THE LIMITATIONS IMPOSED BY WINTER ICE ON POTENTIAL GROW-OUT SITES FOR THE SURF CLAM *SPISULA SOLIDISSIMA*

by
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Abstract

The surf clam *Spisula solidissima,* whish is widely distributed in many regions of South-eastern New Brunswick, displays commercial potential for aquaculture. While progress has been made on the hatchery side, information on the animal's ecology, so vital for developing appropriate grow-out techniques, is still lacking to a large extent. One aspect, which is in many ways unique for our region, and which has not received any attention, is that related to the presence and possible effects of winter ice. The current project proposes to examine the short and long-term effects of ice on the grow-out culture of *Spisula solidissima* in the Richibucto region.

Ice thickness, as well as physical and biological measurements were taken during the ice-covered season in two sites. The foot of the ice cover reached 1.2 mat the mean high water mark. Ice thickness varied between 24 and 200 cm. The ice-cover was never observed to touch bottom in the sheltered site, but touched bottom in the exposed site. Sieve analyses in both sites showed a shift towards slightly coarser material in the spring than in the fall.

Salinity varied between 19 and 28 PPT and dissolved oxygen concentration were greater in the exposed sites than in the sheltered site. The sheltered site is more prodoctive than the exposed site, as measured by chlorophyll a. Seston measurements showed that the inorganic fraction accounted for the larger portion of suspended matter. The study showed that both sites would be suitable for surf calm grow-out, but ice dragging on the bottom at site A could increase mortality.

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INTRODUCTION

The Richibucto Estuary is located in the Southern Gulf of St-Lawrence. The estuary drains 1089 km^2 of relatively low lands (mean elevation 45.5 m). The four larger rivers feeding this system are the St-Nicholas in the southern portion of the estuary, the Richibucto in the center and the Little Aldouane and St-Charles rivers in the Northwest Arm (Figure 1). All three rivers open up into a shallow bay, with depth seldom exceeding 1 m, except for a navigation channel where depths sometimes exceed 12 m (St-Hilaire et al., 1996). The bay covers an area of 35.4 km^2 and the mean tidal range is 0.7 m while the maximum range is 1.1 m (Petrie et al., 1993).

A dune system (South and North dunes) separates the bay from the Northumberland Strait. Dunes are generally very dynamic, with continual changes in configuration and significant breaching and infilling. Over the last 50 years, at least 5 important breaches of the Richibucto-Kouchibouguac dune systems have occurred (McCann and Bryant, 1973). Littoral drift and the construction of protection walls in the Richibucto Gully are important factors in influencing the dynamics of erosion and accretion around the dune (Dagneau, 1996). On either side of the dunes were areas, known in the past to house high densities of bar clams. Today, natural population are no longer evident at these sites, even though occasional groupings of clam shells, are recovered.

The question of whether the clams were decimated by excessive harvesting or by environmental conditions was never fully answered. What is however, pertinent, is that certain areas display water properties that may make them conducive for clam culture (SEnPAq Consultants, 1989), specific regions that may provide viable commercial opportunities.

A potentially serious adverse environmental condition in our area, is the long winter season during which an ice cover forms in the bay on both sides of the dune system. The effect of the presence and the dynamics of the ice cover on molluscs in general, and of course on potentially harvestable clams, have not been examined. Even if all conditions for site (productivity, water quality, temperature, salinity, etc.) suitability are met, if ice formation and its behaviour threaten the animal's survival, commercial aquaculture would have to be abandoned, at least during the winter season.

Ice conditions in the Littoral zone of the South Richibucto dune have previously been studied during the winter of 1973-74 and were summarized by Owens (1974). Ice began to form on the outer side of the dune, near the mean high water mark early in January. One month later, the freeze-up was complete and the ice cover could be separated into three zones:

- (i) the ice foot which is the narrow bump formed at the high water mark and is always grounded;
- (ii) the hinge which is the part that is lifted from the beach at high tide
- (iii) the sea ice.

Small amounts of sediments were incorporated with the ice through freezing in the hinge zone. This was facilitated by wind transportation and wave action. Open water conditions were observed from mid March to mid April (Owens, 1974).

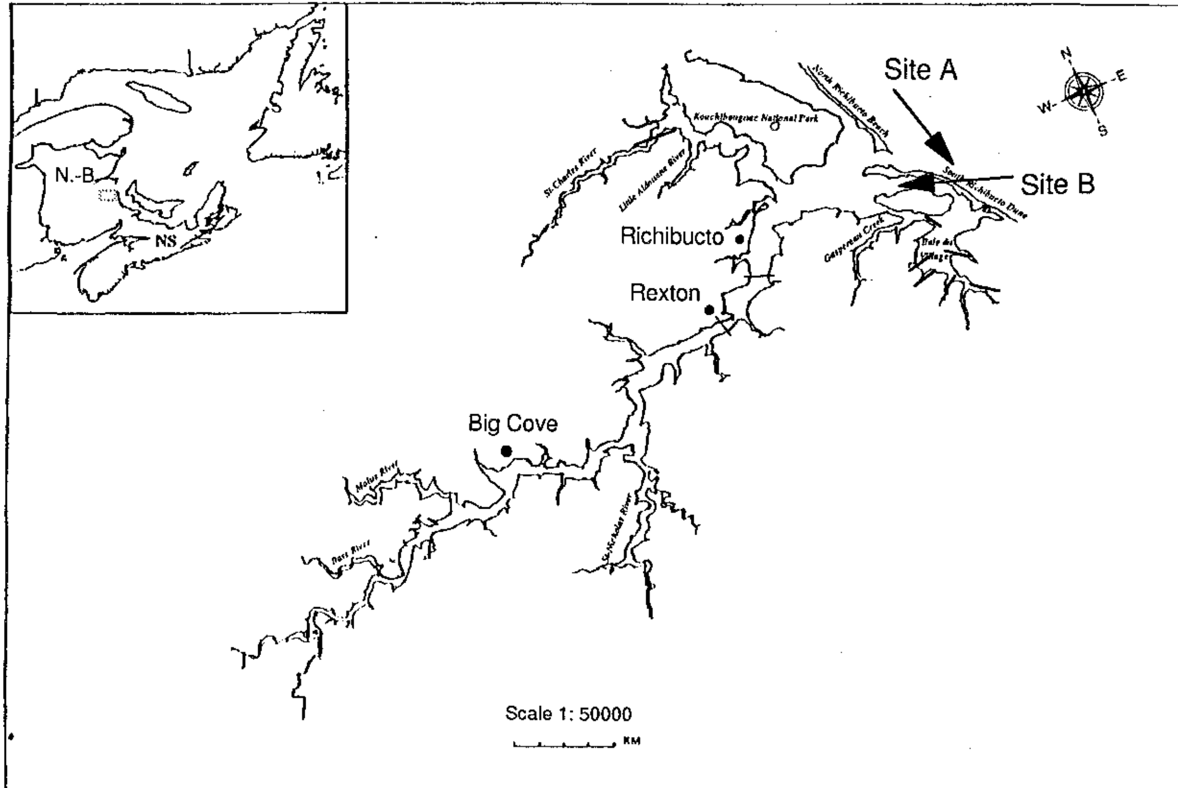


Figure 1. Map of the Richibucto Estuary and site locations.

The objective of this project is to identify an appropriate site for the culture of the surf clam *Spisula solidissima* in the Richibucto area, and acquire a better understanding for predicting the impact of ice behaviour on site selection.

METHODS

A three-year (1995-1998), 3-phase project was proposed whereby two sites, each believed to display potential for the culture of the surf clam *Spisula solidissima*, one on the east (exposed) side of the northern Richibucto sand dune, the other on the west (closed side) of the dune (see figure 1) were chosen.

Regular surveys were done from 27 November 95 (before ice cover formation) to 6 May 95, after ice-out (Table 1). Two sites were visited: Site A, on the outer side of the South Richibucto Dune and Site B on the inner side (Figure 1). An intensive survey was undertaken on 29 February 96, to evaluate the variability of the conditions with tide.

Table 1. Dates of sampling and tidal information.

Date	Tide	Measurements
27-11-95	neap flood	Site selection
11-12-95	neap flood	Substrate sample
20-12-95	spring flood	Ice Thickness, Water Depth, Sal. DO,Seston, Chla
8-01-96	spring ebb	Ice Thickness, Water Depth, Sal. DO,Seston, Chla
23-01-96	neap ebb	Ice Thickness, Water Depth, Sal. DO,Seston, Chla
9-02-96	neap ebb	Ice Thickness, Water Depth, Sal. DO,Seston, Chla
29-02-96	spring flood	Ice Thickness, Water Depth, Sal. DO,Seston, Chla (intensive sampling)
1-04-96	neap flood	Ice Thickness, Water Depth, Sal. DO,Seston, Chla
6-05-96	spring ebb	Substrate, DO, Chla, Sal.

Do : Dissolved Oxygen
Chla: Chlorophyll A
Sal: Salinity

Physico-chemical measurements

Measurements taken at each site included ice thickness and water depth, measured in cm ($\pm$ 0.1). Salinity measurements were obtained by using a YSI salinity meter ($\pm$ 0.2 PPT). The YSI Meter was also equipped with a dissolved oxygen probe. Concentrations were measured *in situ* ($\pm$ 0.1 mg l^{-1}).

A *McNeil-type* sampler (Bourgeois, 1995) was used to obtain grab samples of the top 20 cm of sediments in order to perform a sieve analysis at each site. One sample was taken at sites A and B on 11 December 95, before the formation of the ice cover. A second sample was removed from both sites on 6 May 1996, after the ice melted.

Biological measurements

Water samples were obtained from each of the two sites (at locations A2 and B2) during all sampling periods. Standard methods were employed, based on filtration, drying and incineration techniques, to determine inorganic, organic and total (integrated) seston composition.

Water samples were collected and standard spectrophotometric techniques were employed to measure productivity. Even though chlorophyll represents the most recurrent method for productivity measurement, the presence of chlorophyll b, c as well as carotene measurements were likewise recorded according to the methods described by Stickland and Parsons (1972).

RESULTS

Physico-chemical data

On site A, The ice build-up began between 27 November and 11 December 95. On December 11, the foot of the ice cover, as described by Owens (1974) had already risen to 1.2 m at the mean high water mark and was built up by frazil-ice accumulation from crashing waves. The hinge was not evident, but *pancake* ice was observed from a water depth of 2 m, extending offshore over a distance of 100 m. Frazil ice thickness exceeded 1 m near shore.

The hinge of the ice cover formed on site A between 11 and 20 December 95. Ice thickness at site A Varied between 24 cm and 175 cm when present. There was great variation in thickness form one location to the other at site A.

The ice cover was already in contact with the ice bottom at numerous sites, extending even beyond the hinge. Open water conditions beyond the hinge were observed on 8 January, 29 February and 1 April 96. Frazil ice was present from 20 December to 29 February, with a thickness varying between 70 cm and 200 cm (Table 3).

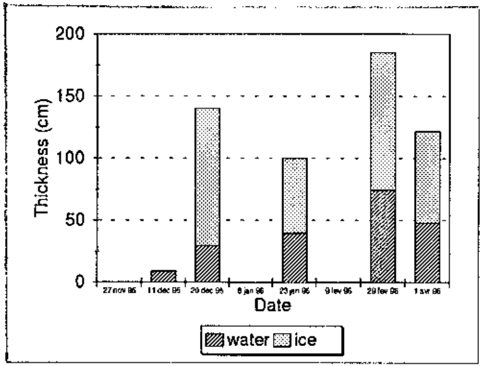


Figure 2. Ice and water depths, Site B1

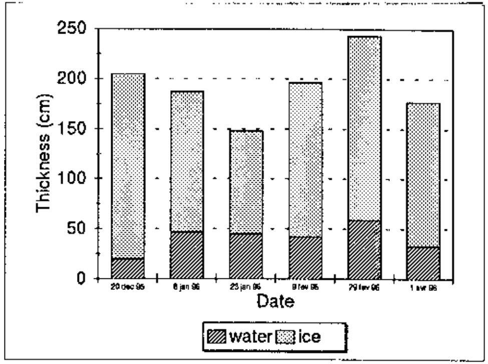


Figure 3. Ice and water depths, Site B2

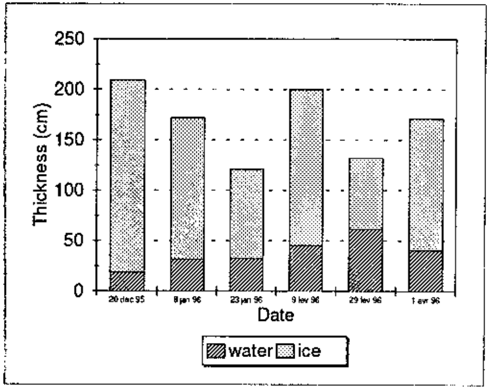


Figure 4. Ice and water depths, Site B3

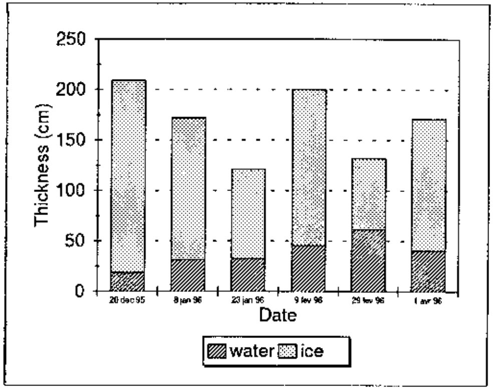


Figure 5. Ice and water depths, Site B4

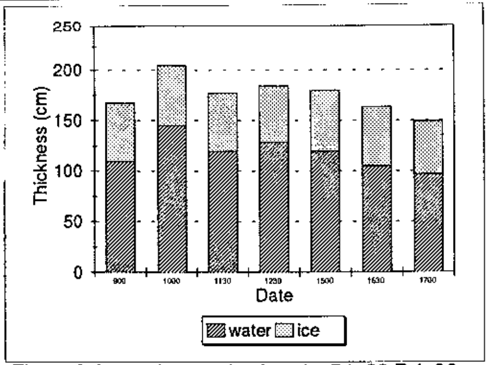


Figure 6. Ice and water depths, site B1, 29 Feb 96

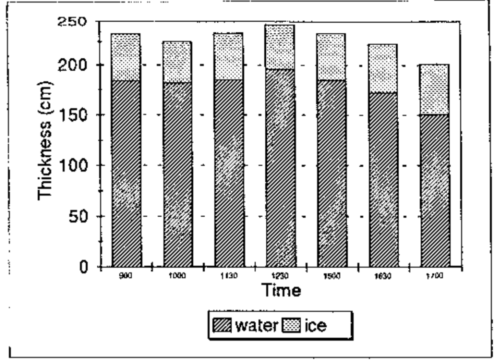


Figure 7. Ice and water depths, site B2, 29 Feb 96

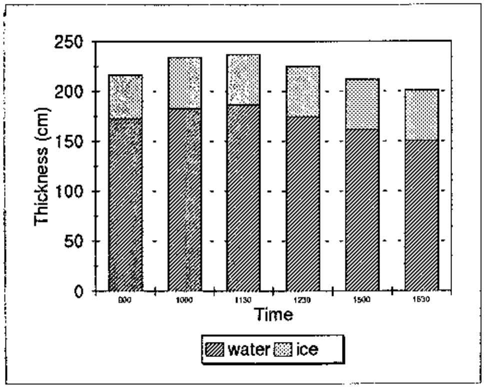


Figure 8. Ice and water depths, site B3, 29 Fev 96

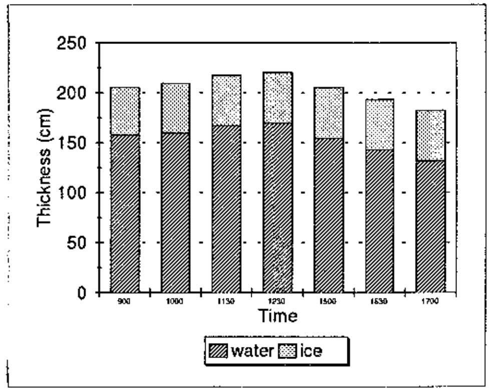


Figure 9. Ice and water depths, site B4, 29 Feb 96

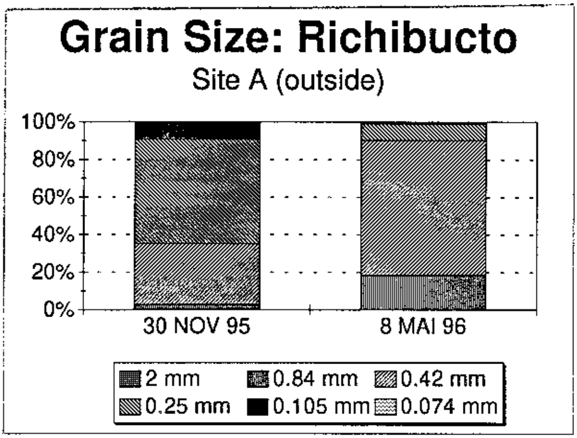


Figure 12. Sieve analysis, Site A.

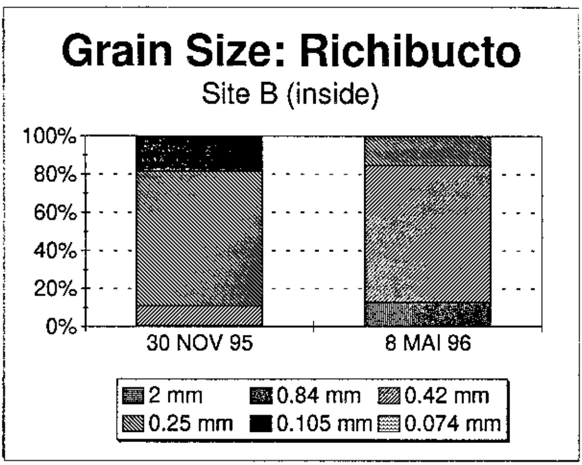


Figure 13. Sieve analysis, Site B

Table 3. Ice conditions on the outer side of the South Richibucto Dune (Site A) during the winter 95-96.

Date	Ice Thickness (cm)	Water Depth (cm)	Frazil Ice (cm)
20 Dec	--	200	100
8 Jab	24	240	--
23 Jab	--	200	100
9 Feb	80	188	132
29 Feb	175	148	70
1 April	--	156	--

On site B (inside), the ice cover was already formed on 11 December 95, with ice thickness varying between 24 and 30 cm (Figures 2 to 5). The ice was thicker near shore. The thickness of the ice generally increased from 11 December 1995 to 29 cm February 1996. Average Ice thickness by stations varied between 38.3 (station B3; sad. de. = 13.3)) and 42 (station B4; sad. de. = 10.92). Station B1 (ag. 40.4, sad de. 21.6) showed greater variation in ice thickness because of the low value measured during the ice formation process (9 cm on 11 Dec 95).

Results from the intensive sampling show relatively constant ice thickness throughout the day (Figures 6 to 9). In some instances such as at site B1 (not showing), fluctuations in thickness were probably caused by slight variations in the exact location of measurement and perhaps, supercooling at the sample hole. The maximum tidal range measured at site B3 was 1.1 m on 29 February (Figure 8).

On the outer side of the Richibucto Dune (Site A), the ice thickness remained constant and relatively thin (average = 32 cm) on the hinge (Figure 10) while it varied between 99 and 175 cm beyond the hinge (Figure 11).

Sieve analyses (particle size) on both sides of the dune display little variability with particle size varying between 0.074 and 2 mm (silt, fine sand and sand according to Bourgeois et al., 1995). The bulk (more than 80%) of the sediment material can be classified as fine sand (0.25 and 0.42 mm). At site A (Figure 12), the fine sand is divided evenly between two grain size categories. There is a shift in the dominant grain size between 30 Nov and 8 May at sites A and B (Figures 12 and 13). Slightly coarser materials were dominant in the spring, which may be indicative of erosion by ice or flushing by the spring freshet.

Salinity measurements varied between 19 and 28 PPT - 14 and 24 on the outer side of the dune (Site A) and 15 and 24 PPT at site B, during the sampling period (Table 4). This is consistent with solenoids reported by Sephton (1984) for the distribution of surf clams In the Gulf of St. Lawrence. Solenoids could rise higher in the deeper parts of site B. The salinity meter was mal-functioning during the intensive sampling period on 29 February 96 and therefore no salinity data were available to describe the changes with flood and ebb.

Measured dissolved oxygen concentrations varied between 11.5 and 18.1 mg l^{-1} during the sampling period (Table 4). Averages were calculated for sites A and B4. Site A has a significantly ($t = 2.25$, $P < 0.05$) greater mean DO concentration (16. 74 mg l^{-1}) than site B4 (15.35 mg l^{-1}).

The DO measurements taken during the intensive sampling show an increase with time (Table 4). this is probably due to the fact that the sampling holes were kept open for a long period, thereby allowing increased contact between the water surface and the atmosphere.

Instantaneous current velocities and approximate directions were measured at sites A and B. Velocities varied between 0 and 0.4 $m.s^{-1}$. At site A, the current direction was generally parallel to shore, while at site B, the directions varied with the tidal stage, indicating the possibility of topographic steering in the bay (Table 4).

Biological Data

Seston values (Figure 14) display similar patterns for sites A (external) and B (internal). Total seston (ST), consisting of the inorganic (SI) and organic (SO) fractions, was particularly high (31.30 mg/L) (Figure 14) on 9 February 1996 at site B, with the inorganic component, making up as much as 21 mg/L. No significant differences in seston content was observed between the sites recorded at other times. It is, however, notable, that in all instances and for both sites, the inorganic fraction accounted for the greater part of the seston.

Chlorophyll a (CHLa) is the most commonly employed index used to measure water productivity, even though chlorophyll c (CHLC) is often employed as well. As for seston, consistent productivity fluctuation patterns (Figure 15) are noted for both sites. The present findings, do however suggest, that site B (internal) is considerably more productive than site A (Figure 15). This is especially evident on the 29th of February (Figure 16), when the chlorophyll a reading is 0.84mg/m^3 at high tide in the morning, dropping to levels of 0.205 at low tide in the afternoon (Figure 15).

Given the fact that water is sampled at identical times for both seston and chlorophyll analyses, it appears from the inverse correlation between productivity and seston, that the latter does not usually include phytoplankton as a significant portion of its composition (as determined by chlorophyll a readings).

Table 4. Oceanographic data.

Date		Site	Sal (PPT)	DO (mg l^{-1})	Current Speed (m s^{-1})	Direction
20 Dec 95		B2	19	15.0		
		B3	19	15.7		
		B4	19	15.7		
		A1	20	16.4		
8 Jan 96		B2	19	11.5		
		B3	24	13.6		
		B4	19	13.6		
		A1	20	16.5		
23 Jan 96		B1	19.5	17.4		
		B2	19.0	17.0		
		B3	21.0	18.1		
		B4	20.0	18.0		
		A1	21.0	13.2		
29 Feb 96	0900	B1	15.0	14.3	0.0	
		B2	21.0	13.8	0.0	
		B3	17.0	13.9	0.0	
		B4	18.0	14.4	0.8	NW
		A1	19.0	16.3	0.8	S
29 Feb 96	1000	B1	15.0	16.2	1.2	
		B		2.8	0.7	SE
		B3		13.4	0.7	S
		B4		12.5	0.7	NW
		A1		16.2	1.3	
29 Feb 96	1130	B1		14.6	0.6	S-SE
		B2		14.7	0.0	
		B3		15.3	0.5	SE
		B4		15.2	0.0	
		A1		17.5	1.5	W
29 Feb 96	1230	B1		15.5	0.0	
		B2		15.5	0.0	
		B3		15.1	0.0	
		B4		14.9	0.0	
		A1		18.5	0.7	E
29 Feb 96	1500	B1		15.8	0.0	
		B2		17.5	1.2	W-NW
		B3		15.2	0.7	W-NW
		B4		15.2	0.7	W-NW
		A		18.6	0.7	E
29 Feb 96	1630	B1		15.2	0.0	
		B2		15.4	1.0	W-NW
		B3		15.4	1.0	SE
		B4		16.2	0.5	SE
		A		17.9	--	
29 Feb 96	1730	B1		15.1	0.5	W-NW
		B2		15.5	1.2	SE
		B3		16.6	1.0	NE
		B4		16.4	0.5	
		A		19.0	0.5	
1 Apr 96		B1	14	14.8	--	
		B2	19	19.0		
		B3	21	17.8		
		B4	18	18.1		
		A	28	18.0		

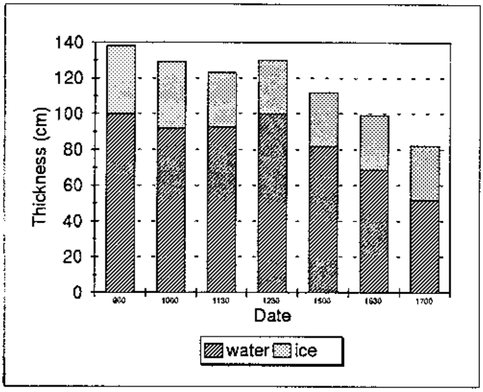


Figure 10. Ice and water depths, site A1, 29 Fev 96

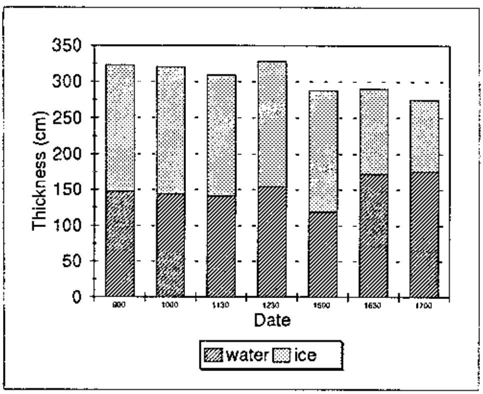
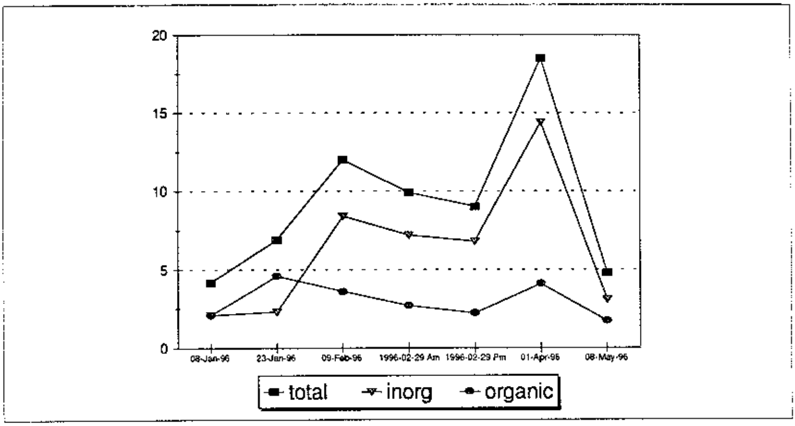


Figure 11. Ice and water depths, site A2, 29 Fev 96

Site A



Site B

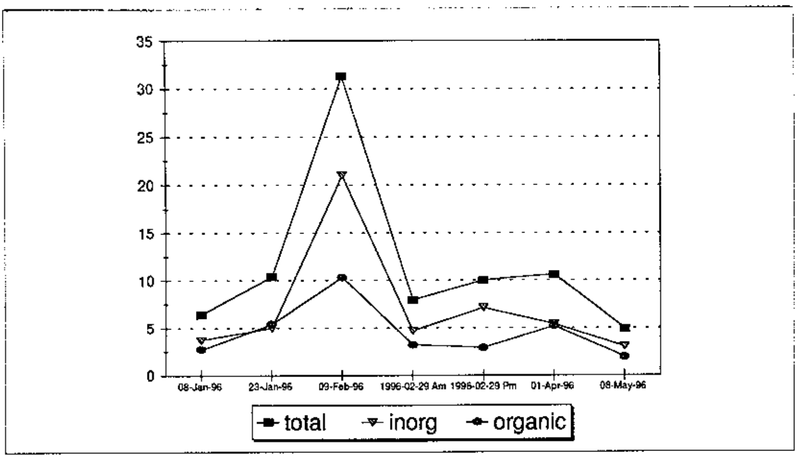
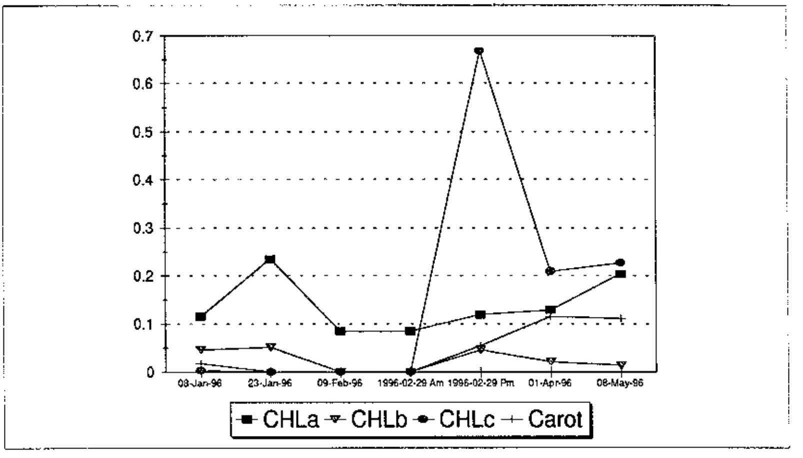


Figure 14. Seston concentrations at sites A and B, Richibucto.

Site A



Site B

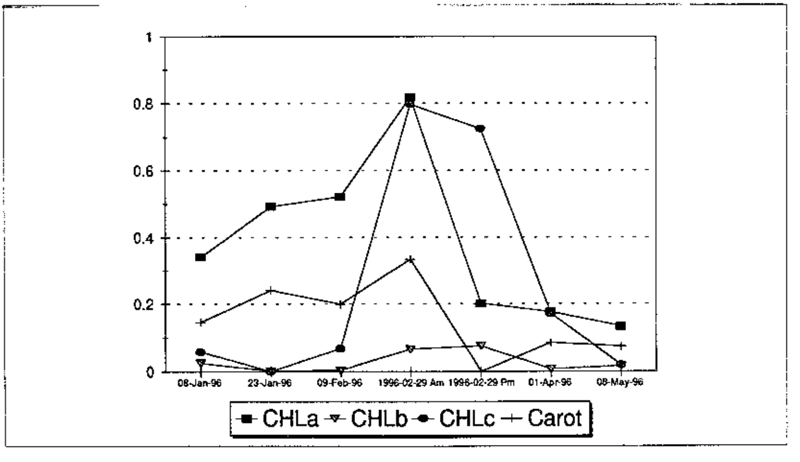


Figure 15. Chlorophyll Measurements at sites A and B, Richibucto.

DISCUSSION AND CONCLUSION

The current work focused on the first of a 3-part investigation on the potential effects of ice on grow-out culture of the surf/bar clam *Spisula solidissima.* It recognizes, in a general way, the importance of this critical, yet little understood aspect, i.e. the impact that ice can have in determining the suitability of sites for shellfish culture.

The situation contrasts with finfish culture, where work on ice has been ongoing for several years and where significant progress has already been made (Rosenthal et al, 1995). Our program also explores the subject from a number of other perspectives and makes use of the expertise provided by a multi-disciplinary team.

Despite a relatively short lead time (project began in November 1995), considerable information has been collected and major inroads have been made. Our work suggests that both sites A (exposed) and B (less exposed) may lend themselves to clam culture, although the sheltered location, appears to be more amenable for such activities.

As the results also indicate, at certain times, ice cover, especially at the exposed site (A), was in contact with the bottom at several spots and this extended well beyond the ice hinge. At site B (sheltered), sustained contact with the bottom was observed in the shallower waters only (B1),making sampling impossible after the ice set in. Fluctuations in ice thickness were evident, however, beyond 400 meters from shore.

Sieve analysis (particle size) demonstrated limited variability between particle size (figure 13 and 14) on both sites (mostly between 0.25 - 0.m diameter). And while slightly larger particles were more predominant during spring vs early winter (suggesting either some erosion or even flushing by the spring freshet), bottom texture appears to conform with what several workers describe as suitable for *Spisula* growth and development (Bernie and Parer, 1979; Maurer and Walting, 1974).

Our study reveals that bottom texture would probably not be altered enough by ice to become detrimental for the animal. The question to be answered, however, is whether the clams themselves could be vulnerable to "ice-drag", "raking" "crushing" or excessive suction as the ice becomes displaced in the spring.

Surf clams, are known to survive well in waters that are not necessarily very productive. They are very efficient food converters and grow rapidly. Whether they develop even faster when more food is available, remains to be determined. What is important to retain from our study, however, is that phytoplankton is present (as measured by chlorophyll a and other indicators) throughout the winter months, and that site B (sheltered) consistently displayed higher values (Figure 16).

Surf clams demonstrate salinity preferences ranging between 15-24 ppt. This could vary somewhat, depending on the geographic locality. In our study, salinity values ranged between 14 and 24 ppt on the outside of the dune, and even went as high as 28 ppt on one occasion. Site B (sheltered) varied between 15 and 24 ppt, and this is consistent with what is reported to be the preferred range for the species.

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