steering committees have been proactive in alerting management agencies, such as Environment Canada, and affected resources users, such as First Nations and wild shellfish harvesters to developing issues in water quality and biotoxin monitoring. Depending on the status of future budgets and funding, steering committees (with other resource users) may develop recommendations or facilitate the development of self-funding mechanisms for water quality and marine biotoxin monitoring. Steering committees have also expressed to regional governments their willingness to co-operatively address water quality issues.

Environmental Carrying Capacity and Site-specific Impacts

While shellfish aquaculture is generally considered to be environmentally-friendly, members of the Clayoquot committee have expressed concern about the lack of site-specific research on benthic or other impacts of shellfish farming. Other environmental concerns of committee members include solid waste management (e.g., rope ends, Vexar® bags etc.) and sewage disposal at farms where owners or operators live on a part-time or full-time basis. Clayoquot committee members have also expressed concern about the environmental carrying capacity or productive capacity for bivalve culture of local inlets.

The Clayoquot committee is working with local First Nations, local researchers, biological consultants, and BC government staff to address carrying capacity and site-specific impact issues through research and monitoring. In addition, the community criteria of both the Clayoquot and Barkley Committees reflect local concerns about solid waste and sewage management.

Relationship building and effective communications

A successful multi-stakeholder process requires good working relationships between parties. This is not always easy where First Nations, communities, governments, and industries do not see "eye-to-eye" on particular issues. A significant development in the establishment and operation of the shellfish aquaculture steering committees is the substantial improvement in working relationships and communication between both committee members and the groups or organizations they represent. For example, individual shellfish growers and First Nations have developed previously absent relationships that will likely result in the formation of joint ventures or mentorship and training opportunities. Such a relationship is beneficial to both parties.

Key requirements of successful relationship building and effective communication in the Clayoquot and Barkley Committees include: (1) face-to-face communication (i.e., conducting meetings rather than 'bi-lateral' discussions by letter, e-mail, or telephone); (2) the consistency of agency or organization representatives (i.e., the same person attends meetings and does not send alternates unless absolutely necessary); (3) regular attendance by committee members; (4) regular and timely communication on meeting dates, agendas, and minutes by the Committee's facilitator, and (5) respectful conversations and attitudes at committee meetings.

Conclusion — Outlook for Shellfish Aquaculture on the WCVI

The meaningful involvement of First Nations and communities in development of a resource-based industry is a new and welcome opportunity on the west coast of Vancouver Island. However, the community consultation processes that the Province initially envisioned have taken substantially longer than was originally thought. This is probably due to several factors, including: (1) the inexperience of the particular government agencies, First Nations, community groups, and the shellfish industry in working together in a consensus-based-decision-making environment; (2) the time and personal commitments required to establish good working relationships that are based on mutual trust and respect; and (3) the parallel process of First Nations and BC government negotiations on access to shellfish aquaculture sites. This longer timeline, however, is critical for what local First Nations and communities are striving for: successful and meaningful input into the Province's shellfish development initiative.

Thank you to all members of the Clayoquot Sound and Barkley Sound Shellfish Aquaculture Steering Committees for their participation and commitment to building community-based recommendations on the future of shellfish aquaculture on the WCVI. In particular, I thank Andrew Day (RAMS), Elaine Story (Clayoquot Sound CRB), and Bill Mottershead (BC Assets and Lands) for their contributions to this paper and the Aquaculture Canada 1999 conference presentation. I also thank Paul Bagordo (Clayoquot Sound CRB) for reviewing this paper and for his insights and discussions about First Nations and community-based processes, Roger Dunlop (Nuu-chah-nulth Tribal Council Fisheries Program) for information about the Nootka/Kyuquot Shellfish Aquaculture Steering Committee, and Jim Russell (BC Assets and Lands) and Barron Carswell (BC Fisheries) for discussions and information about BC government policies and programs. I thank Bill Heath for organizing the special session on 'Shellfish Farming and Fisheries in Transition' at the 1999 Aquaculture Association of Canada conference.

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Area F Intertidal Clam Fishery Community Management Board: Emerging Community-Based Management in Nuu-chah-nulth Ha'houlthee[1] on the West Coast of Vancouver Island

Roger Dunlop

The Area F Intertidal Clam Fishery Community Management Board for the west coast Vancouver Island clam fisherywas formally established in 1998, after nearly 10 years of work by the Nuu-chah-nulth First Nations. The Board is composed of elected licensed clam harvesters and representatives from local communities, First Nation governments and guardians, as well as Fisheries & Oceans Canada and the BC Ministry of Agriculture, Food & Fisheries. The objectives of the Board are conserving the clam resource, producing long-term benefits from the fishery, and increasing the involvement of stakeholders in decision-making. This community management board, guided by a board development strategy, is developing a comprehensive inventory of area clam beaches, implementing a resource-based self-funding mechanism, and evaluating a set of licensing and technical micro-management options to improve the local intertidal commercial clam fishery. Vetting the micro-management options with the harvesters and communities will provide management direction to the Board. This approach will support development of a stock assessment program to complement existing data collection and meet the needs of the preferred management options. The intertidal clam fishery and several key board issues, including license transferability and expansion of shellfish aquaculture, are briefly described.

Introduction

The Area F Intertidal Clam Fishery Community Management Board (Area F CMB) was formally established for the west coast Vancouver Island (WCVI) clam fishery in 1998. The Governments of Canada and British Columbia, the Nuu-chah-nulth Tribal Council (NTC), and others involved in the clam fishery, co-operated to establish this community management board in Area F as a component of the reform of intertidal clam fishery management in British Columbia. I briefly describe the geographic scope of the Area F CMB, and its objectives, membership composition, decision-making process, and responsibilities. Also described are the clam fishery and the progress that has been made towards improving the way the WCVI intertidal commercial clam fishery is managed.

Geographic Scope

Area F includes the region from Bonilla Point, south of Nitinat Lake, to Cape Scott on the west coast of Vancouver Island, and includes Fishery Statistical Areas 21-27 (Fig. 1). The Area F Intertidal Clam Fishery Community Management Board is responsible for managing the fishery in Barkley, Clayoquot, Nootka and Kyuquot Sounds (Statistical Areas 23–26). This management area, which extends from Carmanah Point to Cape Cook, corresponds to the Ha'houlthee of the Ha'wiih of the Nuu-chah-nulth First Nations or dominion, government, and jurisdiction of the Nuu-chah-nulth Chiefs.

Board Objectives

The objectives of the Area F CMB are to:

- ensure conservation of the intertidal clam resource;
- maximize long-term social, cultural, and economic benefits from the comprehensive management and harvesting of intertidal clams, so that this resource might sustain and contribute to the well being of those directly involved in the fishery, local communities, and future generations; and

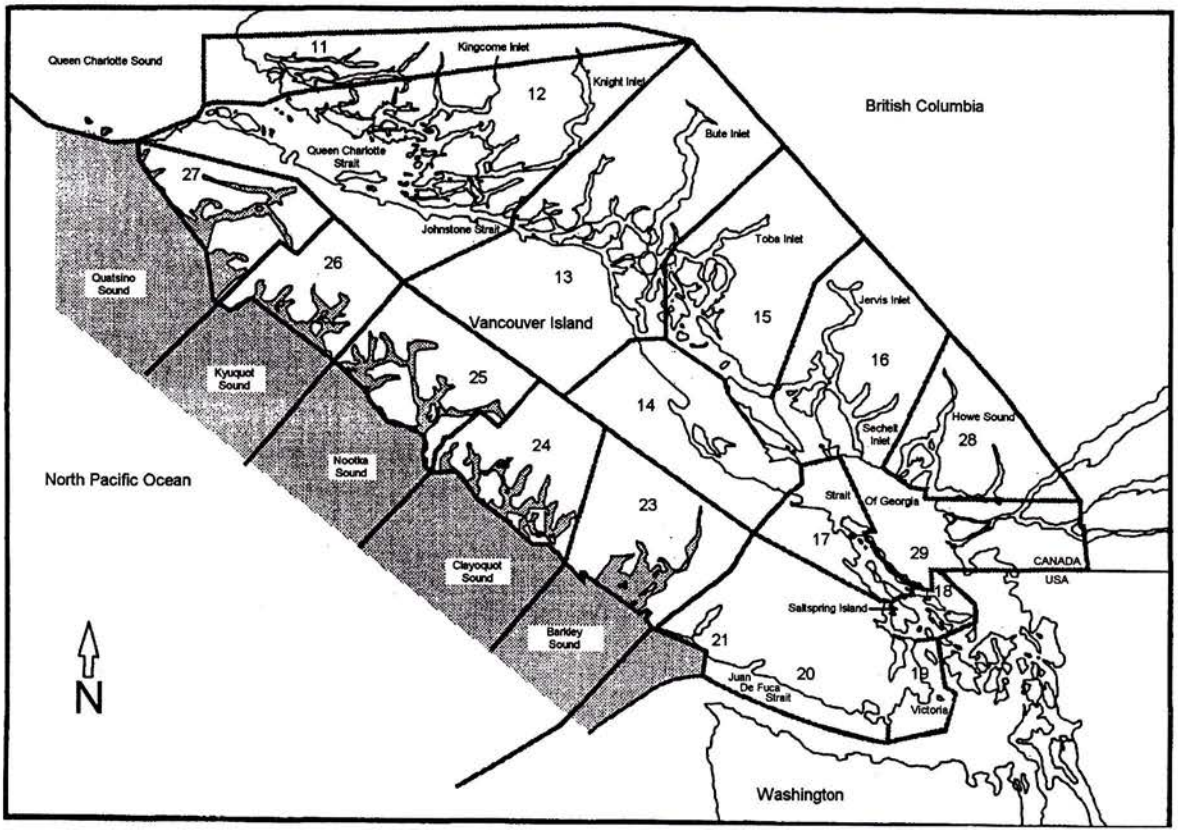

Figure 1. Pacific fishery management areas of the West Coast of Vancouver Island, British Columbia.

- explore local management options to increase involvement of First Nations, local communities and stakeholders in management decision-making.

Board membership

The Board currently includes 13 full members, plus three ex-officio management agency seats for provincial and federal governments. Those represented with full decision-making memberships include eight diggers elected every three years by the licensees, two members representing community perspectives appointed by the RAMS (Regional Aquatic Management Society), and one appointee each from the NTC, the processing industry, and the BC Shellfish Growers Association (BCSGA). Fisheries and Oceans Canada (DFO), BC Ministry of Agriculture, Food and Fisheries (BCMAFF) and the Nuu-chah-nulth Fisheries Guardians are represented in an *ex-officio* capacity. Staff members include two Nuu-chah-nulth Tribal Council fishery biologists who provide technical assistance and a secretariat provided by the WCSA/RAMS (West Coast Sustainability Association/RAMS).

Linkage to regional management processes

The Area F CMB is linked to the larger, umbrella group, the Pacific Region Clam Management Committee (PRCMC). The PRCMC provides a forum for discussion and provision of advice to government on common management issues facing the various area clam fisheries, harvesters, and management boards. To date, only the Area C clam fishery has organized a management board in addition to the Area F CMB. The Area C Board differs in that it is composed entirely of licensed harvesters, First Nation representatives, and *ex-officio* government members, but does not include specific representation from local communities.

The Area F CMB Terms of Reference also allows for the strengthening of a linkage or integration with a larger local area-based fisheries management initiative: the WCVI Regional Fisheries Management Board, which is currently being negotiated with governments. This larger organization is currently operating as the Regional Aquatic Management Society (RAMS) with objectives similar to the Area F CMB. The RAMS provides administrative support for the

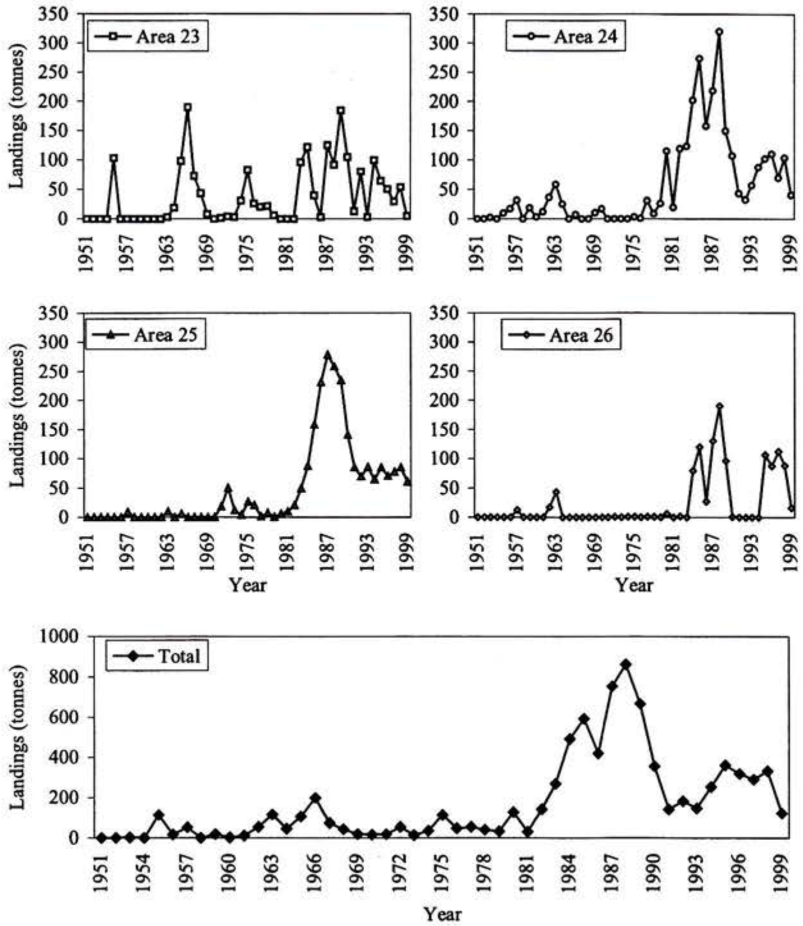

Figure 2. Annual intertidal clam landings by area (23-26) and total clam landings (area 23-26) from 1951 to 1999. Values for 1951 to 1995 taken from the Area F DFO Clam Atlas. Values for 1996 to 1999 are preliminary and subject to change.

Area F CMB, along with the West Coast Sustainability Association (WCSA).

Decision-making and responsibilities

The management board makes decisions by consensus. On only one occasion has the Board not been able to reach consensus. The Board could have resorted to a vote to decide this particular issue, but instead they chose to articulate both sides of the issue when giving advice to the federal Minister of Fisheries and Oceans. The Board's authority is limited at present to serving an advisory role to DFO and BCMAFF. Authority will increase over time as the capacity of the Board to deal with issues increases.

The Board has an evolving mandate and responsibilities. Initial responsibilities included refining its terms of reference, establishing and following a board development strategy, providing advice that was incorporated into annual fishery management plans and in-season management, and interacting with the Pacific Region Clam Management Committee. Longer term responsibilities include further refining objectives, developing strategies and plans for habitat protection, rebuilding and managing intertidal clam stocks, providing advice on economic opportunities, preparing an annual report and annual fisheries management plans, and continuing in-season management. Other responsibilities include making recommendations to the federal Minister of Fisheries and Oceans on the issues of aquaculture development, allocation of economic opportunities, and license transferability.

The Board also provides advice to Environment Canada and the Canadian Food Inspection Agency on local issues concerning water quality in shellfish growing areas and marine biotoxin monitoring programs, respectively. The Board is accountable for local consultation and co-ordination, establishment of self-funding and capacity building initiatives, as well as participation in other planning processes. Additional areas of responsibility include monitoring and evaluating the implementation of management plans, progress toward objectives, operating procedures, government responses to recommendations, and the Board process and achievements.

Area F Intertidal Clam Fishery

History of fishery and licensing

The Area F intertidal fishery for Manila clams (*Tapes philippinarum*) is relatively new. The first recorded commercial landings on the WCVI occurred in the mid 1960s (Fig. 2). Effort remained low and landings were less than 100 metric tons until 1982. With unrestricted access to the fishery, effort increased due to market demand. Landings quickly rose and crested in 1988 at over 800 tonnes. This peak was followed by a rapid decline in landings over the next three years. Part of this decline can be attributed to a 5-year conservation closure in Kyuquot Sound (Area 26), induced by the decline in landings. By 1991, landings had decreased to their present annual range of about 250 to 300 tonnes. In less than 8 years, the accumulated biomass of intertidal clams had been depleted.

As a consequence of this history, and later as part of clam management reform in British Columbia, DFO implemented area-based licensing in 1989, followed by license limitation in 1998. Area licensing was intended to stabilize the fishing effort in each clam fishery management area in British Columbia. License limitation was undertaken to reduce fishing effort in each fishery area to more reasonable levels. Prior to license limitation and area-licensing in the clam fishery, anywhere from 500 to 700 harvesters could operate during an Area F fishery opening. Qualification for a limited-entry regular commercial clam license (category Z-2 commercial clam license) required a record of purchase of a Z-2 clam harvesting license in 5 of the 6 years between 1989 and 1994. It was originally expected that approximately 68 licenses would remain after license limitation. After an unexpectedly large number of appeals, however, the final number of Z-2 licenses in Area F will reach approximately 100. Finalization of the number of licenses awaits the outcome of several appeals launched just before the closure of the appeal process at the end of 1999.

At the same time that the Z-2 licenses were being rationalized, DFO issued 237 Aboriginal commercial licenses (ACL) for the clam fishery to the 14-member First Nations of the NTC. An ACL has the same restrictions and requirements of a regular Z-2 license, except that the number of licenses was negotiated with individual bands and was not tied to the eligibility criteria. These licenses were issued when it was realized that Nuu-chah-nulth First Nation participation in the fishery would be virtually eliminated by license rationalization. Therefore, although a large number of aboriginal clam licenses were issued, the total number of licenses in the Area F fishery has been reduced to approximately 337. Although this number of eligible licenses seems large, the number of licenses actually fished each year is considerably less. There were 237 aboriginal and 96 Z-2 licenses eligible to be issued for Area F in 1998, but only 280 (84%) of the 333 licenses were issued during the 1998 license-year. By the conclusion of the 1999 spring fishery, 83 Z-2 licenses and 133 aboriginal clam licenses were issued (65% of those eligible), although more license subscriptions were anticipated to occur during the late autumn and winter 1999 fishery.

Recent clam fishery

Area F clam landings in 1997 were 262.3 tonnes (577 000 lbs), taken in 18 days of fishing with an unlimited number of licenses. The first year of Board operation and limited licensing was in 1998 and clam landings in that year were 301.4 tonnes (663 125 lbs.) harvested in 38 fishing days that were spread over eight openings between January and December (7.9 tonnes/fishing day). Landings in 1999 were 155 tonnes harvested in 19 fishing days by 180 to 220 active licensees (8.1 tonnes/ fishing day). To the end of February 2000, 74 tonnes (162 000 lbs) were landed by an estimated 160 diggers in 6 fishing days spread over two openings (12.3 tonnes/fishing day). These trends indicate the Board is setting fishery openings more conservatively, as the Board has supported fewer and shorter openings to allow larger quantities of legal- size (mature) clams to remain for reproduction.

Average earning per license was $2686 in the winter 1998 and spring 1999 fishery. Average landings per licensee increased by 318 kg (700 lbs) between 1997 and 1998 (Fig. 3). This increase reflects the fact

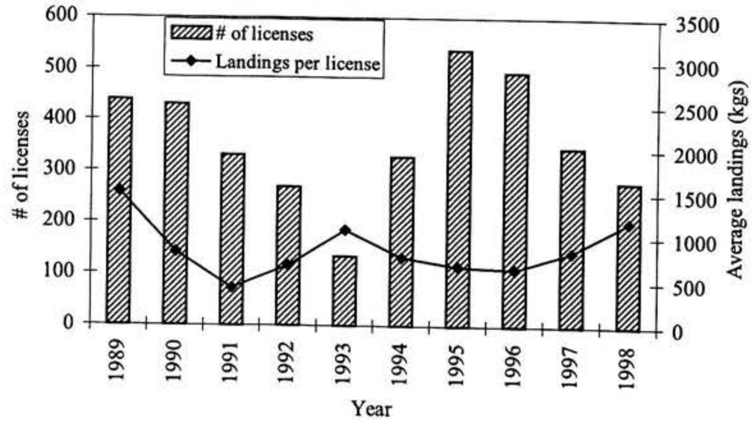

Figure 3. The number of intertidal clam licenses issued for Area F between 1989 and 1998 and the average landings in lbs. per license. This shows that though the landings have decreased in recent years the landings per license has increased.

there were fewer harvesters due to license limitation, as it occurred concurrently with the establishment of the Area F CMB and was, therefore, not a result of Board actions. Landing reductions in 1999 were the direct result of the Board reducing fishing effort to conserve clam stocks.

Area F Board Activities

Much of the Board's early work was limited to dealing with administrative tasks, setting clam fishery openings, and dealing with a few specific management issues related to the clam fishery. Administrative tasks included securing initial funding, building the Board development strategy and developing timelines, securing a secretariat and staff, and reviewing options to establish the Board as a legal entity. More recently, a discussion paper was developed to address options for improving enforcement through coordination, improving stock assessment, and securing permanent funding. Support staff are developing an inventory data set for the more than 350 clam beaches in Area F. Recently, a management options paper was commissioned to assist in evaluating and determining the most appropriate management direction for the wild clam fishery.

Funding options

Funding and in-kind support for Board operations to date have been provided by DFO, BCMAFF and the Nuu-chah-nulth Tribal Council. The Board is working toward developing a long-term self-funding mechanism based on the resource and independent of government sources. After reviewing the alternatives outlined in the option review, the Board is focusing on facilitating controlled harvests for depuration (the artificial purification of marginally contaminated bivalve shellfish) that have the greatest potential for revenue generation without the onerous requirement of legislative change. The Board is developing a joint-venture agreement with licensed clam fishermen and licensed depuration facility operators.

Although it has yet to implement a cost-recovery depuration harvest, the Board was instrumental in establishing two depuration harvests in the Kyuquot Sound area for the Ka: yu: 'k't'h/Che:k'tles7et'h' First Nations and local diggers. These fisheries, on two marginally contaminated beaches at Malksope and Cachalot Inlets, provided capacity building in stock assessment techniques and clam management experience and injected over $137 000 in harvesting opportunities into the local economy in 1999. Further benefits included causing the community to "buy in" to the depuration program and self-police the local fishery. In so doing, an illegal digging problem in a contaminated area was resolved. These depuration harvest opportunities should continue indefinitely as they are based on a sustainable harvest rate established after rigorous stock assessments were completed. Kyuquot clam harvesters now wonder "Why isn't the entire fishery run this way?"

Beach inventory database

The Board's beach inventory database will combine digital and spatial data from DFO's WCVI Clam Beach Atlas and BCMAFF shellfish aquaculture capability mapping studies, and identify the status of individual beaches (e.g., wild fishery beach, fronts First Nation reserves, pilot program beach, and tenures, etc.) and water quality classification (e.g., approved, closed). There are omissions and overlaps in both data sets, so combining the two documents will provide the Board with a more comprehensive inventory tool. This project will also identify areas suitable for Board self-funding opportunities through depuration, in addition to stock assessment and management purposes.

Clam fishery management options

Historically, the Area F clam fishery in British Columbia has been managed using fishery-dependent catch per unit effort (CPUE) information and anecdotal information from fishermen. The commercial catch is estimated for each statistical area and fishery opening through a mandatory sales-slip reporting requirement of licensed buyers and/or processors (Fig. 2). Additional recreational and First Nations clam fishery catches (and effort) are unknown, so the total catch is uncertain. Fishing effort information is also incomplete. Effort counts are subjective and provide only an estimated range of numbers of active fishermen in each opening. Certain illegal practices in the fishery further erode the value of CPUE by making effort estimates even less accurate. Effort is estimated in digger days and measures neither shifts in effort patterns (e.g., fishing small beaches now instead of larger beaches as formerly), harvesting tactics (e.g., moving beach debris to reach previously unavailable stock or harvesting in standing water on marginal tides), nor fishing efficiency. It is well known that CPUE information can be an unreliable indicator of stock abundance. Consequently, the Board has commissioned an options paper to review the pros and cons of alternate licensing and technical options for management (Table 1). The Board plans to review these options with the Area F licensed diggers at a workshop to provide feedback and management direction. Each of the options under consideration will be evaluated in relation to the objectives of conservation, long-term commu-

Table 1. Area F Intertidal Clam Fishery Community Management Board licensing and technical management options.

Number	Option	Description
1	Area-based licensing	Explore statistical area licensing to stabilize effort (50 to 80 licenses/ statistical area).
2	Status quo: fishery-dependant data	Use catch-per-unit-effort (CPUE), total landings, and anecdotal information.
3	Use fishery-independent data with improved fishery-dependent data	Use detailed stock assessments with more accurate landing data to set harvest rates/quotas.
4	Individual beach management:	
	a) Close single beaches (CSB)	e.g., Heiltsuk clam fishery where beaches are checked visually and those that look poor are closed. This option can be modified to include thorough stock assessment and, later, indexing and less comprehensive assessment.
	b) Open single beaches (OSB)	Similar to depuration fishery; beach-by-beach detailed stock assessment completed, quota is set based on conservative harvest rate prior to harvest.
5	Sub-area management:	Similar to option 4a and 4b, but open and closed sub-areas containing multiple beaches instead of individual beaches.
	a) Rest-rotation system	Suggested in Kyuquot Sound, division into three sub-areas, two closed and one open, monitoring required to determine appropriate length of rotation period and effort.
	b) Close sub-areas	Based on visual and/or index assessment of beaches in sub-area.
	c) Open sub-areas	Identify sub-areas, conduct detailed or index stock assessment at beaches, set quota for sub-area.
6	Size limits:	
	a) Slot size limits	Specify minimum and maximum size to preserve older, more fecund clams.
	b) Examine validity of current minimum size limit	Determine if 38-mm current minimum size limit is effective or should be altered.
	c) Examine use of different size limits for different populations.	Determine whether environmental gradients and slower growth rates in some areas require alternate size limits.

nity benefits, increasing local participation and the additional objectives of ease and cost of management, administration, data requirements and enforcement.

Although stock assessment options had been reviewed in a preliminary manner, a stock assessment process can not be established until the management directions are determined to more rigorously define the stock assessment needs of the particular management system to be employed.

Clam harvesting license transferability

One of the issues before the Board recently was the transferability or sale of Category Z-2 commercial clam fishing licenses. The current moratorium on transfers (i.e., sale) was due to expire in 1999. The Board was unable to reach consensus on the transferability issue, as there were arguments both for and against transferability. Most licensed diggers wish to be able to sell their license or stack several area licenses together to allow them to dig clams full-time. Community and Nuu-chah-nulth representatives are against the sale of licenses and stacking. They argue that, among other reasons, transferability will increase pressure on the resource (to pay off licenses) and result in the fishery contributing to the profits of lending institutions rather than benefitting local communities. Both points of view were put forward verbally via the Pacific Region Clam Management Committee and in writing to DFO for a decision by the year 2000. DFO responded by deferring removal of the moratorium until the year 2001, citing "compelling arguments against transferability articulated by community and First Nation representatives".

Aquaculture and the wild clam fishery

The license transferability issue will be revisited as part of the development of a process to make recommendations to government on how best to reconcile shellfish aquaculture expansion with the wild clam fishery. The BC government announced an initiative[2] for the expansion of shellfish aquaculture in November 1998. Expansion of tenures for the beach culture of clams and oysters will displace wild clam harvesters that have historically fished the same beaches. Most wild clam harvesters understand that cultured production levels from the area would far surpass production from the wild fishery as currently managed. However, loss of even the small economic benefit provided by the wild clam fishery can represent a loss of a substantial portion of an income in small, remote communities, particularly in this area, which is already reeling from employment losses in the forestry and salmon fishing industries. The question that must be resolved is: Who gets access to the beaches and at whose expense? During the interim, while a process to reconcile this issue fairly is established, the Area F CMB has recommended that no potential intertidal clam habitat in the area be tenured until a reconciliation process is established to first look after those displaced from the fishery. It will take considerable cooperative effort by federal, provincial, First Nation and local governments, the communities, and participants to determine how to best look after those who might be displaced. How we look after these people will also be a measure of our society.

Summary

The Board has yet to complete its most important task: establishing a fishery management regime that will allow it to aggressively rebuild the intertidal clam resource to its most productive level, and maintain the area fishery at productive and sustainable levels. By adhering to the Board Development Strategy, it is expected that, within the next year, the following will have occurred:

- A new management scheme will be in place in at least one statistical area.
- The beach inventory and status project will be completed to define the sampling universe and sampling strata required for stock assessments.
- A practical stock assessment program will be providing critical fishery-independent management data and feedback to supplement improved fishery-dependent data.
- Having identified depuration opportunities in the inventory, the Board will be self-funded and in doing so, will be providing additional fishing and economic activities for the clam harvesters and communities of the west coast of Vancouver Island.
- A process will have been established to determine the appropriate regional mix between the wild clam fishery and the expansion of shellfish beach culture.

Thanks are extended to Fisheries and Oceans Canada, BC Ministry of Agriculture, Food & Fisheries, and the Nuu-chah-nulth Tribal Council for their efforts, financial contributions and in-kind support in developing and operating the Area F Intertidal Clam Fishery Community Management Board. I thank Bill Heath and Edward Black of BCMAFF who encouraged me to participate in the workshop I am grateful to Lynn West who kindly digitized several figures for inclusion, and Randy Webb who reviewed the manuscript. I thank the Area F Intertidal Clam Fishery Community Management Board for their work in striving to make the changes necessary in the fishery to realize the Board's objectives.

Notes and References

1. Ha'houlthee of the Ha'wiih of the Nuu-chah-nulth First Nations is the dominion, government and jurisdiction of the Nuu-chah-nulth Chiefs.

2. Osborne J. 2000. *Bull. Aquacul. Assoc. Canada* 100-2:23-29.

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Development of the Mussel Industry in Eastern Canada

David J. Scarratt

Wild mussels have been harvested in eastern Canada for centuries, but it was not until the early 1970s that there was serious experimentation with their culture. Early trials based on Spanish experience using rafts were unsuccessful, and there was no real success until the Japanese floating longline technology was adopted in the late 1970s. This technology was adapted to winter conditions where the lines could be sunk below the ice, and harvested through it, allowing year-round operation. Seed mussels are collected in one year, socked later that same fall, and on-grown for 15-18 months depending on the location. The industry successfully survived the domoic acid crisis of 1987 and the current harvest in Atlantic Canada exceeds 30 million pounds (15 000 t). There is evidence that some areas are approaching, or have reached, their natural productive capacity. Early ventures relied heavily on hand labour for loading socks, and for harvesting. Initial mechanization focused on the adoption of hydraulic harvesting systems for lifting heavy socks out of the water, but recent developments include the use of automated continuous socking systems which allow for better management of mussel leases. This technology is not universally adopted. There has been some specialization in that some farms in favourable areas, supply seed to others where seed is less suitable. While there are some very large, vertically-integrated growing and processing enterprises serving international markets, there remain many smaller farms that meet purely local requirements. There is increasing market diversification and a move toward value-added products. In contrast to the cultured oyster industry which still suffers from the impediment of regulations designed to protect wild stocks, licensed mussel growers are free to manage their stocks according to best commercial practice, commensurate with meeting the normal sanitation and toxicological standards. This has undoubtedly contributed to the success of the industry.

Introduction

Wild mussels (*Mytilus* spp.) have been harvested in small amounts in parts of eastern Canada for centuries, but have never, until recently, matched the popularity of other shellfish, such as soft shell clams (*Mya arenaria*) and oysters (*Crassostrea virginica*). In the early 1970s a number of people experimented with suspending mussel seed in mesh strings from floating rafts, much in the same manner as the Spanish technology, but on a much smaller scale. The disadvantages of raft culture in winter were immediately apparent when it became clear that floating rafts and ice could not co-exist. Since mussels take more than one season to grow to market size, some method was needed to suspend mussels below the ice, yet far enough off bottom that they were out of the reach of crabs and starfish. A number of people began adopting the Japanese suspended long-line technology in the late 1970s, and the modern east coast mussel industry has developed from that early work.[1] There is some interest in raft culture in parts of Maine, where winter ice conditions are less severe.

It was initially believed that the blue mussel of eastern Canada was *Mytilus edulis*, but it is now recognized that some areas, principally in Nova Scotia, have relatively high proportions of a similar looking, but nonetheless different mussel: *M. trossulus*.[2] On average, *M. edulis* has a more robust shell usually with a blue-black periostracum. *M. trossulus* shells are usually more elongate, with a brownish-coloured periostracum, and they are lighter, less robust and more likely to suffer breakage in processing machinery. While consumers can rarely detect any differences between the species, *M. trossulus* may provide a lower economic yield, and is less favoured by the industry.

Suspended Longline Culture

The standard longline comprises a 200-m length of 12- to 15-mm polypropylene rope, securely and permanently anchored to the bottom. Some growers use discarded weighted seine warps, which will sink when not in use. Anchors may be concrete weights, lengths of railroad rail, embedded screw anchors, or whatever else serves the purpose and pocket of the grower. Flotation initially was plastic cans and bottles, and the ubiquitous polystyrene 'popcorn' lobster trap buoy, which in time became specially adapted with a wire bail top and bottom. More recently, in the Maritimes, spherical, foam-filled plastic buoys which support about 20 kg have become the industry standard, while in Newfoundland the large 200-L plastic barrel (usually recycled) is still commonly used.

Mussels are grown on 'socks' or 'sleeves' suspended from the longlines at intervals of 60-90 cm (2-3 feet). The length of the socks varies from farm to farm, being limited by the depth of water at low tide. Socks, which drag on the bottom, will soon pick up a crop of crabs or starfish, noted for their predatory habits.

Typically the lines are buoyed at the surface during the open water season. Prior to freeze-up, weights will be added on drop-ropes, somewhat longer than the socks, so that the longline and buoys are below the anticipated depth of the ice, while the socks still remain clear of the bottom. Increasingly, mussel farmers are sinking their gear in this manner all year round, keeping the buoys a meter or more below the surface. This keeps the socks well below the surface wave action, reducing drop off, and goes some way toward minimizing interference from recreational boat traffic.

It is interesting that in Maine, where there was some early longline culture, the industry has relied largely on bottom culture, and has only recently begun to experiment again with rafts, which can be used more easily where there is less winter ice to contend with.

Mussel seed

Mussel seed is captured on lengths of rope, or plastic mesh, fastened to longlines set in areas of the mussel farm favourable for spat collection. Collectors are set out, usually in May or June, but the exact timing depends on the breeding cycle of mussels in the area. The spat are allowed to grow until late October or November when they are about 12-15 mm long, at which time they will be harvested, culled and graded. Mesh sleeves cut to predetermined lengths suited to each individual site, are filled with seed mussels. There are several styles and sizes of mesh; the choice being largely determined by the size of the mussel seed. The mesh openings must be big enough to allow the mussels to work their way through, but not so large that they all fall out. A number of designs of socking table are in use. In principle, each socking table has a sloping tray filled with mussels and a nozzle at the lower side over which a length of sock is loaded, concertina fashion. The operator controls a gate, which allows a flow of water and mussels down the nozzle, so filling the sock like a sausage in its casing. A skilled operator will adjust the flow of mussels to achieve an optimum density of mussels in the sock. This depends on the size of the seed, but may average 120-180 per meter. Filled socks are transported to the lease and tied off on the long lines.

Some farms specialize in spat collection, and sell seed to other growers. This has the advantage of not having to operate the farm over winter. Some growers rely heavily on purchased seed if spat collection is unreliable on their own farms. Farms in Nova Scotia which have high proportions of *M. trossulus* may purchase most, or all, of their seed from farms that grow *M. edulis*. This will give them a better quality product and may, in time, shift the local balance in favour of the commercially preferred species.

The most significant recent change in the Canadian east coast mussel industry is the adoption by a few growers of the New Zealand "continuous socking" technology. This highly mechanized, and semi-automated system that uses "fuzzy" rope, and a cotton cover, which decays relatively rapidly, enables growers to do their socking out on the lease, saving considerably on time and labour. Peter Darnell[3] describes this technology and its advantages, so details need not be provided here. Canadian-designed machines are now available, as is the fuzzy rope and cotton cover. Not all growers have adopted the technology.

Grow out

Grow out may take 15-24 months depending on location. Growth rate is a function of temperature and available phytoplankton. Essentially, the grower must monitor the growth of the mussels and ensure there is adequate flotation on the lines. During certain periods, depending on the site, there may be problems with predation by ducks, principally eider and scoter, which can cause significant loss if precautions are not taken. These include bird scarers of various forms, and routine patrolling of the lease by boat.

Mussels do not thrive if water temperatures approach 20°C, or exceed it for any length of time. Prolonged warm temperatures may result in summer die-off. Mussels at this time of year will likely have spawned and have no reserves; phytoplankton density is usually low and metabolic rates are high. The mussels are highly stressed. Where water depths permit, some growers will sink their lines so that they are in cooler water. By controlling the depth where mussels are grown, it is possible in some areas to avoid summer-kill, and even extend the harvest season and provide high quality mussels more or less throughout the year.

Harvesting

Traditionally, harvesting required a small winch mounted on a boat or scow to haul the longline out of the water. Then the socks were cut off and hauled aboard by hand and loaded into 45 kg (100 lb.) totes to be taken ashore. Some of the early harvesting systems were very simple and used readily available and recycled material. This has been progressively mechanized, and most harvest boats now use hydraulically operated hauling and lifting gear designed to save the harvesters' backs. Disposal of used socks is sometimes a problem. The modern continuous fuzzy rope system is harvested continuously, the mussels being stripped off automatically into heavy fabric bags carrying up to a tonne. This significantly reduces the need for manual labour. The fuzzy rope is cleaned and re-used. Culled mussels too small for processing are sometimes re-socked and returned to the water.

Winter time adds other problems. There is a period when ice may too thick to be broken by harvest vessels and too thin to support the weight of harvesting equipment. However, once ice is thick enough, crews go onto the ice, locate the lines and cut holes through to them. Divers hook the mussel long lines onto retrieving lines and the mussels are winched up through the ice and taken ashore to the plants. Often, suitable weather 'windows' for harvesting are short and relatively infrequent, so processing plants have tended to build extensive wet storage systems enabling them to store several days' supply, and so ride out any extended period of severe winter weather.

Processing

Given the development of this harvesting technology, the mussel industry operates year-round. Most mussels are simply harvested and brought to a processing plant where they are de-clumped, washed, graded and debyssed, then sold alive to markets throughout North America. Some go to the Orient and Europe. Most short and intermediate shipment is by truck, with transcontinental shipping generally being by air. There is some developing use of longer range (transcontinental) transport of live mussels by truck, with mussels being placed into wet storage at the destination prior to resale.

There has so far been little development of value-added products, although that is beginning to change. Some producers are experimenting with vacuum packs, salad mussels, and microwaveable products.

Landings Statistics

These are provided in Table 1 (1999 tonnages are all estimates).

Prince Edward Island

Prince Edward Island (PEI) has been the leader in the east coast mussel industry, almost from the beginning, due to a very forward-looking leasing and licensing policy adopted in the early 1980s. There are suggestions that the available space for mussel culture in PEI is now completely occupied, and the industry is beginning to experience some signs of over-stocking (i.e., slower growth rates and lower yields). Nonetheless, the annual statistics continue to climb. Some of the processors are importing mussels from Newfoundland and the mainland, to meet market demand, and a number of the larger growers are attempting to establish new farms on the mainland.

In the late fall of 1987, PEI experienced the 'domoic acid' crisis when a hitherto unknown shellfish toxin contaminated mussels from a number of estuaries in the eastern part of the Island. The incident was sufficiently serious (an unknown toxin affecting about 150 consumers, including 3 deaths) that the whole of the shellfish industry was closed for a period of about 2 months while the problems were resolved. A major scientific enquiry was conducted that established the identity of the toxin, and stimulated the development of analytical protocols and monitoring programs for consumer safety. The industry began to re-establish itself early the following year, but some companies, both on the Island and elsewhere, did not survive. This interruption in the growth of the industry is visible in the landings data shown in Figure 1.

Nova Scotia

There was once a large number of small farms in Nova Scotia, but the number has been reduced to a handful of serious producers, with a few smaller farms serving purely local markets. Production is in-

Table 1. Mussel aquaculture landing statistics of the four Atlantic provinces and Quebec.

Province	1997	1998	1999
PEI	11 000	13 700	15 000
NS	819	835	900
NF	752	946	1800
NB	200	680	1000
QC	100		1200

creasing. Attempts by some PEI growers to find sites in Nova Scotia are meeting some local resistance, and expansion of the industry here may be due to the increased utilization of existing leases rather than the opening of new ones. Many Nova Scotia growers with high proportions of "*trossulus*" mussels, purchase seed from New Brunswick.

Newfoundland

Production in Newfoundland has doubled in the past few years and is growing rapidly as the industry moves out of the early experimental phase. Due to long distances to market, more attention is being paid to product development, and perhaps half the current production is going to value-added products. There are 50 growers occupying more than 100 sites, but 90% of production is from a dozen, or so, farms.

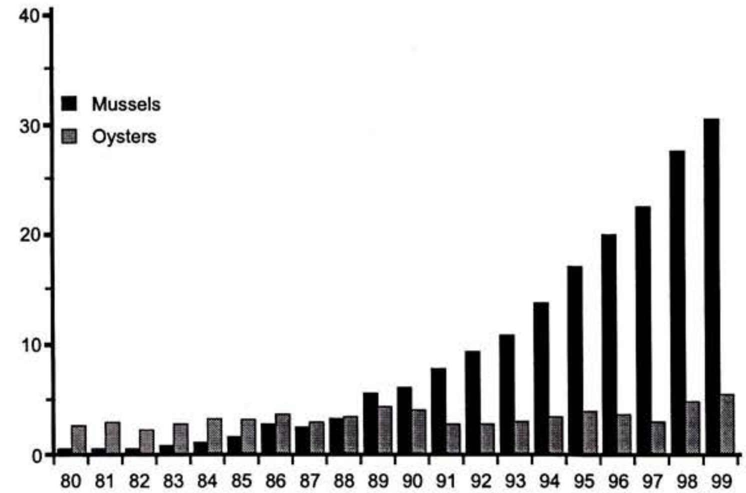

Figure 1. Prince Edward Island mussel and oyster landings since 1980.

New Brunswick

Production is from a limited number of farms on the Gulf of St. Lawrence shore and for several, a large part of their business is in selling seed mussels. Production is gradually increasing.

Quebec

Mussel production in Quebec has been relatively modest, but has recently begun to increase rapidly with the development of deep water longline technology in the Baie des Chaleurs.

Comparison with the Oyster Industry

A comparison with the oyster industry is instructive. American oysters (*Crassostrea virginica*) have been harvested in the Gulf of St. Lawrence for centuries, and for at least a hundred years have been cultivated using relatively simple technologies. Spat were collected on brush or veneer collectors, grown for a few months in nursery trays and then seeded on bottom. The destruction of stocks by Malpeque disease, initially on Prince Edward Island and later on the mainland, led to serious disruption of the industry. Even now that mainland stocks are disease-resistant, the industry is constrained by a very complex management regime, ostensibly designed to conserve wild stocks and protect consumers. Notwithstanding the availability of modern culture technologies, the wild stock conservation regulations seem inextricably linked to controls governing the cultivated product; the net result being virtually no growth in the oyster industry. While the essentially unregulated (apart from public health constraints) mussel industry has flourished, the oyster industry has remained largely stagnant. The data for Prince Edward Island illustrate this perfectly. The lesson is clear. With any cultivated species, there must be clear and early separation of regulatory regimes from those governing the traditional fisheries.

I am indebted to Parnell Trainor (PEI), Marian Vezina (NS), Monique Niles (NB), Ron Scaplen (NF), Maurice Gaudet (QC) for information concerning mussel production in the five Atlantic Provinces.

References

1. Scarratt DJ. 1993. *A Handbook of Northern Mussel Culture.* Island Press Ltd., Montague.
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***David Scarratt** was a research scientist and research manager with the Department of Fisheries and Oceans for 31 years before establishing his own consulting firm in 1992. He works closely with the aquaculture industry in Atlantic Canada. In 1993 he published* A Handbook of Northern Mussel Culture *which describes the operation of the industry at that time. He also edits the aquaculture publications* Hatchery Magazine *and* Shellfish World, *and writes a regular column for* Northern Aquaculture. *His e-mail address is scarratt@ns. sympatico.ca.*

Transfer of New Zealand Mussel Farming Technology to Nova Scotia, Canada

Peter Darnell

Indian Point Marine Farms Ltd. recently switched from socking mussels in the traditional style to using continuous sleeving technology developed in New Zealand. In this paper, I discuss the limitations of the old method of socking mussels, and describe the New Zealand system and how we imported the technology to Nova Scotia. There have been both difficulties and successes in getting local manufacturers interested in producing the required machinery, specialized "fuzzy" rope, and biodegradable cotton sleeving. We have experienced challenges and made progress in learning to use the new system. New options and strategies for mussel culture result from being able to sleeve our seed mussels quickly and relatively inexpensively. Although the transition to the new technology was far from seamless, we were determined from the beginning to make the new system work for us because of its obvious advantages.

Introduction

Until 1996, mussel production in Atlantic Canada was based on filling polypropylene mesh socks with mussel seed using a sleeving table, water, and considerable labour.(1) At our operation, we were always uncomfortable with this process, as we felt we were trying to accomplish two diametrically-opposed goals: to use a mesh size large enough so that the mussels could migrate through the mesh and subsequently grow successfully, while keeping the mesh small enough so that the mussels did not fall out when the sleeve was hung. In addition, it was necessary to hire a lot of temporary labour for four weeks in the fall and workers were not always easy to find. Even with the additional labour, there could be problems. For example, one of the critical factors in successfully growing mussels is to strictly control the density of the seed in the sleeves. This is difficult to do when relying on part-time workers as they often prefer to get the job done quickly by overfilling the sleeves! We felt there had to be a better way.

In the winter of 1996, Peter Millett and I from Indian Point Marine Farms Ltd., along with Gerald Mossman of the Nova Scotia Department of Fisheries and Aquaculture, made a trip to the Marlborough Sounds area of the South Island of New Zealand. Through the exceptional hospitality of Keith Yealand of the Marlborough Mussel Company, we were able to observe the New Zealand greenshell mussel *(Perna canaliculus)* industry. Our aim was to study firsthand the continuous mussel socking technology that has transformed the New Zealand mussel industry from its starting point in 1970 to a highly competitive industry that in 1999 exported $100 million worth of mussels to over 40 countries. We wondered why the New Zealand mussel industry was so much more successful than the Nova Scotia industry and what we could learn that would benefit our mussel business. We found that New Zealand had developed greater efficiencies in production by using a fully-mechanized socking, or sleeving, system in which mussels and "hairy" or "fuzzy" rope(2) are placed inside a biodegradable cotton-thread sleeve (Fig. 1). The cotton breaks down within two to three weeks, but the mussels remain attached to the hairy rope. Instead of individual drops or socks, they use a continuous operation in which a seeded rope drops down a pre-set distance and then loops back to the longline where it is tied by twine and then drops back down, and so on, for a distance of several kilometers. This process is accomplished by a "seeder", which is a relatively simple machine, consisting of a hopper with a conveyor at the bottom that delivers mussel seed into a tube, on which up to a kilometer of cotton socking can be placed. The fuzzy rope is also fed into the tube. A hydraulic motor pulls the rope, cotton socking, and mussels through the tube and over the side of the boat. A computer meters the amount of sleeve being made and, by means of a bell, tells the operator when to tie the sleeve to the longline. Seeding rates of up to 3 kilometers per hour may be attained using this method. The cotton socking is pre-loaded on a number of tubes and as one tube is emptied, the operator just replaces the empty tube with a full one.

Figure 1. New Zealand fully-mechanized socking, or sleeving, system where mussels and "fuzzy" rope are put inside a biodegradable cotton-thread sleeve.

Problems with the Traditional Method of Mussel Seeding

Attracting value-added processing

We realize that, sooner or later, a value-added sector will develop within the Canadian mussel industry. In most mussel-producing countries, the fresh, live market only represents 10-20% of production, while in Canada over 90% of production goes into the fresh market. At the same time, we recognized that mussel value-added processors were not going to pay high prices, so we it was important to become low-cost producers to remain profitable selling into that growth sector.

Controlling stocking density

Filling mussel socks using the traditional method was dull, repetitive work, but critically important in getting a good final product. Finding and training part-time workers to do this job was difficult and had to be repeated every year. The New Zealand method allows much greater control of grow-out density and there is a great reduction in the amount of seed that is lost (in the traditional method, a considerable amount of seed falls out of the sock).

Transportation costs for seed

We purchase our seed mussels in the Gulf of St. Lawrence and the cost of transporting this seed long distances was prohibitively expensive for the small quantities that we could handle in the two to three days we had to get the seed back into the water. In other words, the cost of transporting two tonnes of seed was just about as high as transporting eleven tonnes of seed.

Controlling duck predation

In Mahone Bay, we face a predation problem in the winter from scoters and old squaw ducks, which are on our farm sites from October until April. These ducks prey upon the seed mussels for which we had just spent \$0.44/kg (\$0.20/lb.), plus transportation and sleeving costs. We had to devise a viable strategy to prevent this predation so that we did not have to spend the winter chasing ducks with a small boat.

Improving utilization of small seed

The seed that we buy usually consists of several different sets or sizes, and often a fairly large component of this seed is "pepper seed" (very small seed). Unfortunately, much of it fell out of the sleeves. It was almost impossible to get a proper density in the sleeve because of the difficulty in accurately accounting for this small seed. Also it was very tedious making small mesh sleeves to handle this size of seed. It is important to utilize the small seed, however, as it represents good value; the transportation cost of this small seed is minimal and the seed soon grows into bigger mussels.

Advantages of the New Zealand Mussel Technology

After seeing the efficient New Zealand system, we could not see any reason why this technology could not be transferred to Nova Scotia. The big question in our minds was: Would our mussel (*Mytilus edulis*) remain attached to the rope as well as it does to the polypropylene socks that we were using? We felt quite sure that it would, as we often see mussels attached and growing on the longlines and anchor lines. Indeed, we felt that the rope would likely prove to be a better substrate for mussel growth than the socks. In addition, we could see several other advantages of the New Zealand system.

New Zealand has a successful mussel culture industry, and it is based on farmers receiving $0.55/kg ($0.25/lb.) for their mussels. In Nova Scotia, farmers receive $1.10-1.21/kg ($0.50-0.55/lb.) and are struggling to remain viable. Because profit margins in Canada are so slim, we realized that we had to become more efficient and reduce our labour costs. Labour is one of the highest costs in mussel farming and we could see that the New Zealand method would allow us to substantially reduce labour requirements per unit of production. Finding and training part-time workers to do this job was difficult and had to be repeated every year. The New Zealand method allows much better control of grow-out density and also greatly reduces the amount of seed lost compared to the traditional system in which a large proportion of the seed falls out of the socks.

Pilot Project to Evaluate the New Zealand Method in Nova Scotia

To tackle the above problems in our operations, and seeing apparent solutions for many of these problems in the New Zealand technology, we developed a pilot project in conjunction with the Co-operative Agreement on Economic Diversification program and the Nova Scotia Department of Fisheries and Aquaculture. The initial equipment imported from New Zealand to Nova Scotia was a high-volume, high-speed seed declumper/grader and seeding machine, some cotton sleeving material, and 15 km of fuzzy rope. We had seen in New Zealand that it was possible to operate the seeder on an 11-m boat and that happened to be the size of the boat that we had just ordered to be built. We were told by the New Zealanders that lots of hydraulic capacity was needed, so we designed that capability into our new boat. In the fall of 1997, we assembled the equipment on board and quickly completed the pilot project, which consisted of deploying 15 km of *M. edulis* seed with New Zealand-style sleeving at our site in Nova Scotia. The advantages we had hoped for, which are discussed below, were largely realized and at that point we knew that we did not want to return to using traditional methods. Although the scale of the trial simulated

Figure 2. "Fuzzy" or "hairy" rope produced by roughening standard polypropylene rope.

that fall's seeding, so we requested more cotton socking from New Zealand. The fuzzy rope (Fig. 2), however, was a different matter. It was very expensive in New Zealand and the transportation costs involved in importing it were prohibitive. In addition, Canada Customs imposed a duty on the rope. Consequently, we were faced with producing our own fuzzy rope. This we did by "cutting" or roughening up standard 13-mm (0.5-inch) diameter rope and we were able to finish hanging out the year's crop. Since then, we have not done any traditonal-style sleeving.

Components for the complete New Zealand-style mussel seeding system

Based on our observations and experience with the New Zealand mussel technology, the essential components of an effective, continuous mussel socking system[2] are as follows:

1) *Work vessel:* An 11-m (36-foot), or larger, boat with lots of hydraulic capacity;
2) *Declumper/grader:* A high-volume, high-speed seed declumper/grader;
3) *Rucker:* The device for putting the cotton sock on the tubes (Fig. 3);
4) *Bulk seed containers:* Large bags or wharf boxes for holding mussel seed;
5) *Bulk seed handling equipment:* Some means of effectively handling large volumes of mussel seed — in our case, this is a fork lift truck, a wharf crane, and a deck crane on the boat;
6) *Supply of cotton socking:* Convenient and affordable access to cotton socking material;
7) *Supply of culture rope:* Convenient and cost-effective access to fuzzy mussel rope;
8) *Seeding machine:* Mussel "seeder";
9) *Mussel harvester:* A hydraulic harvester to remove mature mussels from the culture rope.

If any of these components are not available, it is impossible to realize the full potential of the seeder, although it may be possible to gain some advantages. I want to emphasize that the key to realizing the full potential is having the capability to move large volumes of seed quickly and easily.

Figure 3. The rucker, which is used for putting the cotton sock on the tubes.

Progress update, Fall 1999

At Indian Point Marine Farms, we are fully committed to growing mussels using the New Zealand technology:

- We have all of the necessary components as listed, but there could be even greater efficiencies if we had more carrying capacity in our boat. The goal is to keep the seeder running during a shift, and the difficulty is providing the constant supply of seed to the seeder for as long as possible.
- We now have the ability to seed out mussel lines quickly and efficiently, but we are short of the necessary lease space for further development. In the short term, we plan to utilize more of the water column to farm our available sites more intensively.
- We no longer have to hire part-time people in the fall for socking. Our regular staff are very efficient in handling seed, so we get our seed in shipments of 12 tons (11 tonnes), rather than 2 tons

(2 tonnes). The crew can declump and grade that amount of seed in 4 or 5 hours and have it seeded out on lines in 8 or 9 hours from the time the truck is unloaded. By purchasing large lots of seed at a time, our per unit trucking costs are much reduced.

- We now have an effective strategy for dealing with predator ducks: a safe nursery area. We designated a nursery site, quite close to shore and to houses, which as of yet is not frequented by the ducks. This is where we put our seed in the fall, at about three times the final grow-out density. Thus, we need to keep only one-third of the area duck-free. This lease is covered by ice in cold winters, while our other leases are rarely ice-covered. The ice, of course, is the best protection against ducks. Because the seeding function is so efficient, we can strip the seed ropes in April after the ducks have left and re-deploy the mussels at the final grow-out density on our other leases. This strategy could not be implemented using the former system because it would have been too expensive and time-consuming.
- In the spring, the pepper seed is large enough to grade effectively, enabling us to get the proper density of seed on our ropes, allowing full use of the pepper seed.
- Lease space is used more efficiently, as we now have empty lines available from the winter harvest for restocking in spring.
- We no longer lose the 10 to 20% of seed that floated out of the old socks when we put them in the water, and we are able to get a more accurate density of mussels on our ropes.
- We are also able to obtain huge savings in labour at harvest time. The continuous ropes are extremely easy to harvest. We only have to insert one end of the rope into the hydraulic hauler, which pulls the rope through a scraper and lets the mussels slide down a ramp into a tub. We can also rinse the mussels at this point. Our boat has a cut-away on the deck with a roller in the water, and the ropes are pulled up a ramp into the scraper.
- Because the mussels are always supported when they are out of the water, we have greatly reduced loss due to sloughing during harvesting. The only work involved is cutting the twine, which holds the grow-out ropes to the longline, and moving the full tubs of mussels with the deck crane.
- The harvested fuzzy rope is stored in a rope bag where it stays until re-use.
- An environmental bonus is that we no longer have to make trips to the local landfill to dispose of old polypropylene socks.
- All the components for the operation are now manufactured in Canada,[(2)] although the cotton–knitting capacity does not keep up with the demand, so some material is still being imported from New Zealand. Atkinson & Bower Ltd. of Shelburne, Nova Scotia, had the vision to realize the potential in Atlantic Canada (and elsewhere) of this new way of growing mussels and has been very active in refining and manufacturing the equipment here. They now build a seeding machine similar to the one that we imported from New Zealand. They also manufacture a high-speed seed grader, which allows the grower to declump and grade seed at a rate that matches the output of the seeder. The old seed graders in common use were able to keep up with the hand sleevers, but cannot match the speed of the seeding machines. They manufacture a rucker (Fig. 3) that pulls the cotton sleeving onto the tubes and have also developed a cutter, which converts regular polypropylene rope into a very useable fuzzy rope (Fig. 2), and with this, they have become a supplier of culture rope to the mussel farmers. They also manufacture a harvester which efficiently harvests mussels grown on the fuzzy ropes. Sam Bower, of Atkinson & Bower Ltd., tells me that they have now sold 14 seeding machines, 13 in Atlantic Canada and one to the United States. Negotiations are almost finalized to send 5 machines to Norway, and potential buyers from Chile and Australia visited his plant in the spring of 2000. Atkinson & Bower have sold 1400 coils of their fuzzy rope, and also have sold several declumpers and ruckers.
- Although the "hairiness" of the rope is important, the limpness or ability to hang straight down without twisting is also very important and must be of prime consideration when selecting a suitable rope.
- The cotton sleeving is now more accessible, as it is manufactured in Canada by Warp Tech of Yarmouth, Nova Scotia, and is marketed by Go Deep International of Fredericton, NB.
- We are seeing the beginning of a value-added sector for mussels in Atlantic Canada. Several companies are starting to produce frozen, vacuum–packed mussels. In the near future, this will likely become a more significant segment of the mussel industry.
- Finally, because the work is now less backbreaking and labour intensive, our workforce is more stable.

On the Downside

Obviously, we are very positive about the whole technology transfer project, but there have been some drawbacks.

Cost of supplies

Indian Point Marine Farms Ltd. is a small company with limited financial resources and the change to new technology has been an expensive undertaking.

The cost of the fuzzy rope, in particular, has been very high. The cost of the cotton sleeving is comparable to the old polypropylene sleeving, but the culture rope is an additional cost. However, we expect to re-use the rope many times, thus amortizing the cost over several crops of mussels. Nonetheless, it is a real factor for mussel producers to consider in switching grow-out methods.

Access to supplies

In the first year, we were not able to get the fuzzy rope and cotton sleeving when we needed it and because we were forced to do some of the sleeving later in the year than we would have liked, some of the results were not what we had hoped for. The results of the sleeving done in the spring were fine, but the results from the summer sleeving were less than optimal. The next year, we re-seeded all of the seed lines in April and early May and were very pleased with the results. Now the supply of the cotton and rope is not an issue.

Capital costs

The initial expenses for the boat, cranes, forklifts, seeding machine, rucker, harvester, etc., were very high. The result was that we have had to neglect, to some extent, our processing plant which has aging equipment, even though we know we have increased production soon coming online. Also, the marketing budgets had to be increased to develop a broader market for the increased production. The financing of the higher initial capital and the cost of supplies of the continuous socking system will be a strain on small companies with limited resources.

Operational Hitches

Learning the art

Some problems still exist here and there, but that occurred with the old sleeves as well. What we have found is that although the technology is sound, there is a learning curve for the operators of the seeder. Great attention to detail is required; like all farming, there is still an art involved in sleeving mussels, and even if one does not understand what the art is, one acquires it over time if one strives always to improve.

The photographs in this article were generously provided by Sam Bower, President of Atkinson & Bower Ltd, Shelburne, NS.

Conclusion

For Indian Point Marine Farms, the vision and the promise of the experiment are now reality. We are fully committed to growing mussels this new way. In addition, other growers are evaluating this system too, as Atkinson & Bower's sales figures will attest. Beyond Nova Scotia, many other growers, especially from Newfoundland, Quebec, and New Brunswick, as well as from Prince Edward Island and British Columbia, have observed our process. I have spoken about this subject at conferences in St. Andrews, NB, in July 1998, Rockport, Maine, in November 1998, and at the Aquaculture Canada '99/Aquaculture Pacific Exchange in Victoria, BC, in October 1999. For us it is the only way to go. The economic benefits won't immediately be realized because we are still at the investment stage, however they will appear once the savings from the new production efficiencies start to accrue. However, these benefits will not occur if the mussel industry in Nova Scotia is not given the necessary lease space so that we can expand and use our new technology. If we can expand, I believe this new system will foster the development of a large value-added mussel processing sector. We now have the means to grow mussels cheaply and efficiently and there is a a processing plant in Nova Scotia producing a secondary-processed product (Blue Gold in St. Margaret's Bay). The essential ingredient we are lacking is enough space to grow more mussels to expand the industry.

We, at Indian Point Marine Farms Ltd., would like to express our gratitude to the Nova Scotia Department of Fisheries and Aquaculture and the Co-operative Agreement on Economic Diversification, Resource Competitiveness Program for the support they gave us with this project. The assistance and hospitality of Keith Yealand of Marlborough Mussel Company during our visit to the New Zealand mussel industry are also greatly appreciated.

Notes and References

1. Scarratt DJ. 2000. *Bull. Aquacul. Assoc. Canada* 100-2:38-41.
2. Bower S. 1999. *Shellfish World* 1(1):11-12.

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Calendar

conferences, workshops, courses and trade shows

• **The Cultivation of Salmon II**, 7-11 May 2001, Bergen, Norway. Contact: Cultivation of Salmon, Institute of Marine Research, Bergen (tel 47 55 23 85 00, e-mail salmon@imr.no, website http://www5.imr.no:591/salmon/)

• **International Workshop on *Artemia*,** 12-15 May 2001, *Artemia* and Aquatic Animals Research Center, Urmia University, Urmia, Iran. Prominent scientists will give special oral sessions on the most crucial issues on *Artemia*, while other participants will present some of their research on culture, genetics, ecology and resource assessment, enrichment and use of *Artemia* in larviculture of fish and shrimp. Contact: *Artemia* workshop, Urmia University, PO Box No. 165, Urmia 57153, Iran (e-mail artemiaworkshop@urmia.ac.ir).

• **Diseases of Warmwater Fish (2-week course)**, 14-25 May 2001, University of Florida, Tropical Aquaculture Laboratory, Ruskin, FL, USA and Whitney Laboratory, St. Augustine, FL, USA. This is an intensive two-week class designed to provide instruction in the methodology of diagnosis and treatment of parasitic, bacterial, viral, nutritional, and environmental diseases of warmwater food fish and aquarium species. Also advanced procedures in fish anaesthesia and surgery have been included in this year's schedule. The course is open to students, veterinarians, fish biologists, aquaculturists, and professional aquarists. Enrollment is limited and registration will be accepted on a first-come first-served basis. Contact: IFAS Office of Conferences & Institutes, University of Florida, PO Box 110750, Gainesville, FL 32611-0750 (tel 532-392-5930, fax 352-392-9734, website http://www.ifas.ufl.edu/~conferweb/wwf)

• **Seafood China Expo 2001**, 14-17 June 2001, Dalian Xinghai Convention and Exhibition Centre, China. Opportunity to explore the China seafood market. Information: Ms. Ling Chan, Business and Industrial Trade Fairs Ltd., Unit 1223, HITEC, 1 Trademart Drive, Kowloon Bay, Kowloon, Hong Kong (tel (852) 2865 2633, fax (852) 2866 1770 or 2866 2076, e-mail enquiry@bitf.com.hk).

• **Open Ocean Aquaculture IV**, 17-20 June 2001, St. Andrews, New Brunswick, Canada. Theme sessions: Marine Policy, Ocean Engineering, Ocean Environment, Candidate Species and Integrated Open Aquaculture. Information: Open Ocean Aquaculture IV Symposium, 703 East Beach Drive, PO Box 7000, Ocean Springs, Mississippi 39566-7000, (tel 228 875-9341, fax 228 875-0528, email ooa@usm. edu, website: http://www-org.usm.edu/~ooa/ooa_iv.html).

• **Symposium on Microalgae and Seaweed Products in Plant/Soil Systems**, 20-22 June 2001, Faculty of Agricultural Sciences, University of West Hungary, Mosonmagyaróvár, Hungary. The main topics of the Symposium will cover the following areas: (1) synthetic and natural plant growth regulators in plant production, (2) antimicrobial compounds of algal origin in plant protection, (3) algae as soil conditioners and their use in soil bioremediation, (4) plant nutrition by seaweed products, cyanobacteria, and microalgae, and (5) microalgal and seaweed products for plant or soil treatments. Information: Vince Ördög or Zoltán Molnár, Faculty of Agricultural Sciences, University of West Hungary, H-9000 Mosonmagyaróvár, Kolbai K. Str. 8, Hungary (tel +36 96 578 637, fax +36 96 215 931, e-mail plantph@mtk.nyme.hu, website http://mtk.nyme.hu/~plantph/symp2001.htm).

• **Atlantic Aquaculture Conference, Trade Show and Fair,** 21-24 June 2001, St. Andrews, NB, Canada. The 14th annual fair will explore the concept of "smart farming", and will include a trade show, industry sessions, and workshops on both freshwater and marine topics. Iinformation: Atlantic Aquaculture Exposition Conference & Fair, 157 Water Street, Unit G, St. Andrews, NB E5B 1A7 (tel 506 5294578, fax 506 5294284, email aquafair @nbnet.nb.ca, website http://www.aquafair.com).

• **4th International Symposium on Sturgeon**, 8-13 July 2001, Park Plaza International Hotel and Convention Center, Oshkosh, Wisconsin, USA. Symposium objectives are to provide a forum for exchange of information and knowledge on the biology, culture and management of Acipenseriformes of the world, and to provide an opportunity for scientists, biologists, enforcement specialists and commercial interests working with sturgeon around the world to network, share experiences and develop new research and management initiatives for the benefit of sturgeon populations and their users. Info: 4th ISS, PO Box 109, Oshkosh, WI, 54903-0109, USA (tel 920 424-3059, fax 920 424-4404, e-mail bruchr@dnr.state.wi.us, website: http://www. sturgeonsymposium.org/).

• **Aquaculture Europe 2001**, 4-7 August, Trondheim, Norway. Biennial meeting of the European Aquaculture Society. Conference program: New Species (juvenile production, optimum production, feed/flesh quality, marketing, economics, impact and positioning of new aquaculture products), and New Technologies (re-circulation, polyculture, feed technology, offshore technology, feed management, waste management). Special workshop on Aquaculture Chain Management. Information: European Aquaculture Society (tel + 32 59 32 38 59, fax +32 59 32 10 05, e-mail ae2001@aquaculture.cc, website http://www.easonline.org).

• **Larvi 2001,** 3-6 September 2001, Ghent University, Belgium. The aim is to bring researchers and professionals together to evaluate progress, identify problem areas and stimulate cooperation in research and industrial production of fish and shellfish larvae. Tentative sessions: Session 1 (broodstock, egg and larval quality epigenetics, broodstock feeding and offspring quality, fish and shrimp maturation, wild versus domestic strains, evaluation methods, etc.), Session 2 (genetics, biotechnology and developmental biology), Session 3 (nutrition, feeding and growth, nutritional physiology (functional effects of various compounds), feeds and feeding strategies (live food optimisation, live food substitution/ supplementation diets, formulated feeds, dietary requirements), quantification of food uptake, behavioural interactions (vision/predation in relation to nutritional status)), Session 4 (larviculture zootechniques and economics, extensive vs intensive culture techniques, backyard hatcheries, interaction with the environment, cost effectiveness, zootechnical aspects, automation, upscaling methodology, etc.), Session 5 (microbiology and disease control, bacteriology: probionts and pathogens, virology, chemotherapeutics, immunostimulants, immunology, etc.). Information: Laboratory of Aquaculture & Artemia Reference Center, Ghent University, Rozier 44, B-9000 Ghent, Belgium (tel +32-9-2643754, fax +32-9-2644193, e-mail larvi@rug.ac.be, website: http://www.rug.ac.be /larvi/).

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

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

• **Aquaculture America 2002,** January 2002, Town and Country Hotel, San Diego. The US National Annual Conference and Exposition of the US Chapter of the World Aquaculture Society, the National Aquaculture Association, and the US Aquaculture Suppliers Association. Contact: Director of Conferences (tel 760 432-4270, fax 760 432-4275, e-mail: worldaqua@aol.com).