GROWTH COMPARISON FOR OYSTERS GROWN ON ROPE AND IN FLOATING BAGS

NEW BRUNSWICK DEPARTMENT
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1. INTRODUCTION

The floating bag method has been used to rear oysters along the east coast of New Brunswick for nearly 10 years. It has proven to be highly successful, generating measurable economic spinoffs with more than 12 million oysters processed annually. Nonetheless, this rearing method is constantly questioned given the growth rates recorded for floating bags. In addition, many aquaculturists find that some of their stock does not reach market size fast enough.

The feasibility of growing oysters glued in vertical position has been demonstrated, but the technique is not suitable for all sites. Furthermore, new flotation structures for glued oysters have been developed in New Brunswick. This report presents the conclusions of a more probing evaluation of the potential of this method.

More specifically, this study was intended to:

a) measure the average growth rate of two test lots on four oyster production sites;
b) qualify the shape of the oysters;
c) compare the performance of glued oysters with that of oysters in floating bags;
d) measure the impact of monthly evaluations on final average length;
e) assess the efficiency of a new rearing device;
f) determine the percentage of oysters reaching market size using the different techniques.

2. EQUIPMENT AND METHODS

2.1 Experimental lots of oysters

In spring 2008, oysters were sorted and divided into two size groups, with individuals 20 mm to 30 mm long in one group and 40 mm to 50 mm long in the other. The oysters placed in floating bags were identified by labels numbered from 1 to 15. The count per bag (density) was 500 individuals in the 20-30 mm group and 200 in the 40-50 mm group. The effect of experimental manipulation on linear growth and weight gain was also examined by comparing the results for test lots measured only twice, i.e., in spring and fall, with those for lots measured monthly.

2.2 Production sites

The study covered four commercial production sites: Brantville Aquaculture Ltd. site MS-0749 in Tabusintac Bay, L'Étang Ruisseau Bar Ltd. site MS-0789 in Baie Saint-Simon Sud, Aquaculture Chaleur Inc. site MS-1177 in Caraquet Bay, and MP Aquaculture site MS-0382 at Caraquet Island. Basically, those sites were chosen because the growers were interested in the "glued oyster" technique, which is likely to improve oyster yields on their production sites.

The Saint-Simon Sud production site is sheltered from most prevailing winds, with the exception of westerlies. The water at high tide can be more than two metres deep in the area farthest from shore. Although the ocean bottom is more silty in the deep part of the site, eelgrass grows there in abundance. The Tabusintac production site is much the same as the Saint-Simon Sud site, except that it may be strongly affected by northeasterly winds. The water at high tide can be more than two metres deep in the area farthest from the shore. Although the ocean bottom is more silty in the deep part, eelgrass grows there in abundance. The water at the Caraquet Bay production site is shallow, silty, and the most exposed to the wind. The MP Aquaculture site, in Bas-Caraquet bay, differs considerably from the other oyster production sites in New Brunswick. Used mostly for growing mussels, it is very deep and exposed, with fairly cool summer temperatures.

2.3 Rearing system

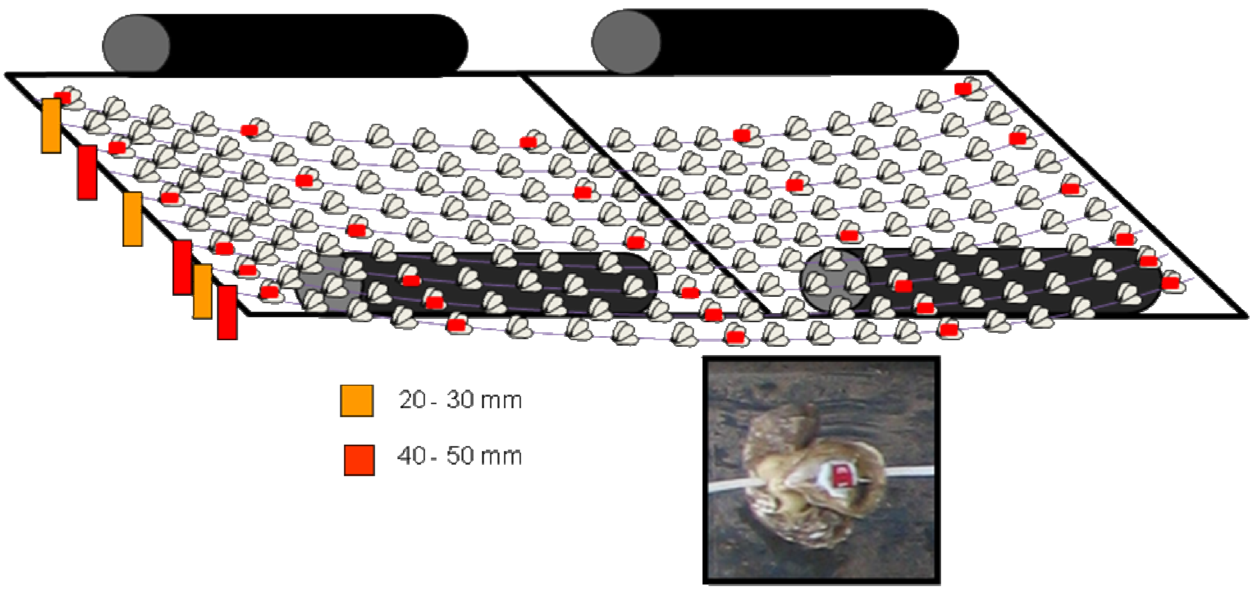

Figure 1 : Diagram of Brantville Aquaculture structure. This floating structure designed for rearing glued oysters can accommodate 540 oysters on nine lines.

Oysters were suspended on lines arranged in groups of three, glued shell (left valve) to shell. The groups of oysters in positions 1, 5, 10, 15, and 20 were measured in the order shown in Figure 1. Three lines per structure and 15 oysters per line were measured, and the positions were marked with coloured tape indicating the monitored group. Oysters in this structure were measured monthly.

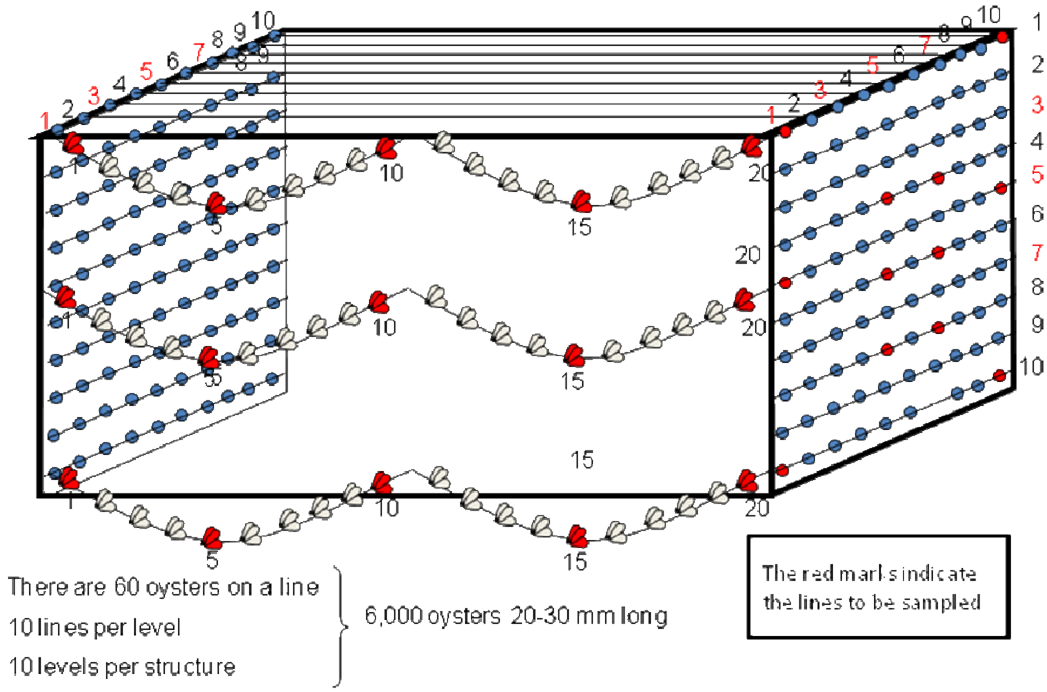

Figure 2: Diagram of glued oyster structure designed by MP Aquaculture

MP Aquaculture's glued oyster setup can accommodate about 6,000 oysters. Lines holding the experimental oysters were arranged in the structure so as to measure the effect of position (see Figure 2). Oysters in the middle of the structure were measured only twice, in spring and fall. Oysters that were positioned more towards the outside and therefore easier to access were measured monthly.

Figure 3: MP Aquaculture's glued oyster structure

In comparison, the traditional floating bag consists of a 9-mm mesh pouch having two plastic or Styrofoam floaters attached to the side. Floating bags used for this study were randomly distributed on both sides of a double longline at three different locations, as indicated in Figure 5.

Figure 4: Longlines of floating bags on the Saint-Simon Sud site

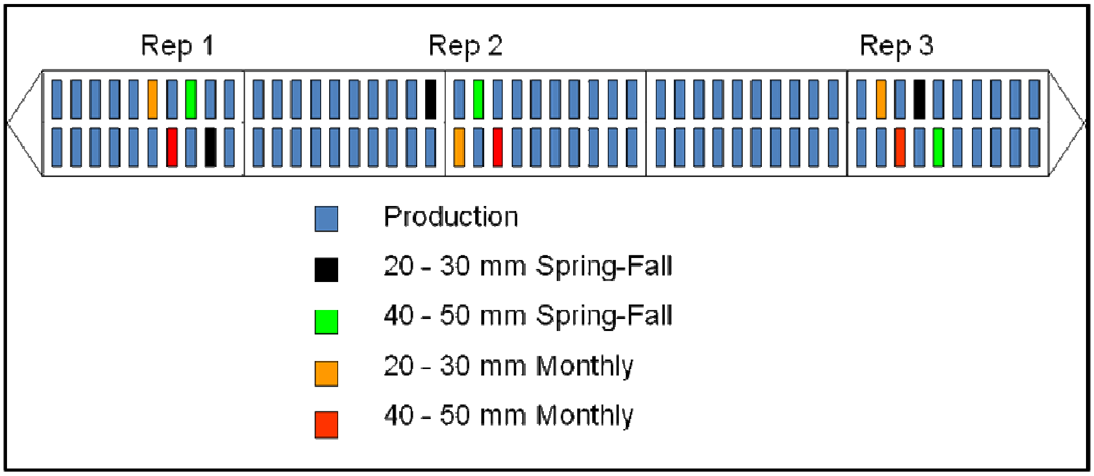

Figure 5: Diagram of a standard floating bag longline and sampling details

2.4 Experimental setup

In mid-May 2008, lots of 15 oysters identified by unique numbers were deployed in three replicates in the floating bag and glued oyster rearing systems.

Table 1: Description of experimental oyster lots distributed on the production sites

SITE	SYSTEM	GROUP	FREQUENCY	REP	NUMBER
Saint-Simon Sud Tabusintac Caraquet	Glued	20-30	monthly	1,2,3	15
		40-50	monthly	1,2,3	15
	Floating	20-30	start/end	1,2,3	15
			monthly	1,2,3	15
		40-50	start/end	1,2,3	15
			monthly	1,2,3	15
Bas-Caraquet	Glued	20-30	start/end	1,2,3,4,5,6	15
			monthly	1,2,3,4,5,6	15
		40-50	start/end	1,2,3,4,5,6	15
			monthly	1,2,3,4,5,6	15

2.5 Statistical analysis

A three-level mixed variance analysis was used to evaluate the experimental setup. The statistical model shown below was used for most of the analyses, though some changes were made in particular cases.

Len_{ijklm} or $Wgt_{ijklm} = \mu + SITE_i + SYS_j + GRP_k + Rep_{ijkl}(GRP) + Error_{ijkl}$

where:

μ = overall average of population

$SITE_k$ where k=1,..,4 – four test sites – Baie Saint-Simon Sud, Tabusintac, Caraquet, and Caraquet Island

$SYS_{i,}$ where i = 1,2 floating bags vs. glued oysters

GRP_j where j=1,2 –two test lots of oysters (20-30 mm and 40-50 mm)

Rep (GRP_{ijkl}) where l=1,2,3 – three samples from test lots

and

$Error_{ijklm}$ where m=1,…, 15 – 15 numbered oysters in each frame

3. RESULTS

3.1 Average length in May and October 2008

Rearing site and system have a considerable effect on final oyster size (Table 2). There was no significant difference in average oyster size between the tests lots when the study began started in May. However, tremendous variation was observed between the rearing systems in October. Differential performance for glued oysters and oysters in floating bags is greater at Caraquet, a very windy site.

Table 2 : Differential average length (mm) at start of study (May) and end of study (October), and total growth (mm) for two oyster lots in both systems on the four sites

Site	Group	System	May	se	October	se	Total growth
Bas-Caraquet	20-30	Glued	27.1	0.2	46.6	0.4	19.5
	40-50	Glued	45.4	0.2	57.5	0.4	12.1
Caraquet	20-30	Glued	27.2	0.3	45.5	0.6	18.3
		Floating	27.3	0.2	35.9	0.5	8.6
	40-50	Glued	45.6	0.5	58.1	0.9	12.5
		Floating	44.9	0.4	47.4	0.9	2.5
Saint-Simon Sud	20-30	Glued	26.8	0.3	44.8	0.7	18.0
		Floating	26.6	0.3	40.2	0.6	13.6
	40-50	Glued	45.5	0.5	56.5	0.6	11.0
		Floating	45.8	0.4	53.9	0.6	8.1
Tabusintac	20-30	Glued	27.0	0.3	45.9	0.8	18.9
		Floating	26.2	0.3	39.9	0.6	13.7
	40-50	Glued	45.5	0.5	58.0	0.7	12.5
		Floating	45.2	0.3	52.8	0.5	7.6

3.2 General trend observed between the different groups and systems on each site

a) Tabusintac

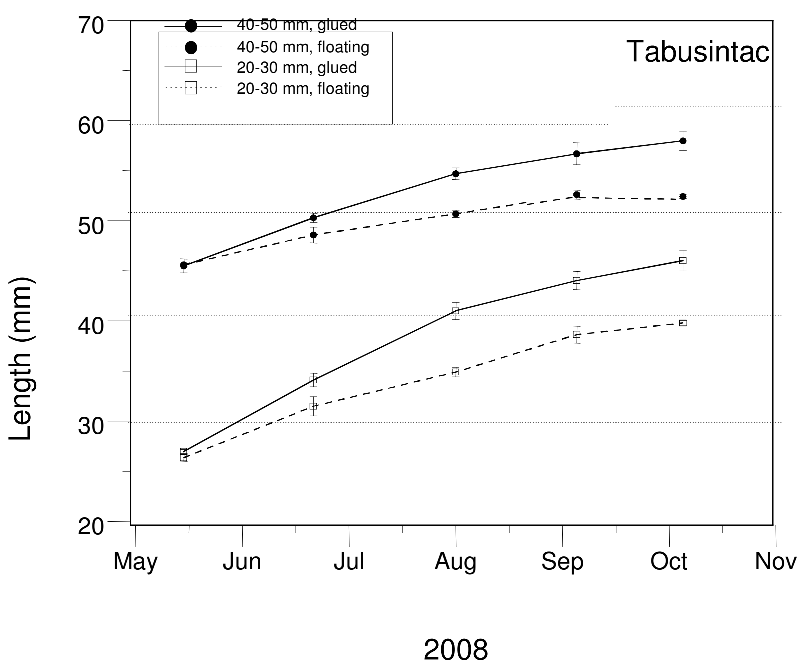

Figure 6: Average length (mm) for two test lots of glued oysters (solid line) and oysters in floating bags (dotted line) in Tabusintac Bay, May 15 to October 1, 2008

The profile of average oyster length for both test lots in the two rearing systems gives some idea of oyster growth rate on the Tabusintac site in 2008. The data shows linear growth for glued oysters continuing during the fall, whereas average oyster length decreased in the 40-50 mm lot. The data collected in October shows a 5-mm difference in length between the glued and floating bag lots.

b) Baie Saint-Simon Sud

The growth profile at Saint-Simon Sud site differs from that at Tabusintac. Data collected at Saint-Simon Sud show linear growth stopping in early September, even with glued oysters. Available data provide no ready explanation for the halted growth; however data collected in a concurrent study at the same location shows a considerable slowdown in oyster growth in late summer, whereas oysters near the shore continue to grow. There is a 4-mm length difference between the glued oysters and those in floating bags.

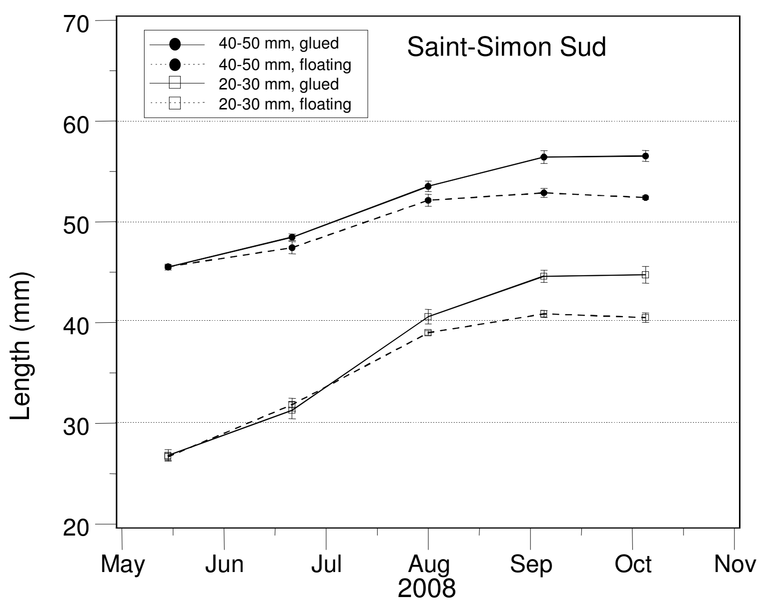

Figure 7: Average length (mm) for two test lots of glued oysters (solid line) and oysters in floating bags (dotted line) at Baie Saint-Simon Sud, May 15 to October 1, 2008

c) Caraquet

Caraquet is the site with the greatest length difference between glued and floating bag oysters. The average growth rate for glued oysters compares with that recorded on the other sites, demonstrating that the site has good biocapacity. However, the strong winds observed at this location greatly erode new growth. Average growth in floating bags is the lowest recorded within this study.

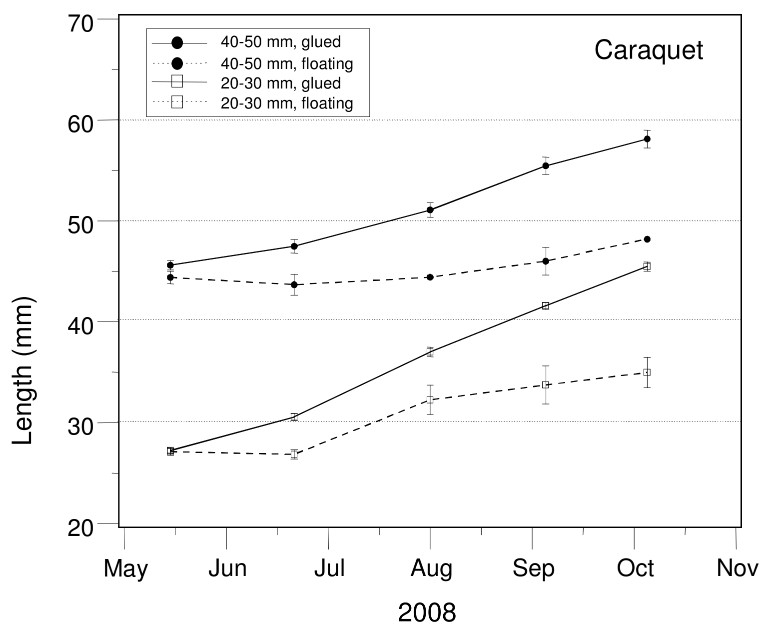

Figure 8: Average length (mm) for two test lots of glued oysters (solid line) and oysters in floating bags (dotted line) in Caraquet Bay, May 15 to October 1, 2008

d) Bas-Caraquet

There was no floating bag system at MP Aquaculture, an offshore site where mostly mussels are farmed. The grower has designed and developed a rather impressive rearing structure based on the glued oyster technique. The structure requires a fairly large mechanical and hydraulic infrastructure to lift the structure from the water in order to eliminate biofouling. As seen in Table 3, oyster position in the structure does not have a significant effect on length (p=0.1) or weight (p=0.78). We do see a significant statistical relationship between size group and position, though the effect is probably attributable to the smaller average for 20-30 mm oysters which were positioned on the perimeter of the structure and subject to monthly manipulation for measurement purposes. The difference is most likely due to the shells crumbling during handling. Figure 8 shows that linear growth for the two lots is comparable to the performance of glued oysters on the other three oyster production sites.

Table 3 : Variance analysis evaluating the influence of oyster position in the rearing structure designed by Marcel Poirier

		Length		Weight	
Source	DF	MS	Pr > F	MS	Pr > F
Position	1	105.2	0.10	1.6	0.78
Group	1	9,375.4		5,741.8	<.01
Pos*Grp	1	240.4	0.02	112.4	0.03
Rep (Grp*Pos)	20	35.8	0.16	19.8	0.25
Error	858	35.6		16.5	

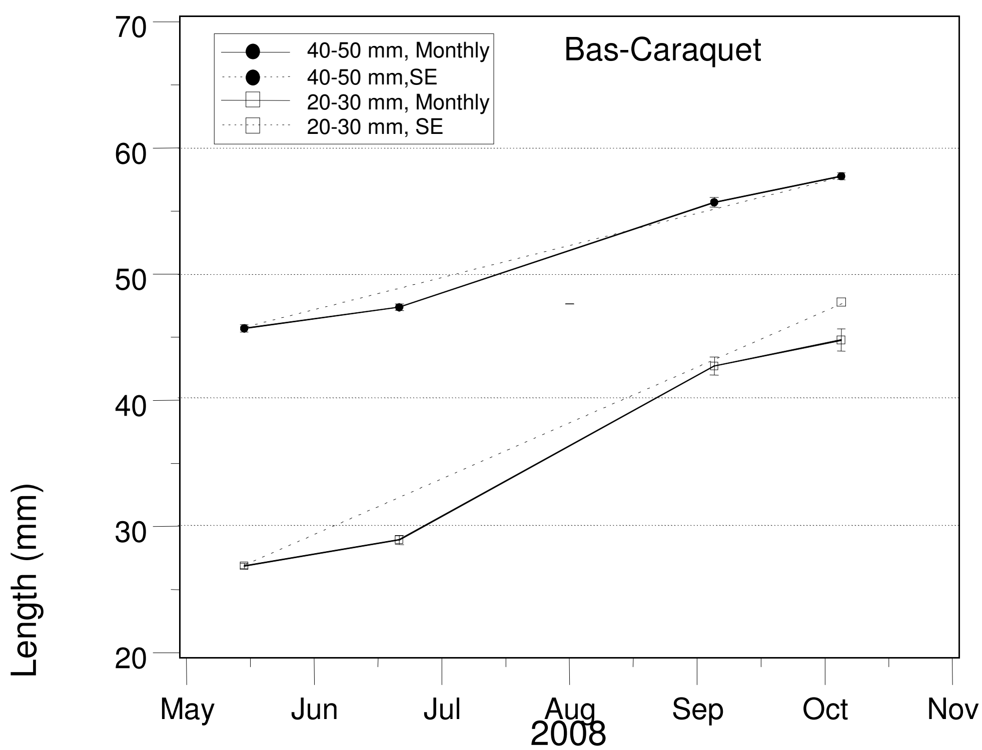

Figure 9: Average length (mm) for two test lots of glued oysters measured monthly (solid line) and at the beginning and end of study (BE) at Caraquet Island, May 15 to October 1, 2008

3.3 Statistical analysis of effect of rearing methods

Considerable differential growth was observed between glued and floating bag oysters ($p<0.01$, Table 4). The comparative analysis did not include the Bas-Caraquet site because floating bags are not used at that location. Linear growth of the 20-30 mm oyster lot averaged 6.5 mm more than linear growth for oysters in floating bags, whereas linear growth for the 40-50 mm oysters averaged 5.3 mm more (Fig 10). Uniform performance for the replicates and lack of any extensive interaction between the lots increases confidence as to the trends observed in this study. These results suggest similar performances for the test lots.

Table 4 : Variance analysis to determine the effect of rearing methods on linear growth

Source	DF	MS	Pr<F
System (Sys)	1	5,200	<0.01
Group (Grp)	1	5,271	<0.01
SysxGrp	1	48	0.13
Site	2	586	<0.01
Rep (Site)	6	14.6	0.65
Error	654	14.8	

Figure 10: Average total growth (mm) recorded for 20-30 mm and 40-50 mm lots for both rearing methods

3.4 Glued oysters: linear growth and weight gain

The above data show oyster growth differing considerably depending on the rearing method used (floating bag vs. glued). That explains why only the results for glued oysters can be compared to determine whether there are significant differences in oyster growth performance and site biocapacity.

Table 5 : Variance analysis of site impact on linear growth of glued oysters

Source	DF	MS	Pr<F
Site	3	35.6	0.20
Group (Grp)	1	4,664	<0.01
Site x Grp	3	12.7	0.63
Rep (Site Grp)	22	21.9	0.39
Error	518	20.7	

In northeastern New Brunswick, the lack of statistical differences in the performance of glued oysters from one site to another suggests similar biocapacity of the sites (Table 5). This interesting finding is also important because the similar performances (Figure 11) suggest potential for commercial production, provided that a method suitable for the site in question is used. The results further demonstrate that the floating bag rearing method results in substantial losses in terms of linear growth and that this method will never be able to yield satisfactory commercial results on some sites.

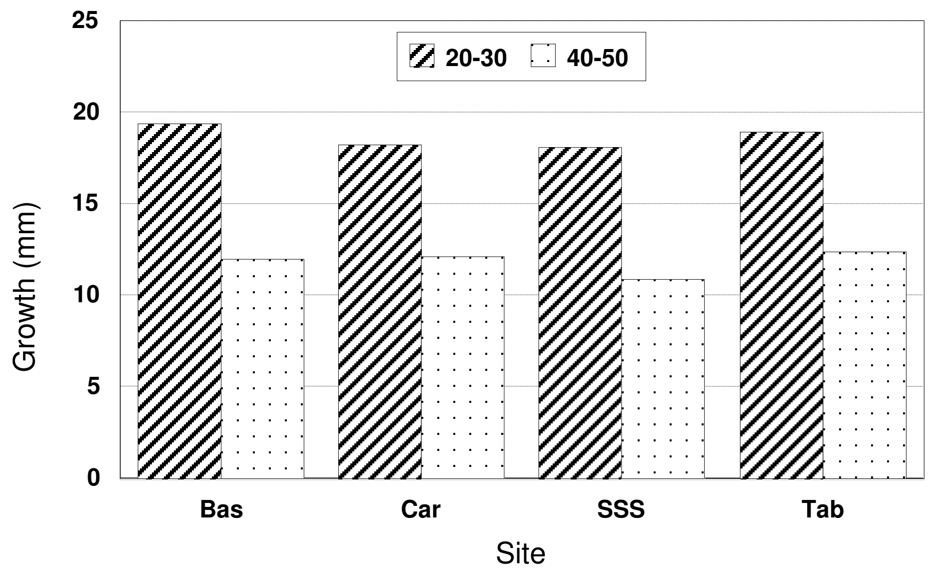

Figure 11: Average linear growth (mm) of glued oysters in 20-30 mm and 40-50 mm lots for the different production sites, May to October 2008

The initial weight of the glued oysters was not measured in May; however, individuals were weighed at the end of the study. Weight gain for the glued oysters was determined on the different sites by taking the initial average weight of the oysters in floating bags on the corresponding sites as the initial weight for the glued oysters. Initial weight was then subtracted from the final average weight of the glued oysters to obtain the average net growth for each lot (Figure 12). In all cases, the best weight and linear growth performances were observed with the glued oysters in comparison with the results obtained for the oysters in floating bags (cf. Mallet et al. 2006, 2008).

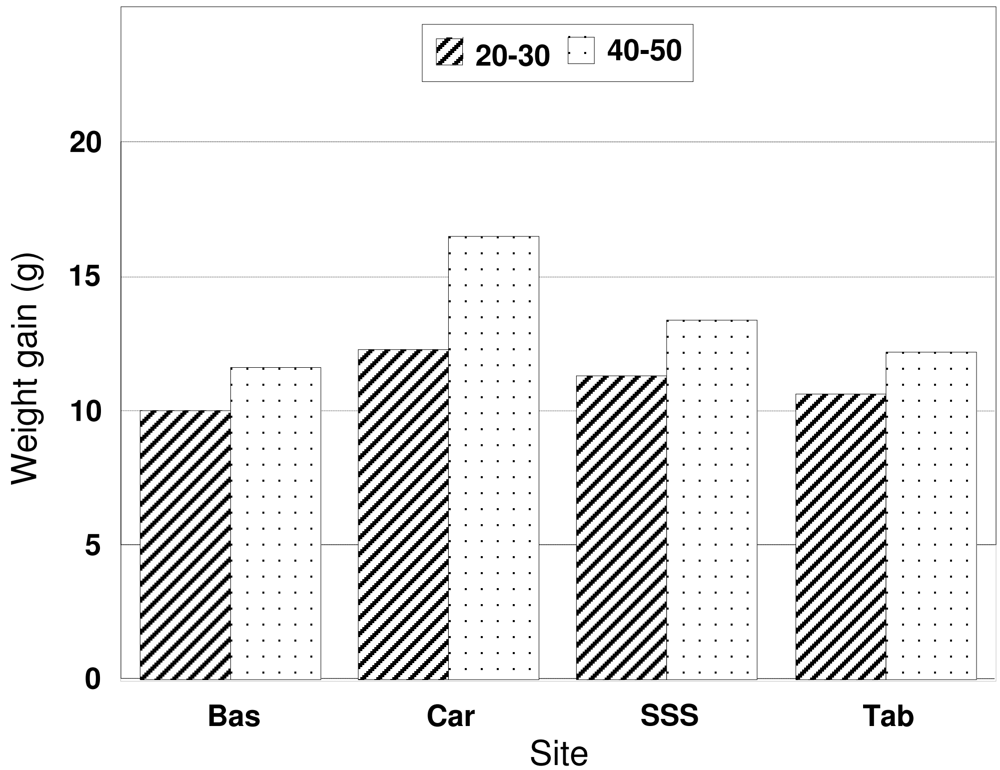

Figure 12: Average weight gain (g) of glued oysters in 20-30 mm and 40-50 mm lots for the different production sites, May to October 2008

3.5 Floating bags: linear growth and weight gain

Unlike for glued oysters, there were significant differences in the linear growth of oysters in floating bags between the sites, although weight gains are comparable (Figures 13 and 14, Table 6). The worst performances were observed in Caraquet Bay, whereas oysters reared in Saint-Simon Sud and Tabusintac bays yielded comparable results for both size groups.

Table 6 : Variance analysis of linear growth in floating bags

Source	DF	MS	Pr<F	MS	Pr<F
Site	2	1,045.6	<0.01	28.0	0.13
Group (Grp)	1	3,255.2	<0.01	268.2	<0.01
Site x Grp	2	0.87	0.96	4.6	0.68
Rep (Site Grp)	10	28.0	0.13	11.0	0.16
Error	411	18.3		7.7	

Weight gain gives comparable results and corroborates the inferior performance of the floating bag rearing method in comparison with the performance of glued oysters. Indeed, weight gain for glued oysters on all sites is almost double what was observed for oysters in floating bags.

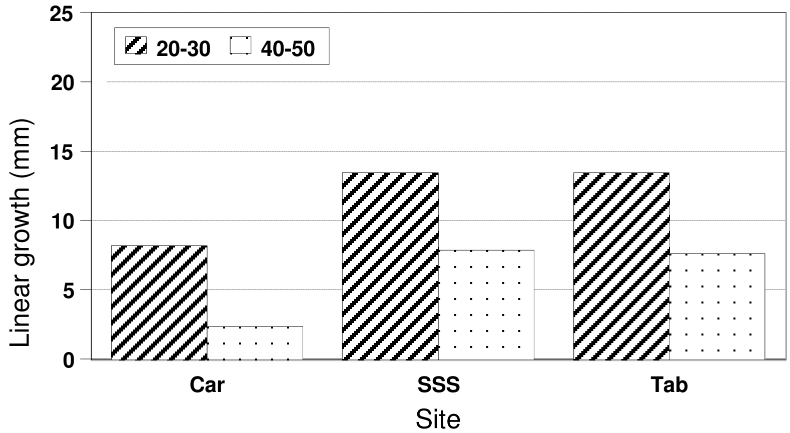

Figure 13: Average linear growth (mm) of oysters in floating bags in 20-30 mm and 40-50 mm lots for the different production sites, May to October 2008

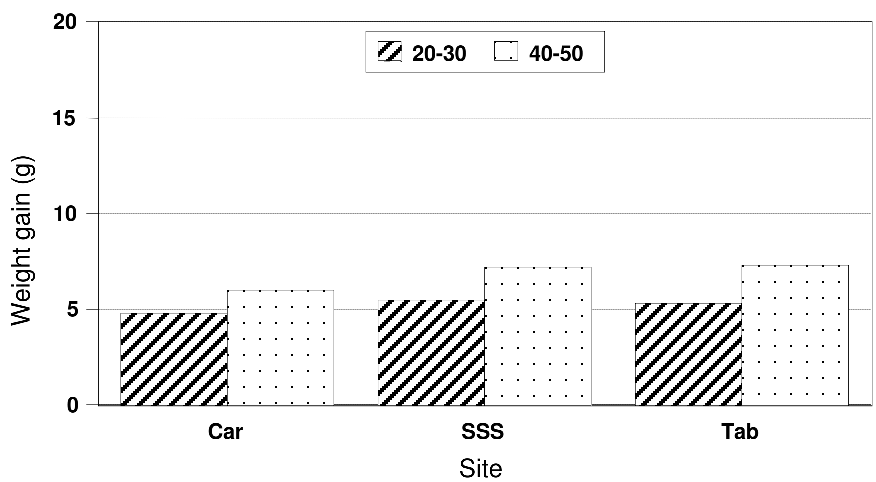

Figure 14: Average weight gain (g) of oysters in floating bags in 20-30 mm and 40-50 mm lots for the different production sites, May to October 2008

3.6 Comparison of individual growth rates

Greater variability in linear growth was observed between oysters in the 20-30 mm lot reared in floating bags compared with glued oysters (Figure 15). In fact, only 2.5% of glued oysters exhibited growth of less than 10 mm, whereas this percentage was definitely higher with the floating bag system. This is indeed an interesting observation for it calls into question the practice of eliminating a large percentage of oysters during sorting because of supposed genetic inferiority. This result suggests that the choice of rearing method can be a considerable source of variability.

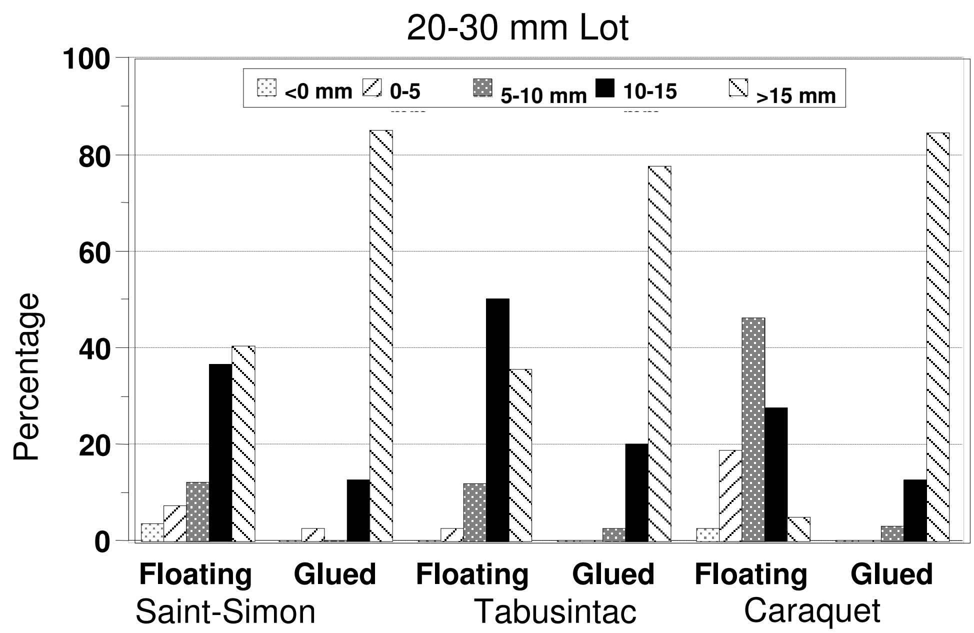

Figure 15: Percentage of individuals for each linear growth class in 20-30 mm test lot for each rearing system on the three production sites

Greater variability in linear growth was observed with the oysters in the 40-50 mm lot (Figure 16). Once again, however, the percentage of oysters having achieved linear growth exceeding 10 mm is clearly higher with glued oysters, where at least half of the individuals exhibited growth greater than 10 mm.

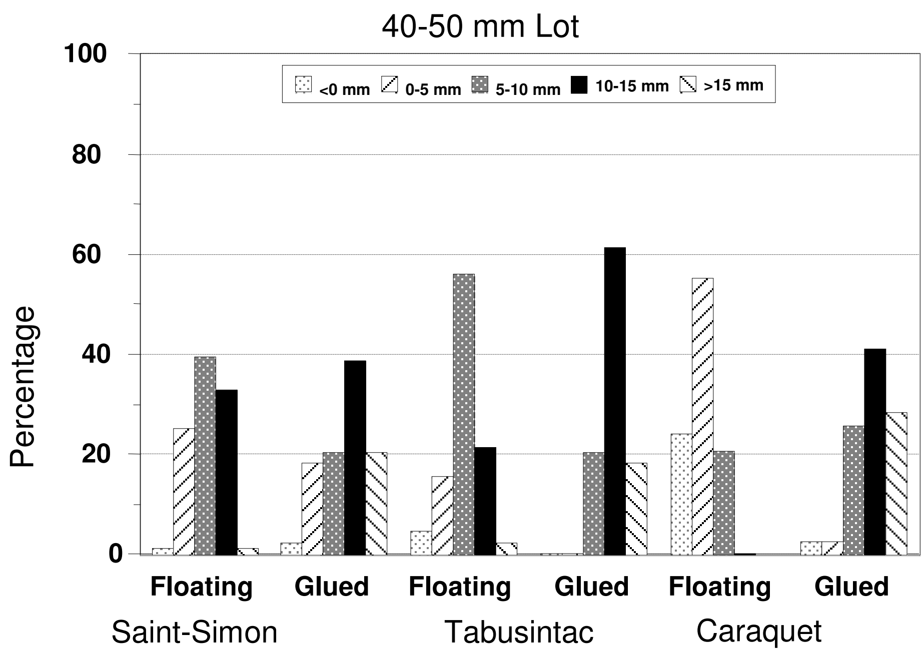

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Figure 16: Percentage of individuals for each linear growth class in 40-50 mm test lot for each rearing system on the three production sites

Table 7: Length distribution according to rearing method and site for the 40-50 mm group. A higher percentage of market size oysters is observed for glued method.

Site	40-50 mm group							
	Length (mm) October 2008							
	System	40-44	44-48	48-52	52-56	56-60	60-64	> 64
Caraquet Island	Glued	1.9%	4.4%	11.9%	20.0%	27.5%	21.3%	13.1%
Caraquet	Glued	2.6%	2.6%	5.1%	20.5%	33.3%	23.1%	12.8%
	Floating	27.6%	31.0%	20.7%	13.8%	6.9%	0.0%	0.0%
Saint-Simon Sud	Glued	0.0%	2.2%	8.9%	35.6%	33.3%	15.6%	4.4%
	Floating	2.9%	2.9%	14.7%	20.6%	50.0%	5.9%	2.9%
Tabusintac	Glued	0.0%	0.0%	11.4%	20.5%	34.1%	25.0%	9.1%
	Floating	1.2%	10.7%	35.7%	26.2%	21.4%	3.6%	1.2%

3.7 Effect of rearing method on oyster shape

Oysters can be graded into different classes according to shape by dividing length by width. This classification method grades the oysters as follows: Commercial (>2.0), Standard (1.75 to 2.0), Choice (1.5 to 1.75), and Fancy (<1.5). Data collected in May showed the oysters to be of uniform shape (Table 8) at the start of this study, the effect of rearing method (system) being insignificant (p=0.34). The fact that this factor becomes significant in the fall demonstrates that rearing method has a significant effect on oyster shape (p<0.01). Table 9 shows that the shape of cultivated oysters is usually excellent, making it possible to categorize them as Fancy, but that the glued oyster method tends to improve shape.

Table 8: Variance analysis of the effect of different factors on oyster shape

		May		October	
Source	DF	MS	Pr<F	MS	Pr<F
Site	33	0.021	0.41	0.029	0.098
Sys (Site)	3	0.023	0.34	0.526	<0.01
Group (Site Sys)	7	0.77	<0.01	0.272	<0.01
Rep (Site Grp)	34	0.2	0.13	0.013	0.72
Error	1,102	0.017		0.015	

Table 9: Oyster shape index (length/width) for both size groups in the two rearing systems on the different production sites, October 2008

	20-30 mm		40-50 mm	
Site	Glued	Floating	Glued	Floating
Caraquet	1,266	1,408	1,363	1,439
Saint-Simon Sud	1,195	1,371	1,341	1,438
Tabusintac	1,278	1,347	1,385	1,400

3.8 Effect of experimental manipulation frequency on linear growth

The experimental design (Table 10) shows that experimental manipulation (i.e., debagging the oysters once a month to measure them) has a significant effect on linear growth. For the 20-30 mm lot, the 0.3 mm difference is not significant. However, the 40-50 mm lot exhibits a significant difference of 1.5 mm. Experimental manipulation does not appear to have an effect on weight gain. This result should be considered when planning future studies.

Table 10: Variance analysis of effect of measurement frequency on linear growth. Only data concerning oysters in floating bags were used in this analysis.

		Length		Weight	
Source	DF	MS	Pr<F	MS	Pr<F
Frequency (Fre)	1	117	<0.01	0.27	0.8
Group (Grp)	1	3.310	<0.01	256.1	<0.01
Fre x Grp	1	45.3	0.11	12.0	0.21
Site	2	1.044	<0.01	7.7	0.14
Rep (Site)	6	24.4	0.23	8.9	0.32
Error	415	18.1		8.9	

3.9 Temperature profiles on the four sites

Table 11: Monthly mean temperature and degree-days on the four experimental sites

Site	Month	Mean temperature	Degree-days
Tabusintac	May	13.3	
	June	17.1	514
	July	23.0	714
	August	20.1	624
	September	16.3	488
Saint-Simon Sud	May	11.9	
	June	16.3	489
	July	21.9	678
	August	19.8	613
	September	16.2	485
Caraquet Island	May		
	June	13.6	
	July	18.4	571
	August	18.1	560
	September	15.9	478
Caraquet	May		
	June	16.2	406
	July	21.8	675
	August	19.7	610
	September	16.2	484

Table 11 gives monthly mean temperatures, degree-days, and temperature profiles for the four production sites. Peak temperatures observed at Bas-Caraquet correspond to times when the glued oyster structure was exposed to air for a few days to control biofouling. The coldest temperature profile was recorded at Bas-Caraquet, but growth performances are comparable to those observed on the other sites.

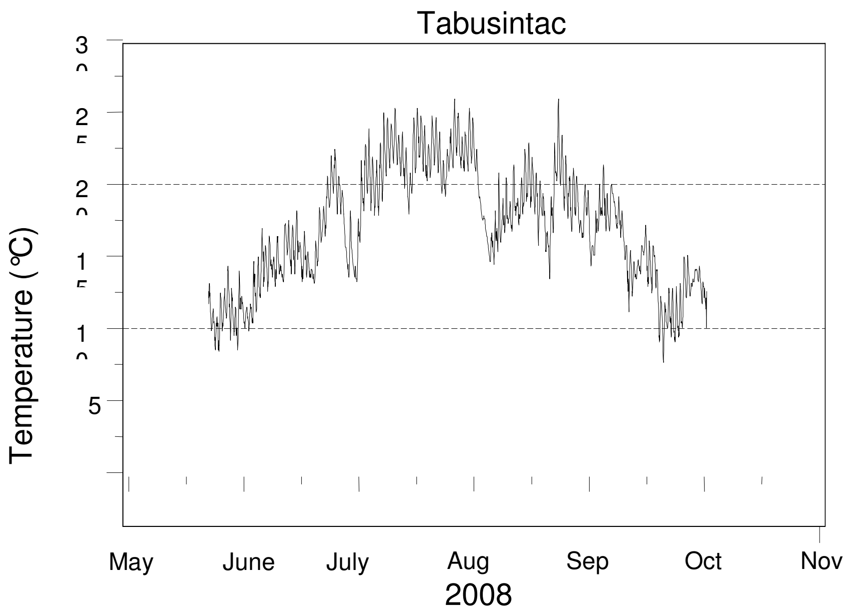

Figure 17: Temperature profile at Tabusintac, 2008

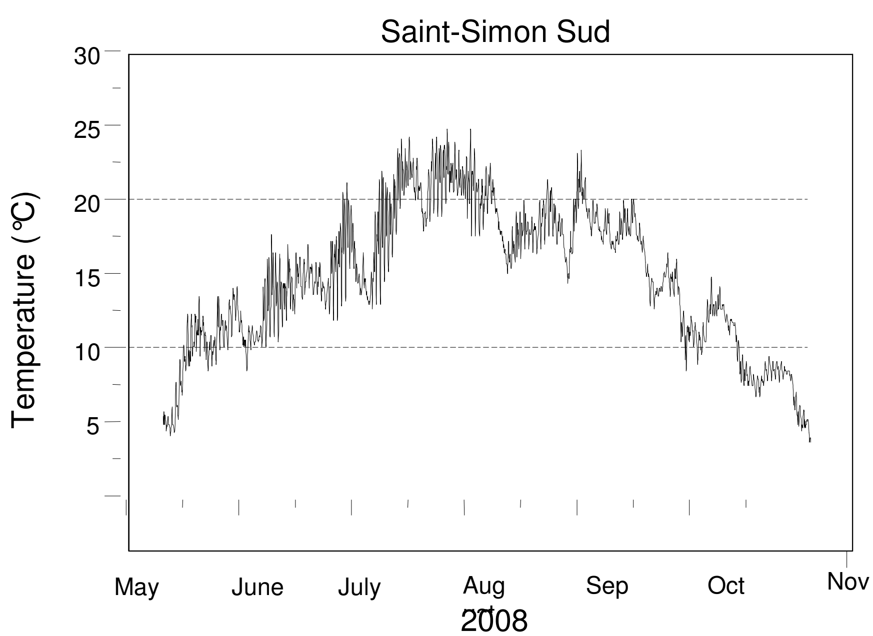

Figure 18: Temperature profile at Saint-Simon Sud, 2008

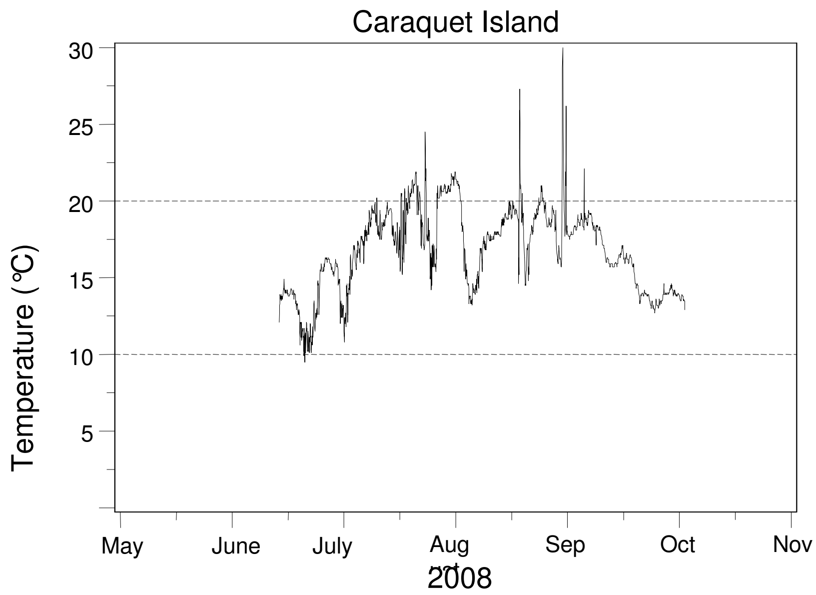

Figure 19: Temperature profile at Caraquet Island, 2008

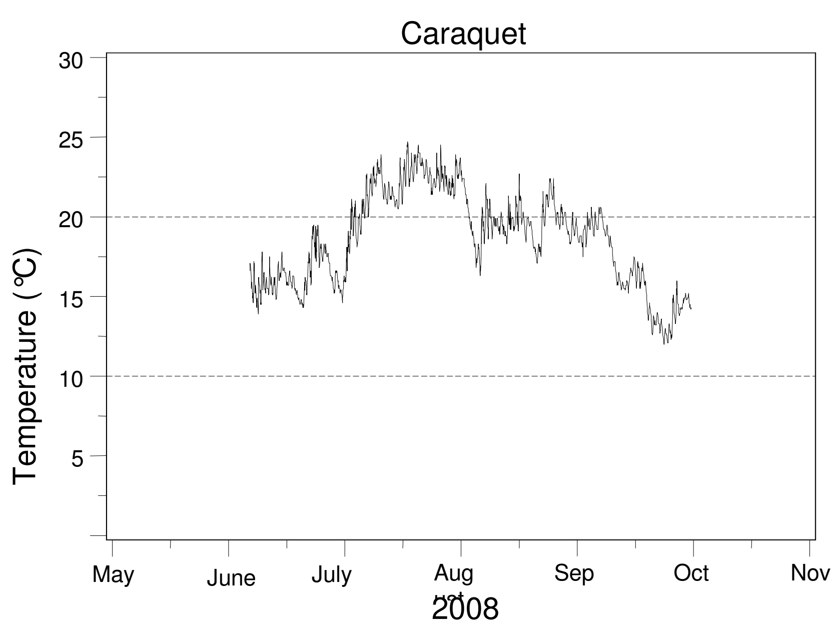

Figure 20: Temperature profile at Caraquet, 2008

4. DISCUSSION

An earlier study by Mallet et al. (2005, 2008) described how the production site influences the performance of oysters reared in floating bags. It was impossible at the time to say whether the differences observed were caused by the biological environment (e.g., food quantity) or physical factors (e.g., buffeting of the bags by the wind). For the purposes of this study, the lack of any statistical difference between the performance of glued oysters on the different sites is strong corroboration for the hypothesis that biological conditions are comparable from one site to the next. We can also state that the floating bag rearing method is itself a meaningful factor that contributes to poorer growth performance, that the magnitude of that poorer growth varies from site to site, and that there is a significant link between rearing site and method (probably owing to the buffeting of the bags).

The average performance of oysters in floating bags varies from 10 mm to 13 mm for the 20-30 mm lot and from 2.5 to 7.5 mm for the 40-50 mm lot. In comparison, the performance of glued oysters varies from 17 mm to 18.5 mm for the 20-30 mm lot and from 11 m to 13 mm for the 40-50 mm lot. Weight gain is also greater in glued oysters, almost double in fact. The oyster shape index shows that growth with respect to width is greater for glued oysters than for oysters in floating bags and that shape quality improves with time. We can therefore state that, in terms of biological and commercial productivity, the glued oyster method clearly yields better results than the floating bag method.

Interestingly, this study found that the number of oysters exhibiting no growth or negative growth is significantly reduced in the case of glued oysters. In fact, in the 20-30 mm test lot, the proportion of oysters with less than 10 mm growth is less than 10% on all the sites. For oysters reared in floating bags, however, that proportion increases from 20% to 50%, depending on the site. In fact, the floating bag rearing method is apparently a leading cause of individual variability.

According to the temperature profile at Caraquet Island, temperatures recorded there are much colder than those recorded on the other sites, but growth data for the glued oysters observed on that site are comparable to those for the other sites. This suggests that sites in more open environments have much greater potential for commercial oyster production than once believed and that farming those sites could help boost total production in New Brunswick. Admittedly, however, the floating bag rearing method is not advised for highly exposed locations owing to strong buffeting of the bags, and some other rearing method should be chosen in order to obtain a more satisfactory commercial yield.

5. RECOMMENDATIONS FOR FUTURE STUDIES

1) The biological performance of commercial production sites in New Brunswick could be compared by analyzing the performance of glued oysters on the sites in question. That approach could be used to determine whether there are any noteworthy biological differences between the different production areas.

2) The production costs associated with the glued oyster rearing method should be determined later for a production scale of 200,000 individuals.

3) Given the clearly superior commercial production results observed with glued oysters, more effort should go into improving the technology of this rearing method. Research in this regard should be encouraged.

4) With respect to biological assessment for experimental purposes, the glued oyster method seems to provide uniform conditions and could become a preferred tool for evaluating inter-annual variations in growth between different lots and different sites.

5) Successful gluing requires that the average size of oysters is about 30 mm. As such, the time required for the majority of 30 mm oysters to reach a size greater than 65 mm should be determined

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7. REFERENCES

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