



# *Bulletin*

of the  
Aquaculture Association of Canada

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Association Aquacole du Canada

**Édition 99-3, septembre 1999**  
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# Bulletin de l'Association aquacole du Canada

septembre 1999 (99-3)

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# Bulletin of the Aquaculture Association of Canada

September 1999 (99-3)

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Cover: Cultured mussels grown at Sweet Bay Mussel Farm in Bonavista Bay, Newfoundland (Sean Macneill photo).

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# President's Message

**I**n a previous issue of the *Bulletin* I mentioned that the Board of Directors had undertaken a strategic planning session at the 1999 mid-year board meeting. AAC began 16 years ago when the aquaculture industry in Canada was in its infancy. As the industry has grown over the last 2 decades, the AAC has become widely recognized for its contribution to the aquaculture sector through the production of the *Bulletin* and the annual organization of a national meeting, *Aquaculture Canada*. The AAC has a large and stable membership and is self-supporting through membership dues and profits from the annual meeting. The organization has now reached the point where it has the ability to undertake new initiatives to increase its contribution to aquaculture.

Consistent with AAC's objectives — to foster an aquaculture industry in Canada, to promote the study of aquaculture and related science in Canada, to gather and disseminate information relating to aquaculture, to encourage teaching, support for education, and research and development, and to create public awareness and understanding of aquaculture — two annual awards are being instituted. The *Research Award of Excellence*, co-sponsored by the Office of the Commissioner for Aquaculture Development, will recognize excellence in research, while a second award will recognize contributions to the field of aquaculture and/or to AAC.

The Board of Directors is also exploring other avenues. At the Aquaculture Canada '99 conference, a session organized by Shawn Robinson explored the concept (and approach) of establishing a national list of aquaculture research priorities. Such a list of research priorities could be of tremendous use to

funding agencies and government departments charged with research mandates in directing their efforts and dollars to the needs of the industry.

Other ideas for expanding AAC's mandate include the communication of information and technology to the general public in order to increase public awareness of aquaculture. As well, in conjunction with the Canadian Aquaculture Industry Alliance (CAIA), the AAC is exploring the development of a national education and training curriculum and certification programme.

I invite members to provide comments and suggestions on these and other initiatives which can help ensure a successful future for aquaculture in Canada.

The AAC is of course a volunteer organization and relies on members devoting their time to ensure the smooth and successful operation of the organization. Volunteers spend tremendous amounts of time serving AAC in a variety of capacities and I would encourage any member interested in assisting in the organization of the annual meeting, serving on a committee or standing for election to contact members of the Board of Directors. While continuity of volunteers is important to AAC, so is a new source of blood! As the saying goes "our future depends on it".

As a final note as my term ends, I thank the AAC membership for giving me the opportunity to serve as President over the past two years. The spirit, energy and enthusiasm of the many people I have met from across the country gives me a sense that we can collectively develop the Canadian aquaculture industry into a great success story.

*Jay Parsons*

## Call for Nominations AAC Board of Directors

Members wishing to be considered for nomination as a candidate in the upcoming election (spring of 2000) should contact any board member or Dr. Jay Parsons at [jay.parsons@mi.mun.ca](mailto:jay.parsons@mi.mun.ca) (telephone 709 778-0307). Expression of interest from student members is particularly encouraged.



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# Introduction

**T**he rationale for the Aquaculture Canada '98 workshop on Mussel Production Capacity was outlined in detail in the preceding issue of the *Bulletin*. Briefly, Canadian production of cultivated mussels and shellfish is expected to increase at a rate of 20% per year over the next 3 to 5 years, and the industry is raising questions concerning production capacity at individual farm sites. A farm's production capacity is determined by the biophysical factors related to carrying capacity, husbandry practices, and the performance of the species under consideration. In the previous *Bulletin*, papers presented in the first session of the workshop outlined recent advances in the study of

carrying capacity; the current *Bulletin* issue contains presentations made in the last two sessions of the workshop on shellfish husbandry and species performance.

Considerable discussion was generated in the session on species performance, particularly with respect to the perception that the co-occurring species *Mytilus trossulus* and *Mytilus edulis* differ in their culture performance on the east coast of Canada. Both species are present in the Atlantic Provinces and the general consensus at the session was that no firm conclusions can presently be made on this issue. In fact, it is likely that stock and site specific considerations outweigh species differences and that within each species in Atlantic Canada some stocks probably perform poorly while others can be found that perform well.

Financial support for the workshop was provided by the Canada/Newfoundland Economic Renewal Agreement – Aquaculture Component (ACERA), the Canadian Centre for Fisheries Innovation, the Atlantic Canada Opportunities Agency, and the Marine Institute of Memorial University. The ACERA provided funding for the workshop proceedings and the informal luncheon, and this is gratefully acknowledged. Finally, Thomas Landry, Department of Fisheries and Oceans, Gulf Fisheries Centre, Moncton, was instrumental in the organization of the session on mussel species performance and is to be congratulated on the success of that session.

Cyr Couturier  
Workshop Convenor

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# Maritime Distribution and Commercial Production Performance of *Mytilus edulis* and *Mytilus trossulus*

André L. Mallet and Claire E. Carver

Natural populations of mussels were sampled throughout the Maritimes to determine the geographic distribution and incidence of the two species, *Mytilus edulis* and *Mytilus trossulus*. Electrophoresis was used to classify each population on the basis of mannose phosphate isomerase (MPI). Mixed populations with varying proportions of the two species were frequently found along the Atlantic coast of Nova Scotia. Pure populations of *M. edulis* were found in Prince Edward Island and New Brunswick, and in the upper reaches of the Bay of Fundy. Pure populations of *M. trossulus* were found exclusively in the Bras d'Or Lakes (Cape Breton), Nova Scotia. The following year, a production study was carried out at a commercial mussel farm to evaluate the feasibility of switching from the locally-available mixed seed stock to pure *edulis* seed stocks from other regions. The production value of some of the *edulis* stocks was comparable to that of the mixed *edulis-trossulus* stock, but several of the other *edulis* stocks performed poorly. Should growers want a more uniform product and lower losses at grading, then growing *M. edulis* seed from the other regions is apparently a viable option. However, production trials are recommended in order to identify the most suitable *edulis* stock(s) for a given site.

## Introduction

Nova Scotian mussel producers are now aware of several commercial constraints associated with the presence of *M. trossulus* in their crop, specifically the lower meat yield, the poor shell appearance, and the higher incidence of shell breakage. Comparative trials confirmed that *M. trossulus* has a lower production output than *M. edulis*; 1.7 times more *M. trossulus* seed are required to produce the same economic return.<sup>(1)</sup> In a survey of the mussel industry, it was argued that problems associated with *M. trossulus* were partly responsible for the slow development of the mussel industry in Nova Scotia.<sup>(2)</sup>

The data presented in this paper originate from two projects. First, in 1991-1992, natural populations of mussels throughout the Maritimes were surveyed using electrophoresis to determine the relative incidence of the two species. This was followed by a commercial study in 1993-1994 which compared the performance of a locally available mixed seed stock with several pure populations of *M. edulis* at Indian Point Marine Farms (IPMF) in Mahone Bay, Nova Scotia. The

implications of switching from a *trossulus*-dominated stock to a pure *M. edulis* stock are discussed.

## Materials and methods

### Population survey

Sixty juvenile mussels from 48 populations were collected in 1991-1992 and brought back live to the Fisheries Research Laboratory in Halifax. The mussels were dissected and their hepatopancreas tissues were frozen at -40°C for subsequent electrophoretic analysis. Cellulose acetate electrophoresis was used to separate allozymes of mannose-6-phosphate isomerase (MPI, EC 5.3.1.8) in Tris-glycine buffer.<sup>(3)</sup> The MPI allozyme is considered diagnostic for distinguishing between *M. edulis* and *M. trossulus*.<sup>(4)</sup>

### Production performance

Samples of mussel seed from 8 populations (Fig. 1) were either purchased from mussel producers or collected by the authors between November 20 and De-



cember 22, 1992. The mussels were immediately sleeved and deployed from one longline at Indian Point Marine Farms. This longline was sunk in late December and raised in late April in both 1993 and 1994.

The populations were sampled on May 14, September 6 and November 30 in 1993, and May 26, July 11,

August 8, September 16, October 13, November 17 and December 15 in 1994. Samples for dry tissue weight, shell length and shell weight were obtained from the sleeves at each sampling event. In 1993, a random sample of 60 mussels was measured (shell length and shell height), dissected, dried at 60°C, and weighed. In 1994, a total of 50 mussels were measured,

but only 20 individuals were dried for shell weight and tissue weight. Least square estimates were calculated for mean shell length, shell weight and tissue weight.

Survival rates were assessed by placing 25 individuals from each population in labeled pearl nets which were then deployed at two depths (surface and 10 m). The number of surviving mussels was determined at each sampling event, and each net was then reset with 25 individuals. Survival values for the various populations were compared using the log rank test.<sup>(5)</sup> Annual production values for 1993 and 1994 were calculated as the increase in shell and tissue weight minus losses due to mortality.

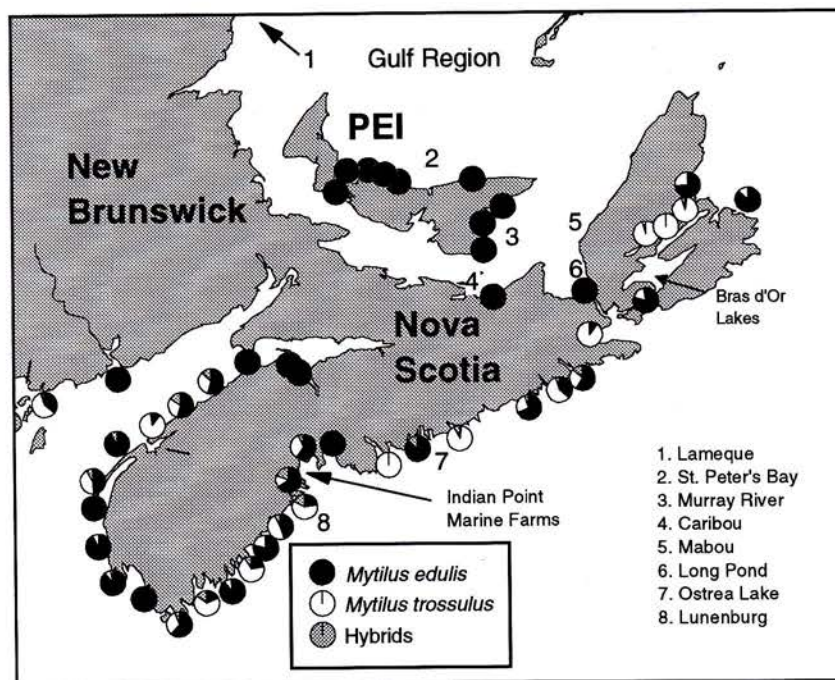


Figure 1. Origin of the 8 seed stocks (1-8) used in the study at Indian Point Marine Farms in Mahone Bay. The pie charts indicate the distribution and incidence of the two mussel species at the various Maritime sites.

Table 1. Frequency of *M. edulis* and *M. trossulus* in the various seed populations.

Origin	<i>M. edulis</i>	<i>M. trossulus</i>
Lameque, NB	100%	0%
St. Peter's Bay, PEI	100%	0%
Murray River, PEI	100%	0%
Caribou Harbour, NS	100%	0%
Long Pond, NS	100%	0%
Mabou Harbour, NS	100%	0%
Ostrea Lake, NS	98%	2%
Lunenburg, NS	32%	68%

## Results

### Population survey (1991-1992)

The survey indicated that all the populations from Prince Edward Island and the Northumberland Strait region were pure *M. edulis*, whereas those from the Bras d'Or Lakes were pure *M. trossulus* (Fig. 1). In contrast, populations from the Atlantic coast and the Bay of Fundy were generally a mixture of the two species with occasionally some hybrids. Two areas where *M. edulis* predominated were the southern tip of Nova Scotia and the upper reaches of the Bay of Fundy. Although this survey established the presence of both mussel species at most sites



on the Atlantic coast, any local temporal or spatial variability in their relative proportions remains unknown. Observations of mussel shell morphology at a long-term experimental site in Lunenburg, Nova Scotia, suggested that cohorts do contain different proportions of the two species.

### Production performance (1992-1994)

Populations of mussel seed originating in northern New Brunswick (Lameque), Prince Edward Island (Murray River, St. Peter's Bay), or the Northumberland Strait area of Nova Scotia (Caribou, Mabou, Long Pond) were found to be pure *M. edulis* (Table 1). In contrast, approximately 68% of the mussels from the Lunenburg site on the Atlantic coast were *M. trossulus*. Ostrea Lake, the second Atlantic coast seed stock, was predominantly *M. edulis* with 1 mussel in 50 classified as *M. trossulus*. These results were consistent with the geographic distribution study.

### Shell growth

Initial shell length in December 1992 varied substantially among the 8 seed populations, from 25 mm for Lunenburg to 35 mm for Caribou (Fig. 2). Over the 2-year period, shell growth was typically highest from May to September and lowest from December to May. All the populations had similar shell length values in December 1993 with the exception of Long Pond and Lameque which had significantly lower values. In December 1994, the mean shell length values fell into three groups: Caribou and Lunenburg were statistically equal but larger than Long Pond, Ostrea Lake, and St. Peters, which were in turn larger than Murray River, Lameque, and Mabou. The variation in initial mean shell

length had no statistical effect on the final mean values in December 1994.

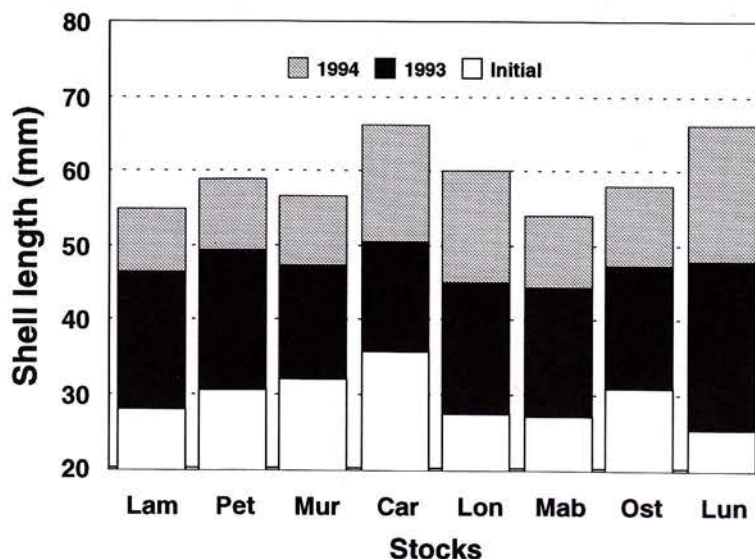


Figure 2. Increase in shell length (mm) from December 1992 to December 1994 for the eight populations (LAM – Lameque; PET – St Peter's Bay; MUR – Murray River; CAR – Caribou Harbour; LON – Long Pond; MAB – Mabou Harbour; OST – Ostrea Lake; LUN – Lunenburg Bay). "Ini92" indicates the original size of the seed at the time of sleeving.

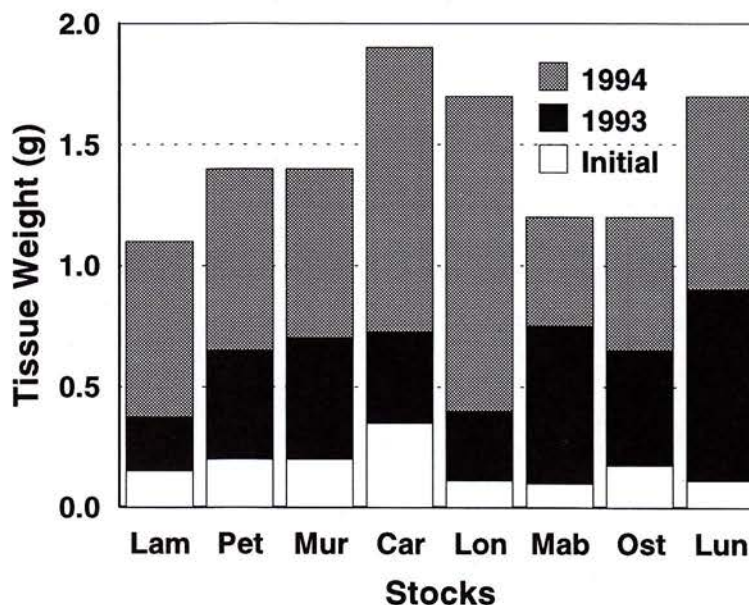


Figure 3. Mean dry tissue weight for the populations in December 1992 (Ini92), December 1993 (Fal93) and December 1994 (Fal94).

### Tissue weight

In December 1993, the Lunenburg stock had the highest tissue weight, while Lameque and Long Pond had the lowest values (Fig. 3). Note that the variation

in tissue weight among stocks was consistent with observations of shell length. In December 1994, Caribou, Long Pond and Lunenburg had the highest tissue weight values (1.7 to 1.9 g) whereas the remaining populations had values less than or equal to 1.4 g. This pattern was again consistent with the shell length data.

In order to follow the tissue weight of specific stocks over time as well as compare among stocks, all the tissue weight values were standardized to a shell length of 55 mm (Fig. 4). Of the 6 Gulf Region stocks, 5 showed very similar tissue profiles ("REM") with maximum values in May, spawning in June, and low values from July to October at which time rebuilding of the tissue was observed. The exception was the Mabou stock which was in very poor condition in the spring and gradually increased in weight until mid-November with little indication of spawning. The Ostrea Lake stock initially behaved similarly to the "REM" stocks, but showed lower tissue values through the summer and more gradual rebuilding in the fall. The Lunenburg stock showed peak values from late May through June, followed by spawning in mid-July. Tissue weight continued to decline gradually through the summer with some indication of rebuilding in November.

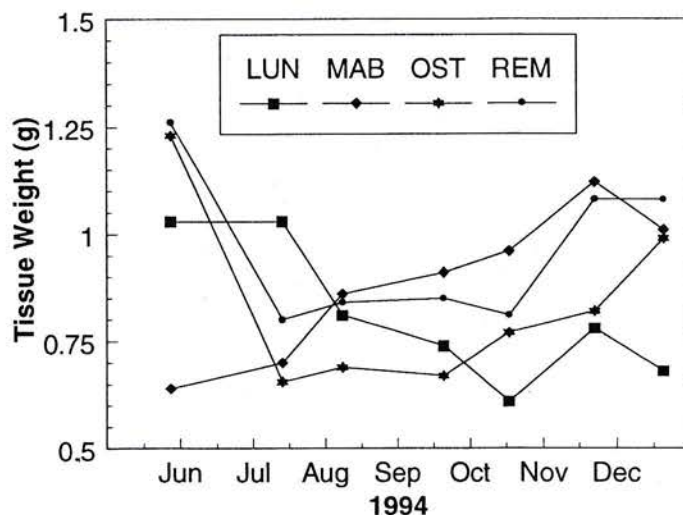


Figure 4. Profiles of dry tissue weight for a 55-mm mussel from Lunenburg, Ostrea Lake, Mabou, or one of the five remaining (REM) populations. Data from these five stocks were pooled because they showed very similar tissue profiles.

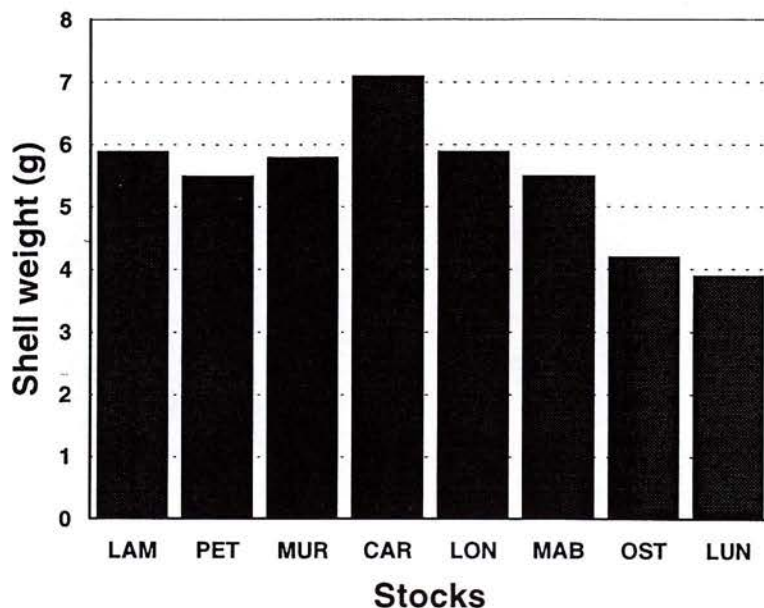


Figure 5. Mean shell weight at 55 mm for the seed stocks.

### Shell weight

Shell weights were standardized to a 55-mm shell length in order to illustrate the variation among stocks (Fig. 5). In December 1994 Caribou had a significantly higher shell weight (7.1 g) than the other five stocks from the Gulf region (5.5 to 5.9 g), which in turn were substantially heavier than the two Atlantic coast stocks (3.9 to 4.2 g). Although the mixed stock from Lunenburg was expected to have a low shell weight because of its high *trossulus* component, the low value for Ostrea Lake was unusual for a predominantly *edulis* stock.<sup>(6)</sup>



## Mortality

The overall mortality for the eight populations was 14% during the first year and 6% in the second year

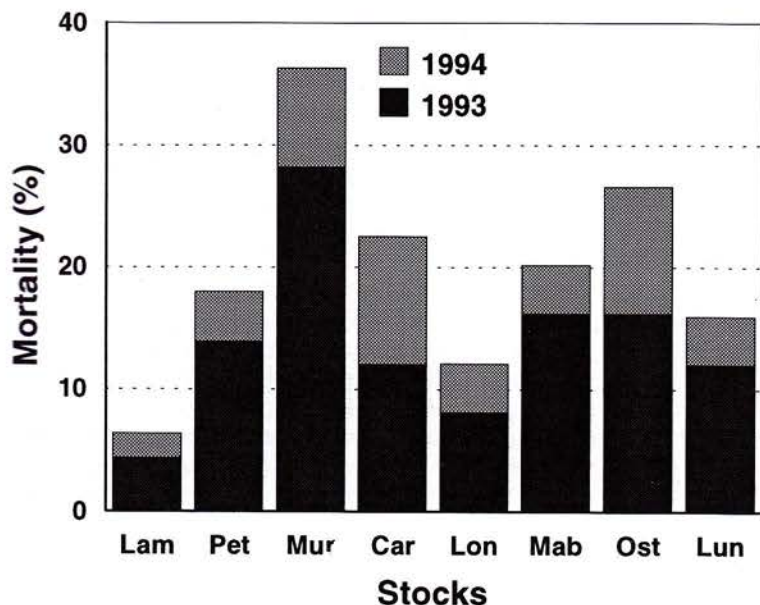


Figure 6. Cumulative mortality (%) of each population from December 1992 to December 1994.

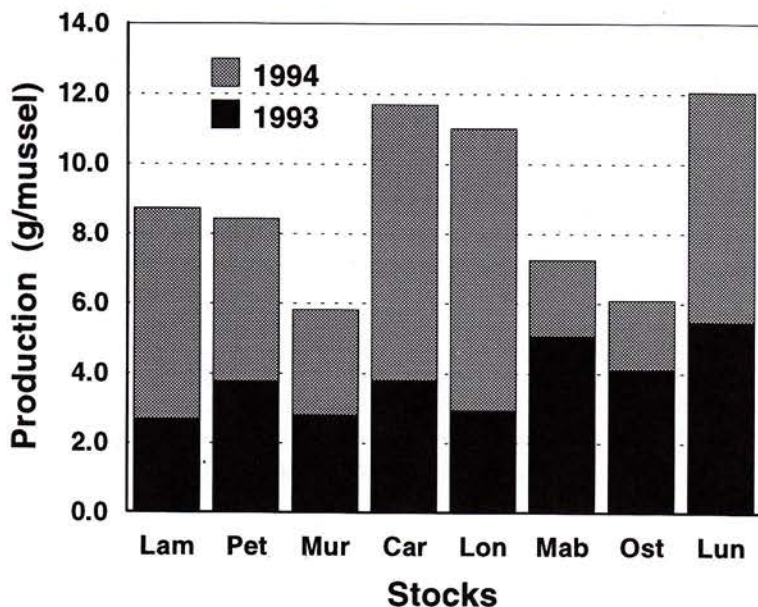


Figure 7. Production estimates for each population based on the increase in shell and tissue weight minus the losses due to mortality in December 1993 (Fal93) and December 1994 (Fal94).

(Fig. 6). In 1993, mortality rates were highest for Murray River at 28%, followed by St. Peters, Caribou, Mabou, Ostrea Lake and Lunenburg at 12 to 16%, and Lameque and Long Pond at 4 to 8%. In

1994, mortality rates were generally lower; Murray River, Caribou and Ostrea Lake showed 8 to 11% mortality whereas the remaining populations showed 2 to 4%. When calculated over the 2-year period, values ranged from a maximum of 36% for Murray River to a minimum of 6% for Lameque. Mortality levels were statistically different among populations (Wilcoxon:  $P < 0.01$ ).

Variations in mortality were observed both among seasons and among stocks. As expected for mussels, winter losses were negligible,<sup>(7)</sup> and most of the mortality occurred in the summer and early fall when water temperatures exceeded 10°C.<sup>(7,8)</sup> The Murray River, St. Peters and Mabou populations exhibited their highest mortality in the fall, whereas Ostrea Lake, Lunenburg, Caribou, and Long Pond sustained most of their losses between May and September.

## Production

Production per mussel was calculated from the tissue growth, shell growth and survival data for the 8 populations (Fig. 7). The 3 stocks with the highest production rates were the mixed *edulis-trossulus* stock from Lunenburg and two of the *M. edulis* stocks from the Northumberland Strait, Caribou and Long Pond. All three showed high shell and tissue growth rates (Figs. 2, 3), but in the case of Caribou this was offset by above average mortality rates. Lameque and St. Peters showed lower but similar production rates followed by Murray River, Mabou and

Ostrea Lake which generally showed poor growth and/or high mortality.

## Discussion

### Population survey

The survey revealed that mussel populations along the Atlantic coast of Nova Scotia and up into the Bay of Fundy are a complex patchwork of varying proportions of *M. edulis* and *M. trossulus*. Pure *M. edulis* populations occur along the Northumberland Strait, and in Prince Edward Island, as previously described,<sup>(9)</sup> whereas pure *M. trossulus* populations are primarily concentrated in the Bras d'Or Lakes. No obvious large-scale environmental factor can account for this complex distribution pattern, except perhaps for the lower salinity levels in the Bras d'Or Lakes which may favour *M. trossulus*. This information is currently being used by growers to select seed collection sites with high levels of the more desirable species, *M. edulis*.

### Production performance

Previous studies have indicated that natural mussel populations vary in their production performance when grown under similar environmental conditions.<sup>(6,7,10)</sup> This study also showed that stocks vary substantially in terms of tissue and shell growth, as well as mortality. In a commercial context, these

variations translate into significant differences in production potential; estimates varied by a factor of 2, from 6 to 12 g/mussel. Given this variation in performance, it is advisable for a company to undertake performance trials prior to selecting any particular seedstock for their commercial production.

A second observation from this study was that the pure *M. edulis* stocks did not consistently outperform the mixed *edulis-trossulus* stock. In this case, the mixed stock was from the local area and may have been better adapted to the environmental conditions. A previous study<sup>(1)</sup> showed that *M. edulis* mussels from the mixed Lunenburg stock had a higher summer tissue weight, higher shell weight per unit length, similar shell growth, and lower survival than *M. trossulus* mussels. The excellent performance of the Lunenburg mixed stock in the IPMF study may be related to the above-average performance of the *M. edulis* component of this population in relation to mussels from other pure *M. edulis* populations.

Movement of stocks from one region to another may be associated with an increased risk of mortality. For example, Baltic mussels transplanted into the North Sea showed excellent growth and survival initially, but suffered very high mortality one year later.<sup>(11)</sup> In the present study, the overall losses were consistent with the expectation of 15 to 20% natural mortality over a 12-month production cycle,<sup>(7)</sup> although certain stocks exceeded this expectation. For example, the Ostrea Lake population which exhibited above aver-

**Table 2. Comparative estimates of wet tissue weight, shell weight, whole weight, and the number of mussels per kg for the eight populations. Values were estimated assuming a standard shell length of 60 mm in December 1994.**

Stock	Tissue Weight per mussel (g)	Shell Weight per mussel (g)	Whole weight per mussel (g)	Number of mussels per kilogram
Lameque	6.5	6.3	12.8	78
St. Peters Bay	6.9	6.0	12.9	78
Murray River	7.0	6.3	13.3	75
Caribou	6.6	7.7	14.3	70
Long Pond	7.3	6.4	13.7	73
Mabou Harbour	6.8	6.0	12.8	78
Ostrea Lake	5.9	4.6	10.5	95
Lunenburg	5.8	4.3	10.1	99



age mortality rates<sup>(7)</sup> had already been tested and rejected as a seed stock by the local producer.

### Commercial considerations

To illustrate the commercial implications of the variation in shell and tissue weight among stocks, the whole live weight per individual (wet tissue weight + shell weight) at a standard size of 60 mm was calculated (Table 2). Whole or live weight varied from 10 g/mussel for Lunenburg to 14 g/mussel for Caribou, a variation accounted for by differences in shell rather than tissue weight. In effect, this means that 99 Lunenburg mussels would be required to make up 1 kilogram as opposed to only 70 Caribou mussels.

Another advantage of growing one of the *edulis* stocks with a higher shell weight than the Lunenburg mixed stock is the lower level of shell breakage during processing. If we assume a 20% loss of Lunenburg mussels during grading,<sup>(1)</sup> then 123 Lunenburg mussels would be required in order to obtain one kilogram of marketable product. The ratio of 70 Caribou mussels to 123 Lunenburg mussels is consistent with the previous statement that 1 *edulis* mussel is roughly comparable to 1.7 *trossulus* mussels.<sup>(1)</sup>

### Concerns regarding seed transfer

In a growing industry, instances of spatfall failure will inevitably prompt producers to introduce seed from other areas as a means of ensuring continuity in the production cycle. The movement of seed across provincial boundaries and geographic zones is, however, of concern to both regulatory agencies and producers. The primary issue is the risk of introducing unwanted organisms such as parasites, pathogens or potential pests that could reside on the shell, in the gut, in the mud, or in the intervalve fluid of the mussels.<sup>(12)</sup> In practical terms, one must consider each transfer of mussel seed in the light of the best available information, and weigh the risks against the potential benefits.

### Conclusions

Several Nova Scotian producers have recently switched from their pure *M. trossulus* or mixed seed stocks to pure *M. edulis* seed stocks even though the full economic impact of this strategy still remains to be determined. Their rationale is that the higher shell weight per unit of length of *M. edulis* will translate into lower shell breakage and fewer mussels per kilogram. Alternative *M. edulis* seed populations should however be evaluated for two years prior to being fully integrated into commercial production since

several of the *M. edulis* stocks had lower production values than the local mixed *trossulus-edulis* stock.

*M. trossulus* does have an economic value and is currently accepted in the market place. It would be useful to undertake a more balanced study involving multiple populations of both species in order to evaluate the variability among stocks within species. Some stocks of *M. trossulus* may even outperform *M. edulis* stocks under specific environmental conditions and should be used for commercial production.

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# Genetic and Ecological Consequences of Contact between Species of *Mytilus*: Lessons from California, Puget Sound and Europe

Thomas J. Hilbish

The blue mussel genus *Mytilus* contains three closely related species that hybridize wherever they co-occur. We have examined the genetics of contact between *M. edulis* and *M. galloprovincialis* in Europe and between *M. trossulus* and *M. galloprovincialis* in California and Puget Sound. In Europe, *M. edulis* and *M. galloprovincialis* form an extensive hybrid zone that has led to extensive movement of genes between the two species. Despite genetic communication the two species remain discrete, exhibit different production characteristics and form the basis of highly successful aquaculture industries. In California and Puget Sound, *M. galloprovincialis* has been introduced and hybridizes with the native *M. trossulus*. In this case, hybridization appears to be less successful and while genetic contamination does occur it is not pervasive. At least one aquaculture company has been successful in maintaining genetically pure stocks. Preliminary results indicate that in both California and Puget Sound the introduction of *M. galloprovincialis* appears to be largely the result of shipping activities and not aquaculture.

The blue mussel genus *Mytilus* contains three closely related species. *M. galloprovincialis* is endemic to the Mediterranean and the Atlantic coasts of North Africa, Spain and Portugal,<sup>(3)</sup> and has been introduced to South Africa,<sup>(4)</sup> the Sea of Japan,<sup>(14)</sup> southern California,<sup>(7)</sup> and Puget Sound. *M. edulis* is endemic to the cool temperate waters of the North Atlantic; in the eastern Atlantic it occurs from France to Iceland and in the western Atlantic from Cape Hatteras to the Canadian Maritime Provinces.<sup>(3)</sup> *M. trossulus* occurs in the North Pacific from Monterey Bay to the Sea of Japan, in the Atlantic in the Maritime Provinces, and in the Baltic Sea.<sup>(8)</sup> Closely related mussels occur in the Southern Hemisphere but their taxonomic status is presently unclear.<sup>(8)</sup> In the Northern Hemisphere these three species can be distinguished genetically and with the use of multivariate morphological data.<sup>(8)</sup> Wherever the species co-occur they hybridize. *M. galloprovincialis* hybridizes with *M. edulis* in Europe<sup>(1)</sup> and *M. trossulus* in the Sea of Japan, California and Puget Sound.<sup>(8)</sup> *M. edulis* and *M. trossulus* hybridize at the entrance to the Baltic Sea and in the Canadian Maritime Provinces.<sup>(6)</sup>

Hybridization between mussel species has several potential consequences that should be of interest to the aquaculture industry:

1) Different species and genetic stocks may

have different production characteristics and hybridization may disrupt or destroy the integrity of these stocks.

- 2) In regions where species co-occur the genetic composition of populations may vary dramatically from one location to the next which can influence the composition of seed stocks.
- 3) Increased public concern over the consequences of species introductions and stock translocation has led to regulations that restrict such activities and may influence aquaculture practices. It is also important that management regulations be based upon sound scientific assessment on the taxonomic status and potential for hybridization among mussel stocks.

My laboratory has examined the genetics of contact between *Mytilus edulis* and *M. galloprovincialis* in Europe and between *M. trossulus* and *M. galloprovincialis* in California and Puget Sound. In this report I summarize some of these results from the prospective of how hybridization may influence these species. For purposes of this discussion it is necessary to distinguish two forms of hybridization. Unfortunately, the term hybrid can encompass several different genetic events that potentially have distinct long-term conse-



quences. First generation, or F1, hybrids may form between two species but be relatively unfit such that hybridization results in little or no exchange of genetic information between the two taxa. Alternatively, hybridization may result in pervasive exchange of genetic material between species with the potential consequence that the distinctive characteristics of the species may be eroded or destroyed.

### ***Mytilus edulis/galloprovincialis* in Europe**

*Mytilus edulis* and *M. galloprovincialis* hybridize throughout the Atlantic coasts of Great Britain and France.<sup>(1)</sup> Mussel populations within this region are genetically complex and may change from virtually pure stands of one species to almost pure stands of the other in distances of only a dozen kilometers. Our studies in southwest England exemplify this complexity. Mussel populations on the south shore of Devon are composed exclusively of *M. edulis* while those on the north shore of Cornwall are populations that have a very high frequency of *M. galloprovincialis* alleles. In between these areas mussel populations contain high frequencies of hybrids. The transition from one genetic patch to another can occur in distances of less than 10 km. Hybrids exhibit strong size structure. Small mussels have very high frequencies of *M. edulis* alleles (90%), while the frequency of these alleles among large mussels is typically less than 30%. This change in the genetic composition of these populations is the result of strong viability selection; hybrid mussels most like *M. edulis* suffer mortality rates of about 80% per year while *M. galloprovincialis*-like mussels have only a 50% per year mortality rate.<sup>(2,13)</sup>

Genetic analysis of these hybrid populations indicates that the majority of mussels, at least among those 3 cm in shell length, are hybrids. Indeed, many of the genotypes found in southwest England are indicative of advanced or multiple generation hybridization. Hybridization also appears to be a long-term property of the history of these two species. Studies of nuclear versus mitochondrial gene distributions indicate that hybridization has resulted in the movement of mitochondrial genomes from *M. edulis* into *M. galloprovincialis*<sup>(9)</sup> and this effect is particularly prominent among all populations of *M. galloprovincialis* in the Atlantic. For such an extensive infusion of mitochondrial genomes from one species into another to take place implies that hybridization has been occurring between these species for an extended period.

Despite the evidence for extensive and long-term hybridization *Mytilus edulis* and *M. galloprovincialis* differ in several regards that may have consequences on their production characteristics. Hilbish et al.<sup>(5)</sup> showed that under warm-water conditions *M. gallo-*

*provincialis* has greater feeding and absorption rates that probably result in differential growth in the field. Secor<sup>(12)</sup> showed that the two species have similar fecundity but *M. galloprovincialis* exhibits a slight delay in spawning relative to *M. edulis*. Most striking is that Secor<sup>(12)</sup> demonstrated that these two species have very distinct mantle storage cycles; *M. galloprovincialis* stores very little energy in adipogranular cells or vesicular connective tissue relative to *M. edulis*. These storage tissues represent the primary sites of glycogen storage in mussels and these results suggest that the two species may be very distinct in the timing and level of glycogen deposition.

The picture that emerges for these two species in Europe is that hybridization is common place and pervasive yet these species maintain their distinctiveness, even with regard to several traits that may influence their production characteristics. It is worth noting that three of the world's largest aquaculture industries, those in Spain, France, and the Netherlands, occur in regions influenced by hybridization between these species. Aquaculture operations in France occur within regions containing mussel populations that are as genetically complex as those found in southwest England. Some culturists in France even exploit this heterogeneity; by placing spat collectors in specific areas they specialize in the culture of one species over the other.

### ***Mytilus trossulus/galloprovincialis* in California**

*Mytilus galloprovincialis* was introduced to southern California in the first half of the twentieth century and began to expand its range in the 1940s.<sup>(7)</sup> Along the coast of central and northern California *M. galloprovincialis* is sympatric with the native mussel *M. trossulus* and the two hybridize.<sup>(7,11)</sup> We have completed a detailed study of the distribution of these two species and their hybrids along the California coast. The two species are sympatric and hybridize in the region between Monterey Bay and Cape Mendocino. The majority of genetic variation among populations is caused by the relative ratio of the two parent species; hybrids usually comprise only about 20% of any population within the region of sympatry. In addition most hybrids are early generation hybrids and there is little evidence for pervasive gene exchange between these two taxa. Based on the disruption of normal mitochondrial inheritance in inter-specific hybrids there is evidence that *M. trossulus* is more genetically incompatible with both *M. edulis* and *M. galloprovincialis* than these latter two species are with one another.<sup>(10)</sup> We think that in California *M. trossulus* and *M. galloprovincialis* have only limited capacity to form advanced generation hybrids, which limits exchange between these taxa.



## ***Mytilus trossulus*/*galloprovincialis* in Puget Sound**

*Mytilus galloprovincialis* has also been introduced to the Puget Sound where it hybridizes with the native species *M. trossulus*. *M. galloprovincialis* was imported for purposes of aquaculture and the largest grower of this species is presently Taylor United, Inc., which produces over one million pounds of marketed product each year. Taylor United maintains hatchery facilities to perpetuate seed stocks and their largest grow-out locations are in the extreme southern end of Puget Sound. *M. trossulus* has been cultured in Puget Sound in several small operations for many years but this species is susceptible to summer mortality that frequently follows spawning activities. Consequently, several culturists turned to *M. galloprovincialis* as an alternative to *M. trossulus* for aquaculture. Mussel culturists have come under criticism for the introduction of an exotic species that hybridizes with an indigenous species. In the United States there is growing political pressure to restrict introductions and stock exchanges such as the importation of *M. galloprovincialis* to Puget Sound. However, aquaculture is not the only and perhaps not even the most important route of species introduction. In this case *M. galloprovincialis* may have been introduced by shipping activities or incidentally by the introduction of oysters from Japan. We are examining the distribution and level of hybridization of *M. galloprovincialis* in Puget Sound. We have two objectives: 1) evaluate the possibility that aquaculture activities are responsible for the introduction and dissemination of this species and 2) determine the extent of hybridization. This later objective also allows an evaluation of the extent of hybridization between these two species under different environmental circumstances compared to those in California.

We examined the frequency of *Mytilus galloprovincialis* alleles as a function of distance from the primary grow-out locations used by Taylor United. There was no evidence of a diminution of the frequency of *M. galloprovincialis* alleles with distance from the grow-out locations. Mussels from Taylor United had a 100% frequency of *M. galloprovincialis* alleles. All wild populations exhibited a frequency of < 10% of these alleles regardless of distance from the grow-out locations. There also was no difference in the frequency of *M. galloprovincialis* alleles among young and old individuals. This observation is significant because while the culture of *M. galloprovincialis* began in Puget Sound about 10 years ago it did not become a significant crop until about five years ago. Many wild mussels that contain *M. galloprovincialis*

alleles are older than five years and pre-date the expansion of *M. galloprovincialis* culture. While this study is ongoing the initial results do not implicate aquaculture operations as being a major source of *M. galloprovincialis* in Puget Sound. Finally, all specimens obtained from Taylor United were exclusively *M. galloprovincialis* which indicates that hatchery, nursery, and grow-out practices have been successful in culturing this species and avoiding contamination by the endemic *M. trossulus*.

In summary, blue mussel species will hybridize in any region in which they are sympatric. This has many potential implications to the aquaculture industry. In general hybridization appears to result in relatively little genetic exchange between taxa, particularly if one of the species involved is *M. trossulus*. Perhaps this is because *M. trossulus* is more distantly related to *M. galloprovincialis* and *M. edulis* than they are to each other.<sup>(9)</sup> But even in cases where *M. galloprovincialis* and *M. edulis* pervasively hybridize they remain distinct probably as a result of strong natural selection.

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# Reproduction and Pre-settlement Behaviour of *Mytilus edulis* and *Mytilus trossulus* in Controlled Environments: Implications for Mussel Culture in Mixed-species Assemblages

K.R. Freeman and S.P. MacQuarrie

On Canada's Atlantic coast the presence of *Mytilus trossulus* among commercially-cultivated *M. edulis* limits farm production and has prompted inquiry into ways of circumventing the problem. Reports that the species spawn simultaneously and have larval periods of equal duration eliminate timing of collection as a means of avoiding *M. trossulus* at mixed-species farms. Anecdotal reports of the post-settlement behaviour of these species suggest the depth preferences may differ and prompted us to conduct mesocosm experiments examining the vertical migration of larvae of each species. Initial results suggest the species have similar distributions to a depth of 8 m, which appears to eliminate the possibility of using collection depth to selectively avoid *M. trossulus*. Further, laboratory examination revealed that fertilization success in between-species matings is frequently reduced by as much as 85%. Therefore, *M. trossulus* is easily self-sustaining in mixed species assemblages and its undesirable effects on farm production are unlikely to be improved through natural hybridization with *M. edulis*. Growers who have recognized the production advantage of harvesting and processing pure *M. edulis* voice concern about *M. trossulus*, but greater worry is expressed by growers who have reported increasing harvests of *M. trossulus* over the relatively short histories of their farms. This trend may simply reflect natural cycles within local mussel populations or may reflect the ability of *M. trossulus* to adapt to off-bottom cultivation.

Eastern Canadian blue mussels, while originally thought to be entirely *Mytilus edulis*, have been shown to include a second species, *M. trossulus*.<sup>(10,19)</sup> Examination of numerous populations of *Mytilus* in Nova Scotia and Prince Edward Island showed that mussels in Prince Edward Island were only *M. edulis* but that Nova Scotia had pure and mixed populations of each species as well as hybrids.<sup>(7)</sup> Widespread populations of *M. trossulus* also occur among *M. edulis* in waters around Newfoundland.<sup>(16)</sup> The known distribution of *M. trossulus* also includes New Brunswick,<sup>(8)</sup> Gaspé, and the Magdalen Islands,<sup>(15)</sup> and a recent report even suggests its presence in low percentages in Prince Edward Island.<sup>(11)</sup>

While *M. trossulus* was not originally seen as noteworthy in the developing mussel culture industry in Atlantic Canada, observations by growers and investigators alike have shown that its generally lower condition and thin fragile shell combine to establish its commercial status as second to *M. edulis*.<sup>(6)</sup> It has been estimated that when differences in individual weight,

survival and grading losses are accounted for, the number of *M. trossulus* farmed would have to be increased by a factor of 1.7 to achieve the same return as with *M. edulis*.<sup>(13)</sup> Consequently, *M. trossulus* has gained notoriety among Nova Scotian growers and even among other Maritime aquaculturists not directly affected by the species. When questioned during an industry survey, growers ranked *M. trossulus* fourth in a list of 10 biological concerns and a few individuals rated it first.<sup>(4)</sup> In recent years, as the production disadvantages and the distribution of *M. trossulus* have become known, interest has risen in importing pure *M. edulis* seed rather than using seed collected on-site and contending with reduced farm output.

A rising incidence of *M. trossulus* has been reported on two mussel farms in Nova Scotia,<sup>(4)</sup> in one case from an estimated 20% to 80% during the life of the farm. While mixed-species proportions have yet to undergo long-term monitoring anywhere in the Maritime Provinces, a complete shift of species in a 2-species mussel population has been reported else-



where.<sup>(2)</sup> Therefore, the reported increase in the incidence of *M. trossulus* in what are effectively modified environments is a matter of more than casual curiosity to growers who have both species but prefer to grow only *M. edulis*. If, through provision of shallow habitat using suspended culture gear, an environmental advantage is given to *M. trossulus*, then growers should be aware of the potential impact of this practice.

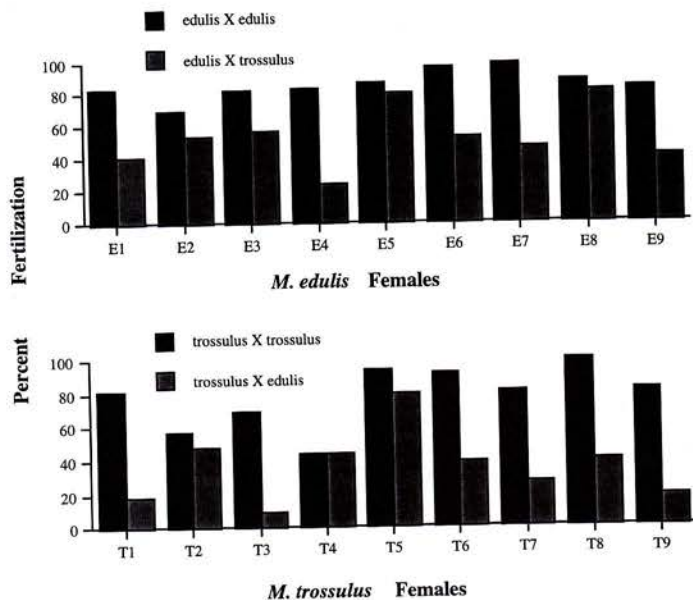
Examination of aquaculture sites occupied largely by *M. trossulus* may provide insights into mussel behaviours that may have husbandry implications. The predominance of *M. trossulus* in the Baltic Sea and locally in Cape Breton's Bras d'Or Lake — two low-salinity water bodies — suggests that reduced salinity sites may favour *M. trossulus*, even though the species also thrives in areas with more oceanic salinities. The association, however, between *M. trossulus* and reduced salinity could be due as much to differential survival as to behaviour. Direct observations suggesting site-selective behaviour in *M. trossulus* have not been reported. However, on one occasion hatchery-reared *M. trossulus* and *M. edulis* spat were held overnight in separate, identical containers of seawater (salinity ~30 ppt) and by the next morning the *M. trossulus* spat were observed to have crawled to the air-water interface whereas the *M. edulis* spat had re-

mained attached near their container's bottom.<sup>(17)</sup> Suspended cultivation would position *M. trossulus* higher in the water column where there is an improved chance of encountering reduced salinity, but it is unknown whether *M. trossulus* would move to a shallower site if provided with the opportunity. A further advantage to settling off-bottom might be reduced vulnerability to predation, in particular by starfish whose time of settlement is concurrent with that of *Mytilus*. A predilection of the sea star *Asterias* for *M. trossulus* has been demonstrated in experiments where the predator was exposed to both mussel species.<sup>(9)</sup> Starfish do not settle well at low salinity,<sup>(1)</sup> so surface-deployed substrates may in some instances provide a predation-reduced niche for mussels.

In addition to information on the mussel populations at the site, any understanding of the genetic interaction of these species will depend on a thorough elucidation of life history events. At one site in Nova Scotia, spawning times and larval periods of the two species have been almost identical.<sup>(5)</sup> Hybridization, both natural<sup>(7)</sup> and experimental,<sup>(6)</sup> has also been examined. Hancock et al.<sup>(7)</sup> indicate the maximum hybridization rate is only 19.5%. Perhaps connected with this low hybridization rate is the fact that fertilization success in hybrid matings can be as much as 85% lower than in pure matings (Fig. 1),<sup>(3)</sup> although

the reasons for these consistent declines are unknown. Beyond these studies, there are a host of unknowns concerning the behaviour and fate of mussel larvae in natural settings. Indications of preferred settlement depth of the two species, and even post-settlement movement, have been based largely on conjecture and unconfirmed rumour.

From a scientific perspective, the co-occurrence of *M. edulis* and *M. trossulus* raises intriguing ecological questions, particularly in view of the similar spawning times and length of the larval periods, and the ability to hybridize while continuing to exist as separate species. Answering some of these questions might provide insights that would aid in the development of husbandry practices that reduce the incidence of *M. trossulus*. Reports suggesting that *M. trossulus* might preferentially select upper (shallower) depths in the water column instigated experiments to examine pre-settlement behaviour of this species. Logistic problems occasioned by sampling for, and identification of, closely related species



**Figure 1.** Comparison of fertilization percent between pure and hybrid matings of *M. edulis* and *M. trossulus*. For each species, 9 females and 9 males were individually spawned. Pure and hybrid matings (female x male) were attempted as follows where "E" refers to *M. edulis* and "T" to *M. trossulus*: E1xE1, E1xT1; E2xE2, E2xT2, etc., and T1xT1, T1xE1; T2xT2, T2xE2, etc.



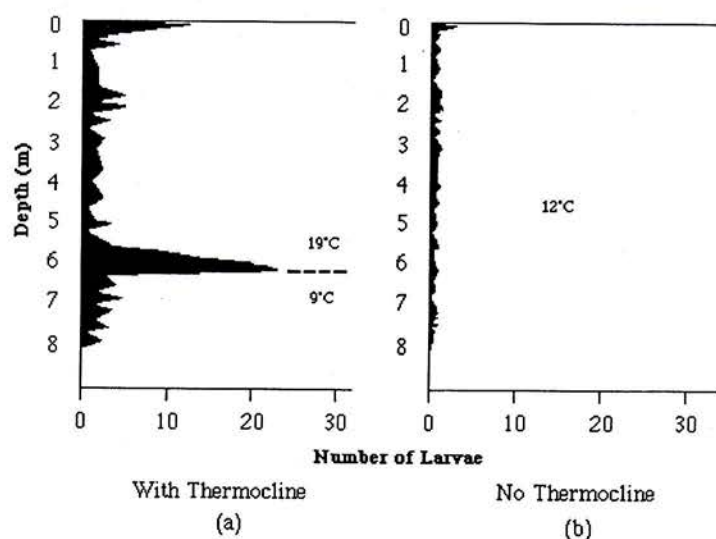


Figure 2. Typical *M. trossulus* pre-settlement vertical distribution in tower tank mesocosm with thermocline (---) (a), and without thermocline (b). Both species followed similar trends, showing larvae to the bottom but with greater accumulations at the surface and thermocline and virtually even distributions from surface to bottom in the "no thermocline" mesocosms.

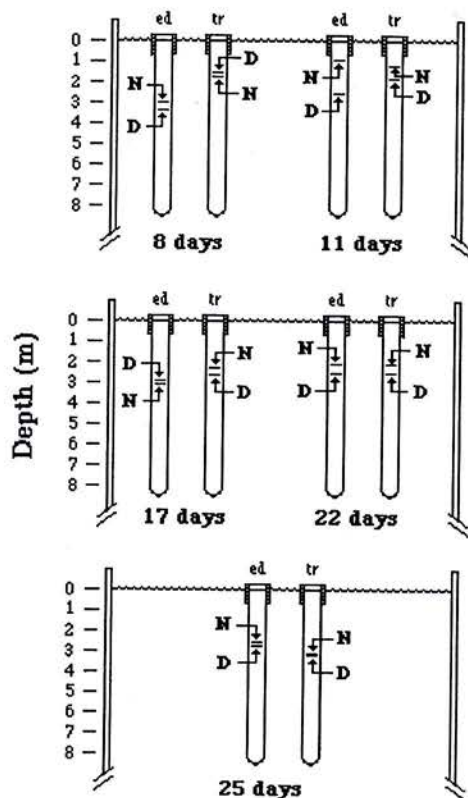


Figure 3. Day (D) and night (N) depth center of mass (ZCM) for *M. edulis* (ed) and *M. trossulus* (tr) larvae from age day 8 to day 25 in 8.5 m deep mesocosms. Each within species day/night ZCM is a mean derived from three replicate mesocosms. Note varying relative positions of day and night ZCMs throughout larval phases both within and between species.

meant that special experimental circumstances would need to be used. Previous work on vertical migrations of scallop larvae had been successfully conducted using mesocosms suspended in the Dalhousie University Aquatron 10-m-deep tower tank<sup>(14)</sup> and this system was chosen for the experimental work on mussel larvae. Using pure cultures of both *M. edulis* and *M. trossulus* larvae, the intention was to compare vertical migrations and eventually to examine settlement and post-settlement depth selection.

Mesocosms were constructed from 8.5 m deep by 0.6 m diameter polyethylene tubing closed at the lower end. Each mesocosm contained 2.4 m<sup>3</sup> of 1.0-µm filtered seawater and was supported from the water surface by Styrofoam collars. Using hot and cold water circulating in vertically adjustable piping around the inside circumference of the tank, a thermocline was established at 6 m. Mesocosms were established in triplicate for *M. trossulus* in the first experiment,<sup>(12)</sup> and in triplicate for *M. trossulus* and *M. edulis* in a second trial. All replicated mesocosms were exposed to the thermocline; the seawater temperature above the thermocline was maintained at 19°C and the temperature below was 9°C. A fourth mesocosm for each species was established with an extra outer polyethylene bag filled with water that was vertically circulated by an air lift, thus eliminating the thermocline within the mesocosm. The seawater temperature in these mesocosms was 12°C.

Larval concentrations to depths of 8.0 m were recorded by using a submersible video camera and lighting system that illuminated larvae within the camera's field of view. The camera and lighting system were lowered by a pneumatically-driven winch to a depth of only 8.0 m in order to avoid damaging the mesocosm bottom. An artificial 12-hour day and night photoperiod (LD12:12) was instituted above the mesocosms and video sampling was conducted at 6-hour intervals (twice during each 12-hour pe-

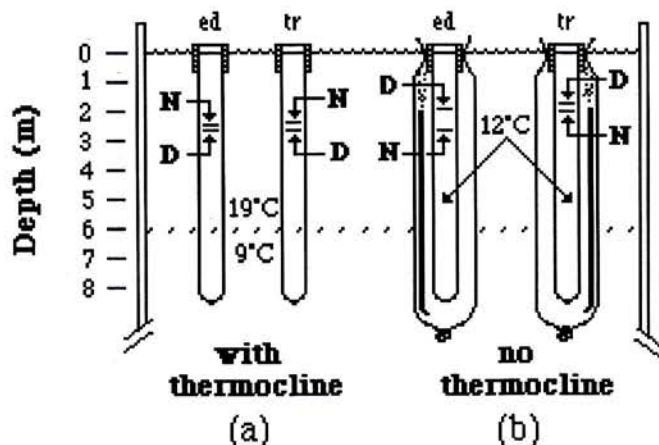


Figure 4 (a & b). Mean day (D) and night (N) larval depth center of mass (ZCM) positions from replicated mesocosms with thermoclines (a), and single mesocosm ZCMs for each species without thermocline (b) over all sampling days. Note reversed relative positions of day and night ZCMs between the "with thermocline" and "no thermocline" sets.

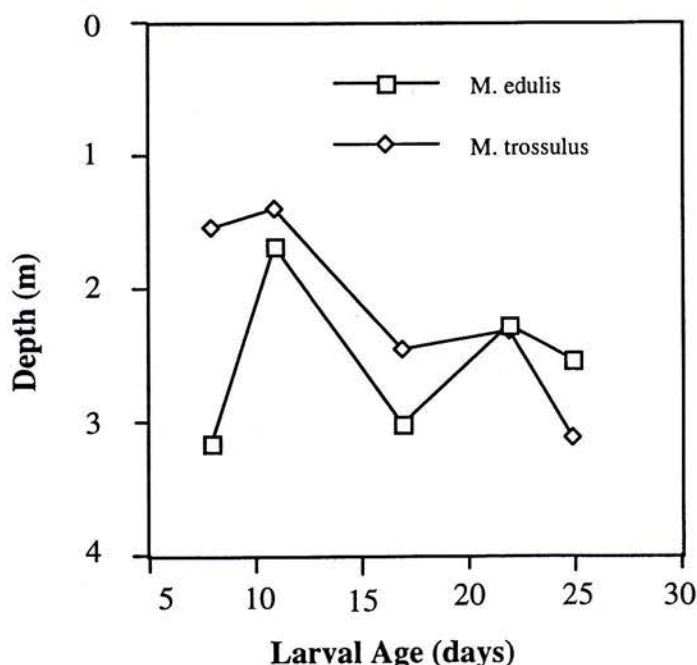


Figure 5. Averaged larval depth center of mass (ZCM) trends for *M. edulis* and *M. trossulus* from day 8 to day 25 post fertilization.

riod). Recordings of vertical transects were timed and the video tapes were later analyzed using an image processing system comprised of a computer, videocassette recorder and monitor. The computer was equipped with a frame grabber digitizing board and Optimas, an image processing software package. The recorder, controlled by the computer, advanced the tape to a specific frame where the number of larvae could be counted automatically by the program. Each video profile was divided into 200 equidistant intervals, based on the descent times recorded during the taping of a vertical transect, and larval counts were taken at these frames and recorded. From these counts, vertical distributions were constructed and the mean depth center of mass (ZCM) for larvae in each mesocosm, for each day and night video transect, was calculated.<sup>(18)</sup> During the two-species experiment, day and night video transects were taken when larvae were 8, 11, 17, 22 and 25 days old.

Two-day old veligers were introduced to filled mesocosms that had been temperature equilibrated for 24 hours. Mesocosms in the first experiment (*M. trossulus* only) were each charged with  $2.0 \times 10^6$  larvae. *M. trossulus* mesocosms in the second experiment began with  $1.65 \times 10^6$  larvae and *M. edulis* mesocosms with  $1.4 \times 10^6$  larvae respectively. Feeding was conducted by pouring cultured phytoplankton through perforated hoses extending to a depth of 8.5 m in each mesocosm. Tahitian *Isochrysis* was used exclusively throughout the first experiment and counts were maintained at approximately  $1.0 \times 10^4$  cells/mL in each mesocosm. Feeding in the second experiment began in a similar manner but when larvae were 12 days old a mixture of *Isochrysis* and *Chaetoceros gracilis* (roughly  $5.0 \times 10^3$  cells/mL of each algal species) was fed to the larvae. Total cell counts were checked and adjusted every two days.

A typical *M. trossulus* vertical transect from the first experiment showed larvae throughout the mesocosm with a major concentration of larvae at the thermocline, a lesser one at the surface, and minimal variation in distribution



between night and day<sup>(12)</sup> (e.g., Fig. 2a). In the second experiment, *M. trossulus* and *M. edulis* larval profiles were generally similar to each other and to those of *M. trossulus* in the first experiment. Thermocline disruption (e.g., Fig. 2b) resulted in an even distribution of larvae of both species from 0 to 8.0 m with an occasional extra surface accumulation. ZCM distributions separately averaged over time for *M. edulis* and *M. trossulus* did not reveal marked species differences. Diel migrations were greatest at day 11 in *M. edulis* (1.6 m) and least in *M. trossulus* at day 25 (0.05 m). In both species, the night time mean ZCM was shallower than during the day except on day 8 in *M. trossulus* and on day 17 in *M. edulis* (Fig. 3). ZCM values for larvae exposed to the thermocline and averaged over all video samplings (separately for days and nights) appeared nearly identical for the two species (Fig. 4a). With no thermocline, averages were shallower and in both species the day and night relative positions were reversed (Fig. 4b). Averaged ZCM values showed similar between-sampling trends in both species, but variability between sampling was more extreme in *M. edulis* while there was an overall decline in *M. trossulus* (Fig. 5). The averaged ZCM species positions on day 25 (close to metamorphosis) were within 0.5 m of each other.

This mesocosm study of mussel larvae suggests that significantly different vertical distribution patterns between the species will not likely be found at metamorphosis. However, data analysis is continuing from the settlement part of this experiment and field trials are scheduled at three Maritime sites to examine initial and post-settlement species depth positioning in natural settings. Changes in the relative numbers of each species at 2-species sites may be merely natural cyclic fluctuations unrelated to cultivation practices. Without long-term monitoring, and examination of the relationship of *M. trossulus* to such environmental variables as salinity and predation, the cause of these changes may never be found. Unless *M. edulis* and *M. trossulus* show major settlement differences by depth in the wild, importation of *M. edulis* spat will remain the only option, short of instituting hatchery production of *M. edulis*, for those growers who have both species on their leases and wish to avoid *M. trossulus*. Although the importation of *M. edulis* spat is expanding, at least in Nova Scotia, there is a concomitant awakening of sensibilities regarding the potential for the inadvertent introduction of nuisance or infectious biota that may accompany such imports. It is uncertain whether the practice will be allowed to continue. If *M. edulis* imports are curtailed — and in the absence of hatchery-produced stock to replace them or husbandry techniques to reduce *M. trossulus* collection — growers with *M. trossulus* on site may have to accept reduced processing efficiency and farm yields.

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# The Distribution of *Mytilus edulis* and *M. trossulus* at Spat Collection Sites in Newfoundland

D.J. Innes, A.S. Comesaña, J.E. Toro and R.J. Thompson

Two morphologically similar species of mussels (*Mytilus edulis* and *M. trossulus*) coexist in Atlantic Canada. The species composition of spat samples was determined at 28 mussel spat collection sites in Newfoundland with approximately 30 spat analyzed in each sample. The samples consisted of spat from 1996 (approximately 10 months old) and 1997 (approximately 3 months old). Species were distinguished by PCR amplification of a diagnostic nuclear DNA marker (*Glu-5*). Of the total samples analyzed ( $n=1142$ ), 62% of the mussels were *Mytilus edulis*, 35% were *M. trossulus*, and 3% were hybrids. Both species were detected at all 28 sites. Although there was a high degree of variation in the species composition among sites, the Notre Dame Bay sites were consistently dominated by *M. edulis*. For most of the comparisons of the 1996 spat samples, shell length was slightly greater in *M. edulis* than in *M. trossulus*, which may indicate differences in growth rate or survival. This hypothesis is presently being tested by following cohorts of mussels as they age at several mussel aquaculture sites. Mussel aquaculture will benefit from studies on the ecological differences between the two species of *Mytilus*.

## Introduction

Blue mussels are important for aquaculture in Atlantic Canada, where two morphologically similar species (*Mytilus edulis* and *M. trossulus*) coexist.<sup>(1,2)</sup> Although *M. trossulus* has been identified in Nova Scotia as a less desirable species for aquaculture because of a slower growth rate,<sup>(3)</sup> further research is required to confirm these results for Newfoundland sites. Studies on the distribution, ecology, and physiology of the two species have been hampered by the difficulty in distinguishing between the two species. Data on the distribution of each species is of particular importance because the aquaculture industry depends on spat from the natural environment. Fortunately, several genetic markers have been developed that can be used to identify species even at the larval and spat stage. There are a large number of spat collection and mussel culture sites around the coast of Newfoundland, but there is limited information on the distribution of *M. edulis* and *M. trossulus* at the various sites.

## Materials and methods

Random samples of about 30 spat were collected from spat collectors for the 1996 cohort in July 1997 (about 10 months old) and the 1997 cohort in Novem-

ber 1997 (about 3 months old). Samples were preserved in 95% ethanol until DNA extraction. The shell length of each individual spat was measured and a small piece of mantle tissue was removed and macerated for DNA extraction following the methods of Heath et al.<sup>(4)</sup> The *Glu-5* marker was used to distinguish the two species and their hybrids. The *Glu-5* genotype was detected following PCR (Polymerase Chain Reaction) of extracted DNA using the methods of Rawson et al.<sup>(5)</sup> Differences in shell length were analyzed using a two-way ANOVA (site, species).

## Results and discussion

Of the 1142 spat analyzed, 62% were *Mytilus edulis*, 35% were *M. trossulus*, and 3% were hybrids. The species composition of the 1996 cohort ranged from a low of 28.6% *M. edulis* for one site on the south coast to an average of 95.7% *M. edulis* among the five sites sampled in Notre Dame Bay (Table 1). Mean shell length  $\pm$  standard error (*M. edulis* 21.84  $\pm$  0.69 mm, *M. trossulus* 18.03  $\pm$  0.69 mm) was not significantly different ( $F_{[2, 366]} = 3.01$ ,  $P > 0.05$ ) between the two species for the entire data set, but at 9 of the 12 sites, *M. edulis* had a greater shell length than *M. trossulus*. Further samples of the 1996 cohort will be taken as



**Table 1.** Mean percentage and standard error (SE) of *Mytilus edulis* among spat sampled from sites in six coastal regions of Newfoundland for the 1996 (10 months old) and 1997 (3 months old) spat cohorts. Approximately 30 spat were analyzed from each site.

Region	1996			1997		
	Number of Sites	Number of Spat	% <i>M. edulis</i> (SE)	Number of Sites	Number of Spat	% <i>M. edulis</i> (SE)
Northern Peninsula	3	87	49.8 (16.18)	1	29	17.2 (–)
Notre Dame Bay	5	139	95.7 (1.77)	9	248	82.2 (6.51)
Trinity Bay	2	49	37.5 (12.50)	2	58	62.0 (30.90)
Placentia Bay	1	29	37.9 (–)	4	108	40.7 (16.56)
Fortune Bay	2	60	43.3 (13.33)	9	255	65.3 (5.76)
South Coast	1	30	28.6 (–)	2	50	57.6 (37.60)
Totals	14	394		27	748	

they age to determine if this difference indicates a greater growth rate for *M. edulis*.

Composition of the 1997 cohort ranged from a low of 17.2% *Mytilus edulis* for one site on the Northern Peninsula to an average of 82.2% among the 9 sites sampled from Notre Dame Bay. Again, mean shell length  $\pm$  standard error (*M. edulis*  $6.39 \pm 0.24$  mm, *M. trossulus*  $7.14 \pm 0.40$  mm) was not significantly different ( $F_{[2, 677]} = 0.99$ ,  $P > 0.05$ ) between the two species.

*Mytilus trossulus* and *M. edulis* are widely distributed around the coast of Newfoundland, with a large amount of heterogeneity in the relative frequency of the two species. *M. trossulus* was found at all spat collecting sites, but the Notre Dame Bay sites showed the lowest frequency of *M. trossulus*. The wide distribution of *M. trossulus* makes it difficult to avoid collecting spat of this species. Future studies should determine the production of the two species and whether areas with a high frequency of *M. trossulus* exhibit significantly lower production than areas with a high frequency of *M. edulis*.

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# **Increasing Spat Collection for Mussel Culture: Newfoundland Aquaculture Industry Association Larval and Spatfall Monitoring Program**

*Sean Macneill, Miranda Pryor, Cyr Couturier and Jay Parsons*

The Newfoundland Aquaculture Industry Association began monitoring mussel larval production and spatfall in 1994. The fourth year (1998) of the program has been the most successful to date. Forty-four mussel growers representing 58 sites took part in the monitoring program which ran from early June to November. During that time, growers were taught basic mussel biology and introduced to site-monitoring techniques, including assessing meat-yield, towing for plankton, analyzing the plankton samples microscopically, identifying invertebrate larvae, and collecting and analyzing spat in the fall and spring. Information gathered was used to determine the optimum time to deploy collectors and measure spatfall success after settlement. Deployment of mussel collectors began in late June or early July on the south coast of the island, while ice and cooler water temperatures delayed deployment on the northeast coast, Notre Dame Bay, and Northern Peninsula until early to late August. Good spat numbers were obtained at most sites, with rapid growth occurring on the south coast. However, the spat size was smaller and more fouling occurred at many sites in Notre Dame Bay than in the previous year. Comparisons of results from spat collectors from 19 sites sampled in the fall of 1996 and in June 1997 indicated, on average, a 530% increase in collector weight, a 334% increase in mean spat size ( $n=600$  per site), while spat number/collector and density of spat/cm<sup>2</sup> of collector rope decreased 67% and 78%, respectively. For sites with 3 or more years of data, definite trends in spawning and larval settlement are becoming apparent. Growers feel this information is vital for forming a database about their sites and making spatfall prediction easier.

## **Introduction**

As the Newfoundland mussel industry continues to grow, reliable sources of mussel seed will become increasingly important. In years past, deploying collector ropes in early to mid summer was met with mixed success as collectors often became fouled with starfish and other unwanted organisms, resulting in poor growth and reduced numbers of mussels. To improve the reliability of seed collection, the Newfoundland Aquaculture Industry Association (NAIA) launched a mussel larval and spatfall monitoring program in 1994. In this program, mussel growers are taught about mussel biology and the importance of site monitoring, introduced to monitoring techniques and basic microscopy, and provided with technical assistance and equipment for monitoring their sites. As each site is unique with ever-changing oceanographic and environmental conditions, regular monitoring of site conditions and their impact on the mussel life cycle can aid the grower significantly in organizing and preparing farm activities. When sites are monitored, growers are better able to predict the time of spawn-

ing, rate of larval growth, time of settlement, and optimum locations and deployment times for collectors. Analyzing spat collectors after settlement can help determine spatfall success, assess biofouling and spat drop-off, as well as enable growers to set general socking timetables based on growth during the first year.

## **Field season summary**

### **Spring spat collection**

The field season began in early June and ended in late November. During that time, more than 50 culture sites around Newfoundland were monitored. At the start of the season, collectors were retrieved from 19 sites that had participated in the monitoring program in 1996.<sup>(1)</sup> A number of the growers were concerned about the sudden and high drop-off of mussel spat during the late spring period. Visually, the collectors looked spotty with some being nearly empty until they filled in later in the summer. For some sites, this sudden drop-off in spat dashed hopes for a good col-



lection as the collectors became covered with fouling organisms.

To determine the change in collector characteristics from the fall of 1996 to mid June 1997, three collectors (one taken each from the inside, middle, and outside of each site) were sampled at random and later analyzed for spat number, spat density (number per cm<sup>2</sup> of collector rope), spat size (mm), and collector weight (g), as well as the amount and type of biofouling. By averaging the values of the 3 collectors, an average for each character at each site was determined and compared with the average values from the fall of 1996. Figure 1 shows the overall average percent change in collector characteristics for the 19 sites sampled in the fall of 1996 and June 1997. The overall average weight per collector (seed only) had increased from 234.2 g after about 100 deployment days to 1475.6 g after an average of 346 days (a 530% increase). Spat size (shell length) increased 334%, from 3.8 mm in the fall to 16.3 mm in June.

With such large increases in growth of spat, it is not surprising that overall the average number and density of spat in the collectors declined 67% and 78%, respectively, in the first year following settlement (Fig. 1). Higher food demand and limited space may be reasons why so many mussels drop off when rapid growth starts in late spring. Another reason may be the amount of biofouling. At some sites, fouling got much worse over the winter. In addition to filamentous algae, silt, and "slime" (the growth of broad leaf kelps and rock weed on collectors often referred as "slubbing") may have

had an impact on drop-off. Finally, wave action and ice damage surely influenced spat drop-off. Because this is only the first year of an in-depth comparison between fall and spring collectors, the reasons for spat drop-off can only be speculated upon. More data are needed to better understand the factors influencing spat drop-off.

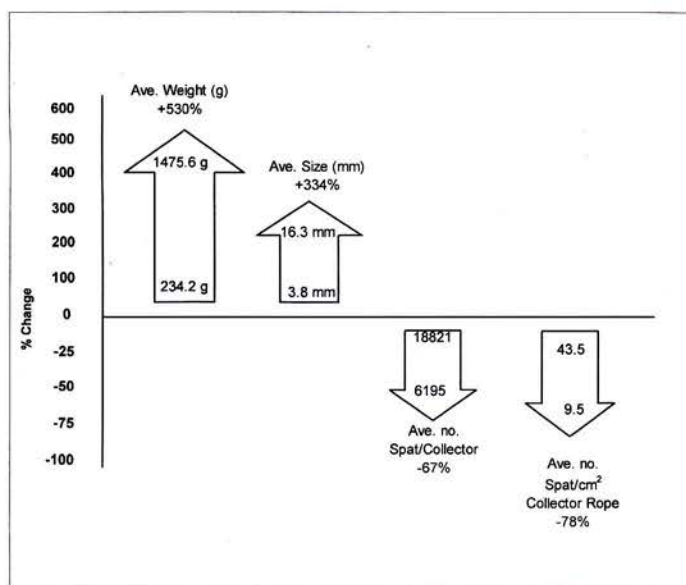
### Larval monitoring and collector deployment

Throughout the larval monitoring period, plankton tow samples were analyzed for larval size and abundance. When more than 50% of mussel larvae in the sample are > 200  $\mu$ m in length, growers should start deploying collectors. Larval abundance was found to be site-dependent, with some sites consistently seeing several hundred larvae per mL of seawater each monitoring season at peak times, while others barely had 10 larvae per mL. While both larval size and abundance are important in determining when to deploy collectors, many growers used larval size as the primary indicator and then decided if larval numbers were high enough to warrant deployment of collectors.

For sites with 3 or more years of data, trends in spawning, larval growth, and settlement are becoming apparent. Figure 2 shows an example of such trends at a site in Placentia Bay. The white bar indicates the time period where the majority of larvae sampled are < 200  $\mu$ m in length. The hatched bar indicates when the majority of larvae have moved from the < 200  $\mu$ m size class to > 200  $\mu$ m and the black bar indicates when 50% of mussel larvae are > 200  $\mu$ m in length. In 3 of the 4 years, larvae

were ready to settle around the second or third week of July. The "x" marks the start of collector deployment. This kind of information can help growers plan ahead so that necessary equipment can be ordered and collector lines readied for deployment. For other sites, trends are not easy to identify, as the timing of settlement differs greatly between years. Regular monitoring is necessary as settlement may occur at a different time each year, even in sites where settlement success is fairly consistent.

Figure 3 shows the general deployment times for participating sites around Newfoundland. Sites on the south coast west of the Burin Peninsula generally deployed collectors between the end of June and the end of July. Sites in Placentia Bay and St. Mary's Bay deployed from mid July to mid August. Sites further north generally deployed later. Trinity Bay, Bonavista Bay



**Figure 1. Percent change in mussel collector characteristics from fall 1996 to late spring 1997 (average of 3 collectors per site, 19 sites total).**



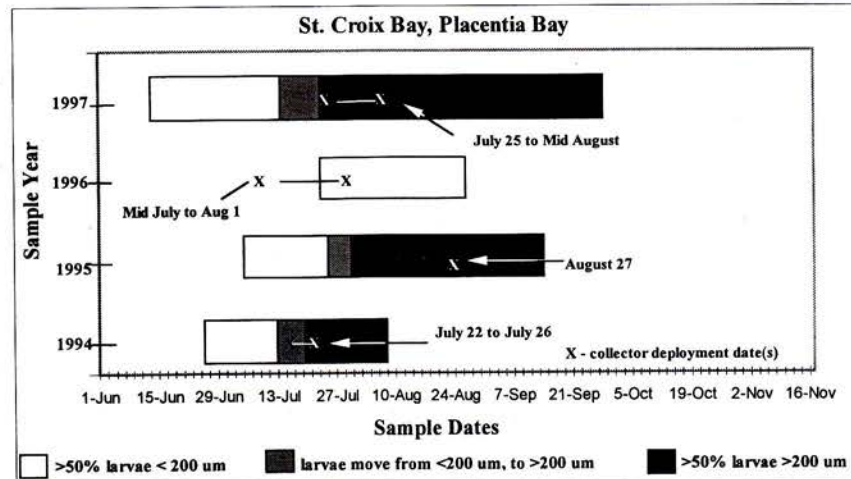


Figure 2. Results of larval monitoring for St. Croix Bay from 1994 to 1997.

and eastern Notre Dame Bay sites deployed from mid or late July to late August, while the western half of Notre Dame Bay and the Northern Peninsula de-

ployed from early to late August. Differences in deployment times had a large impact on the number of spat collected as well as on growth after settlement.

Sites on the south coast that deployed early had more rapid growth because of warmer waters and several sets settled over the summer. Sites on the east coast, parts of Notre Dame Bay, and the Northern Peninsula that deployed late had, for the most part, only one set and the cooler waters at the time of deployment in August appeared to slow growth.

#### Fall collector retrieval

As an ongoing part of monitoring after settlement, 3 collectors from each of 43 sites were retrieved in the fall of 1997 to determine spatfall success. Although individual sites differed in the amount and size of seed collected, there were similarities among sites located in the same geographic region.<sup>(2)</sup> Figure 4 shows the average spat size (mm) and number summarized by region, with the approximate length of deployment (days) for each region given underneath. For many south coast sites, more than one set of

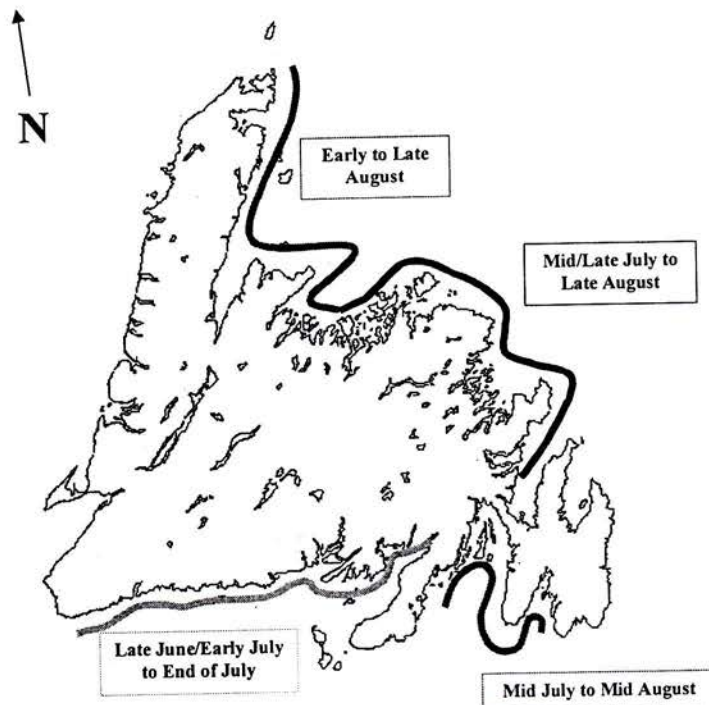


Figure 3. General mussel collector deployment times in the summer of 1997.



spat settled throughout the summer; the first set occurred by early July, the second in late August and, for one site, there was a third set in October as evidenced by the huge amount of pepper spat covering earlier, much larger spat. Thus, the average number of spat for sites in southern regions was much higher than in northern areas, where only one major set was observed at most sites.

Average spat size (shell length) varied considerably among sites.<sup>(2)</sup> However, the average spat size was slightly larger for the south coast (SC), Placentia Bay (PB), and Notre Dame Bay east (NDBE) regions (Fig. 4). On the south coast, early settlement meant a longer growing season and spat grew quickly. At the site shown in Figure 5, some collectors had spat nearly 2 cm in length after about 100 days. For sites in the western part of Notre Dame Bay, the east coast and Northern Peninsula, spawning occurred later. In these areas, water temperature reached 12 to 14°C for a short while during the late summer but the water cooled quickly in September, perhaps shortening the growing season. In addition, more fouling was reported at many sites in Notre Dame Bay and the east coast in 1997 than in the previous season. On the south coast, fouling did occur in late July and early August, but it appears that the growth of spat was so rapid that it had little effect on the collector and later disappeared.

### What is a successful spatfall?

The question of spatfall success often arises when looking at the summaries of results from each site. Is a site with 80 000 spat/collector more successful than a site with only 15 000 spat/collector? A visual inspection of the two collectors would probably suggest an affirmative answer as a collector that has a solid mass of mussels along its length looks impressive. However, that may not necessarily be the case as demon-

strated by comparing results from collectors in June 1997 with those of the previous fall. Of the 19 sites sampled at 100 deployment-days and again at about 350 days, those with significantly higher than 10 000 spat per collector lost up to 80% of the seed by late spring (overall average loss of 67% (Fig. 1)). All but 2 sites lost some seed over the first year. These 2 sites showed an increase in the number of spat per collector, from a few hundred in the fall to about 4000 in June. A common range of spat numbers per collector at the 19 sites sampled in June appears to be between 4000 and 8000, despite some collectors having very high numbers in the fall.<sup>(2)</sup> Therefore, sites with 15 000 spat on each collector may be just as successful as a site with 80 000 spat/collector. The ideal number of spat is difficult to determine as many factors affect the growing seed and those determining whether the spat stay or leave are not well understood, except that space, food, and wave action may all play a role. Thus, a successful spatfall *may* be considered one where collectors are deployed at an appropriate time to maximize seed collection, are free of algal fouling when socking time arrives, have few predatory invertebrates, and have site conditions that allow rapid growth and ensure early socking.

### Conclusions

There is no doubt that the larval and spatfall monitoring program is helping mussel farmers secure a seed supply each year. Many growers now have the

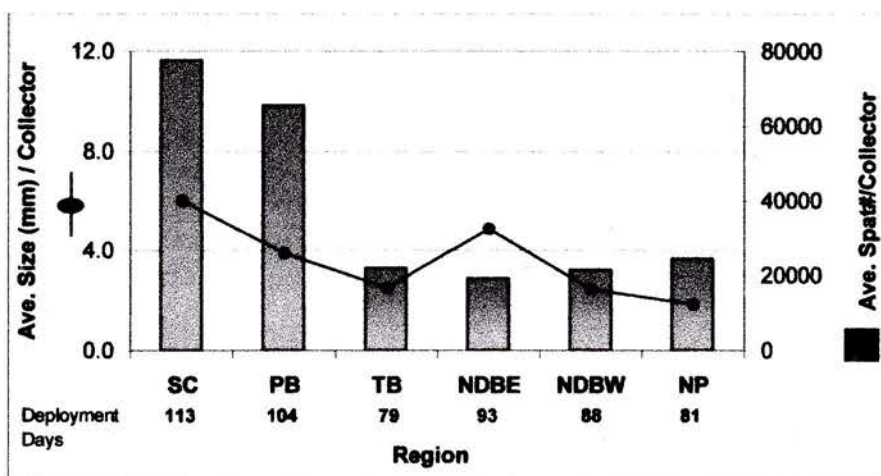


Figure 4. Summary of fall 1997 collector retrieval showing average spat size/collector (mm), average spat number/collector and average deployment days, for each region of Newfoundland with sites participating. SC = South Coast, PB = Placentia Bay, TB = Trinity Bay, NDBE = Notre Dame Bay East, NDBW = Notre Dame Bay West, NP = Northern Peninsula.





**Figure 5.** Example of rapid spat growth on the south coast: left) spat about 18 days after settlement, right) spat at approximately 100 deployment-days.

skills necessary to monitor their own sites and are quite adept at doing so. For sites involved in the program since its inception, trends in spawning, larval growth, and settlement are becoming apparent. Regular site monitoring can help build a database of information about each site so growers can quickly refer back to previous years and compare results with the current site conditions.

Although much has been gained, there is more to learn. Future monitoring will also include following starfish and clam settlement patterns and the biofouling of collectors. Efforts will also be made to develop an understanding of spat growth and the factors that influence drop-off. In addition, monitoring staff are working on a key index of color photographs of the phytoplankton and zooplankton found on farms around Newfoundland, which should be very useful in the identification of organisms found during the monitoring period.

*We thank Lewisporte Wholesalers for transporting samples. Keith Rideout provided technical assistance. Many mussel growers were involved in the program and actively took part in providing samples and transportation, allowed us to use their equipment, and shared their knowledge of mussel culture with us and others in the industry. Funding was provided through the Aquaculture Component of the Canada/Newfoundland*

*Economic Renewal Agreement (ACERA), the Atlantic Canada Opportunities Agency (ACOA), and the Canadian Centre for Fisheries Innovation (CCFI).*

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# Newfoundland Aquaculture Industry Association Environmental Monitoring Program of Shellfish Farms

*Tony Clemens, Cyr Couturier, Jay Parsons and Patrick Dabinett*

Shellfish aquaculture sites in Newfoundland have been monitored since 1993 for water quality parameters that can affect shellfish growth, spatfall abundance and post-spawning tissue recovery. Temperature, salinity, chlorophyll-*a* concentration (food index) and oxygen concentration have been sampled at regular intervals using a conductivity-temperature-depth (CTD) meter equipped with additional sensors. Water samples have been collected simultaneously with the CTD samples to estimate seston (food) quantity and quality (ratio of organic to inorganic seston). Mussel condition indices have been correlated with environmental variables and advice provided to growers on site production characteristics.

## Introduction

In eastern Newfoundland, mussels and scallops inhabit an environment dominated by the Labrador Current and characterized by low water temperatures and relatively low seston (food) levels for several months of the year. Arctic ice is a concern in these areas and shellfish farms have tended to develop in relatively closed estuaries and small basins with reduced oceanic water exchange.

Shellfish such as mussels and scallops feed by pumping seawater across their gills and filtering particulate matter (seston) from the water. Earlier work on the clearance (feeding) rate of mussels in Newfoundland waters demonstrated there was little seasonal variation (range 1.5 to 2.0 L/h)<sup>(2)</sup> and that mussels were able to maintain a relatively high clearance rate at very low temperatures. Shell growth is reduced at temperatures below 0°C, but when food is available significant growth occurs at temperatures below 5°C.<sup>(3)</sup> Mussel growth is an integrated response to the combined effects of environmental variables.<sup>(4)</sup> Understanding such effects will be a key factor in maximizing mussel production in Newfoundland waters. Little information is available concerning the contribution of seston to the seasonal diet of farmed mussels in Newfoundland waters. With 4 months of water temperatures ranging from -1° to +2°C, the opportunities for winter growth, regardless of the level of food available, are limited in many areas. Therefore suitable temperature and food abundance during the

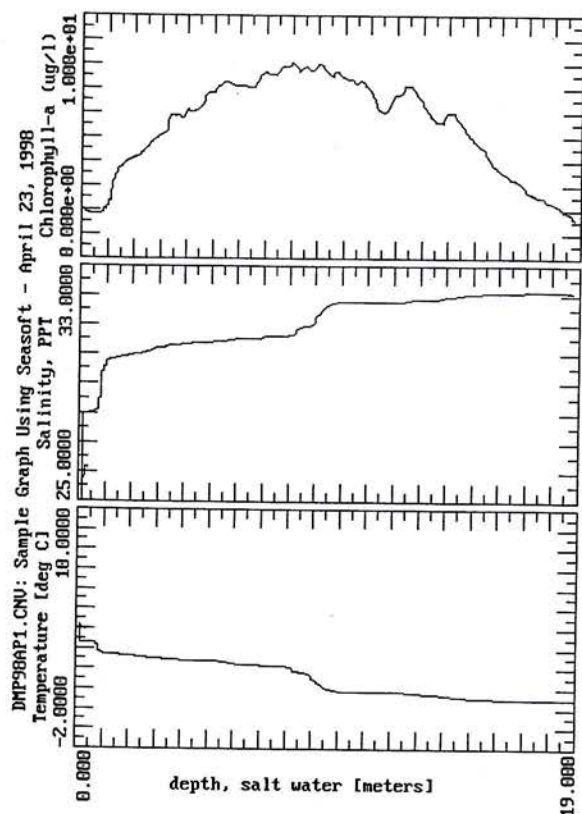
warmer months are important factors for shellfish growth.

Shellfish farm sites are stocked typically with much higher densities than occur under natural conditions, yet the food supply is limited to that provided by natural processes. In the interest of prudent management of a site, it is important that the stocking density not exceed the carrying capacity. As farms develop, stocking densities are increased every year and it is probable that food limitation will occur at some point and growth rates will decline. Information is required to predict the optimum stocking density, or carrying capacity, from feeding rates, food levels, water exchange and circulation patterns. There is a lack of data at present, so carrying capacity is determined by trial and error (i.e., the stocking density is gradually increased until a reduction in growth rate is observed). Differences in carrying capacity occur among sites due to variation in phytoplankton growth (primary production) and supply, which in turn depend on fac-

**Table 1. Fourteen sampling sites with names and locations.**

Site 1 - Reach Run	Site 8 - Little Bay Arm
Site 2 - Burnt Island	Site 9 - Prince Edward Bay
Site 3 - Burnt Arm North	Site 10 - Northeast Cove
Site 4 - Charles Arm	Site 11 - Dublin Cove
Site 5 - Fortune Harbour	Site 12 - Millers Passage
Site 6 - No Good Island	Site 13 - Pools Cove
Site 7 - Flat Rock Tickle	Site 14 - Belleoram





**Figure 1. A sample Seasoft graph showing temperature, salinity, and chlorophyll-a with depth**

tors such as nutrient supply, water circulation and tidal amplitude.

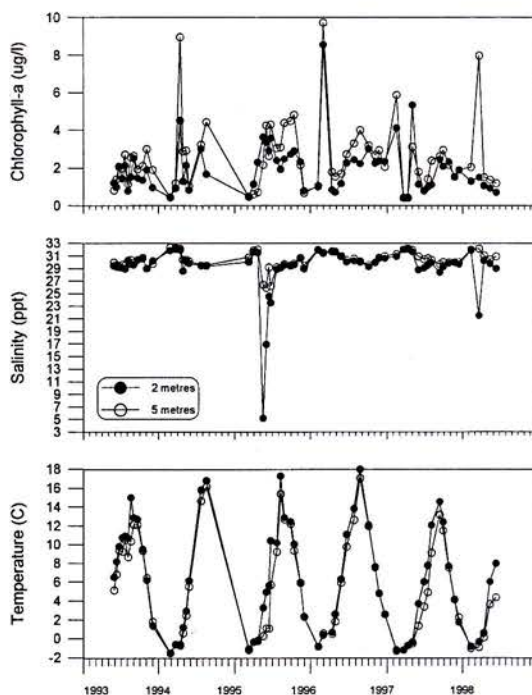
Shellfish aquaculture is a developing industry in Newfoundland. In 1997, there were 119 mussel aquaculture licenses and the industry employed 275 people and produced 750 MT of product valued at \$635 000.<sup>(1)</sup> In the early 1990s, several mussel growers experienced significant declines in the number of spat collected and slow recovery of mussel meats after spawning, which resulted in decreased production. Unfortunately there was little environmental data from which to base any conclusions on possible causes for the decline in production. Significant cooling or warming of the seawater or changes in food availability can seriously impact shellfish aquaculture, yet without an information base environmental trends cannot be identified and correlated with production.

This lack of environmental data provided the rationale for the present work and a program was initiated to monitor water quality parameters that can affect mussel growth (temperature, salinity, oxygen and food levels) and will, hopefully, allow us to relate environmental conditions to mussel production. The project was designed to establish a database of environmental parameters relevant to shellfish production that can be used by the industry for management purposes (i.e., indices of carrying capacity, spat collection characteristics, site selection and site production).

## Methods

The environmental monitoring program for shellfish has been ongoing at several sites in the Notre Dame Bay (northeast coast) and south coast regions since 1993.<sup>(5-8)</sup> The program was extended in 1997 to include 14 farms located strategically in all shellfish production areas of the province (Northern Peninsula, southwest coast, south coast and northeast coast; Table 1). The present paper gives examples of the type of information provided to individual growers on a regular basis.

A conductivity-temperature-depth meter (CTD), equipped with additional sensors to measure chlorophyll-a and oxygen concentration (Seabird Electronics Inc., Washington USA), was used to measure seawater characteristics. This instrument records these parameters and their variation with depth. Seabird casts were taken at several stations at each farm and each grower received Seabird graphs of temperature, salinity, and chlorophyll-a across



**Figure 2. Sample line graph of temperature, salinity, and chlorophyll-a.**



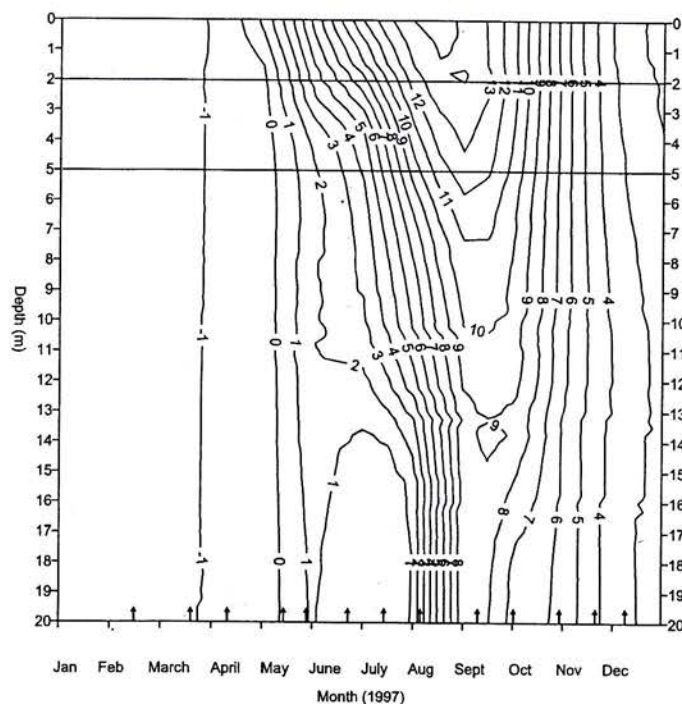
depths. Sampling was done at 3-wk intervals in the spring and summer and 5- or 6-wk intervals during the winter.

Line graphs of environmental data from the 2- and 5-meter depths were prepared after each site visit by averaging the data from all stations within a site. These were plotted with Grapher<sup>(9)</sup> and given to the growers within a week of a site visit.

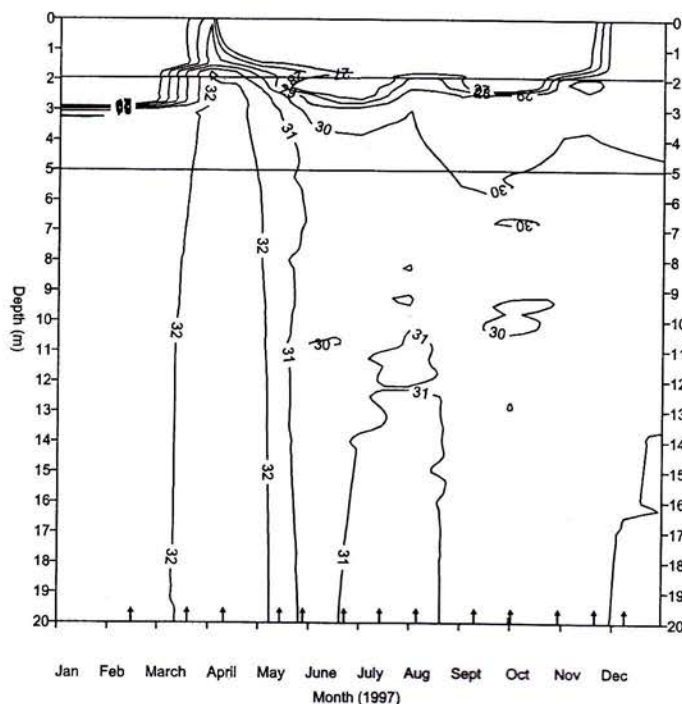
Contour plots of temperature, salinity, chlorophyll-*a*, and dissolved oxygen were prepared using Surfer<sup>(10)</sup> and later distributed to growers. The temperature and chlorophyll data were further examined using methods analogous to calculating the volume of ground from a topological map. The artificial volume units for temperature and chlorophyll data were calculated as follows: temperature volume = depth x days x temperature; chlorophyll-*a* volume = depth x days x chlorophyll-*a* concentration. Volume indices were calculated for depth intervals of 2 to 5 m for the years 1995 to 1997.

Estimates of suspended food quality and quantity were obtained by determining the total particulate matter (TPM), particulate inorganic (PIM), and inorganic matter (POM) of water samples. Subsurface water samples were collected and filtered through a 100- $\mu$ m mesh screen to remove large detritus and zooplankton. TPM was determined by filtering a known volume of water (1-2 L) under vacuum through a pre-ashed and pre-weighed Whatman GF/C filter. Filters were rinsed with 10 mL of a 3% ammonium formate solution to remove salts and prevent cell lysing. Sample POMs and PIMs were determined by first drying the filters at 80°C for 24 hours, then weighing and combusting at 450°C for 3 hours, and finally reweighing after cooling in a desiccator. Thus:  $TPM = PIM + POM$  (units are mg/L). The organic ratio of  $POM/TPM$  is a useful general indicator of the quality of seston as food, and was calculated for each water sample. The higher the ratio, the better the food quality.

Cooked meat yields were determined regularly on 2-year-old mussels during each site visit. Approximately 250 grams of mussels were placed in boil-

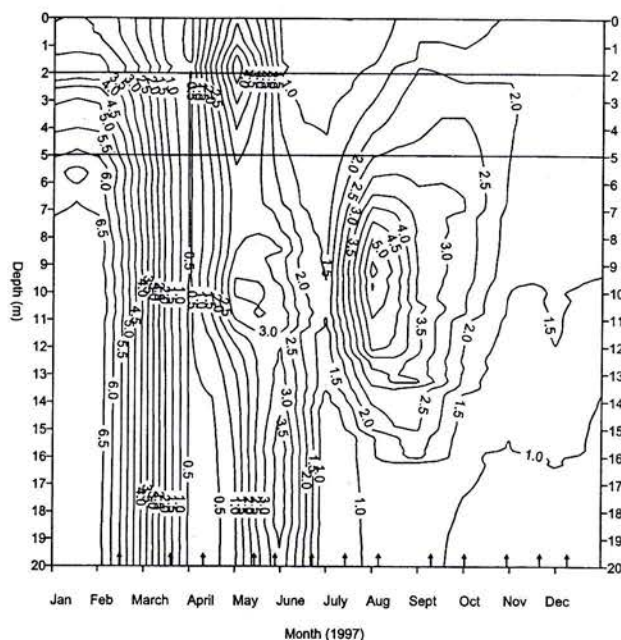


**Figure 3. Sample temperature contour plot with depth for 1997. Arrows indicate sampling dates. Boundary lines show usual mussel growing zone.**

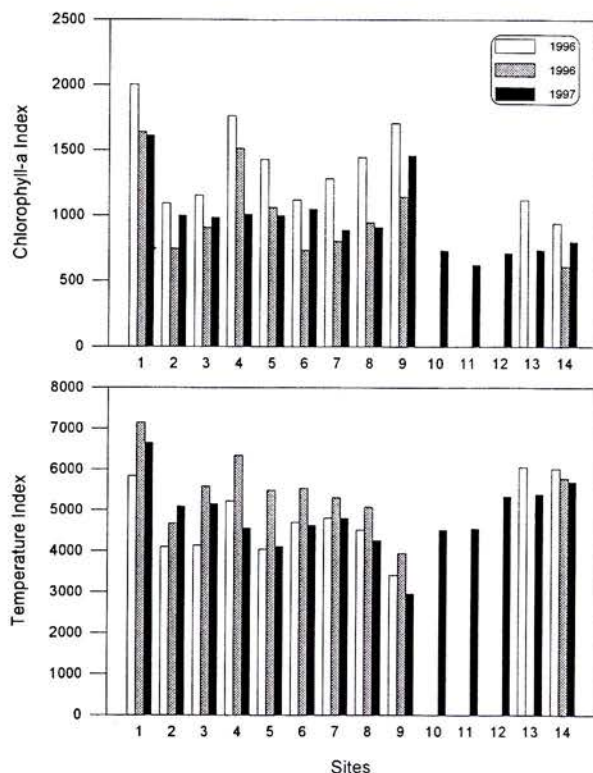


**Figure 4. Sample salinity contour plot with depth for 1997. Arrows indicated sampling dates. Boundary lines indicate usual mussel growing area.**





**Figure 5. Sample chlorophyll-a contour plot with depth for 1997. Arrows indicate sampling dates. Boundary lines indicate usual mussel growing zone.**



**Figure 6. Volume index of temperature and chlorophyll-a for 14 sites for 1995, 1996, 1997.**

ing water for 2 minutes until the shells opened. Mussel meats were removed and weighed, and meat yields were calculated according to:

$$MY = \frac{\text{cooked meat weight (g)}}{\text{cooked meat weight + shell weight}} \times 100$$

## Results and discussion

A sample CTD graph is shown in Figure 1. These graphs are provided to growers at the time of each visit with a general explanation of the findings.

Figure 2 shows a typical line graph of the type provided to growers within a week of the site visit, along with a few brief comments on the environmental trends at the site. There were obvious differences among years in the timing of the temperature maximum and in the rates of cooling and warming at the site. The annual temperature volume index for each site is shown in Figure 6; it also demonstrates among-site and among-year differences.

A representative temperature contour plot from one of the study sites is shown in Figure 3. Temperature varied with depth and the time of year at all sites (data not shown). The general pattern observed at most sites is a rapid warming of well-mixed waters in the late spring (June), thermal stratification in the summer, and waters becoming well mixed again in the fall as the temperature declines. A few of the sites displayed mixed waters during the entire year (data not shown).

Studies have reported that rate of growth in mussels increases rapidly between 3° and 20°C, and declines above and below these values.<sup>(12)</sup> However, in another study, temperatures below 5°C did not reduce mussel growth substantially when there was an ample supply of food from the spring phytoplankton bloom.<sup>(13)</sup>

Figure 4 shows the yearly contour plots for salinity at one of the sample sites. In general, salinity fluctuated between 28 and 32 ppt, with a period of reduced salinity in the spring during the period of snowmelt. For the most part, the reduced salinities were confined to the first few meters of the surface water (Fig. 2) and likely did not affect the mussels which are located at deeper depths (2-5 m).

Rapid changes in salinity may affect mus-



sel growth and even survival if animals can not acclimate to the change. It should be noted, however, that there are examples of mussels growing in salinities as low as 4-5 ppt in the Baltic Sea, but this situation is peculiar to that area.<sup>(12)</sup>

A yearly contour plot for chlorophyll-*a* is shown in Figure 5. Chlorophyll-*a* is regarded as a useful index of phytoplankton biomass and as such has been employed as an indicator of the quality of food present for shellfish. There was considerable variation among sites and among years in the chlorophyll-*a* concentration (Fig. 6). The plot in Figure 5 demonstrated that chlorophyll-*a* levels may be elevated at depths below 5 m. It may be advantageous at some sites to lower mussels into this zone of elevated chlorophyll levels, provided temperatures are suitable.

Food supply is probably the most important factor in determining growth rates of mussels.<sup>(13)</sup> Mussels are efficient filter feeders, removing particles down to 2-3  $\mu\text{m}$  with 80 to 100% efficiency.<sup>(14)</sup> The food particles may include phytoplankton, bacteria, and fine organic detritus. Seasonal variation in quantity and quality of food has major effects on growth.<sup>(15)</sup> The reported relationship between growth rate and increasing water depth is thought to reflect variations in food supply.<sup>(16,17)</sup>

Figure 7 provides an example of the type of information that has been collected on particulate matter levels at the farm sites. Although particulate organic and inorganic matter varied seasonally and among sites, as expected,<sup>(18-20)</sup> the ratio of organic to inorganic matter was usually above 50%, indicating relatively high food quality.

Condition index and meat yield closely paralleled each other (Fig. 8). There were differences in condition indices and meat yields among sites and years (data not shown). The pattern shown suggests a summer spawning followed by gradual recovery into the fall. The south coast sites appeared to have higher values, but stocking densities at most of these farms were lower than at the other sites monitored.

## Conclusions

- Newfoundland shellfish farm sites varied in their

environmental characteristics with respect to temperature, salinity and food levels (chlorophyll-*a*, particulate matter).

- Food quality appeared to be high throughout most of the year, though food quantity varied seasonally.
- Mussel condition showed high values and there was little evidence to date of sites having exceeded the carrying capacity.
- Information will be useful for comparing production differences at farm sites.

## Recommendations

- Mussel producers should experiment with lowering mussel socks deeper into the water column to take advantage of elevated food levels at some sites. Although temperature is likely to be lower in deeper water, increased food levels may offset the negative effect of lower temperature.
- The effect of current flow on food supply should be investigated with respect to mussel growth.
- Growers are encouraged to collect accurate

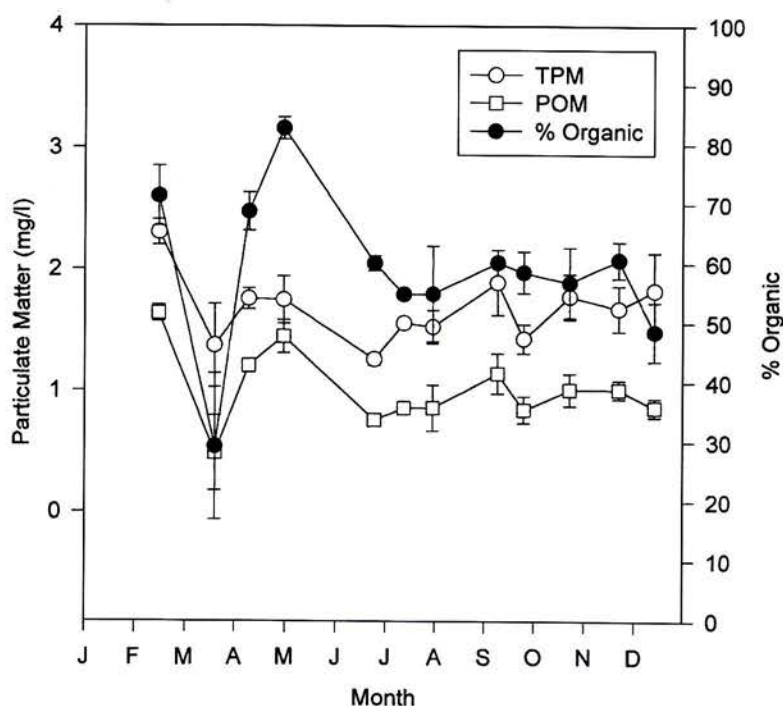


Figure 7. Sample graph of total particulate matter, particulate organic matter and % organic (S.E.) For 1997.



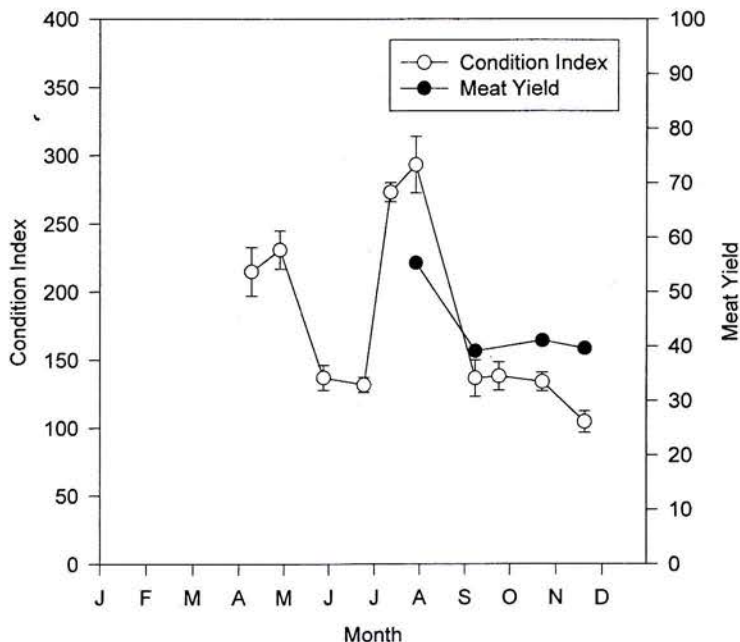
records on mussel growth and condition at their farm sites on a regular basis. This will provide the necessary information for decisions regarding stocking densities.

- An ongoing farm site environmental monitoring program is essential for industry planning and development.

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**Figure 8.** Sample graph of condition index and meat yield for 1997.

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# Newfoundland Cultured Mussel (*Mytilus edulis*) Industry 1997 Health Survey

Kelly Moret, Kate Williams, Cyr Couturier and Jay Parsons

In an attempt to establish a baseline of the health status of Newfoundland cultured mussels, a preliminary health survey was conducted in 1997. A total of 13 farms participated in the survey which examined 772 mussels for parasitic burden. Mussels from 10 of the farms (77%) contained parasites, but none were of pathogenic or disease concern. The most common parasite was the gill ciliate *Ancistrum mytili*. Shell examination revealed a low incidence of the periostracal sloughing disease caused by a fungal infection.

## Introduction

Disease profiles of cultured shellfish in the Canadian Maritime Provinces (New Brunswick, Nova Scotia, and Prince Edward Island) have existed for at least a decade. Scientists in this region have recognized that most major shellfish diseases are associated with transfers of stocks.<sup>(1)</sup> Since there is usually negligible information on the parasite fauna present in shellfish prior to a disease outbreak, tracing the actual source of the disease is extremely difficult.<sup>(2,3)</sup> As a result, policies have been implemented that require shellfish farmers importing, exporting, or transferring stock to submit samples to the Department of Fisheries and Oceans (DFO), Gulf Fisheries Centre, in Moncton, New Brunswick, for health analysis and clearance. The establishment of the shellfish health program at the DFO Gulf Fisheries Centre has benefited the industry in the following ways: (1) a baseline of existing diseases/parasites for different regions of Atlantic Canada has been established; (2) policies for the quarantine of potentially infected samples have been developed; and (3) the importation/transfer of diseased animals into the region has been prevented. In addition to monitoring shellfish health for regulatory reasons, diagnostic services are also provided for farms experiencing unusual mortalities and problems.

To date, the blue mussel (*Mytilus edulis*) industry in Newfoundland has been operating under the assumption that its seed and grow-out stock is free of harmful diseases and parasites. However, circumstances associated with the expansion of the industry have necessitated confirmation of the disease-free status of the cultured stock. Farms wanting to expand their operation hope to meet seed supply demands by transferring stock from one region of Newfoundland to another. Since disease profiles do not exist for cultured mussels in the province, potentially lethal parasites or dis-

eases may be transferred with the stock, thereby spreading pathogenic organisms throughout the entire mussel industry.

Similarly, growers throughout the Atlantic region of Canada are beginning to focus on Newfoundland as a potential source of seed. Marketing high-quality, disease-free seed has the potential to be a profitable supplementary business for local mussel farmers. Since farms across Atlantic Canada rely on the monitoring of stock by DFO for confirmation of disease status before importation, Newfoundland seed suppliers will be expected to adhere to these standards.

The Newfoundland mussel industry is expected to develop rapidly over the next couple of years. If the industry is to compete on a national level and extend itself into seed exportation, it can no longer operate under the premise that it is free of diseases. The implementation of routine diagnostic procedures will allow the industry to compete nationally and prevent uncontrolled disease transfer within Newfoundland.

Based on these facts, the Canada/Newfoundland Economic Renewal Agreement (ACERA), in conjunction with the Canadian Centre for Fisheries Innovation (CCFI), the Newfoundland Aquaculture Industry Association (NAIA), the Marine Institute of Memorial University, and the provincial Department of Fisheries and Aquaculture (DFA), decided to initiate a research project aimed at establishing a health/disease profile of cultured mussels within the province.

The primary objective of the Mussel Health Project is to establish a database of mussel pathogens or diseases in Newfoundland. Although the mussel industry has existed in the province for many years, it is still in the developmental stage. Transfers and importations have been few in number, thereby providing ideal circumstances for establishing a baseline of potential or existing problems.



Other objectives of the project include providing an in-province diagnostic service for farms experiencing unusual mortalities, and establishing collaborative research efforts with other diagnostic facilities in Atlantic Canada. Collaborative research efforts aimed at monitoring and early detection of problems will benefit the entire mussel industry.

## Methodology

The Mussel Health Project was designed as a 3-year study aimed at establishing a database of the parasites and diseases of cultured mussels in Newfoundland. Approximately 25 to 30 farms are being recruited for participation in the study, with farm selection based on commercial status and geographic location.

### Health survey protocol

The health survey was conducted between October and December 1997 and involved 13 mussel sites. Mussel samples were randomly collected at each site and were shipped live on ice to the Marine Institute for examination and histological processing. All sites submitted a sample of 60<sup>(4)</sup> commercial-sized (approx. 4 to 5 cm) mussels and two sites submitted spat samples (n=60).

Each mussel was examined macroscopically for the presence of external parasites, abnormal conditions of the shell surface and inner shell, and gross examination was made of the soft tissue. Representative portions of mussel tissue were dissected, fixed, and then processed and embedded in wax for histological examination. Prevalence and incidence of parasites were

recorded from 7- $\mu$ m sections of stomach, digestive gland, intestine, gill, gonads, and mantle.<sup>(5)</sup>

### Mycotic periostracal sloughing (MPS) disease protocol

Mussel (*Mytilus edulis*) shells from various locations around Newfoundland exhibit brown discoloration similar to that found in mussels from Prince Edward Island that are infected with the fungus that causes mycotic periostracal sloughing disease (MPS).<sup>(6)</sup>

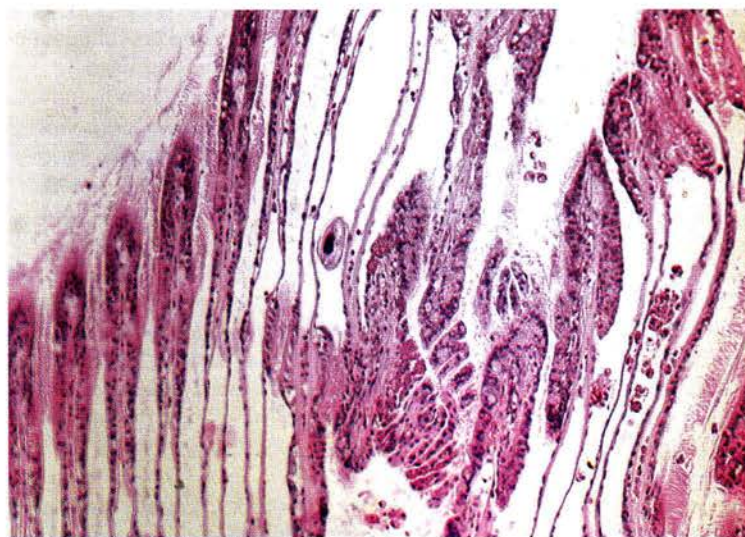
A study was initiated to determine if Newfoundland mussels contained the same fungal agent found in PEI mussels. Shell samples from both locations were examined under a dissecting microscope for gross observable similarities and were then examined under a light microscope for the presence of fungal hyphae. Shells were processed by conventional standard electron microscope techniques and examined in a Hitachi 570 scanning electron microscope for the presence of fungal hyphae. Representative samples of mussel spat used in the general health survey were also examined for the presence of brown shell discoloration.

## Results

A total of 772 mussels from 13 sites were examined macroscopically and microscopically for the presence of parasites. Examination revealed that 77% (10 of 13) of the farms had mussels with parasitic infections, but that none of the parasites were of pathogenic or disease concern.

All parasites found in the samples are present throughout Atlantic Canada<sup>(7)</sup> and include two species of gill ciliates (*Ancistrum mytili*, and *Sphenophyra* sp.), one species of intestinal ciliate, one intercellular digestive tubule ciliate species (mussel protozoan X, "MPX"), one bacterial (prokaryotic) species in the digestive tubules ("blue bodies"), and one species of parasitic copepod. Examination of the samples also revealed a parasitic-induced xenoma and diapedesis.

The gill ciliate (*Ancistrum mytili*) which occurs in approximately 90 to 100% of mussels in the Maritime Provinces was also the most prevalent (54%) parasite in this study, with an incidence of 5% per sample<sup>(1)</sup> (Fig. 1). Like other eastern Canadian mussels infected with *Ancistrum*, the gill ciliate also contained a "hyperparasite" (parasite of a parasite), which



**Figure 1.** *Ancistrum mytili* ciliate found in the gills of blue mussels (*Mytilus edulis*) in Newfoundland.



**Table 1. Prevalence, incidence, and pathology of parasites found in cultured mussel samples.**

Parasite	Location	Prevalence (number and percentage of farms infected)	Incidence (number and percentage of mussels infected)	Pathology
<i>Ancistrum mytili</i> ciliate	gill tissue	7 (54%)	41 (5%)	not a disease concern
<i>Sphenophyra</i> sp. ciliate	gill tissue	5 (38%)	9 (2%)	not a disease concern
"blue body" bacteria	digestive cells	1 (8%)	1 (0.1%)	not a disease concern
Mussel protozoan X "MPX"	digestive tubules	6 (46%)	7 (1%)	not a disease concern
Copepod	outside gill tissue	1 (8%)	1 (0.1%)	not a disease concern
Intestinal ciliate	intestines	1 (8%)	1 (0.1%)	not a disease concern

looks like *Chlamydia* or *Rickettsia*.<sup>(1)</sup> Parasitic incidence was low, ranging from 0.1% to 5%, depending on parasite species. Table 1 outlines the tissue location, prevalence, incidence, and pathology of the parasites found in the study. Histological examination of the spat tissue showed no evidence of parasites or pathological concerns.

### MPS disease

Only two of the 13 farms sampled in the initial health survey (15%) had mussels showing brown discoloration or sloughing of the periostracum.

Macroscopic examination of infected shells from Newfoundland and Prince Edward Island revealed that the colour and structure of the fungus are similar. In both locations, the fungal infection appears to occur beneath the periostracum, thereby contributing to the sloughing condition and making hyphae difficult to observe. Shells examined from Newfoundland appeared to have less periostracal sloughing than PEI mussels. The scanning electron micrographs of the Newfoundland mussels revealed fewer fungal hyphae compared to the PEI mussels.

Examination of spat samples from PEI and Newfoundland exhibited none of the properties associated with the fungus that causes periostracal sloughing.

### Summary

Preliminary results from the first mussel health survey are encouraging for the local industry. No parasites or disease concerns were found at any of the sites. Overall, the prevalence and incidence of parasites was low. However, in order to establish a more representative baseline of mussel health, additional commercial sites and sites of geographic significance must be sampled.

With the discovery of mussel MPS disease in Newfoundland, the situation will have to be closely moni-

tored during the 1998 season. Farmers and processors have expressed concerns about the marketability of infected animals and the possibility of transferring the disease between sites. As a result, collaborative research efforts with other scientists in Atlantic Canada will be essential for understanding and controlling this condition.

*The authors thank the mussel growers who participated in the survey. Appreciation is extended to Miranda Pryor, Sean MacNeill, Chris Brown, and Tony Zokvic for assistance with the collection and shipping of samples from farm sites to the Marine Institute. Thanks to Dr. Sharon McGladdery, Mary Stephenson (DFO-Moncton), and Dave Coffin (DFA-Newfoundland) for their advice and assistance during the project. Work was financially supported by the Canadian Centre for Fisheries Innovation and the Canada/Newfoundland Agreement on Economic Renewal—Aquaculture Component.*

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# Towards Best Practices: A Practical Guideline for Mussel Aquaculture in Newfoundland

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Analysis of the Newfoundland mussel culture industry revealed the need for a guideline that would enhance both the volume and quality of mussels produced. Four main improvements — grading seed, reducing socking density, socking earlier in the season and improving socking performance — were suggested from the initial analysis of 13 mussel growers. The use of graded seed is expected to reduce grow-out periods, reduce size variability and improve quality. By decreasing initial seed density in socks, competition for food and space is reduced, potentially resulting in increases in growth rate. Socking in the spring rather than the fall, which is the norm for Newfoundland growers, may result in higher growth rates by moving the mussels from the collectors to lower density conditions in the socks during the peak growing period during the spring phytoplankton bloom. The final concern is the inefficiency of the socking process, in which high levels of labor are required to stock mussels in socks. Simple modifications to the design of socking tables and grading seed prior to socking are expected to greatly decrease the time required for socking.

## Introduction

One of the common comments of mussel growers in the Newfoundland is that they learned how to grow mussels by trial and error or simply from years of experience. Detailed information on the best grow-out methods is lacking. Consequently, new growers entering the industry make the same mistakes as the original entrants. The fact that mussel growers are successful is a credit to their ingenuity, but because of the trial and error approach to mussel culture the industry now uses a variety of husbandry techniques and equipment, with varying success and efficiency. As a developing industry, it is important that an attempt be made to determine the approach that will maximize production, minimize expenses and ensure the industry is competitive in the market place.

To achieve this goal, a 3-year study of mussel industry practices commenced in the fall of 1997. The study was designed to analyze current husbandry practices and equipment in an attempt to develop "best-practice guidelines" that will provide detailed instructions and suggestions to optimize production from farms.

Initial analysis has suggested potential benefits from modifications of husbandry techniques, primarily size grading of mussel seed prior to socking, reducing mussel density in the socks, socking earlier in the season, and increasing efficiency of the socking process.

## The case for seed grading

Grading in aquaculture is a common tool to ensure similar-sized individuals are grown together. Grading typically results in faster growth, a more uniform-sized product and a more consistent and high quality product. Grading is relatively common in mussel industries in Prince Edward Island, New Brunswick, Nova Scotia, Spain, New Zealand and Ireland.<sup>(1,2)</sup>

Newfoundland farmers harvest mussels of a variety of sizes and consequently have varying yields. In our survey, the average yield of marketable mussels from 9 growers was 29.2 kg ( $s=5.5$  kg) per tote and ranged from 16.36 to 34 kg per tote. An additional 11.8 to 20.9 kg of material was non-marketable mussels. A mean of 11.32% ( $n=8$ ,  $s=4.39\%$ ) of the total weight was empty shells and fouling. The remaining 6 to 14.5 kg was undersized mussels. This represents a huge loss of potentially marketable product and results in considerable extra costs for flotation and maintenance. Seed grading should help ensure that harvested mussels are more uniform in size and reduce the percentage of undersized mussels that are harvested.

Regression analysis comparing the percent of harvest-size mussels to mean shell length (Fig. 1) suggests that under current practices a mean shell length of 66 mm is necessary to obtain a yield where 95 % of the mussels (by weight) are of harvestable size (19



mm shell height and 50 mm shell length). The average shell length of the 5 samples in which 95% of the mussels were market size was 66.3 mm; an average of 67% of the mussels fell between 56.7 and 76.0 mm. This indicates there is a wide size range within the harvest-size mussels and that by the time 90 to 95% of the mussels reach harvestable size many are too large (> 80 mm) for many markets. In addition, 36 months of grow out was commonly required to reach 95% harvest. This grow-out time causes the farmer to have 3 year-classes of mussels on the site and reduces production capacity, as only one-third of the site is harvested annually.

The long grow-out time likely is a result of current socking practices in which little or no seed grading occurs. The expected consequence of seed grading on the Newfoundland industry is an increase in yield, a reduction in grow-out time, and more consistent quality. Seed grading will also reduce labor costs for socking and result in a better distribution of mussels in the sock. Fewer types of socking materials will be required (2 to 3 sizes only) when using graded seed. It is important, however, that proper socking material be used or graded seed will fall through the mesh or slide to the bottom of the sock

### Socking density

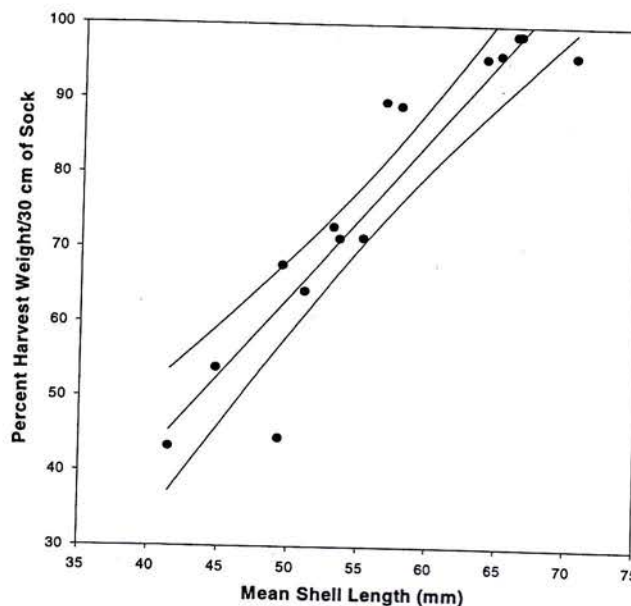
A comparison of mean mussel length to mussel density per 30 cm of sock suggests that shell length is inversely related to mussel density (Fig. 2). This same pattern occurs wherever mussels are cultivated in suspension,<sup>(2,3)</sup> implying that as mussels get larger there is less space available on the sock and some mussels are forced to drop off. This so-called self-thinning is caused by space and/or food limitations and is a well known principle in land-based farming.<sup>(3-5)</sup>

As shell length approaches market size, a 30-cm length of sock can hold only 127 mussels, assuming a mean size of 55 mm and average growing conditions. The 8 growers in this study who had an average socking density of 197.3 mussels per 30 cm of sock experienced a loss of 79.3 mussels for every 30 cm of sock. Their original socking densities may actually have been much higher than 197.3, as counts were done 2 to 4 weeks after socking. If mussels are permitted to grow to a mean shell length of 60 to 65 mm (when 95% of the mussels are market size) then the density drops to 89 to 100 mussels (per 30 cm of sock) and the total is 97 to 115 mussels per 30 cm of sock, approximately half the original number stocked.

A number of factors are responsible for the decline in the number of mussels over the grow-out period, including self-thinning, type of equipment used (floats, socking material), placement of lines (at the surface or submerged) and environmental characteristics (water flow, food, and wave action). Of these, site characteristics, initial socking density, and husbandry techniques are likely to have the greatest influence on the number of mussels that are lost from socks over the grow-out period. It is worth mentioning that mussel producers in other areas typically obtain harvest densities of 60 to 80 mussels per 30 cm of sock or rope regardless of the initial density.<sup>(2)</sup>

In the rest of Atlantic Canada, densities in the range of 125 to 175 graded seed per 30 cm of sock are used.<sup>(1,2)</sup> Given the differences in the operating environmental conditions between Newfoundland and the rest of Canada, initial socking densities should probably not exceed 200 mussels per foot of sock. The preferred density is conservatively estimated at 125 to 175 mussels per 30 cm of sock. This should permit sufficient numbers of mussels to remain in the sock until harvest at an average size of 55 to 60 mm shell length after losses from natural mortality and other sources. An upcoming study on socking density should provide a more precise range of optimum density.

The socking material has to be of a sufficiently narrow tube diameter to prevent the mussels from all slid-



**Figure 1.** The percent (by weight) of harvest-size mussels (shell height of 19 mm and minimum shell length of 50 mm) vs. the mean shell length of mussels from 10 commercial sites in Newfoundland. None of the mussel seed was graded on the surveyed lines. Regression: percent harvest + 2.1259 (shell length) - 42.66,  $r^2 = 0.867$ .



ing to the bottom. The most commonly used socks in Newfoundland are made by Dupont and most mesh sizes would likely not be appropriate for holding mussels at this density. Irish square mesh in diameters of 4 to 6.5 cm, the smaller mesh Dupont (11-mm mesh) and Italian mesh (10 mm) appear to be suitable for densities of 100 to 150 mussels per 30 cm.

Data from mussel collectors in Newfoundland<sup>(1)</sup> indicated that in the spring of 1997, 12 of 19 sites had mussel spat with a mean length greater than 15 mm and 3 sites had seed larger than 20 mm. The remaining sites had mean mussel sizes between 10 and 15 mm. Scarratt<sup>(6)</sup> indicated that 10 mm was the minimum seed size for socking. The mean seed density at these sites was between 800 and 1000 spat per 30 cm of collector. If a density of 125 to 150 mussels per 30 cm of sock was used, approximately four 3-m socks could be generated for each 1.5-m collector. At one site, the mussels on the collector had dropped to a mean density of 408/30 cm by November (Marine Institute Mussel Extension Service Survey, 1997). If socking had been delayed to November, only 1.63 socks could be filled from each collector. This suggests that the later the socking is done, the lower the density of mussels per foot of collector. Consequently, the relatively low mean sock to collector ratio of 1.47 for the 13 growers surveyed may have resulted from socking later in the year.

If socking occurs early in the year when densities are high on collectors, and if seed size is suitable, an esti-

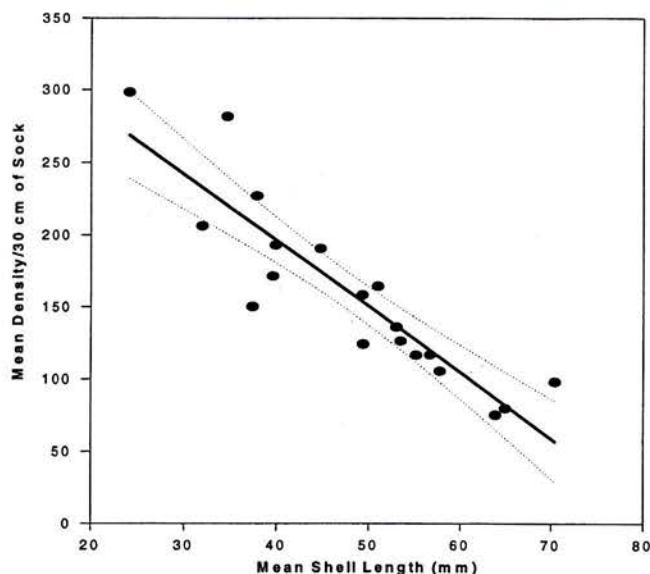
mated 250% increase in sock:collector ratio can be expected. Unfortunately, it is likely that not all sites will be able to sock in the spring due to small seed size and sites which have secondary sets may experience problems if socking density is reduced.

An additional benefit of reducing density is potential for an increase in the number of market-sized mussels. MacMillian<sup>(7)</sup> suggested that mussel lines with lower densities produced higher marketable yields than those lines in which the density was not reduced.

## When to sock

Loo<sup>(8)</sup> suggested that high food quality during the spring bloom increases food absorption efficiencies by mussels, even at seawater temperatures of -1°C. This suggests that temperature that does not have a limiting effect on mussel growth during the spring bloom. In fact, the spring bloom may be the time of maximum growth. Loo and Rosenberg<sup>(9)</sup> suggested that mussel biomass doubled over the spring bloom in Norway. In Newfoundland waters, Sutterlin et al.<sup>(10)</sup> suggested that mussels doubled their shell length from March to August under high density (culture nets) and the fastest growth occurs during May and June. About 75% of the growth of the mussels for the year occurs during the March to August period. This is comparable to the growth pattern of mussels in Nova Scotia<sup>(2)</sup> where most of the growth occurs between June to October, likely due to the presence of the spring phytoplankton bloom. Relatively little growth occurs between October and December, but growth increases between December and April, when the spring bloom occurs again.

The common practice in Newfoundland is to sock between September and December, after the mussels have grown at high densities on the collector during the optimum growth period from March to August. A comparison of 1-year-old mussels socked from June to December at various sites indicated that mussels socked in June had larger mean shell lengths than those socked later in the year. One site that socked in June had mussels with a mean shell length of 44.74 mm when it was sampled on October 27, 1998. This is 5 mm longer than mussels at the same site that were socked in September. The grower indicated that initial densities were approximately the same but initial seed size was not known. In addition, the percent of harvest-size mussels per 30 cm of sock (determined by weight) was 44.7 and 49% for mussels socked in June. Virtually none of mussels socked



**Figure 2.** Regression analysis of mean density per 30 cm of sock vs. The mean shell length (mm) of socked mussels from 9 commercial grow-out sites in Newfoundland (mussel density =  $4.58 (\text{shell length}) + 379.29$ ,  $r^2=0.808$ ).



later in the year had reached harvest size by December of the first year.

Of further note is that the length of mussels socked in June in Newfoundland was similar to that of mussels in socked in Nova Scotia during the same time of the year and sampled in December.<sup>(2)</sup> This suggests that reducing mussel density by socking during the initial part of the spring bloom provides more high quality food for each individual and improves growth to the extent that some grow-out times are comparable to those obtained in Nova Scotia. If this proves true, some Newfoundland growers could harvest mussels after only 12 to 18 months of grow-out in socks, reducing the number of year classes on the site to two instead of the usual three. With only 2 year-classes, there would be more space available to increase the number of socks.

### Socking practices

Socking gives the grower considerable control over the mussel product, but at a substantial cost. Direct labour costs on Newfoundland mussel farms were estimated at \$2.42 per sock,<sup>(11)</sup> the majority of which (\$1.51/sock) is for the stripping and socking of mussels. This value does not take into consideration the variation in efficiencies of socking techniques used in Newfoundland.

The 12 growers surveyed utilized homemade tables during the socking process. Most growers socked on barges and immediately attached the socks to mainlines for grow-out. Two of the growers put socks in tote pans in the ocean for 24 hours to permit mussels to develop byssal threads prior to attachment to mainlines. One of these growers socked on land and the other on a large enclosed floating platform.

The number of socks filled per day per person varied considerably among the growers. Socking performance averaged 108 socks per person per day and ranged from 30 to 225. These values included both the collection and stripping of seed and the attachment of socks to the mainline. This is lower than the PEI industry values, which are in the order of 1200 to 1500 socks per day for a 6-person crew.<sup>(12)</sup> Some sources suggest a maximum of 2500 socks per day using a 6-person crew. Two of the crew run the sock table, one the declumper-grader, and 3 supply seed and hang socks.<sup>(1)</sup>

The number of employees involved in the socking process varied from 3 to 8 in Newfoundland and there was no apparent increase in sock output with increased labour. The differences in socking efficiency between Prince Edward Island and Newfoundland operations is likely a result of more refined husbandry practices in PEI. These include the use of declumped, graded seed, lower socking densities and better-designed socking tables.

### Conclusion

The predictions and estimates expressed in this analysis are preliminary and projects are being planned to determine the accuracy of the conclusions that have been made. A stocking experiment that began in the spring of 1998 is designed to determine comparative performance of different brands of socking material at 3 sites. In addition, a component of the experiment is designed to determine the optimum socking density for mussels under Newfoundland operating conditions. The effect of grading on mussel growth will also be established and socks will be filled in the spring and in the fall to test the hypothesis that earlier socking times reduce grow-out times.

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# The Shellfish Culture Industry in British Columbia

*Brian Kingzett and Don Tillapaugh*

This report provides a brief overview of the British Columbia shellfish culture industry and covers current industry initiatives relating to quality assurance and the Farm Practices Protection Act, and recent discussions on industry codes of practice.

## Industry overview

The three main species of shellfish cultured in British Columbia are Pacific oysters, Manila clams and Japanese (Pacific) weathervane scallops. All three are exotic species introduced intentionally or unintentionally from Japan.

The Pacific oyster was first introduced into the Pacific Northwest about 1900 and introductions continued up until the Second World War. This species is barely established in British Columbia, breeding with regularity in only three small areas.

The Manila clam was accidentally introduced into British Columbia in the mid 1930s with oyster seed from Japan and it is now well established. It is the subject of a large boom and bust fishery which is managed by area restrictions and limited-entry participation.

The Japanese weathervane scallop, marketed as the "Pacific scallop" was introduced from Japan by a joint program of the Department of Fisheries and Oceans and the British Columbia provincial government during the 1980s. Imported broodstock were held in quarantine and bred. Successive generations of offspring were used to develop a scallop culture industry in the province.

Shellfish growers rely primarily on hatchery-produced seed for the culture of all three species. Clam growers also use strategies to enhance the number and increase the survival of clam larvae which settle out on culture beds. Of note is that almost all oyster and clam seed used in British Columbia is imported from the United States.

## Pacific oyster culture

In British Columbia, oysters are generally marketed as shuckers and or in-shell. Shuckers are oysters produced for meats which are shucked in federally-inspected processing plants and sold by the volume (typically quarts or gallons). Shucking oysters are

usually between 10 and 15 cm (4 to 6 inches) in length and usually shuck out at 100 to 120 meats per US gallon. Growers are paid according to how well their product shucks out and usually receive between \$15 and \$17 per US gallon. Current production is about 100 000 gallons per year. In-shell oysters are produced for the single or half-shell market. Single oysters are sold in the shell. They are a higher value product that is sold by the dozen in a variety of size grades ranging from 5 cm (2 inches) to greater than 15 cm (6 inches). Farm gate prices range from about \$1.75 to more than \$6.00 per dozen. A recent development is that a significant proportion of the oyster production is being flash-frozen as meats, whole oysters or TVO (top valve off).

BC growers are a diverse lot and methods used for culturing oysters vary depending on the site, the type of product, and the method preferred by the grower. Seed is acquired as larvae and is remote set, either on site or at a central site, onto substrate (usually old oyster shells). Alternatively, it is acquired as singles and nursed in floating upwellers to a size of approximately 2.5 cm (1 inch). The oldest and simplest grow-out method is to spread oyster seed on the beach and wait for them to grow to a marketable size. Grow-out times for beach product range from 2 years to more than 5 years.

Much of the development of the industry is coming from deep-water or off-bottom culture where oysters remain fully submerged during grow-out. Grow-out time is usually halved with this method and 10- to 15-cm (4-6 inch) oysters, large enough for shucking product, can be produced in 2 growing seasons in most areas. Oysters are never grown-out on the sub-tidal bottom in deep water.

The most common grow-out techniques involve either the insertion of mother shell into specially made 2-strand poly rope or the attachment of oysters to artificial cultch (known as french pipes or "tube" culture). In both these methods, individual strings or tubes are hung vertically from longlines for 2-year



grow-out to a size of 10 to 15 cm. On some farms, single oysters are contained in plastic culture trays and grown for 1 to 2 years before being sold directly or placed into the intertidal zone to harden the shellstock. Whatever the method, farmers working deep-water leases often use longlines or rafts to suspend the oysters being cultured.

### Manila clam culture

Clam farming is a relatively new venture in British Columbia. The first permitted clam farms were established on existing shellfish culture leases in 1988 and the licensing of clam farming became official in 1991. Hatchery-produced clam "seed" are purchased from nurseries in British Columbia, Washington or California. The seed is spread directly onto firm, low-sloping, mud-gravel grow-out beaches. To protect the significant investment in seed from scoter ducks, flounder and crab — all of which consider young clams as prize food — panels of light-weight plastic net are laid down and secured across grow-out plots. Mature clams are harvested after 2 to 3 years of grow-out.

### Scallop culture

The scallop industry is still in its infancy in British Columbia as growers overcome a variety of production hurdles. It is anticipated, however, that production will increase dramatically in the very near future. Production is hatchery based and there is currently one hatchery in the province producing scallop juveniles. The species is fast growing and marketable product can be produced within 2 years of the completion of the hatchery phase. Local scallop producers primarily use nets and ear-hanging for grow-out.

### Shellfish production

A listing of production from shellfish aquaculture in BC is provided in the table below.

Shellfish aquaculture production in British Columbia						
	1994		1995		1996	
	tonnes	\$ millions	tonnes	\$ millions	tonnes	\$ millions
Clams	500	3.1	900	5.3	900	5.5
Oysters	5000	6.9	5400	7.0	5300	8.0
Scallops	30	0.2	20	0.2	140	1.0
<b>Total</b>	<b>5530</b>	<b>10.2</b>	<b>6320</b>	<b>12.5</b>	<b>6340</b>	<b>14.5</b>

### Shellfish quality assurance

The principle components of shellfish quality are:

- Product safety — Quality Assurance (regulatory considerations),
- Product Form — Marketability (economic considerations).

Many within the shellfish industry recognize the need for an industry-based quality assurance program. The British Columbia Shellfish Growers Association (BCSGA) has taken the position that in order to be successful, quality assurance initiatives must:

- be voluntary and reward those who participate,
- provide an economic (market) advantage,
- complement and not interfere or conflict with existing QA programs or trade agreements (such as CSSP/QMP),
- be able to take the form of proposals to extend QMP/HACCP programs to the farm level,
- be able to be linked to environmental monitoring (product safety/regulatory issues).

The BCSGA has examined or is pursuing several quality assurance initiatives, including:

- developing standard quality grades,
- providing examples of BC product types,
- developing proposals for QMP/HACCP-based programs for the primary producer.

Unfortunately the shellfish industry has not been able to reach agreement on the best approach. Production in most companies is individually market driven. At present most industry-wide initiatives have stalled.

### Industry code of practice initiatives

Several factors are influencing the development of an industry-based code of practice. While most of the initiatives are in the discussion phase, the most significant advancement has been prompted by BILL 22—



1995, the provincial Farm Practices Protection (Right to Farm) Act. This act identifies and protects normal farm practices for agri-industries. Primarily developed for resolving disputes such as urban encroachment on farming activities, it provides a mechanism for dealing with complaints and resolving disputes, and established the Farm Practices Board.

In examining the need for industry codes of practice the BCSGA issued a contract to produce a discussion document examining the pros and cons of developing codes of practice. This study entitled *Discussion Framework for a BC Shellfish Industry Code of Practice* was conducted by Don Tillapaugh of Aqua-Vision Consulting Ltd. and was completed in December 1997. The study examined other relevant international codes of practice including:

- the New Zealand Mussel Industry Environmental Management System/Code of Practice,
- the South Australia Oyster Growers Association Oyster Growers Code of Practice,
- the FAO Code of Conduct for Responsible Fisheries,
- the Industry Code of Practice for Quality Irish Oysters.

The study identified the advantages and disadvantages of codes of practice for the industry, individual growers, and the provincial government on whose land the industry operates. Benefits to each group can be summarised as follows:

#### *Potential Benefits to the BC Shellfish Industry*

- Is a public relations tool
- Provides pro-active means of obtaining public/political support
- Reduces conflicts and need for resolution
- Improves access to capital
- Enhances product marketing ability
- Ensures ISO 14000 certification

#### *Potential Benefits to Individual Growers*

- Is a public relations tool
- Expands access to financing and investment
- Eases tenure renewal
- Improves relations with upland neighbours (neighbourly goodwill)

#### *Potential Benefits to Provincial Government*

- Allows government to assure the public that industry is operating in a responsible and environmentally sustainable manner
- Acts as an extension of the Right to Farm Act
- Provides increased credibility of government support

- Reduces conflict between government, industry and the public
- Provides increased advocacy ability and generate political support for the industry

Within the BC Shellfish culture industry there is considerable discussion as to whether a code of practice is a good idea. The study contracted by BCSGA also examined the disadvantages of a code of practice. This was done in order to identify the fears of the industry which can be summarised as follows:

- Will it be restrictive?
- Will this be just another government regulations/code that will be used against growers?
- Will it expose poor or bad industry practices?
- Will it be voluntary or mandatory?
- Will it be enforceable?
- Who will enforce it?
- Will it cause divisions in the industry?
- How much will it cost, who will pay the cost and what is the cost/benefit?

At present no clear decision has been made by the industry and no initiatives are proceeding pending review and industry discussion. Regardless of whether the shellfish industry adopts a code of practice or not, there is a significant need for an expansion of tenures in British Columbia. Recent studies have highlighted the importance of the 1000 new jobs that could be created in coastal communities as result of realizing the economic potential of the BC shellfish industry.<sup>(1)</sup> As the shellfish culture industry operates on provincial tenures (Crown Land) achieving this potential will require the goodwill of the public, or as put by a previous Provincial Cabinet Minister:

"New tenures require good public relations with no political consequences."

An accepted and effective industry Code of Practice may be one way to achieve that goal.

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## **Health Management, Development and Histology of Seed Oysters**

**by Ralph A. Elston**

**World Aquaculture Society, Baton Rouge, Louisiana**

**Price US\$55 (US\$45 for WAS and AAC Members)**

Once again, Dr. Ralph Elston has risen to the challenge of filling a glaring void in mollusc reference information. For those of us blessed with the vocation of working with bivalve molluscs, he has compiled a book that is easy to read, follow and quote to our non-scientific industry partners and less-blessed scientific colleagues! The need for such a guide to oyster seed is well-evidenced by the dearth of references that Dr. Elston has had to draw upon for this work and, although clearly based on *Crassostrea gigas*, it is readily applicable to other commercially-significant oyster species. It provides a welcome partner to another recent contribution on the histology of Japanese scallop, *Patinopecten yessoensis*, seed by Dr. Susan Bower. Both publications will, hopefully, provide the impetus to cajole similar works for mussels, clams and other hatchery-reared species (e.g., pearl "oysters"), which are long overdue!

Dr. Elston's book is well laid out (with well-founded acknowledgment of the assistance received for "desk-top" electronic assembly of the text and images) and the meticulous line drawings provided by Colleen MacDonald give a clear cross-reference for orienting the reader to the micrograph images. The book progresses from fresh-from-the-egg through to metamorphosis and juvenile/sub-adult development. This provides a strong "normal" foundation for subsequent discussion and presentation of health problems. The normal anatomical features are discussed with progressive attention to well-illustrated organ systems in the sub-adult oyster, so that by the time we are introduced to the less-healthy aspects of oyster development, we have no excuse for mistaking normal for abnormal. My only niggly little criticism with the introductory section is

a lack of cross-reference to another oyster species — namely *Ostrea edulis* — which Dr. Elston works with and which does differ significantly from *C. gigas* as it starts life in its parents' mantle cavity... But this doesn't merit "brooding" over too long!

The strong emphasis on providing a "normal" histology foundation is a refreshing component for a health/disease oriented text. We (mollusc disease people) have numerous excellent references for disease agents and diagnosis of clinical signs of mollusc diseases, but too few include the normal "control" images that neophytes (and veterans) in this field rely on for effective and accurate disease diagnoses.

Having progressed from developmental histology, Dr. Elston proceeds to the technical aspects of how to check whether or not your oyster larvae/juveniles/sub-adults are healthy or diseased. This is a hard chapter to place and Dr. Elston has put it in-between "normal" histology and hatchery management... Hmmm. Placement, schmacement — the information is good, wherever it is put (otherwise, why would you need a table of contents!). A couple of routinely recommended fixatives are omitted from the list, but anyone working in histology knows that laboratory preferences are usually built on experience, training and end-point goals. As long as the end results are comparable! The new "kids-on-the-block" for mollusc disease diagnosis (antibody and molecular probe-based technology, p. 49) are alluded to and will probably emerge in the near future as influencing tissue preservation. Until such time, however, the recipes and advice given here are reliable for most diagnostic needs (presumptive and confirmatory).



Another placement-schmacement chapter is Intensive Health Management and Sanitation (Chapter 7). Personally, I'd have liked to see this "up-front" before diving into the microscopic world... but that's just me! Chapter 7 is the most likely to draw the attention of hatchery managers and technicians, and diagnosticians may wonder what it is doing in between techniques and disease description... Regardless, the information included is strong and clearly based on Dr. Elston's disease certification and hatchery disease-management background. One tiny point that "eats" at my reviewer mind's-eye, however, is the short change of the "Feed, Feeding Rate, and Health Management" sub-section as "beyond the scope of this discussion". One of the earliest "red alert" signs of ill health in a hatchery system is reduced feeding. If not caught immediately, feeds build up and result in the proliferation of opportunistic microbes (peritrichous ciliates, vibrios and pseudomonads, etc.). Many "pathogenic" organisms only become criminally responsible when resources promote their proliferation — such resources include non-feeding larvae/juveniles, decomposing food, and resultant mortalities — and the effects can be manifest in a matter of hours.

Chapters 8-21 give very useful reference material and overviews of the diagnosis and significance of a wide range (n=14!) of diseases and agents affecting larval to sub-adult oysters. Most examples are of manageable diseases, including one of the most common problems, vibriosis, which is caused by a build up of ubiquitous Gram-negative marine bacteria. Dr. Elston provides a well-balanced summary of

control options including a precautionary discussion of antibiotic use. Another example discussed is the recent, international emergence of *Herpes*-like viruses in marine molluscs (and finfish). Detection of such viruses probably reflects our convergent improvement in ability to detect and identify viral infections, at the same time as we have refined the culture systems suited to their manifestation! Since this means more viruses are likely to emerge as we delve deeper into "unexplained mortalities", the chapter on *Herpes* will prove to be an especially useful reference point. Control of all the diseases described hinges, as underlined by Dr. Elston, on whether or not they are "exotic" to their hosts or endemic opportunists... As new species are cultured, we should be prepared and cautious with mix and match! With this new book, we are certainly better prepared than before.

In summary, this book is well worth the Canada-US exchange as a hatchery, diagnostic laboratory and teaching reference. As with another broad-reader reference by Dr. Elston, "Mollusc Diseases — Guide for the Shellfish Farmer", this book can be expected to join those dog-eared "just-check" references which all-too-often disappear from specialists' bookshelves... Maybe buy two (one for display and one for the drawer!).

Sharon E. McGladdery  
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## Health Management, Development and Histology of Seed Oysters

By Ralph Elston

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# Calendar

conferences, workshops, courses and trade shows



• **Aquaculture America 2000**, 2 – 5 February 2000, New Orleans Marriott, New Orleans, Louisiana, USA. Annual meeting of the US Chapter of the World Aquaculture Society, the American Tilapia Association, Striped Bass Growers Association, AFS Fish Culture Section, and the Louisiana Aquaculture Association. Sessions: freshwater crustaceans, tilapia, red drum, marine shrimp, tropical fish, reptile, amphibian, salmonid, molluscan, and striped bass culture; water quality; aquaculture regulations; ploidy manipulation and sex reversal; recirculating systems; computers and aquaculture; nutritional requirements and diet formulation for shrimp and fish; and aquaculture as a teaching tool. Information: John Cooksey, Conference Manager, 21710 7<sup>th</sup> Place West, Bothell, Washington, USA (tel 425 485- 6682, fax 425 483-6319, [worldaqua@aol.com](mailto:worldaqua@aol.com)).

• **International Conference on Risk Analysis in Aquatic Animal Health**, 8–10 February 2000, Paris, France. Keynote presentations by invited speakers. Sessions: the need for risk analysis; risk analysis methodology; areas of application to aquatic animal health including problems, research needs and environmental concerns, case histories and field studies; and recommendations and future prospects. Information: Dr. K. Sugiura, Office International des Epizooties, 12 Rue de Prony, 75107, Paris, France (tel 33 (0)1 44 15 18 88, fax 33 (0)1 42 76 09 87, [www.oie.int](http://www.oie.int)).

• **Conference on Aquaculture in the Third Millennium and Aquaculture and Seafood Fair 2000**, 21 – 25 February 2000, Bangkok, Thailand. Sessions: integrating aquaculture into rural and coastal development; aquaculture and poverty alleviation; involving stakeholders in policy making, planning and management; promoting sustainable aquaculture with economic incentives; building the information base for policy making; establishing legal, institutional and regulatory frameworks; aquaculture production systems; genetics, health management and disease control; nutrition and feeding; culture-based fisheries and enhancement; systems approach to aquaculture management. Exhibitions will be held on aquaculture nutrition and health, seafood and cold storage, and or-

namental fish. Conference information: [naca@inet.co.th](mailto:naca@inet.co.th), [www.naca.fisheries.go.th](http://www.naca.fisheries.go.th).

• **National Shellfisheries Association**, 92<sup>th</sup> annual meeting, 19–23 March 2000, Crown Plaza Hotel, Seattle, Washington, USA. Will include presentations on the biotechnology, genetics, physiology, biochemistry, ecology, aquaculture and management of shellfish together with those on the effects of pollution, harmful algae, diseases and invasive toxic species. Deadline for receipt of abstracts is 3 December 1999. Information: Dr. Chris Langdon (tel 541 867-0231, fax 541 867-0105, e-mail [chris.langdon@hmsc.orst.edu](mailto:chris.langdon@hmsc.orst.edu)) or check the National Shellfisheries Association website at [www.shellfish.org](http://www.shellfish.org).

• **AQUA 2000**, 2 – 6 May 2000, Acropolis Convention Centre, Nice, France. Annual meetings of the World Aquaculture Society and the European Aquaculture Society. A special thematic session running the full length of the conference will focus on responsible aquaculture — can it be accomplished? Information: John Cooksey, Conference Manager, 21710 7<sup>th</sup> Place West, Bothell, Washington, USA (tel 425 485-6682, fax 425 483-6319, e-mail [worldaqua@aol.com](mailto:worldaqua@aol.com)). For program information check the WAS and EAS websites: [www.was.org](http://www.was.org) and [www.easonline.org](http://www.easonline.org).

• **Annual Meeting of the Canadian Society of Zoologists**, 3 – 6 May 2000, Algonquin Hotel, St. Andrews, NB. Information: Dr. M. Burt, Huntsman Marine Science Centre, St. Andrews, NB (tel 506 529-1222, fax 506 529-1212, [mburt@nbnet.nb.ca](mailto:mburt@nbnet.nb.ca)).

• **9<sup>th</sup> International Symposium on Nutrition and Feeding in Fish**, 21 – 25 May 2000, Miyazaki, Japan. Topics: Challenges and strategies for aquafeed development, nutrient requirements and availability, nutrient metabolism, and its control, alternative protein sources, fish health with reference to fish feed, larval and broodstock nutrition, and nutritional strategies and management of aquaculture waste. Information: Prof. T. Takeuchi, Tokyo University of Fisheries, Konan 4, Minato, Tokyo 108-8477 (tel +81-3-5463-0545, fax +81-3-5463-0553, [take@tokyo-u-fish.ac.jp](mailto:take@tokyo-u-fish.ac.jp), [www.tokyo-u-fish.ac.jp/fish-nutrition](http://www.tokyo-u-fish.ac.jp/fish-nutrition)).





• **Aquaculture Canada 2000**, 28 – 31 May 2000, Hotel Beausejour, Moncton, NB. 17<sup>th</sup> annual meeting of the Aquaculture Association of Canada. This millennial conference and exposition will cover a broad spec-

trum of aquaculture topics. It will focus on industry and science and will attract growers, suppliers, scientists, administrators, educators and students. Conference information: Dr. Andrew Boghen, Dept. Biologie, Université de Moncton, Moncton, NB E1A 3E9 (tel 506 858-4321, fax 506 858-4541, aac2000@umoncton.ca, www.aac 2000.org). Trade show information: Aquatic Industries Ltd., P.O. Box 2731, Manuels, Newfoundland A1W 1A6 (tel 709 781-0153, fax 709 781-0154, aquaticindustries@nf.sympatico.ca).

• **Fishery 2000 Guang-zhou, The International Fishery Exhibition**, 30 May – 1 June 2000, Chinese Export Commodities Fairground, Guangzhou, P.R. China. Exhibition of seafood, commercial fishing, fish farming and fish processing equipment and technology, seafood transportation systems, refrigeration equipment and technology, and seafood packaging. Information: Top Repute Co., Ltd., Room 2403, Fu Fai Commercial Centre, 27 Hillier Street, Sheung Wan, Hong Kong, P.R. China (tel 852 2851 8603, fax 852 2851 8637, topreput@hkabc. Net).

• **Dalian Seafood Expo 2000**, 14–17 June 2000 at Dalian Xinghai Convention & Exhibition Centre, China. Organized by the Dalian Municipal Government. Will present a full array of fishery and aquacultural technology, seafood varieties, technology and service from processing and packaging to transportation, storage and distribution. Information: Business & Industrial Trade Fairs Ltd. (tel 852 2865 2633, fax 852 2866 1779, enquiry@bitf.com.hk).

• **2nd IFAF, Turkey's International Fair for Aquaculture, Fisheries and Fish Products**, 15–18 June 2000, Izmir, Turkey. Conference will focus on such topics as the investment climate in Eurasia, business opportunities and emerging market opportunities. Full program of technical workshops, equipment demonstrations and tours of aquaculture facilities. Information: Mr. Harald Mol, Royal Dutch Jaarbeurs, P.O. Box 8500, 3503 RM Utrecht, The Netherlands (tel +31 30 29 55 662, fax +31 30 29 55 585, molhd@jaarbeursutrecht.nl, www.jaarbeursutrecht.nl).

• **3<sup>rd</sup> International Conference on Shellfish Safety**,

19– 24 June 2000, Southampton College, Long Island University, New York. As with previous symposia in this series, presentations will be given dealing with shellfish biology and ecology, chemical and microbiological contamination and assessment, impacts of harmful and toxic algae, depuration technology, monitoring and management, aquaculture and harvesting sites, health and sanitation, and quality assurance programs and regulatory controls. Proceedings will be published in the *Journal of Shellfish Research*. Abstract deadline 31 December 1999. Information: Dr. Sandra Shumway, Natural Science Division, Southampton College, 239 Montauk Highway, Southampton, NY 11968 USA (fax 516 287-8419, sshumway@southampton.liunet.edu).

• **International Congress on the Biology of Fish**, 23 – 26 July 2000, Aberdeen, Scotland. Information on the meeting is available at the website [www.fish-biologycongress.org](http://www.fish-biologycongress.org). Plans for symposia are underway. If you have suggestions or would like to be involved in organizing a session, contact Don MacKinlay (tel 604 666-3520, fax 604 666-6894, mackinlayd@pac.dfo-mpo.gc.ca).

• **Coastal Zone Canada 2000**, 17 – 22 September 2000, Trade and Convention Centre, Saint John, NB. Fourth in the Coastal Zone Canada series. Goal is to identify products, policies & research which will further integrate coastal zone management. The foundation for discussion will be a review document on the current worldwide status of coastal zone management entitled *Baseline 2000* which will be distributed to participants prior to the conference. Theme: Coastal Stewardship — Lessons Learned and the Paths Ahead. The conference will focus on four related subthemes: Aboriginal Practices, Community-based Actions, Coastal Health and Oceans Governance. Information: Coastal Zone Canada 2000 Secretariat, Department of Fisheries and Aquaculture, P.O. Box 6000, Fredericton, NB E3B 5H1 (tel 506 453-2253, fax 506 453-5210, czc2000@gov.nb.ca, www.gov.nb.ca/dfa/czc-zcc2000.htm).

• **Third World Fisheries Congress**, 31 October - 3 November 2000, Beijing, P.R. China. Topics: effect of sustainable fisheries on optimizing food composition and improving human health, scientific management, reasonable exploitation and protection of fisheries, fisheries technologies, machinery and instruments, healthy aquaculture and ecosystems, biotechnology, processing, biodiversity, fishery policies and sustainable development, and application of information technology. Secretariat: China Society of Fisheries, Bldg 22, Maizidian Street, Chadyang District 100026, Beijing, P.R. China (tel 86 10 64194233, fax 86 10 64194231, csfish@agri.gov.cn).



# *Aquaculture Canada 2000*


Conference and Trade Show / Conférence et Salon commercial


<http://www.aac2000.org>

**AQUACULTURE IN THE NEW MILLENNIUM:  
INNOVATION AND SUSTAINABILITY**

**AQUACULTURE DANS LE PROCHAIN MILLÉNAIRE:  
INNOVATION ET DÉVELOPPEMENT DURABLE**



 **May 28-31, 2000**  
**Delta Beauséjour Hotel**  
**Moncton, New Brunswick**

 **28-31 mai 2000**  
**Hôtel Delta Beauséjour**  
**Moncton, Nouveau-Brunswick**

17th Annual Meeting - Aquaculture Association of Canada  
17<sup>e</sup> Réunion annuelle - Association Aquacole du Canada

## **For information / Renseignements**

### **CONFERENCE / CONFÉRENCE**

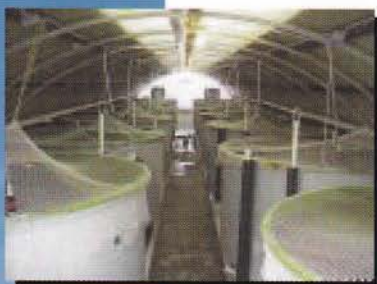
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Université de Moncton  
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Telephone/Téléphone: (506) 858-4321  
Fax/Télécopieur: (506) 858-4541  
Email/Courriel: [aac2000@umoncton.ca](mailto:aac2000@umoncton.ca)  
<http://www.aac2000.org>

### **TRADE SHOW / SALON COMMERCIAL**

Aquatic Industries Ltd.  
P.O. Box 2731  
Manuels, NF Canada A1W 1A6  
Telephone/Téléphone: (709) 781-0153  
Fax/Télécopieur: (709) 781-0154  
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