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An Examination of Biological and other Factors Affecting Mussel Aquaculture Development in the Scotia-Fundy Region of Nova Scotia

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ABSTRACT

Freeman, K.R. 1996. An examination of biological and other factors affecting mussel aquaculture development in the Scotia-Fundy Region of Nova Scotia. Can. Tech. Rep. Fish. Aquat. Sci. 2125: v + 32 p.

Nova Scotian commercial production of mussels has been constrained by a number of factors, some of them biological. A survey was conducted in the Scotia-Fundy Region of the province of twenty-six mussel aquaculture businesses, including five which did not produce mussels in 1994. Ten biological factors were revealed that concern growers and include, in descending order of frequency, predation, phycotoxins, mussel drop-off, species mix (presence of *Mytilus trossulus*), marine fouling, off flavours, spat settlement prediction, summer mortality, carrying capacity and "red" mussels. Six non-biological concerns were also examined. Among the twenty-one producing businesses, production for 1994 ranged from zero to >200,000 pounds, and based on a median landing of 37,500 pounds, they were grouped into High and Low Production categories. This rating allowed preparation of 2 by 2 contingency tables and analysis of each concern or factor using Fisher's Exact Two-Tailed Test. Significant relationships ($p \leq 0.05$) were found between: 1) annual production and numbers of full-time workers, and 2) average experience with concern for marine fouling. Suggestive relationships ($p \leq 0.15$) were found between average experience and the following concerns: phycotoxins, species mix, and secondary product development. Also suggestive were annual production with concern for phycotoxins and off flavours. Correlation coefficients relating to business success of the 21 non-zero producers were also calculated. Significant correlations ($r \geq 0.433$) were found between the number of full-time workers in a business and its annual production. Though that is not surprising, there was also a good correlation between the experience of the full-time workers and production, independent of the number of such workers. A number of growers reported serious difficulties in dealing with various government bureaucracies. Recommendations are given to address some of the problems encountered, both biological and bureaucratic.

RÉSUMÉ

Freeman, K.R. 1996. An examination of biological and other factors affecting mussel aquaculture development in the Scotia-Fundy Region of Nova Scotia. Can. Tech. Rep. Fish. Aquat. Sci. 2125: v + 32 p.

La production commerciale de moules en Nouvelle-Écosse a été freinée par divers facteurs, dont certains de nature biologique. On a réalisé une étude de vingt-six entreprises mytilicoles de la région de Scotia-Fundy, dont cinq qui n'ont pas produit de moules en 1994. Cette étude a permis de dégager dix facteurs biologiques qui préoccupent les éleveurs. Ce sont, pas ordre décroissant de fréquence, la prédation, les phycotoxines, la déperdition de moules, le mélange des espèces (présence de *Mytilus trossulus*), les salissures marines, les flaveurs atypiques, les prévisions de fixation du naissain, la mortalité estivale, la capacité porteuse et les moules «rouges». On a aussi examiné six facteurs non biologiques. La production s'échelonnait entre zéro et >200 000 livres dans les vingt et un établissements producteurs en 1994. En se fondant sur une production médiane de 37 500 livres, on a classé ces établissements en deux catégories, de haute ou de basse production. Ce classement a permis d'établir des tableaux de contingence à double entrée et d'analyser chaque facteur au moyen de la méthode bilatérale exacte de Fisher. On a trouvé des relations significatives ($p \leq 0,05$) entre, d'une part, la production annuelle et le nombre de travailleurs à temps plein et, d'autre part, l'expérience moyenne du souci des salissures marines. On a aussi établi des relations suggestives ($p \leq 0,15$) entre l'expérience moyenne et les facteurs suivants: phycotoxines, mélange des espèces et développement de produits secondaires, ainsi qu'entre la production annuelle, d'une part, et les phycotoxines et flaveurs atypiques, d'autre part. On a également calculé les coefficients de corrélation de réussite concernant les 21 établissements dont la production était supérieure à zéro. Il s'est dégagé des corrélations significatives ($r \geq 0,433$) entre le nombre de travailleurs à temps plein d'une exploitation et la production annuelle de cette dernière. Bien que cela ne soit pas étonnant, se dégageait aussi une bonne corrélation entre l'expérience des travailleurs à temps plein et la production, indépendamment du nombre de ces travailleurs. Des éleveurs ont fait état de difficultés sérieuses dans les rapports avec les diverses administrations gouvernementales. On présente ici des recommandations en vue de régler certains des problèmes rencontrés, de nature biologique ou administrative.

INTRODUCTION

Mussel aquaculture in Nova Scotia has now completed its second decade. Reliable records of annual landings have been gathered by the Provincial Department of Fisheries since 1986 and some landing estimates before that time are available from other sources (e.g. Aiken 1984). Figures for 1994 indicate total provincial landings for cultivated blue mussels equalling 439 tonnes, with a value of $633 thousand. While these recent figures are higher than the 1986 values of 260 tonnes and $360 thousand, they pale beside Prince Edward Island's 1994 landings of 5,936 tonnes and overall more aggressive growth (Figure 1). This lower-level performance by Nova Scotia has occurred despite a plentiful supply of mussels, an inshore area with more potential shellfish growing space than in PEI, and no shortage of motivated entrepreneurs willing to enter the business. It is commonly known that PEI growers were initially subsidized by their provincial government, whereas those in Nova Scotia were not, and this appears to be a principal reason for the difference in mussel culture development between the two provinces.

A review of Nova Scotia's cultivated mussel industry by Muise (1992) confirms "infrastructural problems" in particular markets and related issues, as limiting industry growth. Nonetheless, there is still a question as to whether there are other reasons that might be contributing to the comparatively slow Nova Scotian performance. In light of federal interest in supporting aquaculture, a decision was made to survey the provincial mussel industry within what was then the Scotia-Fundy Region to assess the magnitude of activity and diversity of commitment among mussel cultivation operations, to solicit commentary from growers, ex-growers and growers-to-be concerning the industry, and to identify developmental constraints with an emphasis on those of biological origin which might be addressed through DFO research effort. Beginning in the summer of 1993, visits were made to Nova Scotia mussel producers in the Scotia-Fundy Region and interviews with principal owners of these businesses were conducted over the following twenty months.

PROCEDURES

FIELD

Listings of shellfish growers were initially obtained from a Nova Scotia Department of Fisheries compilation of all provincial aquaculturists. Initial contacts were made by telephone to update addresses, telephone numbers, and to confirm current business status. As a convenience, one person per business was designated as the principal owner and this was the individual interviewed. In August of 1993, the first site visits were made as a test of an initial, tentative set of interview questions (see interview protocol, Appendix). Upon protocol revision, re-visits or telephone interviews were made to obtain information originally overlooked. In the months during which personal interviews were being conducted it became clear that there was a steady flux of entrants and departures from the grower pool. It was therefore decided that when the majority of principal owners had been interviewed, an effort would be made to consolidate information gathered, analyse the portion of it amenable to such treatment and to prepare a report

that described the state of the industry at that time. So, although all mussel growers in the Scotia-Fundy Region had not been contacted by spring 1995, interviewing was nonetheless terminated. While conducting these interviews, encounters were made with individuals who had left the business as well as others who were trying to enter it. These people were all eager to recount their experiences in dealing with the lease application procedures and with specific aspects of mussel cultivation. Their comments, while not identified as to source, have been incorporated into the conclusions.

As production at any site can be affected by a number of factors, information gathered ranged from husbandry practices and personal backgrounds, to purely administrative matters. Information collected was grouped into various categories from employment and business background through lease siting and processing, to the growers' concerns related to the business. Some of the information collected, particularly quantities and types of deployed gear, methods of deployment, and machinery used, was not analysed as insufficient numbers of interviewees could be specific about some of these items. Because of circumstances prevailing at the time certain site visits were being conducted, interviews of a small number of growers of shellfish other than mussels were also conducted. In some cases their problems matched those of the mussel growers. Data gathered in these instances were used only as confirmation of any general consensus among mussel aquaculturists operating within the particular Nova Scotia administrative and marketing milieu existing at the time of the survey, and they do not appear as part of any of the summary tables nor were they included in any of the statistical analyses.

DATA TREATMENT

Production (PROD) ranged from 0 to >200,000 lb. and was categorized at the median (25,000 lb.) into High and Low. However, those 26 mussel operations included 5 for which no production was realized in 1994. When the 5 non-producers are excluded the median cut for the 21 remaining was 37,500 lb.

The operations were also classified as having Many Workers (2.33 or more full-time equivalent employees (NFTEs) including the owners) or Few Workers.

The total years of experience (TYE) of the full-time only workers (including owners) at each operation was classified as High Experience (totals >14 years) or Less Experience.

Finally, the total experience of full-time workers at each operation was divided by the number of full-time workers to yield an average experience measure (AVEX). These averages were then classified as High (when 8 years or more for the 26 operations; >9 years for the 21 non-zero operations), or Low.

Of the sixteen potential problems or concerns, six were regarded as being non-biological in nature as opposed to ten strictly biological issues (Table 1). Five of the concerns were so common or rare (expressed by 23 or more principal owners or by 3 or fewer) that they were

excluded from the analysis of associations. These exclusions were done because, for example, if only 2 or 3 owners expressed a concern one will not find an association of that with High/Low production or High/Low average experience. The 'common' exclusions are marked '*' and the rare are marked '#'.

Table 1. List of concerns and business factors analysed.

Biological Concerns	Other Concerns	Business Factors
* Predation	Vandalism (VAND)	1994 Production in pounds (PROD)
Phycotoxins (PHYCO)	Marketing (MARK)	No. of Full-Time Equivalents (NFTE)
Mussel Drop-Off (DROP)	Second. Prod. Devel. (2ND)	Total Years Experience (TYE)
Species mix (SPEC)	Obtaining Financing (FINAN)	Average Full-Time Experience (AVEX)
Gear Fouling (FOUL)	# Pollution	
Off flavours (OFF)	Boat Traffic (BOATS)	Est. of Production Potential (EPROD)
Spat Prediction (SPAT)		Hectares Leased (HEC)
# Summer Mortality		Number of Full-Time Workers (NFT)
# Carrying Capacity		Total Part-Time Months (TM)
# "Red" Mussels		

These classifications permit all the data, including concerns of the principal owners, to be treated by the same statistical procedure: analysis of 2 by 2 contingency tables using Fisher's Exact Two-tailed Test.

Within all 26 operations, and separately within the 21 which exclude the zero producers, pairwise correlations were performed among the continuous variates including: the number of full-time workers (NFT), total years of experience of these workers (TYE), total part-time employee months per year (TM), hectares leased for mussels (HEC), 1994 production in pounds (PROD), and estimated production potential (EPROD) to the businesses.

RESULTS

DESCRIPTION OF INDUSTRY

The total of all shellfish culture operations contacted (including ex-businesses) came to 37 and these are distributed from Barrington Bay near Cape Sable Island to Aspy Bay near the

northern tip of Cape Breton Island. Twenty-six of these were businesses where mussels were cultivated and these were subjected to analysis. These 26 businesses use 51 surveyed, non-contiguous parcels (leases) of water totalling 660.9 hectares of which 536.7 were set aside for, or were being used for, mussel cultivation in 1994. Of the 26 businesses, 14 derived income primarily or solely from mussel growing whereas the remaining 12 were cultivating mussels, or attempting to, as either a hobby or second income source (one of the 14 indicated equal income from mussels and the alternate income source). Owners in the second group hold a diverse array of principal occupations including fishing, accounting, mining, marine biology, engineering, inspecting, mechanics, pipe-fitting, carpentry, administration and retail sales. Among all businesses examined, the total number of people hired as part-time workers was 40 accounting for an estimated total of 156.5 employee-months of work per year.

Lease locations from the 26 businesses are shown on the map of Nova Scotia (Figure 2) by pointers leading from the icons. No ownership identification is implied by the numbers within the icons which merely indicate the distribution of leases along the Atlantic coast, in the Bras d'Or Lake and west of the Canso Causeway in the Gulf Region, where one business outside the Scotia-Fundy Region was included in the survey. Numbers correspond to mussel leases which may belong to the same person or business entity, whereas in other cases numbers may include more than one business entity.

RESOURCE USE

Table 2 relates 1994 landings to the number of hectares leased by the growers and reveals diverse efficiencies, with some higher producers leasing lower numbers of hectares and some of the lower producers leasing much more water.

BIOLOGICAL CONCERNS

Over both High and Low production levels, and of the 10 items examined, concern for effects of predation was most frequent (95.2%) followed by phycotoxins (66.7%), mussel drop-off (66.7%), species mix -- the presence of *M. trossulus* amongst the preferred *M. edulis* -- (57.1%), fouling on gear (33.3%), off flavours (23.8%), spat settlement prediction and summer mortality (each at 14.3%), carrying capacity and "red" mussels (each at 4.8%). The incidence of these concerns, for the 21 non-zero producers, is shown in Figure 3.

2 BY 2 CONTINGENCY TABLE ANALYSES

A further examination of these items with respect to production and average experience was then attempted using 2 by 2 tables. The results of the 25 analyses of 2 by 2 tables for the 21 businesses in actual production are summarized in Table 3. The probabilities quoted are from Fisher's Exact Two-tailed Test.

Table 3. Probabilities in 2 By 2 Contingency Table Analyses

Variable =	PHYCO	SPEC	VAND	MARK	2ND	FINAN	BOATS
vs. PROD:p=	0.063*	0.387	0.659	0.395	0.395	0.670	1.000
vs. AVEX:p=	0.063*	0.080*	0.659	--	0.086*	0.198	0.311
Variable =	**OFF**	**SPAT**	**DROP**	**FOUL**	**NFT**	**TYE**	**AVEX**
vs. PROD:p=	0.149*	0.586	0.183	1.000	0.030**	0.198	0.395
vs. AVEX:p=	1.000	0.586	0.361	0.024**	1.000	--	--

Explanations of the abbreviations are given in Table 1.

There were only two relationships which reached the 5% significance level among the 25 relationships examined (marked ** in the table). This is close to what one might expect if all 25 relationships were truly zero (i.e. two type-1 errors in 25 tests). However, these associations are explicable and are unlikely to be spurious. One of the relationships was PROD with number of full-time employees (NFT): operations with large NFT were more likely to be High Producers (80%) than Low Producers (27%). This is not a surprising finding and not likely to be a type-1 error. The other significant relation was between concern about marine fouling and High average experience. Operations with High average experience were far more likely (60%) to be concerned about marine fouling on gear than those with Low average experience (only 9% were concerned).

The last-mentioned relationship seems to be basically similar to three others in which High average experience is more likely to raise concerns than Low experience: phycotoxins (90% versus 45%), species mix (presence of *M. trossulus*) (80% versus 36%), and secondary product development (70% versus 27%). None of these three relationships reach the 5% level of significance, but they all reach a "suggestive" criterion of 15% (marked * in the table). There were also two suggestive relationships with production (PROD); High producers were more likely (90%) to be concerned about phycotoxins than were Low producers (45%); High producers were also more likely (40%) to be concerned about off-flavours than Low producers (9%).

CORRELATIONS

Within all 26 operations, and separately with the 21 which excluded the zero producers, pairwise correlations were performed among the continuous variates including: the number of full-time workers (NFT), total years of experience of these workers (TYE), total part-time employee months per year (TM), hectares leased for mussels (HEC), 1994 production in pounds (PROD), and estimated production potential (EPROD) for the businesses. The results are shown in Tables 4a and 4b.

The results are very similar whether all 26 businesses are used or only the 21 businesses in production. Considering the 21 businesses in production any $r \geq 0.433$, would be 'significant' at the 5% level. It is no surprise that the number of full-time workers (NFT) is correlated with their total years of experience (TYE) to the extent $r = 0.64$. But there is no obvious reason why the total years of experience of full-time workers (TYE) is correlated with the total months of part-time help (TM) to the extent $r = 0.59$.

Business Success and Experience

The most interesting correlations are with production (PROD). It is not surprising that this correlates 0.53 with NFT and 0.73 with TM; but the most interesting correlation is PROD with TYE of 0.85. This last correlation may be attributable in part to the total number of workers increasing production ($r = 0.53$ as previously stated), but if the total number of full-time workers is partialled out from the $r = 0.85$ correlation, it remains high at $r = 0.78$. Thus experience improves production, quite apart from how many people are employed.

It is also interesting to speculate how well both the number of full-time workers (NFT) and total months of part-time help (TM), taken together, will "predict" production. The answer is $R_{Prod(NFT,TM)} = 0.79$, a slight improvement over the total part-time months alone ($r = 0.73$). One could also inquire how well total years experience (TYE) and total part-time months (TM), taken together, might "predict" production, and here the answer is $R_{Prod(TYE,TM)} = 0.90$; again, a slight improvement over TYE alone ($r = 0.85$).

BUREAUCRATIC MATTERS

As concerned as many growers were about some of the foregoing issues, their most intense commentaries were reserved for matters surrounding lease application administration by both the Provincial Fisheries Department and Coast Guard bureaucracies. Concern about governmental administration was almost universal, but was found most particularly amongst those attempting to begin aquaculture or expand operations. A frequent complaint focused on the glacial pace of application processing. To paraphrase one grower - "Months, even years go by without resolution of matters concerning, for example, marine rights-of-way". That pales, however, beside (rare) stories of submitted lease applications being lost and without the applicant being informed this had happened.

DISCUSSION AND CONCLUSIONS

Apart from observed variations in lease siting, the mechanics of mussel cultivation itself, work experience, and business acumen, the material and personal resources of the people now cultivating mussels in the province is also quite varied. Intensity of effort varies from the part-time operator who is either otherwise employed or even retired, working with a small boat, his bare hands and perhaps no helper, to the well-equipped

company with two or more permanent employees, heavy-work boats, cranes, and part-time seasonal workers, and whose income is solely derived from mussel cultivation. In addition, the industry is in a state of flux resulting from new entries as well as retirements and other departures because of a host of circumstances that might be typical of any other business, and some that appear exclusive to the industry as it is presently constituted within Nova Scotia (see below). The principal limitation in attempting to derive insight from this study is due to the low number of sources (businesses) available in the Scotia-Fundy Region for analysis. Sample sizes required to yield acceptable power for reasonable true differences between sub-populations is illustrated in the section below.

POWER β AND SAMPLE SIZE N

Power is the probability of detecting a 'true' difference between populations. Since what is really true is known only theoretically, power is necessarily a theoretical calculation.

Data on grower's concerns varied from little concern on some issues to great concern on others. Furthermore, the difference in the frequency of concern between the Low and High producers ranged from zero to some moderate-sized effect. Three examples were constructed to illustrate the power for various patterns, and the sample sizes required to achieve reasonable power. Population A shows a relatively small difference (3 out of 13) while population B shows a moderate difference (7 out of 13). Population C is like population A except that the total frequency of concern is not 50% (13 concerned out of 26) but 19% (5 concerned out of 26); so the differrence (3 out of the 5 concerned) is more 'detectable'. Table 5 below illustrates these three possible true population distributions and what the power β would be for detecting those differences when N = 13.

Table 5. Theoretical business 'populations' and potential power of analysis.

Population	A		B		C	
Production Level	Low	High	Low	High	Low	High
Concerned	5	8	3	10	1	4
Not Concerned	8	5	10	3	12	9
N =	13	13	13	13	13	13
ϕ_j =	0.38	0.62	0.23	0.77	0.08	0.31
ß =	0.06		0.79		0.32	
ß = 0.50, N =	34	34	7	7	23	23
ß = 0.95, N =	113	113	23	23	77	77

At the bottom of the table are shown the sample sizes N required to achieve power $\beta = 0.50$ and 0.95. For example, in population B, the proportion of low production businesses concerned is $\phi_1 = 3/13 = 0.23$, and the proportion of high production businesses is $\phi_2 = 10/13 = 0.77$. When there exists a true difference between proportions of businesses concerned of 0.77 - 0.23 = 0.54 we would require two samples each of N = 23 to provide a power $\beta = 0.95$. The total of 26 businesses provides a power β of only 0.79 for that size of effect. Other population patterns show even poorer power with N = 13, and one would need two samples, each of N = 113 businesses, to have a $\beta = 0.95$ chance of detecting $\phi_2 - \phi_1 = 0.24$ in population A.

THE ANALYSES

Notwithstanding the above limitation, some statistically suggestive differences were found by Fisher's Exact Tests applied to biological concerns and rated against production level. That some differences were not statistically suggestive should not be taken as indicating that no true difference exists. It may be that the power of analysis was too low given the small samples available (see the section Power β and Sample Size N). Also, a concern might be very important to a large number of the businesses, even though the Low and High producers do not differ in that respect.

In addition to the above analyses, there were some suggestive correlation coefficients obtained pursuant to business effort.

The results, when combined with other observations from the principal owners, give a general, if crude, picture of the state of the industry and concerns of the people who run it.

EFFORT AND EXPERIENCE

Table 2 indicates what may be quite diverse efficiencies among businesses, although other factors, such as variable environments, or populations of mussels, might also be at work. For example, the seven businesses in the 50,000+ column range from one which leases quite a small area (<10 hectares) to one which leases the very largest area (100+ hectares). Also, the one business in the highest production category (>200,000 lb.), leases a relatively small area (10+ hectares).

Other measures of "effort" versus production are seen in the division between High and Low producers in terms of whether mussel aquaculture is the primary (or sole) or a secondary income source. Most (13) of the full-time or primary income businesses are in the High category, and only 8 in the Low, and though not statistically significant, the difference is statistically suggestive.

The correlations of Production with Number of Full-Time workers (r = 0.53) and with Total part-time Months (r = 0.73) should be reassuring to the owners. But the high partial correlation (r = 0.78) of Production with Total Years of Experience, after Number of Full-Time

workers has been partialled out, indicates that individual skill and know-how are effective components of this work.

FINANCIAL CONSIDERATIONS

While all growers interviewed had some concerns out of the list of 10 items related to biology, there were many who appeared to regard financial matters (e.g. lack of start-up funding) at least equal in importance to some of the more common biological concerns. As interviews progressed, it became clear to the interviewer that few growers, particularly those whose earnings came solely from mussel culture, felt at ease economically and they often conveyed the sense that, despite some consistent success, they were operating near a precarious financial brink. Others who had regular day jobs and cultivated mussels on the side, although they worried somewhat about their leases and the investment in them, were more accepting of bad years as part of the learning process. These latter growers clearly appreciated the security of their primary occupation. Only a rather small and well established sub-group of those whose incomes came totally from mussel culture, felt that their businesses were secure; but even they constantly mused about market conditions, the possibility of a phycotoxin incident, or the uncertainties of coliform contamination and how such incidents might potentially impact on their incomes. It may be, however, that these ruminations are simply part and parcel of any farming operation -- terrestrial or marine -- whose success or failure is not infrequently tied to intangibles such as weather, market conditions or vagaries of biological events.

BIOLOGICAL CONCERNS

As can be seen in Figure 3, predation was the most common concern raised but attempts at controlling predation by both ducks and starfish have had limited success. For ducks (usually eiders or scoters), the use of a shotgun by someone patrolling the lease in an outboard boat, or automatic noise-makers of various kinds have been tried, but to limited effect. To date the most promising tactic seems to be management-based through careful timing of socking, so that on-site mussels are of a sufficient size during regular migration periods that ducks will be unable to eat them. There are now reports of duck predation from culture areas previously free from such intrusions which suggest that these opportunistic feeders have realized the connection between copious numbers of floats, typical of mussel leases, and food. Perhaps for this reason alone (see below) there is an argument for deploying backlines at depth in those areas where that is possible, and leaving an absolute minimum number of floats at the surface. Starfish control has had some success by the use of hydrated lime (MacKinnon *et al.* 1993) in which collectors containing mussel spat are dipped. The technique was devised in PEI where, because of heavy starfish infestations at some sites, successful mussel collecting would have been next to impossible. The use of this technique in Nova Scotia was not reported during the survey and, given the specific concerns some growers had about starfish, one wonders why not. The current procedure of hand-picking starfish from each collector, or sock, is both tedious and time-consuming and most businesses do not have the staff to adequately perform the task. There is definite need for more effective intervention, perhaps beginning with alerting local growers to the existing methodology for control.

Next in importance were phycotoxins, and mussel drop-off (loss of mussels due to weak byssus attachments), each rating two-thirds of the businesses interviewed (Figure 3). Given the local attention paid to phycotoxins following the 1987 domoic acid crisis, that level of concern is not surprising. However, High producers were more likely to be concerned about phycotoxins than Low producers and a "suggestive" relationship between phycotoxins and average experience was noted (Table 3). The importance of phycotoxins to government and industry is also reflected in current, ongoing programs that deal either directly or indirectly with the subject and is discussed below.

The generally high level of concern for mussel drop-off is also understandable if one considers the loss in product every time a backline is moved, or a suspended sock slightly jostled causing, under as yet undefined circumstances, large clumps of mussels to become dislodged. This is a loss in profit clearly obvious to any grower irrespective of experience. Some growers control mussel drop-off by lowering mussel socks to the bottom for a short while, thus allowing crabs to clamber over them, and this somehow causes mussels to considerably strengthen their byssus attachments. While it has not been determined why there is an apparent weakening of the byssus in the first place, Kautsky (1981) reports "loosely attached" mussels in Baltic Sea areas with limited natural predation, suggesting a relationship between predator absence and weak attachments. In addition, the occasional grower with sufficient lease depth, deploys mussel socks well below the surface. This has the combined effects of reducing fouling, retarding drop-off because the floats are sub-surface thus not being jostled by waves, and making the presence of mussels less obvious to occasional flights of ducks. For those growers who can do so, sub-surface deployment of mussel socks should be considered for all the above reasons not to mention for the significant production gains that can be also be realized (Mallet and Carver 1989).

The presence of *M. trossulus* with *M. edulis* (species mix) despite its overall fourth place rating among the biological concerns, has a very high profile among the top growers (70% concerned). The former are more likely to suffer shell breakage, have lower growth, and generally lower meat weight (Freeman *et al.* 1994) and a much lower economic value (Mallet and Carver 1995) than *M. edulis*. Many of the top growers would like either to selectively collect *M. edulis* (if they have both species), or somehow secure a steady supply of *M. edulis* seed from elsewhere. This is true in spite of the fact that importation would add to operating expenses and could raise questions about inadvertent introductions of unwanted organisms to a grow-out site (Bower and Figueras 1989). Two growers, who for several years have observed the presence of both species in their collections, believe that the proportion of *M. trossulus* to *M. edulis* has risen on their leases and wonder if the process of cultivation itself has not contributed to the rise by perhaps providing a more ideal location for *M. trossulus* in shallower, off-bottom depths. This possibility would be consistent with other anecdotal observations that *M. trossulus* prefers reduced salinity. Such are observations by biologists and growers alike who report high numbers of this species in the Bras d'Or Lakes of Cape Breton Island.

There was no statistically suggestive difference in concern between High and Low producers about marine fouling, an obvious and rather universal problem. High producers were, however, more concerned about off flavours (Table 3). There appears to be a clear recognition

amongst the High producers that their product, if tainted -- no matter how naturally and however temporarily -- might dampen consumer interest; some producers interviewed were simply unaware that the problem could develop and, indeed, the problem may well be site specific. Certain experienced growers, understanding that the phenomenon occurs around the time of the spring freshet, taste test their product and refrain from harvesting while off flavours persist.

In this review, spatfall prediction is rated low as a concern but might be rated higher if more pure *M. edulis* populations were being exploited as seed stock. Summer mortality and carrying capacity, both recognized as problems in the PEI mussel industry, have yet to be noticed in Nova Scotia to any major degree. A minor incidence in Nova Scotia of "red" mussels, presumed to be caused by the protozoan *Mesodinium rubrum*, (Carver *et al.* 1996), which grossly discoloured mussel meats rendering them unappetizing and unsaleable, is not widely known and has not recurred recently, hence its lowest rating in this review.

DFO's RÔLE?

Given the fact that more than half of all the producers were concerned about each of the top four biological factors in the list, there appears to be scope here for investigation by DFO. Because of the potentially negative influence on production of some of these concerns, corrective efforts have already been attempted or instituted by the growers themselves or by investigative groups, including DFO.

World-wide incidence of phycotoxic incidents is apparently rising (Shumway 1989). Because of obvious consumer health consequences, phycotoxins, compared with the other biological concerns, have been paid the greatest attention with regular testing being done by DFO's Fish Inspection Branch to detect the presence of these poisons in meats of wild stock. Nonetheless, there appears to be disagreement between mussel growers and Inspection when it comes to sampling. Growers would like samples to be taken at the processing end-of-line, or at least from the leases themselves, whereas current Fish Inspection protocol specifies shoreline sites for sampling and these are often at considerable distances from mussel leases and thus subject to quite different environmental influences. Part of industry's reason for wanting a change is its contention that by far the greater proportion of mussels consumed in the province today is that produced from aquaculture as opposed to that privately harvested. Two programs, both supported by the Canada-Nova Scotia Co-operative Agreement on Economic Diversification and with additional input from industry, exist to assist growers in the monitoring of these toxins. One program, with support from the Aquaculture Association of Nova Scotia, is the Phytoplankton Monitoring Program conducted by a private company. Its purpose is to serve as an early-warning mechanism for the detection of toxic phytoplankton at specific aquaculture sites in the province. The second, administered through the Provincial Department of Fisheries and currently conducted in DFO's Halifax Fish Inspection Laboratory, is the Scallop Toxin Monitoring Program which performs toxin tests on aquaculturally-produced scallops destined for the whole animal market. In addition to the above, DFO's Science Branch has been conducting a long-term phytoplankton monitoring program (Keizer *et al.* 1996) and while not specifically established to identify dangerous species, the program nonetheless has the potential of being an additional source of information on the occurrence of toxin-producing organisms.

With regard to the mixed species (*M. trossulus*) problem, there are several possibilities for investigation. One is to consider the approach taken in Washington State where the west coast sub-species of *M. trossulus* predominates, and where there is hatchery production of *M. galloprovincialis* by one of the major shellfish companies operating there. It may, however, be some time before hatchery production of *M. edulis* for Nova Scotian growers is seriously considered. Until that occurs, it remains an option to import *M. edulis* seed from elsewhere, but care should be taken to avoid importing disease organisms (Bower and Figueras, 1989) and cysts or motile cells of toxin producers (Shumway, 1989). In addition, studies have been underway for the last two years at Halifax's Dalhousie University Aquatron Tower Tank where larval cultures of each species have been reared in 8 m deep mesocosms and the diel migrations and settlement preferences of the two species monitored under controlled circumstances. Data from these experiments are now being analysed. While there is a vast difference between these mesocosms and the open sea, the Dalhousie Tower Tank is nonetheless an unique facility where insight into possible differences in species behaviour of the larvae may be made. If significant differences are found in, say, depth of settlement or in post-settlement positioning by depth, then there may be husbandry techniques applicable by those growers having both species on site and who would prefer to collect *M. edulis* rather than *M. trossulus*.

Predation in general represents significant difficulties, yet with regard to ducks there does not seem to be a simple answer. Some sobering reports indicate the ability of flocks of eiders to completely, and quickly, wipe out a season's collection of spat. Given the presence, off Nova Scotia's Eastern Shore, of islands set aside for eider protection, growers in this region are particularly concerned. With these conflicting interests, there seems little DFO can do for growers except to relay new information on the latest deterrent devices or techniques; for example, on the use of judicious timing of socking so that during the time these birds are normally present, mussels are too large for ducks to consume. Starfish control may not be as daunting a problem given the success of PEI efforts to thwart regular and heavy infestations at certain sites by using baths of hydrated lime into which collectors, with spat attached, are dipped (MacKinnon, *et al.*, 1993). What is evidently required is communication amongst growers, or from DFO to growers, so that the re-invention of existing methodologies is avoided with concomitant saving of time, energy and money.

The apparent connection between predation and mussel drop-off is one already noted by some growers and requires further examination. However, that some growers can improve the holding capacity of their mussels by temporarily exposing mature stocks to benthic predators is of little benefit on sites where great depths prohibit lowering of the socks to the bottom. There is a requirement to understand the relationship between byssal strength and exposure to predators and to investigate methods to arrest, or at least to retard, byssus weakening. Finally, connected with drop-off and predation, may be the issue of mussel species mix. Given the relatively weaker constitution of *M. trossulus* versus *M. edulis*, it could be that in purely benthic communities *M. trossulus* may be the more vulnerable to starfish predation. In addition to anecdotal (and unproven) evidence that *M. trossulus* prefers shallower depths, it has been suggested that lack of predation on mussels of mixed species held in these upper water layers

may have permitted what has been observed to be a proliferation of *M. trossulus* which otherwise would have been kept in check.

GROWER'S ATTITUDES

Some growers, appear to interpret their work as a partnership with the marine environment, and with others working in the area, for profit or personal gain. Others seem to have little appreciation for such relationships and adopt instead a "indiscriminately aggressive" attitude towards sales and husbandry. This occasionally manifests itself as less than scrupulous attention to product quality. In such cases there seems to be little understanding of the need for the system of checks and balances required in any food industry and giving rise, for example, to resistance to the monitoring for bacteria and phycotoxins. Though far from universal among marginal growers, one meets an occasional, hostile individual who defiles the work area, resists testing, and produces a low quality product; all to the embarrassment of fellow growers. Given the diverse attitudes among growers, it is not surprising that product inspectors and other administrators are sometimes regarded as being officious nuisances and obstacles to profit.

Government agencies have the important rôle of reminding people in the industry, especially newcomers, of the reasons for controls such as leasing, licensing, as well as bacterial and phycotoxin testing. Without foregoing their right to intervene and interdict unsafe practices, agencies should help and encourage healthy, long-term viable, and profitable operations. Courses in aquaculture given by both the provincial government, and by private companies currently operating through federal funding of Regional Industrial Training Committees, must emphasize "partnership with the environment and others" in their teaching if stability and security in the industry is ever to be realized.

BUREAUCRACY

Significant improvement in government administrative procedures is necessary before industry will have confidence in the rôle of government as guardians of the industry's interests. Growers were virtually unanimous in their disappointment with administration of shellfish aquaculture in Nova Scotia and gave clear indications that upgrading of the lease application system, in particular, was not only desirable but urgently needed. The most vociferous complaints were registered by those who attempted to enter the business after March, 1986 when the memorandum of understanding between Nova Scotia and the federal government was signed allowing the province to assume responsibility for aquaculture. Some went so far as to suggest that "certain officials have a hidden agenda to stop attempts to allow aquaculture -- shellfish or finfish -- to develop". Although the very poor comparison that Nova Scotia landings show against those of PEI (Figure 1) might lend some credence to the concept of a negative hidden agenda, more likely there has been a lack of enthusiasm by government agencies, and maybe even some inter-agency rivalries inhibiting development.

Even those who had been in the business for more than a decade grumbled about the way leasing was being administered. As one example, a grower, having applied for a lease extension, discovered after a year that his application had been misplaced so he immediately re-applied. A

further year later the grower was informed that his second application had also been misplaced. Telephoned messages left with the various controlling agencies are reportedly not always answered and more frequently than not when there is a reply, it arrives after a long delay. The end result of this response is frustration on the part of the applicant and disillusionment with government's involvement in aquaculture.

The recounting of these opinions and incidents is done to illustrate the magnitude of the problem which is probably exacerbated by the severe, ongoing cutbacks occurring at all levels of government. Nonetheless, it is clear that if mussel aquaculture is to grow in this province, and become competitive with other jurisdictions, administrative improvements must be made.

RECOMMENDATIONS

1. DFO should begin, or continue, research into the following biological aspects of mussel culture:

a) assist in reducing effects of duck and starfish predation by communicating up-to-date information to those growers requiring it.

b) comparative larval and post-settlement behaviour of *M. edulis* and *M. trossulus* with a view to establishing whether there exists any potentially exploitable behavioural characteristics that would enable growers to selectively collect the more commercially desirable of the two species.

c) explore the possibility of using hatcheries to circumvent mixed-species problems, to generally improve production and to reduce any requirement for transplantation of seed with its attendant risks.

d) natural microhabitat study of the two species, perhaps including predation selectivity by starfish, to help understand reported changes in proportions of mixed-species populations on some leases and the possible relationship between reduced predation and mussel drop-off.

e) search for sites that would be acceptable as mussel seed sources for growers wishing to import pure *M. edulis* stock.

f) continue its long-term program of monitoring phytoplankton at key points around the province and where possible maintain, or encourage, surveillance for potentially toxic species and for the presence of toxic shellfish from aquacultural sites.

g) test for conditions or agents that may cause, or contribute towards, onset of mussel "off flavours" in affected bays.

h) investigate the algae-like foulants that appear in profusion from time to time on submerged gear in mussel leases.

2. DFO should encourage deployment of more resources to Coast Guard's duties associated with assessing lease-site acceptability.

3. It might help develop the industry if someone were appointed by the provincial government to be an information source for people in the industry, and a trouble-shooter to help overcome

problems with the bureaucracy. Such a person would need strong support from senior staff and the political head of the appropriate department.

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TABLES

Table 2. Production (pounds) as a function of hectares leased; distribution of 21 businesses declaring landings in 1994.

Hectares Leased	Range Of Actual Production (Pounds) In 1994				
	0+	10,000+	50,000+	100,000+	200,000+
100+	0	0	1	0	0
50+	1	0	2	0	0
10+	1	4	3	0	1
0+	3	4	1	0	0

Tables 4 a & b. Correlations, variances and covariances of factors potentially related to production in 1994 among all mussel producing businesses examined (top) and among those exclusive of non-producers (bottom). Correlation coefficients are above diagonal; variances on the diagonal (boldface print) and covariances below the diagonal.

Correlations, Variances and Covariances Where N = 26 Businesses (r ≥ 0.388)						
	No. Full-Time Employees (NFT)	Total Years Experience (TYE)	Total Months Part-Time (TM)	Hectares In Production (HEC)	Production (lbs) In 1994 (PROD)	Est'd Production Potential (EPROD)
(NFT)	**1.56**	0.57 *	0.33	0.36	0.50 *	0.11
(TYE)	9.34	**172.98**	0.64 *	0.22	0.86 *	0.39
(TM)	6.54	132.01	**247.07**	0.20	0.76 *	0.41 *
(HEC)	12.25	78.76	87.09	**731.54**	0.19	0.57 *
(PROD)	32.73	591.52	619.23	264.47	**2718.05**	0.43 *
(EPROD)	50.56	1796.16	2287.83	5421.37	7855.09	**125262.82**

Correlations, Variances and Covariances Where N = 21 Businesses (r ≥ 0.433)						
	No. Full-Time Employees (NFT)	Total Years Experience (TYE)	Total Months Part-Time (TM)	Hectares In Production (HEC)	Production (lbs) In 1994 (PROD)	Est'd Production Potential (EPROD)
(NFT)	**1.68**	0.64 *	0.33	0.35	0.53 *	0.09
(TYE)	10.65	**167.48**	0.59 *	0.18	0.85 *	0.29
(TM)	7.01	127.50	**276.90**	0.18	0.73 *	0.35
(HEC)	13.16	67.92	84.50	**841.40**	0.14	0.56 *
(PROD)	37.09	601.00	661.79	222.13	**2964.86**	0.35
(EPROD)	43.77	1384.69	2162.32	6004.75	7135.04	**138035.71**

* = significant correlation coefficients

FIGURES

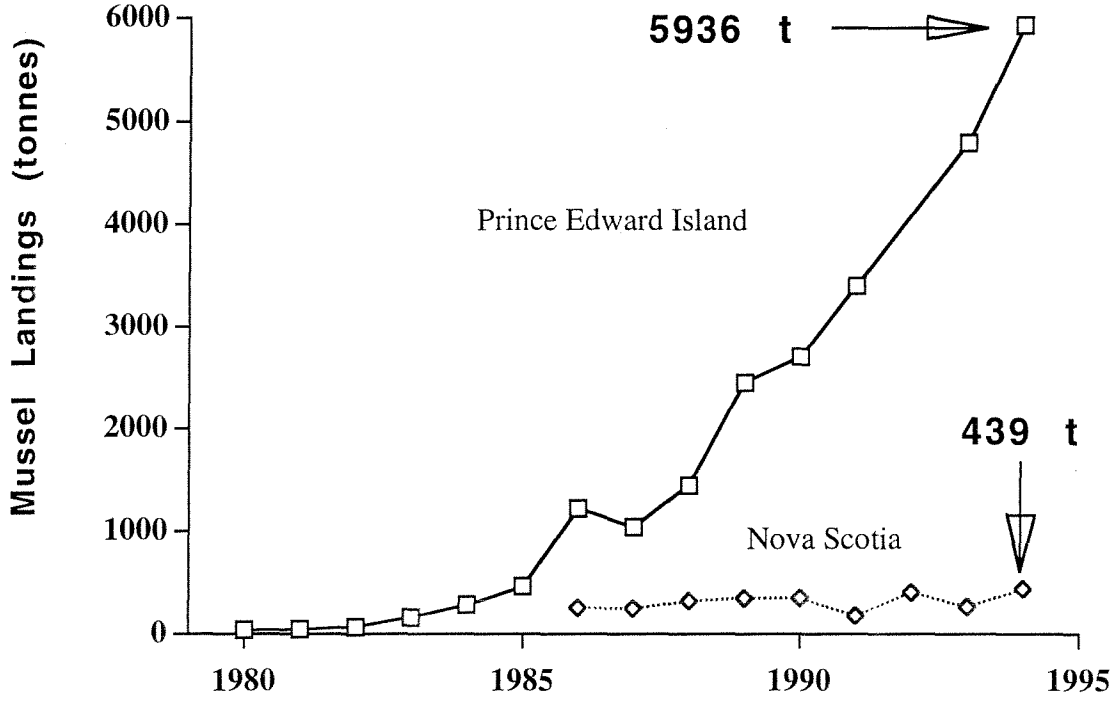

Figure 1. Mussel landings from aquaculture: Nova Scotia and Prince Edward Island.

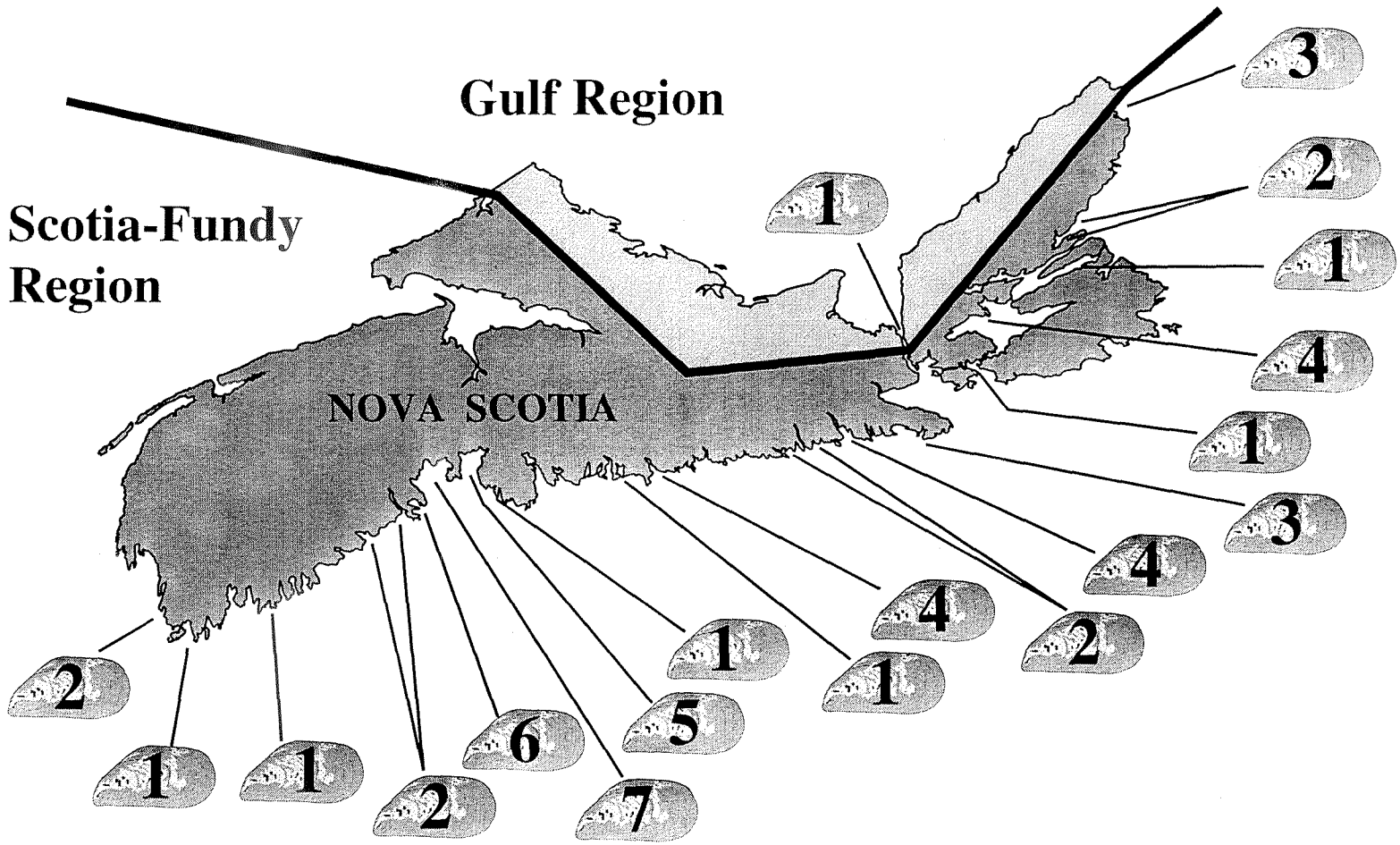

Figure 2. Distribution of 51 leases belonging to all the mussel aquaculture businesses interviewed. Numbered icons with pointers indicate number of leases by approximate location.

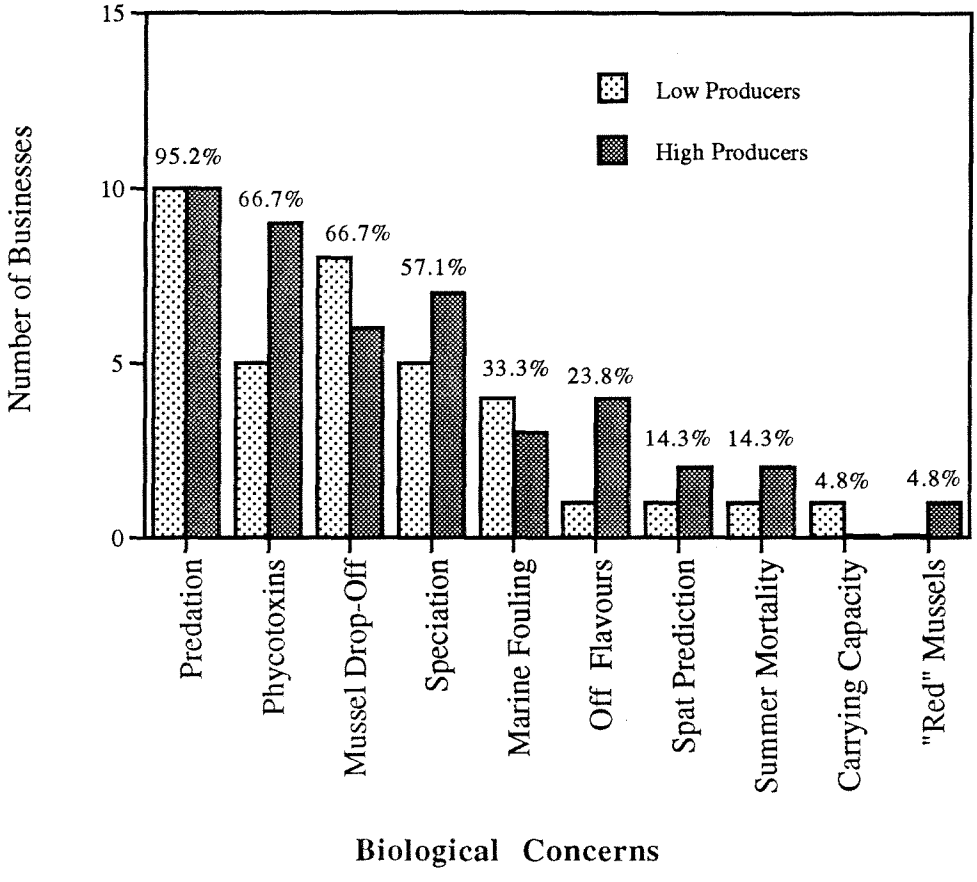

Figure 3. Rated biological concerns between High and Low Producers, 21 businesses excluding non-producers. Percentages of businesses concerned for combined Low and High Producers above double bars.

APPENDIX

APPENDIX

Survey Protocols For Shellfish Growing Sites (p. 1 of 4)

Interview Date:_____ Tape Ref. No.:____ Name Ref:_____

Business Information:

Business Name_____
Business Address_____
Lease Location(s) and No(s)_____
Processing Site_____
Owner / Manager's Name_____Lease Owner's Name_____
Home Address_____
_____
Business Tel. No.:_____Home Tel. No._____FAX No._____

People Working Lease(s), And Experience:

1._____
2._____
3._____
4._____
5._____

Is shellfish culture the primary or secondary business?_____

Shellfish Grown: Mussels ___; Bay Scallops ___; Sea Scallops ___; Oysters: European____, American____; Quahaugs ___; Other_____

Lease Site Information:

Has site been studied by phys., chem. or biol. oceanographers?_____
Lease area(s)_____Has site been described in literature_____
Has site been used previously_____For what_____
Known domestic or industrial pollution sources in vicinity_How close_____
Any history of phycotoxicity_____
Fresh water inputs to lease area_____
Exposure to wind, tide, drift ice_____
Water depths across lease_____Bottom characteristics_____
Other leases adjacent_____
Processing facilities_____
Anything else noteworthy_____
Sketch of lease on reverse side_____

Mussel Gear Deployment, Husbandry, Processing, Markets:

Monoblock_____Standard anchors and backlines_____
Surface backlines_____Backlines at depth_____
Total backlines (lengths)_____
Mussel sock length_____Sock spacing_____Seed per foot_____
Collector type, dimensions_____Collectors set this year_____
No. socks from last year's set _____After grading and re-socking?_____
Spat source: On site _____Imported_____Two species *Mytilus*?_____
Average live weight yield per sock at harvest_____Age at harvest_____
On site processing_____Or processed by _____
Markets are_____
Leases active?_____Other (see also p 2)_____

Map Sketches

Interview Date:_____ Tape Ref. No.:_____ Name Ref:_____

Sea Scallop Gear, Processing, Husbandry, Markets:

Seed collection sites_____Onion sack, monofilament collectors _____
No. of backlines (lengths)_____
Lantern nets_____Pearl nets_____Other?_____
Net string spacing_____Nets per string_____Total nets_____
Initial seed density / net_____Height, age at thinning_____
Est'd numbers or cages now deployed in each yr. class_____
_____
Est'd mortality at time of thinning_____Height, age at harvest_____
Est'd mortality by harvest_____Frequency of cage cleaning_____
On site processing_____Processing elsewhere_____
Markets are_____
Other_____
_____
_____

Bay scallop Gear, Processing, Husbandry, Markets:

Seed source(s)_____
No. of backlines, (lengths)_____
Lantern nets_____Pearl nets_____Other?_____
Net string spacing_____Nets per string_____Total nets_____
Initial seed density / net_____Height, age at thinning_____
Est'd mortality, time of thinning_____Height, age at harvest_____
Est'd numbers or cages deployed now_____
Est'd mortality by harvest_____Frequency of cage cleaning_____
On site processing_____Processing elsewhere_____
Markets are_____
Other_____
_____

Oyster Gear, Lease, For European / American oyster

Lease dimensions and locations_____
_____
Collector type_____Bottom culture_____Cage rearing_____
Cage type_____
Est'd year classes and numbers on lease now_____
_____
_____
_____
_____
_____

Other Species Considered, Or Being Grown, What Numbers:

_____
_____
_____
_____
_____
_____

Rating of Principal Concerns - Mussels:

Phycotoxins Species mix Vandalism
Marketing 2ndary product devel. Financing
Predation Pollution Boat traffic
Carrying capacity Peppery flavour "Red" mussels
Spat settlement prediction Mussel drop-off
Fouling on gear Summer mortality
Other

Processing Machinery Used: