Effect of Oyster Stocking Density and Floating Bag Mesh Size on Commercial Oyster Production

Year 2015

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1. INTRODUCTION

The growing demand for the eastern oyster and a deeper understanding of the rearing methods adapted to heterogeneous aquaculture sites are at the root of the growth of oyster aquaculture in New Brunswick. Currently, the objective of New Brunswick oyster farmers is to produce large quantities of oysters cost-effectively while maintaining the quality for which they are known on Canadian and international markets. In Atlantic Canada, oysters grow between May and September, a very short period compared with other parts of the world. It is therefore essential to know the factors that can affect the length of the production cycle for farmed oysters in order to maximize yield.

The study that is the subject of this report is designed to measure the effect of stocking density and bag mesh size on the growth of pre-commercial oysters (60 mm) deployed at three sites in northeastern New Brunswick. An oyster farmer on Tabusintac Bay, one on Tracadie Bay, and another on South Saint-Simon Bay, worked with the Department of Agriculture, Aquaculture and Fisheries by giving access to their sites and oyster culture gear.

2. EQUIPMENT AND METHODS

In order to evaluate whether stocking density and mesh size of floating bags have an influence on oyster growth, an experimental design was replicated in three bays, i.e. Tracadie, Tabusintac, and South Saint-Simon (Figure 1). The experimental conditions targeted were three mesh sizes of oyster bags, i.e. 9-mm, 14-mm, and 18-mm, and four rearing densities, i.e. 125, 150, 175, and 200 oysters per bag. Each experimental unit was replicated three times in each bay. A lot of hatchery oysters produced in 2013 and averaging 60 mm in size was used in all of the experimental units to ensure that comparable measurements would be obtained from a common group. In May 2015, 1,620 oysters were assigned a unique number and measured in terms of length, width, thickness, and weight. These oysters were introduced into the bags of participating oyster farmers in accordance with the targeted densities. The oysters were measured again in the fall to obtain individual growth trajectories.

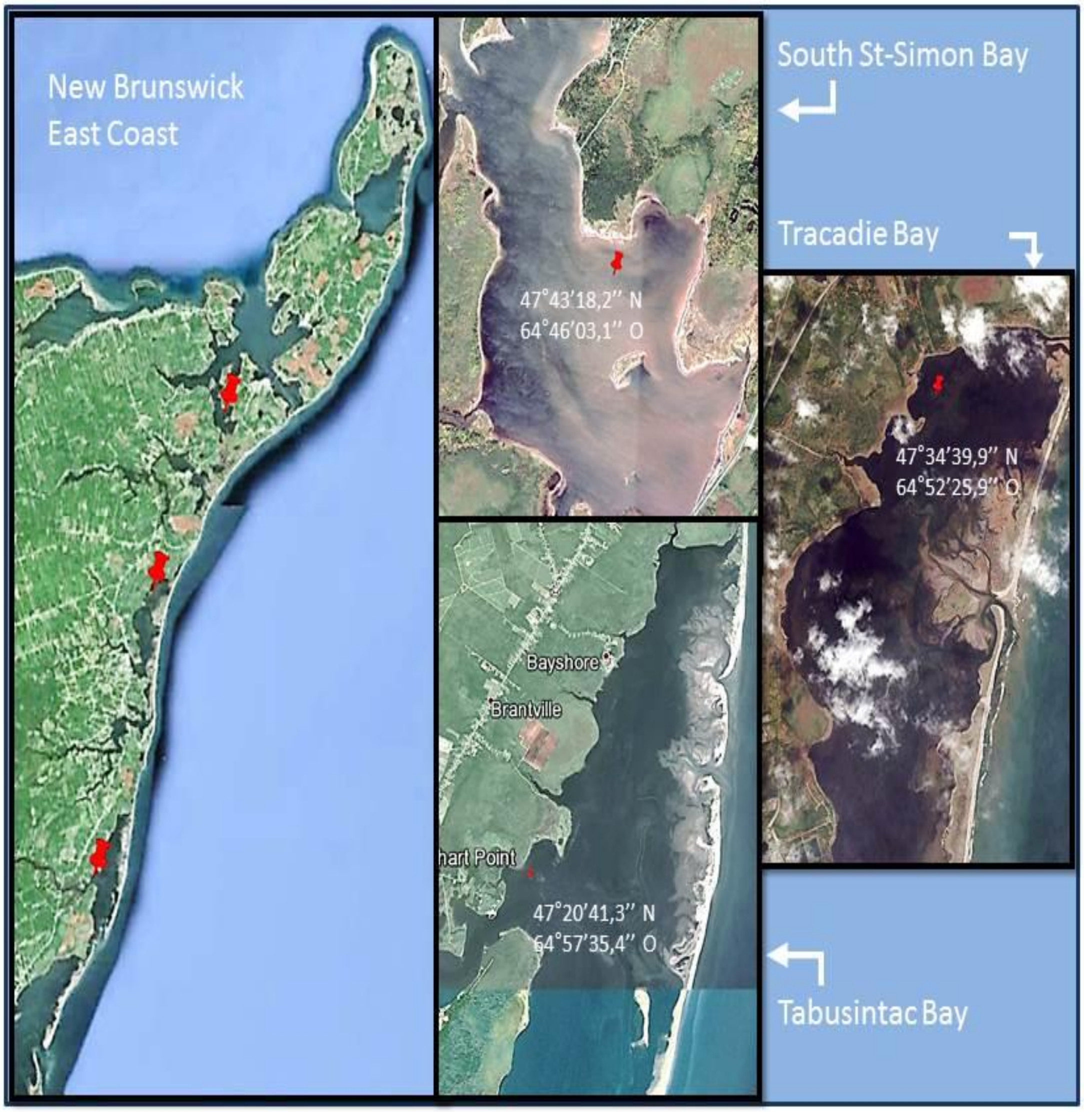

Figure 1 : Map showing the locations of the three experimental sites

The bags were randomly deployed on a longline inside the rearing site and were handled similarly to control biofouling. The following table shows in greater detail the quantity of oysters and the number of bags involved in this study.

Table 1 : Detail of the experimental design used at each site with respect to stocking density in different types of bags.

Bay	Mesh Size	Density	Labelled oysters per bag	# replicated bag	# measured oysters	Total oysters
Tabusintac	9 mm	125	1,2,3	3	45	375
		150	1,2,3	3	45	450
		175	1,2,3	3	45	525
		200	1,2,3	3	45	600
	14 mm	125	1,2,3	3	45	375
		150	1,2,3	3	45	450
		175	1,2,3	3	45	525
		200	1,2,3	3	45	600
	18 mm	125	1,2,3	3	45	375
		150	1,2,3	3	45	450
		175	1,2,3	3	45	525
		200	1,2,3	3	45	600
Tracadie	9 mm	125	1,2,3	3	45	375
		150	1,2,3	3	45	450
		175	1,2,3	3	45	525
		200	1,2,3	3	45	600
	14 mm	125	1,2,3	3	45	375
		150	1,2,3	3	45	450
		175	1,2,3	3	45	525
		200	1,2,3	3	45	600
	18 mm	125	1,2,3	3	45	375
		150	1,2,3	3	45	450
		175	1,2,3	3	45	525
		200	1,2,3	3	45	600
St-Simon Bay	9 mm	125	1,2,3	3	45	375
		150	1,2,3	3	45	450
		175	1,2,3	3	45	525
		200	1,2,3	3	45	600
	14 mm	125	1,2,3	3	45	375
		150	1,2,3	3	45	450
		175	1,2,3	3	45	525
		200	1,2,3	3	45	600
	18 mm	125	1,2,3	3	45	375
		150	1,2,3	3	45	450
		175	1,2,3	3	45	525
		200	1,2,3	3	45	600
			Total	108	1620	17550

a) Statistical Analysis

A three-factor mixed variance analysis with interaction was carried out to evaluate the experimental setup. To obtain the best estimates, the primary statistical analysis focused strictly on mesh size and density by declaring the site as a random factor. The initial measurements were included in the data analysis to correct for the effect of initial size differences on annual growth.

$\text{Growth}_{ijk} = \mu + \text{Site}_i + \text{Density}_j + \text{Mesh size}_k + \text{Density x Mesh size}_{jk} + \text{Rep}_{ijkl}$ (Site, Density, Mesh size) + $\text{Mes\_Ini}_{ijklm} + \text{Error}_{ijklmn}$

where µ represents the overall average of the population

Site_i where i = 1,2,3 represents a random factor representing the three experimental sites

Density_j where j = 1,…,4 is a fixed factor representing the four density levels

Mesh size_k where k = 1,2,3 is a fixed factor representing the three types of mesh

$\text{Initial measurement}_{ijkl}$ is a covariance factor to compensate for growth variances that could be caused by individuals of different sizes.

And Error_{ijkl} where l = 1,…, 15 represents the 15 oysters measured in each bag.

3. RESULTS

a) Density and Mesh Size

Table 2 : Analysis of variance to check the significance of different factors on linear growth and weight gain from May 2015 to October 2015: DF = Degree of freedom, MS = Mean square, F = F value, Pr < F = Probability less than F value.

		Length			Width			Thickness			Wet Weight		
Source	**DF**	**MS**	**F**	**Pr > F**	**MS**	**F**	**Pr > F**	**MS**	**F**	**Pr > F**	**MS**	**F**	**Pr > F**
Bay (B)	2	1261.83	41.38	<0.01	208.06	7.73	<0.01	16.31	1.94	0.15	48.39	0.35	0.71
Mesh (M)	2	213.58	7.00	<0.01	3.83	0.14	0.87	55.02	6.56	<0.01	1012.24	7.30	<0.01
Den (D)	3	41.55	1.36	0.26	106.85	3.96	0.01	37.49	4.46	0.01	321.03	2.31	0.08
MxD	6	9.15	0.30	0.94	75.16	2.79	0.02	5.74	0.68	0.66	8.00	0.06	1.00
Rep(B*M*D)	94	30.51	1.09	0.28	27.04	1.40	0.01	8.43	1.70	<0.01	139.37	1.73	<0.01
Mes_May	1	161.67	5.75	0.02	1119.19	57.92	<0.01	667.05	134.54	<0.01	5506.51	68.32	<0.01
Error	1429	28.10			19.32			4.96			80.60		

In terms of growth in length, the “Mesh and Bay” factors are significant (Table 2). This is illustrated in Figure 2, where the relationship of increasing mesh sizes is reflected in better linear growth, with the exception of a density of 125 oysters per bag. Also, in general, there is an association between lower density and higher length growth. However, with the exception of the 9-mm bag, the growth variations between the densities are not substantial, which explains the lack of significance of this factor.

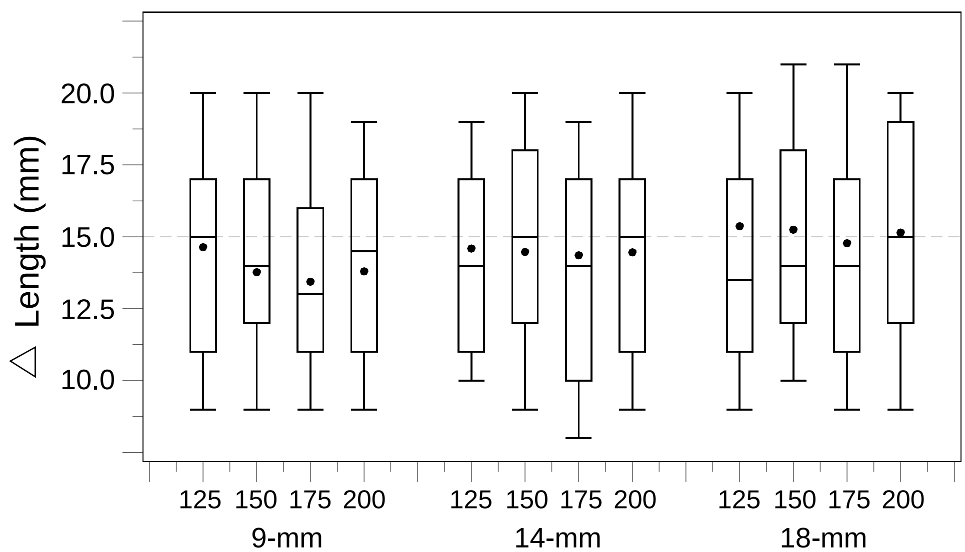

Figure 2 : Box and whisker plot showing length growth for four stocking densities in three types of bags. The middle line of each box represents the median. The box extends from the 25th to the 75th percentiles whereas the whiskers represent the smallest and the largest values of a treatment.

Unlike length growth, mesh size has no effect on width growth (Fig. 3). However, other factors are significant such as the site, the density, and the interaction between the density and mesh size. In general, a density of 125 or 200 produces the best growth, but the replicate term in the analysis is significant. The statistical replication would need to be increased in the future in order to eliminate the significant replicate factor and provide more robust statements.

In terms of thickness growth, the stocking density and mesh size are significant, but no significant interaction has been observed. In general, the lower the density, the better the growth for each type of bag, but what is surprising is that a density of 200 oysters per bag performs better than a density of 175 for all types of mesh, and for 18-mm mesh, a density of 200 oysters per bag seemed to perform just as well as the lower densities.

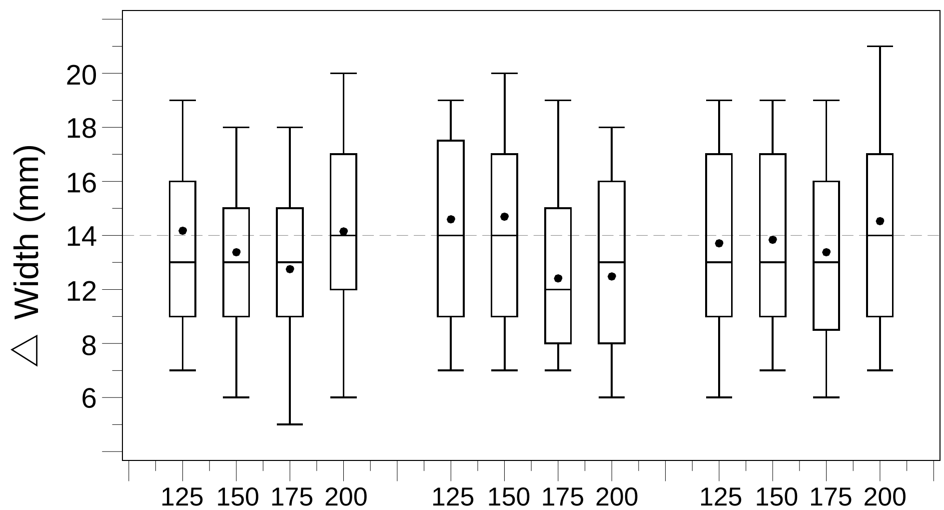

Figure 3 : Box and whisker plot showing shell height for four stocking densities in three types of bags. The middle line of each box is the median. The box extends from the 25th to the 75th percentiles, whereas the whiskers represent the smallest and the largest values of a treatment.

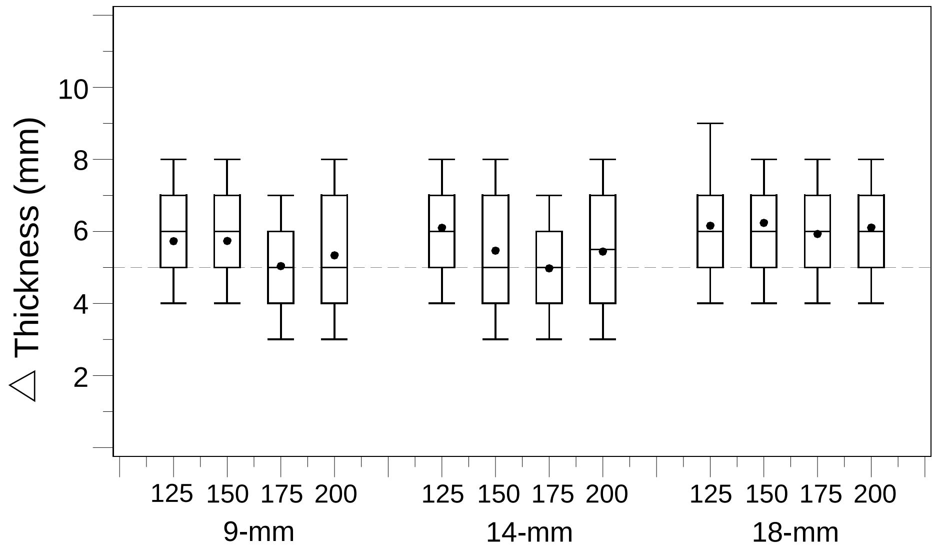

Figure 4 : Box and whisker plot showing shell thickness for four stocking densities in three types of bags. The middle line of each box is the median. The box extends from the 25th to the 75th percentiles, whereas the whiskers represent the smallest and the largest values of a treatment.

The total weight (Fig. 5) provides an indication of the oyster production between the densities in the bags of different mesh sizes. The mesh size factor is significant ($P < 0.01$) and the stocking density is significant at $P < 0.08$. For each level of density, the weight gain increases with the mesh size – a difference of 2.5 to 3.0 g can be calculated between the 9-mm mesh and the 18-mm mesh. The most productive densities are 125 and 200 oysters per bag, whereas in the 18-mm bag, the weight gain is essentially identical for densities of 125 and 200 oysters per bag.

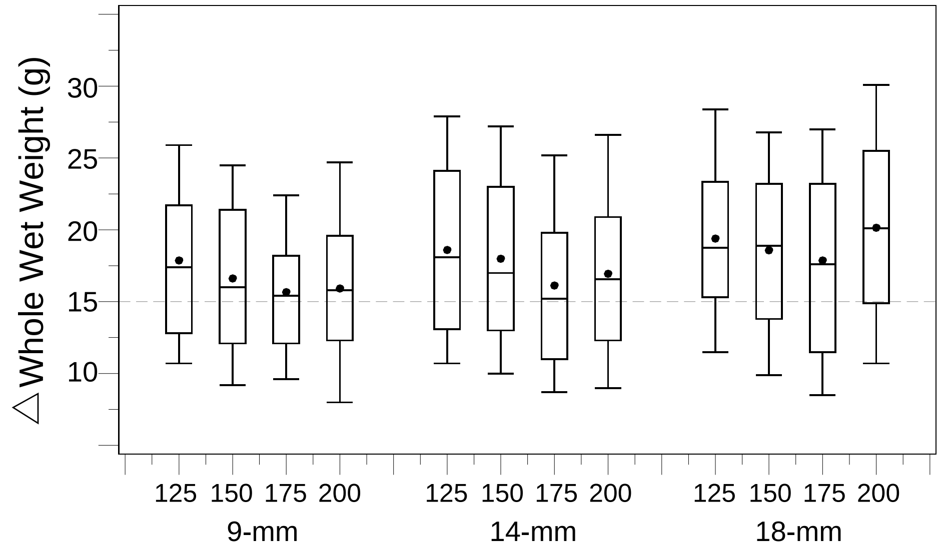

Figure 5 : Box and whisker plot showing total weight gain for four stocking densities in three types of bags.

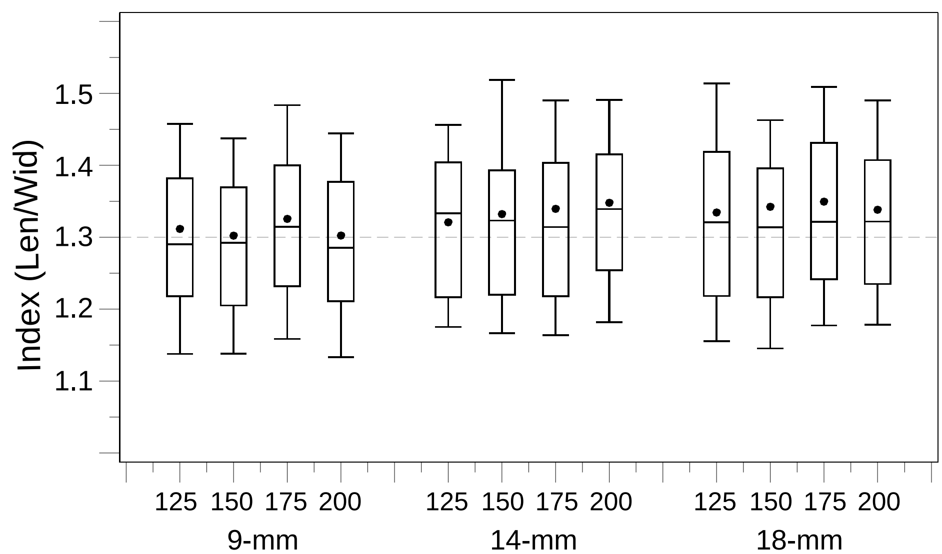

Figure 6 : Box and whisker plot of shell quality in September 2015 for oysters grown in three types of bags at four stocking densities.

No significant difference was observed with respect to the size of the mesh or the stocking density on the shape of the oyster (Figure 6). This result is not surprising, as the variance between the shape ratios is very small and the oyster shape in all treatments is in the Fancy grade.

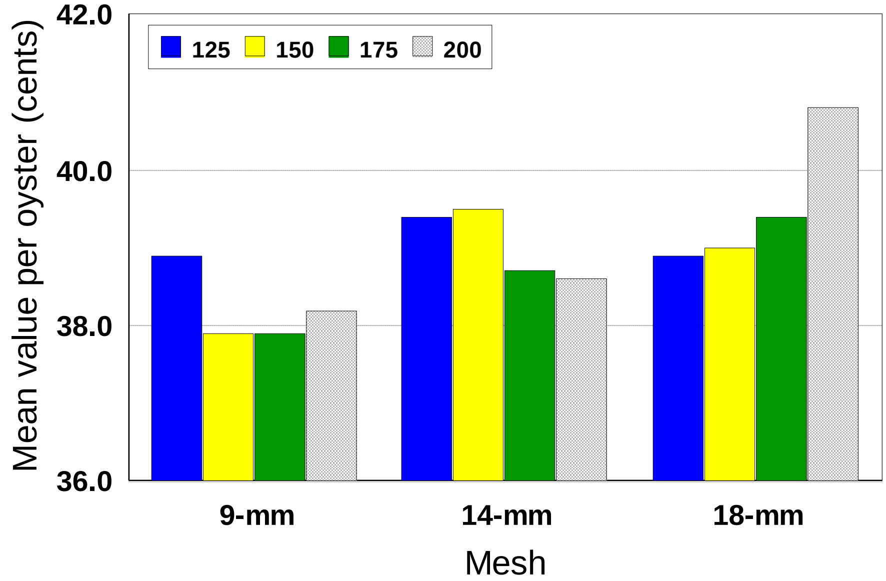

Figure 7 : Effect of mesh size and density on the average price of oysters in the treatment of density and type of bag. Oysters smaller than the Cocktail variety were valued at $0.25, whereas the other grades were given a market value of $0.34, $0.47, and $0.55 for the Cocktail, Choice, and Jumbo grades respectively.

Figure 7 shows the calculation for the average value of an oyster for different stocking densities in different types of bags. The stocking density of 125 or 150 oysters in 14-mm bags produce a higher mean value per oyster than densities of 175 and 200, because there is a higher proportion of choice oyster at these lower densities.

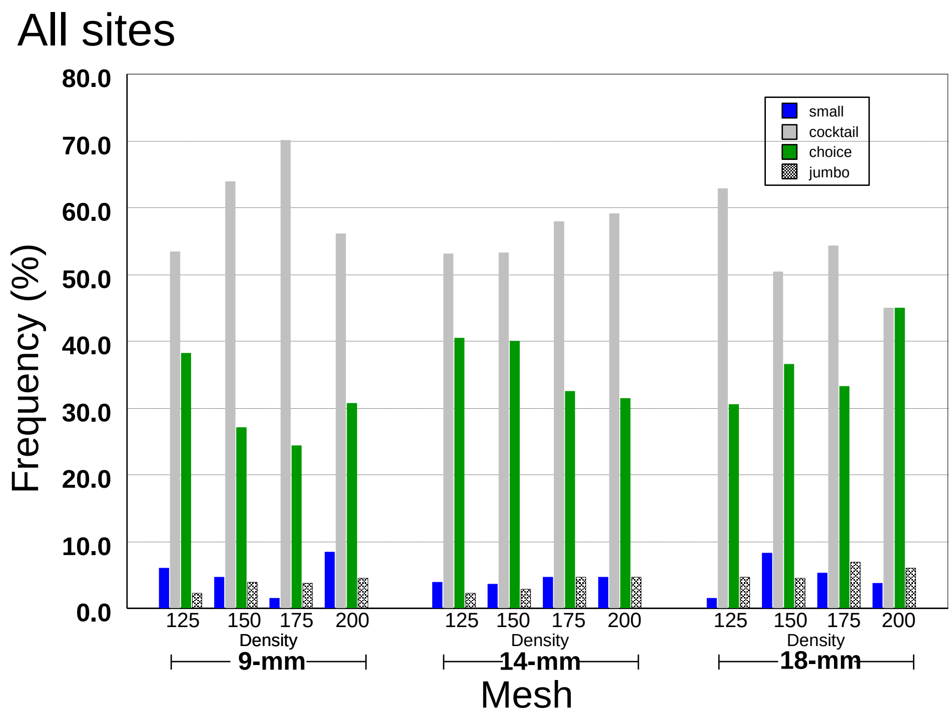

Figure 8 : Relative frequency distribution of oyster grades (Small, Cocktail, Choice, and Jumbo) in September 2015.

Figure 8 shows the distribution of different oyster grades under the same conditions. It can be observed that the 9-mm bag produces a higher number of Cocktail oysters and fewer Choice oysters compared with the 14-mm and 18-mm bags under the same density conditions. Similarly, the greater proportion of Choice oysters in the 18-mm bag at 200 oysters per bag does explain the higher average value of an oyster at this density. For unknown reasons, the trend in the 18-mm bag is contrary to what was observed elsewhere with a lower proportion of Choice grade oysters at the lower stocking densities.

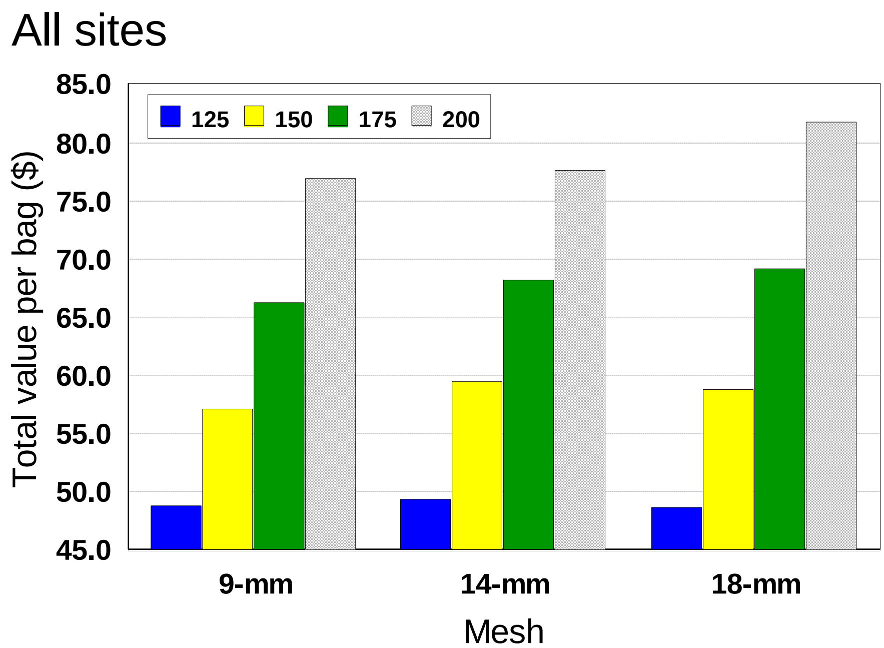

Figure 9 : Total value of oysters from different types of bags at different densities. The value of the different oyster grades is as follows: Small $0.28; Cocktail $0.34; Choice $0.47; and Jumbo $0.55.

The total value of the inventory per bag was calculated by multiplying the frequency of an oyster grade (Figure 9) by the density of the bag and the value of the oyster (see legend Figure 9). Given that in May 2015, the average size of the oysters was 60 mm, most had reached market size by October 2015, and there was not much difference in the proportion of Choice or Cocktail oysters between the densities. Under these conditions, the value of the inventory is essentially a function of the density of oysters per bag with minor influences related to stocking density and bag type.

b) Tabusintac

At the Tabusintac site, the mesh effect is evident with higher average growth in length (Figure 10) and thickness (Figure 12) in the 18-mm bag. This type of bag also seems to produce a positive correlation between density and average growth. With the exception of the 14-mm bag for width growth (Figure 11), the linear growth trends are not predictable between densities. The increase in total weight, with the exception of the 18-mm bag, does not seem related to any of the experimental factors. In terms of the number of Cocktail and Choice oysters produced in the three types of bags at different densities, the relationship between the quantity of Cocktail oysters and the quantity of Choice oysters is relatively stable, except for the 18-mm mesh, where the number of Choice oysters clearly increases with the density (Figure 15). However, the value of the saleable inventory from different types of bags and densities increases with the number of oysters in a bag (Figure 16).

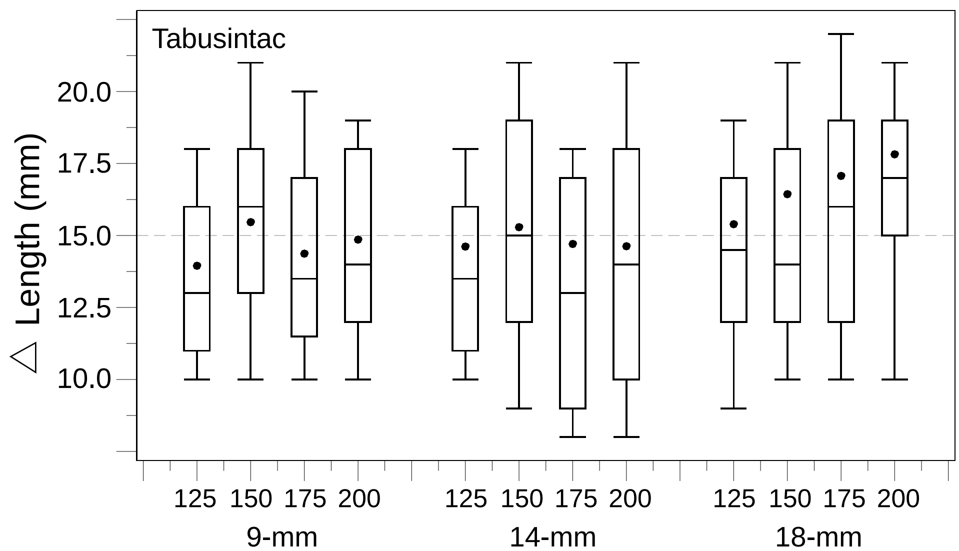

Figure 10 : Box and whisker plot showing lengthwise growth for four stocking densities in three types of bags.

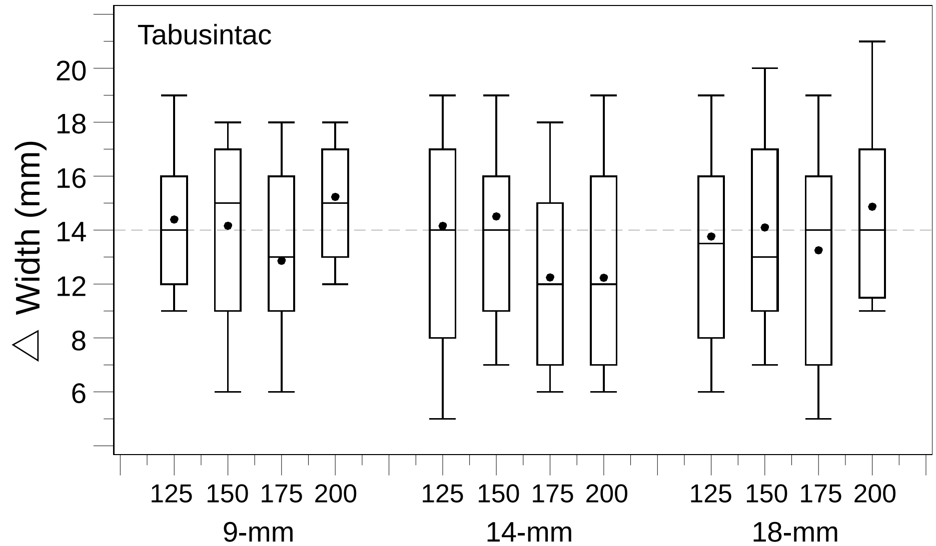

Figure 11 : Box and whisker plot showing width growth for four stocking densities in three types of bags.

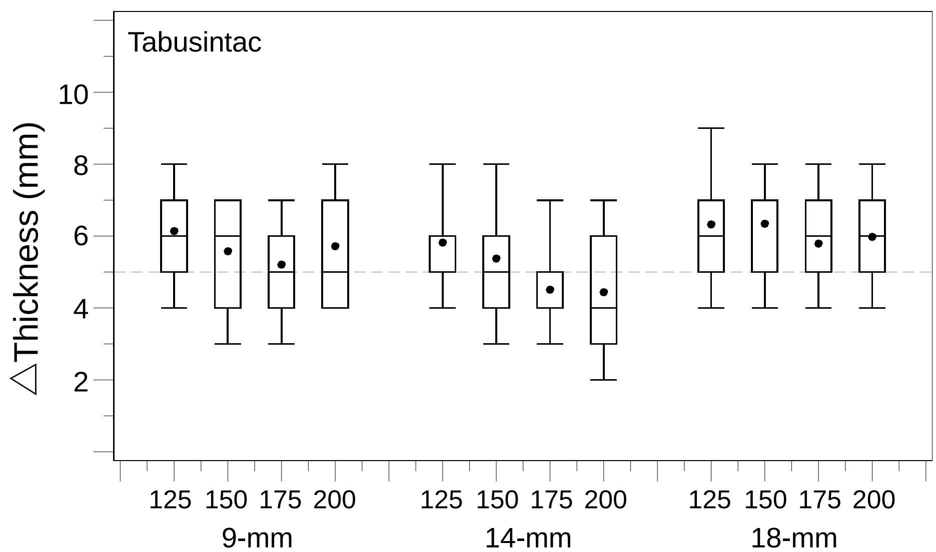

Figure 12 : Box and whisker plot showing thickness growth for four stocking densities in three types of bags.

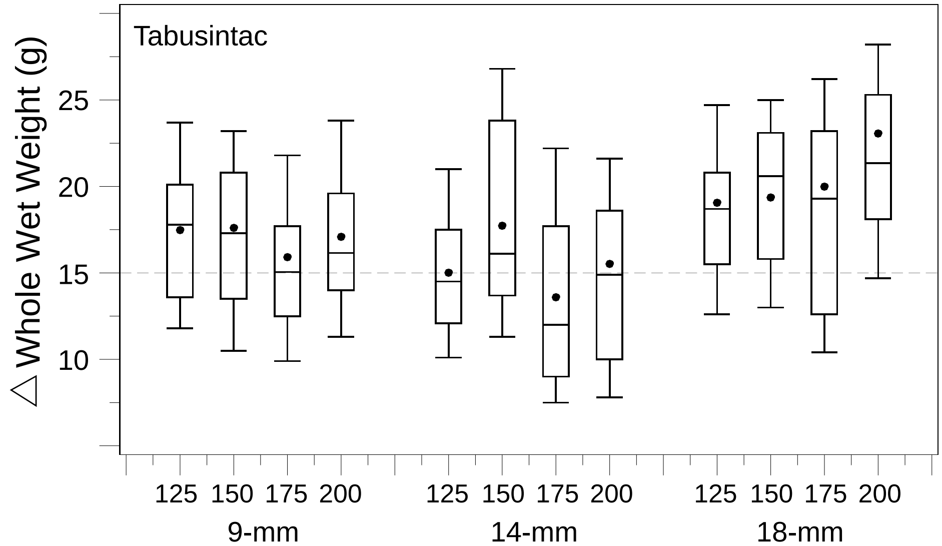

Figure 13 : Box and whisker plot showing total weight growth for four stocking densities in three types of bags.

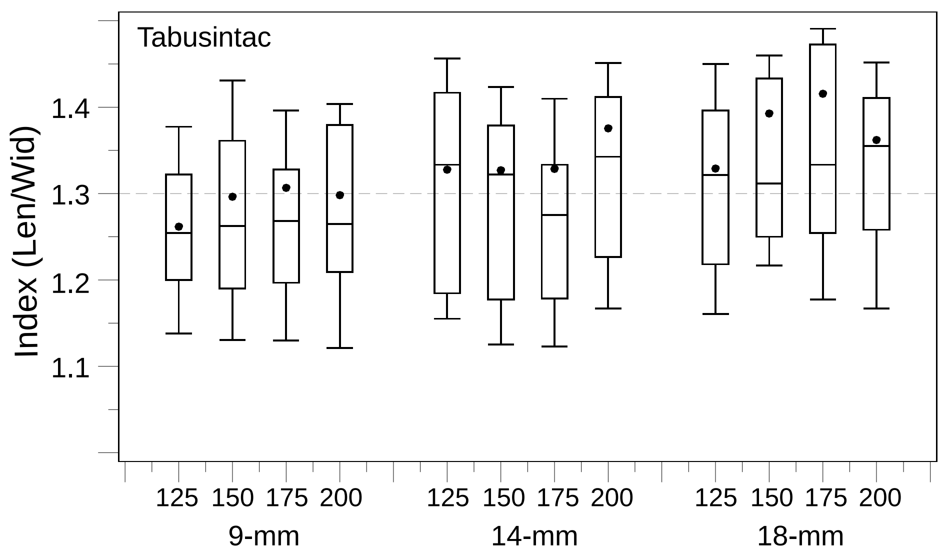

Figure 14 : Box and whisker plot of shell quality in September 2015 for oysters grown in three types of bags at four stocking densities.

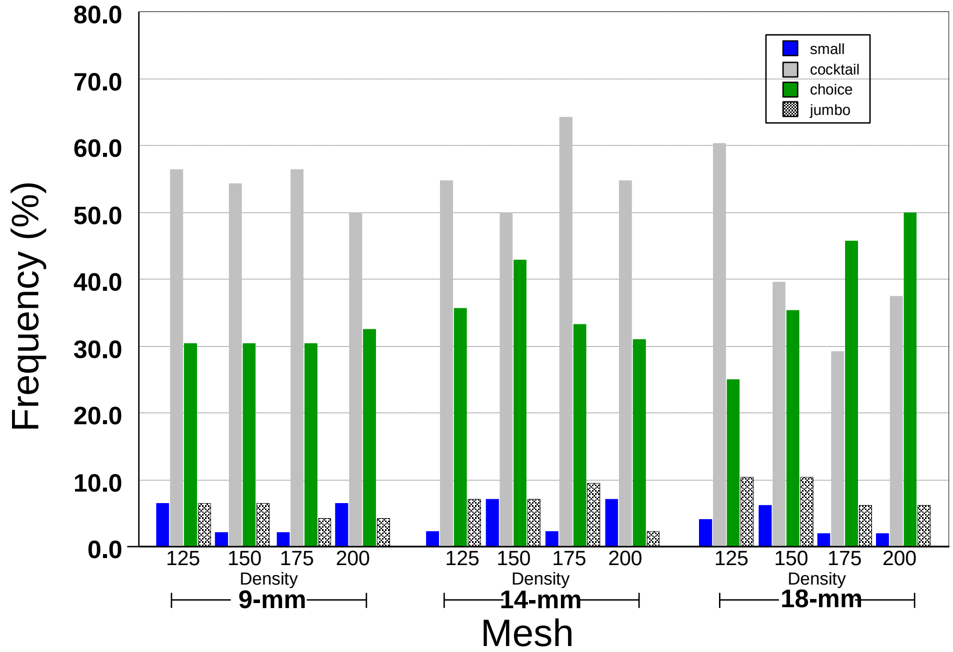

Figure 15 : Distribution of the relative frequency of oyster grades (Small, Cocktail, Choice, and Jumbo) in September 2015.

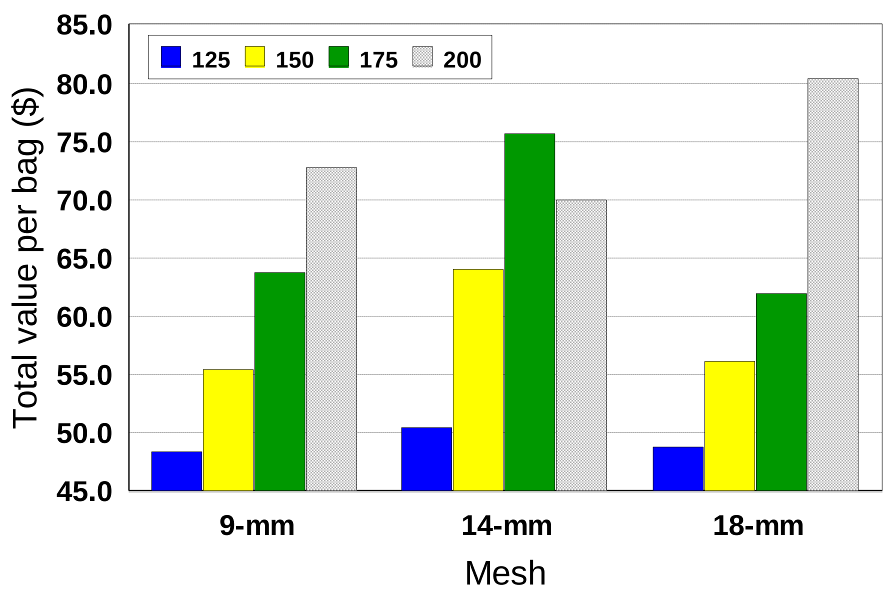

Figure 16 : Total value of oysters from different types of bags at different densities. The value of the different oyster grades is as follows: Small $0.28; Cocktail $0.34; Choice $0.47; and Jumbo $0.55.

c) Tracadie

At the Tracadie site, there is generally a negative association between stocking density and the linear or weight growth performance (Figure 17-21). It is also at this site that the replicate factor is not significant, i.e. similar performance among bags within mesh type and stocking density. The density of 125 oysters per bag, regardless of the type of mesh, produces the best growth performance. Unlike the other sites, the mesh effect is only significant for thickness growth. With the exception of the 18-mm bag, the proportion of Choice oysters is highest in the lowest densities (Figure 22). Despite these trends, the value of the inventory has a positive association with the number of oysters in the bags (Figure 23).

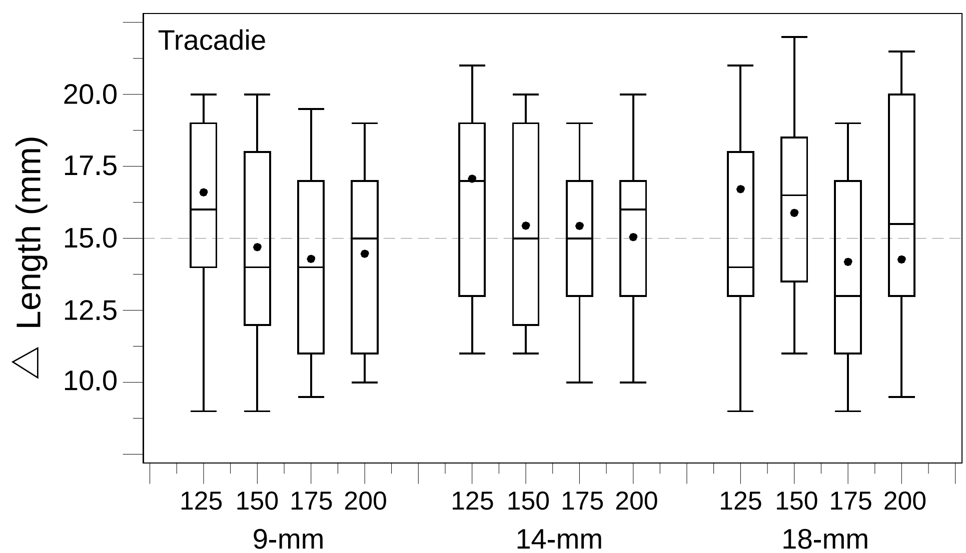

Figure 17 : Box and whisker plot showing length growth for four stocking densities in three types of bags.

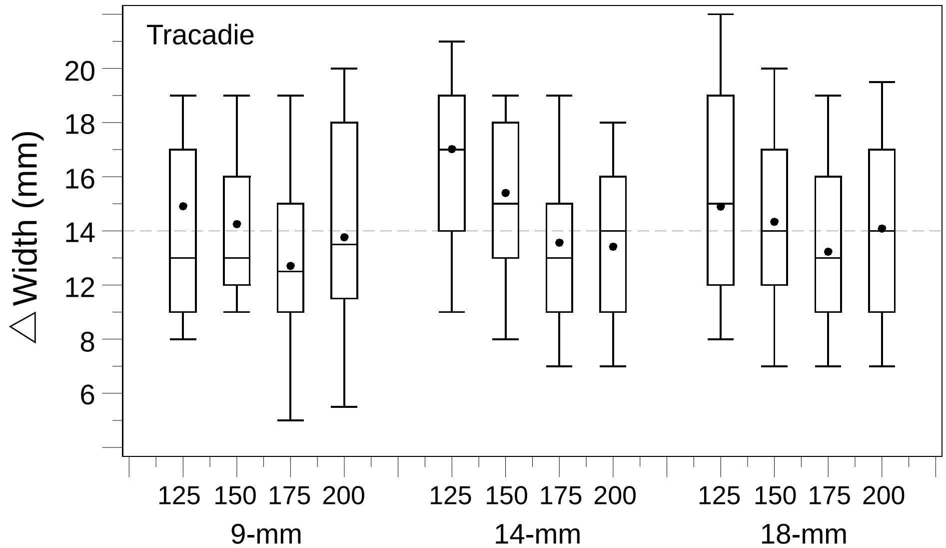

Figure 18 : Box and whisker plot showing length growth for four stocking densities in three types of bags.

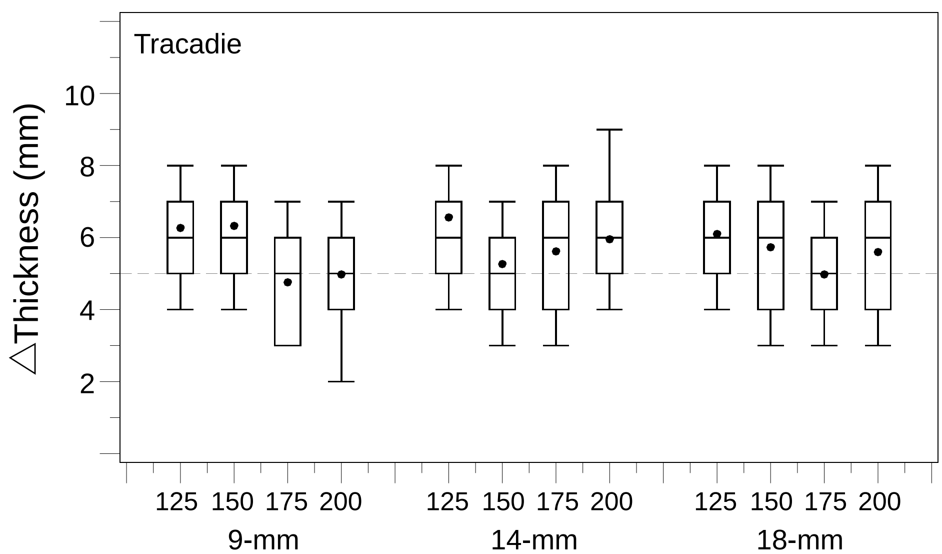

Figure 19 : Box and whisker plot showing thickness growth for four stocking densities in three types of bags.

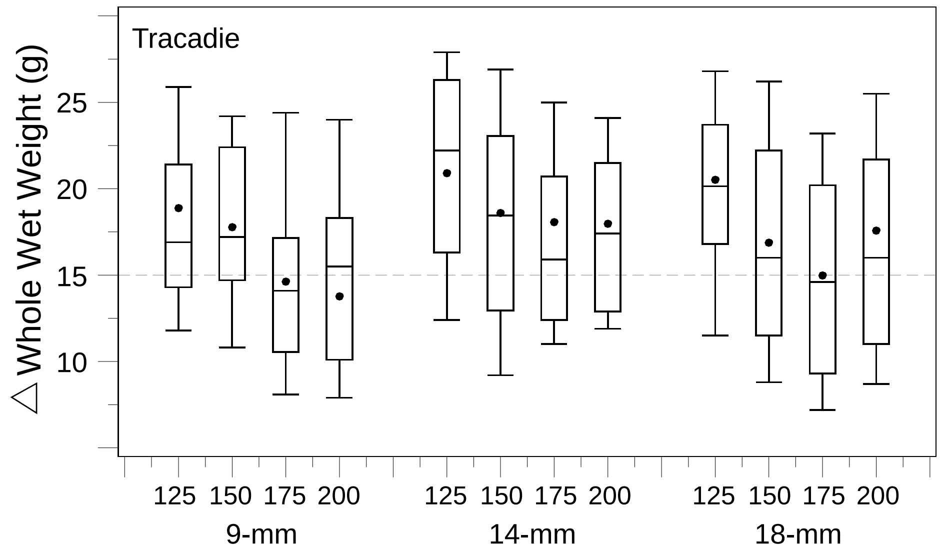

Figure 20 : Box and whisker plot showing total weight growth for four stocking densities in three types of bags.

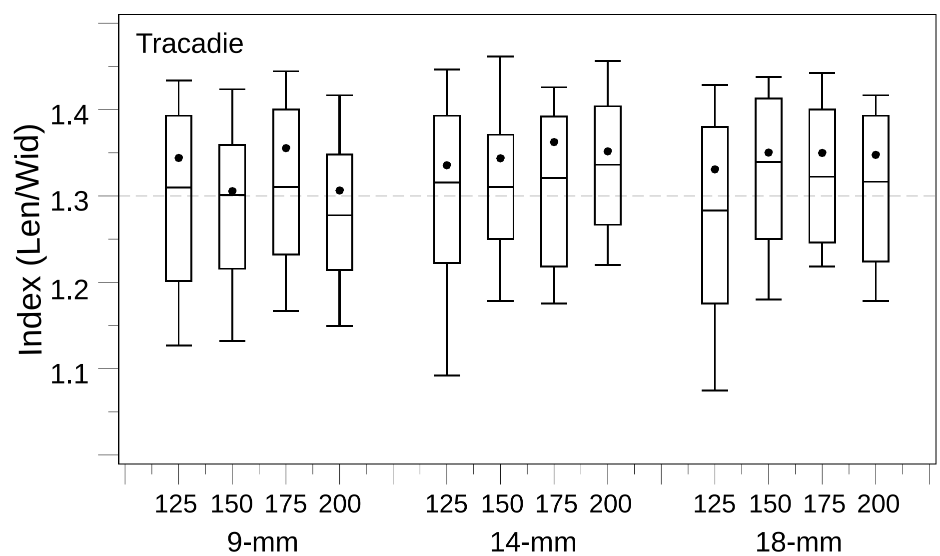

Figure 21 : Box and whisker plot of shell quality in September 2015 for oysters grown in three types of bags at four stocking densities.

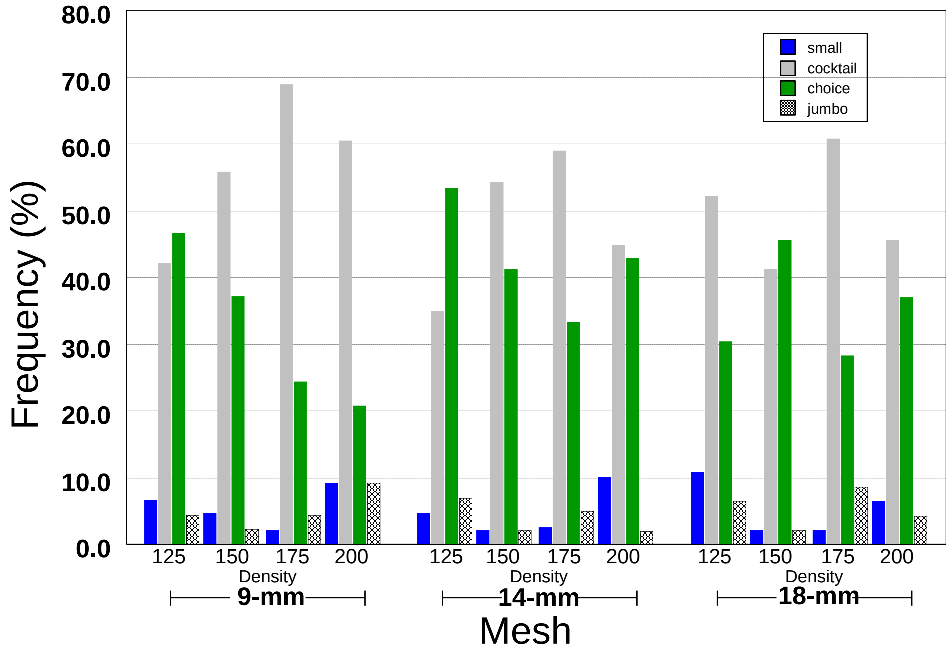

Figure 22 : Distribution of the relative frequency of oyster grades (Small, Cocktail, Choice, and Jumbo) in September 2015.

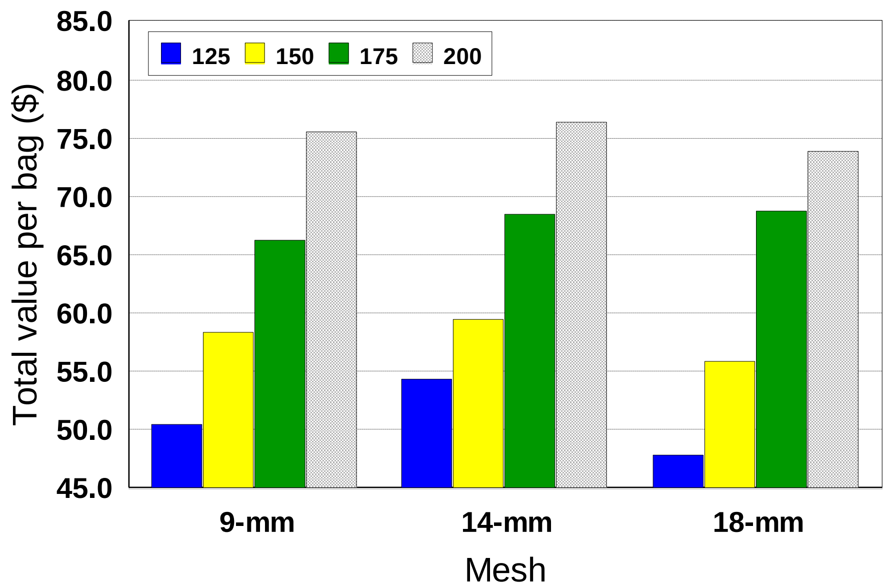

Figure 23 : Total value of inventory for different types of bags at different densities. The value of the different oyster grades is as follows: Small $0.28; Cocktail $0.34; Choice $0.47; and Jumbo $0.55.

d) South Saint-Simon

At the South Saint-Simon site, the length and width growth performance is the lowest of the three bays (Figure 24-25). In terms of total weight, thickness, and length, lower performance is evident in the 9-mm bags, the only factor that was statistically significant at this site. This site also contains the largest proportion of Cocktail oysters compared with the Choice grade (Figure 29), owing to the lower length growth; however, despite this trend, the value of the stock is still related to the number of oysters placed in the bags, regardless of the type of bag (Figure 30).

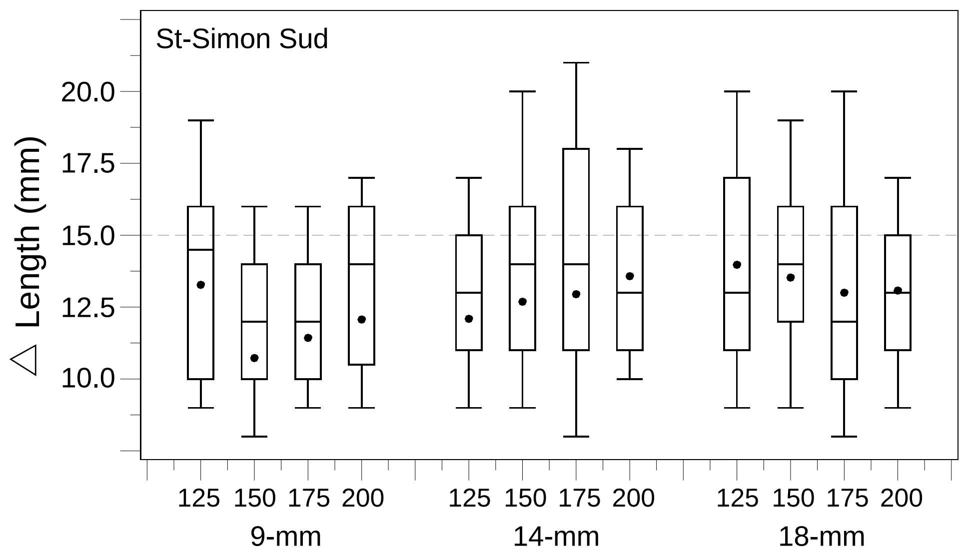

Figure 24 : Box and whisker plot showing length growth for four stocking densities in three types of bags.

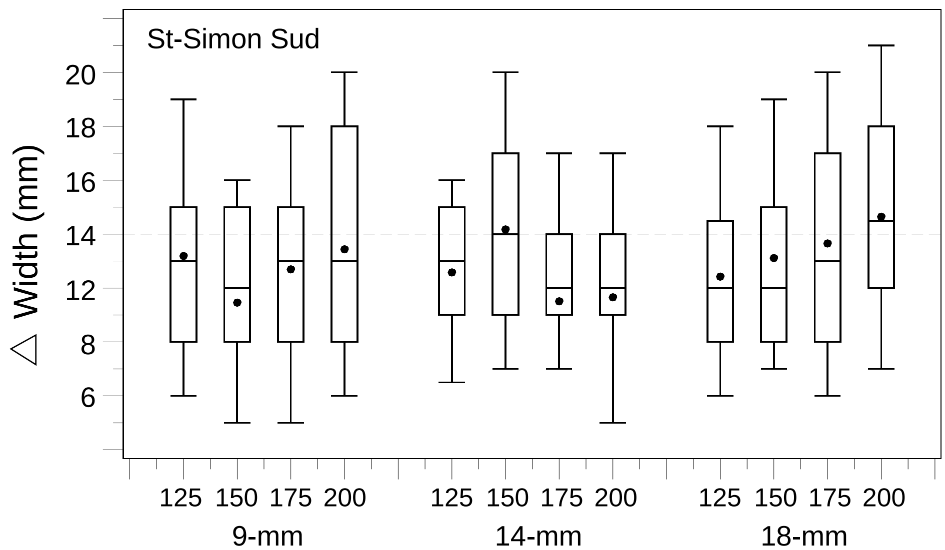

Figure 25 : Box and whisker plot showing width growth for four stocking densities in three types of bags.

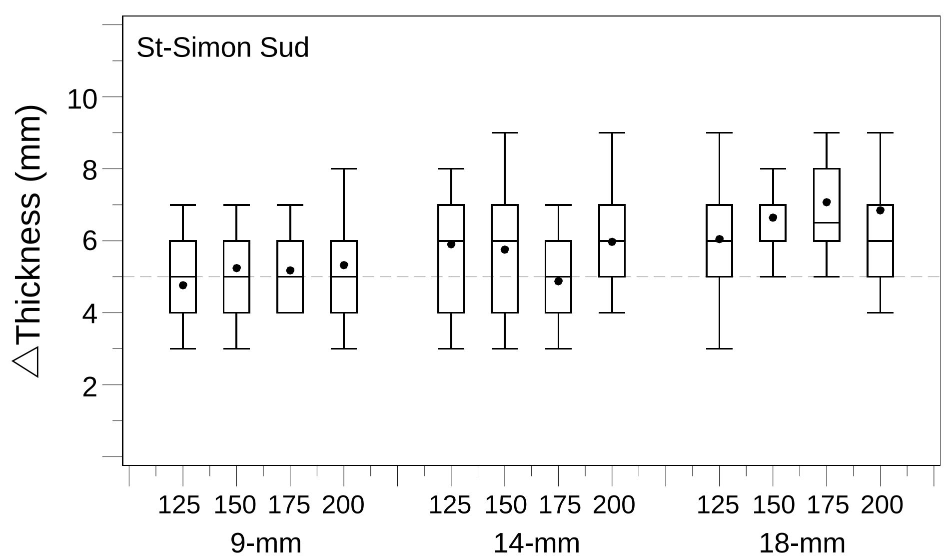

Figure 26 : Box and whisker plot showing thickness growth for four stocking densities in three types of bags.

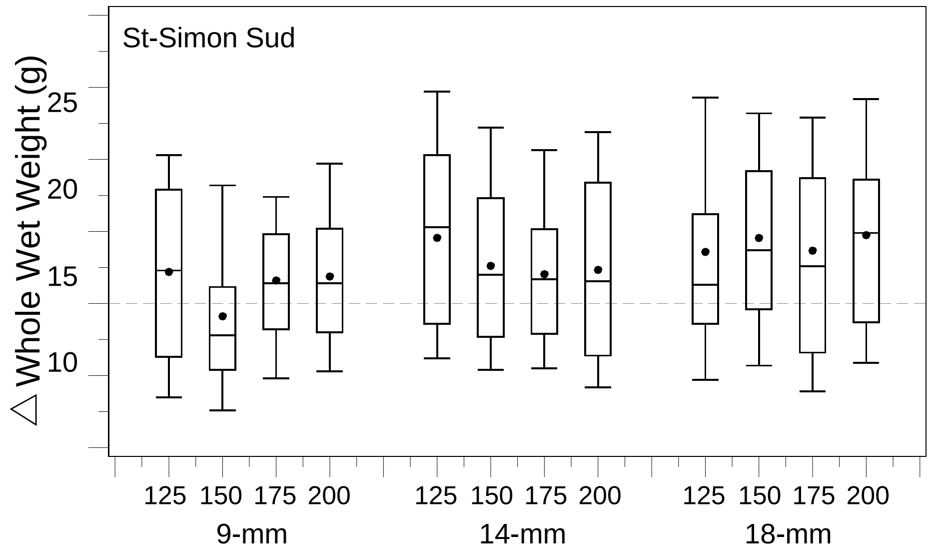

Figure 27 : Box and whisker plot showing total weight growth for four stocking densities in three types of bags.

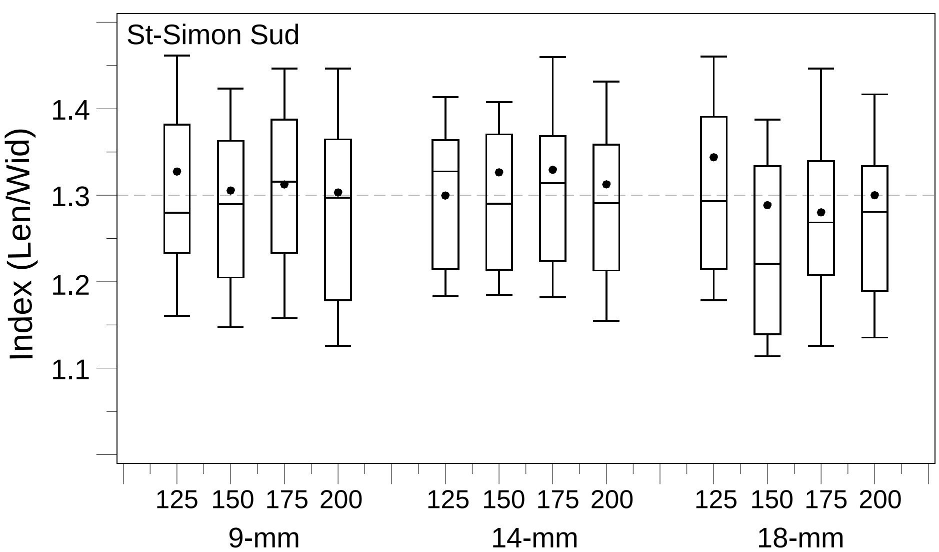

Figure 28 : Box and whisker plot of shell quality in September 2015 for oysters grown in three types of bags at four stocking densities.

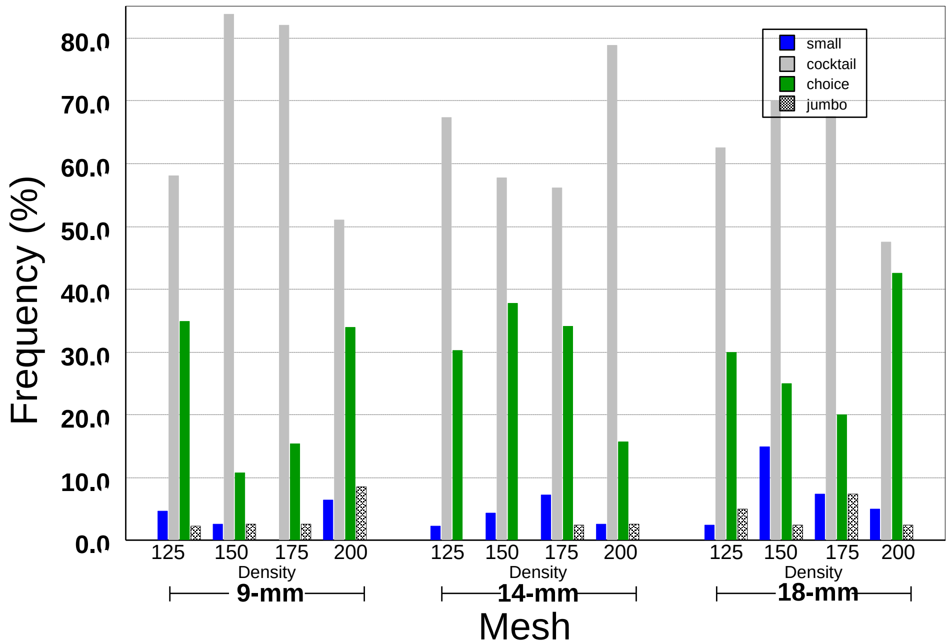

Figure 29 : Distribution of the relative frequency of oyster grades (Small, Cocktail, Choice, and Jumbo) in September 2015.

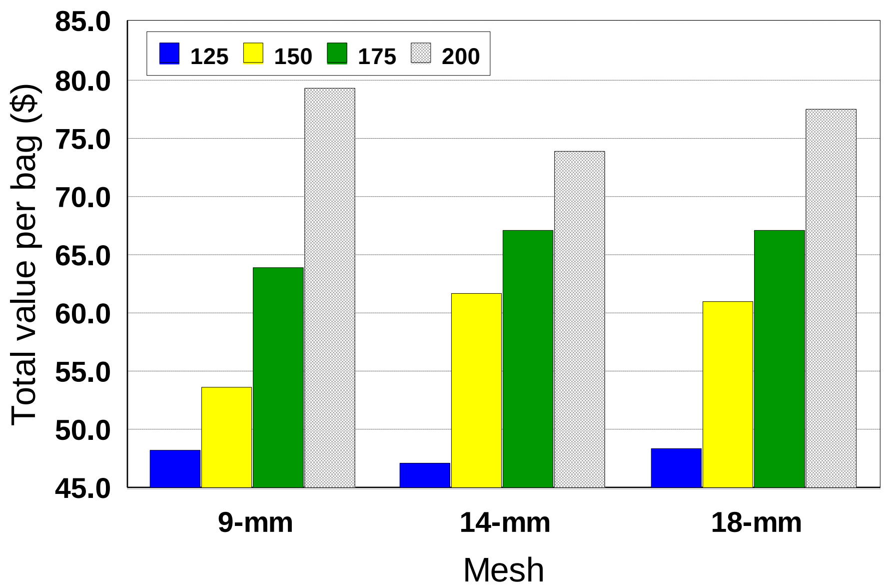

Figure 30 : Total value of inventory from different types of bags at different densities. The value of the different oyster grades is as follows: Small $0.28; Cocktail $0.34; Choice $0.47; and Jumbo $0.55.

4. DISCUSSION

A study conducted as part of the ACRDP program in 2007 compared the results in terms of linear growth of four lots of tagged oysters from a common lot in floating bags and on oyster tables in North and South Saint-Simon Bay. The following figure is an average of the two sites and helps to illustrate the poor growth performance that seemed to be the norm in the Saint-Simon Bay at the time. This poor linear growth resulted in a fairly weak annual production of market-size oysters, which caused several companies to cease operations. Linear growth is certainly variable from one year to another, and for oysters over 50 mm, additional results in subsequent years indicated annual growth of between 4 and 8 mm with returns of less than 50% in market-size oysters over two years. It is this weak growth that led the L'Étang Ruisseau Bar company to use the glued oyster technique in which annual yields were reliable with approximate annual growth of 12 mm in South Saint-Simon and 15 mm in North Saint-Simon.

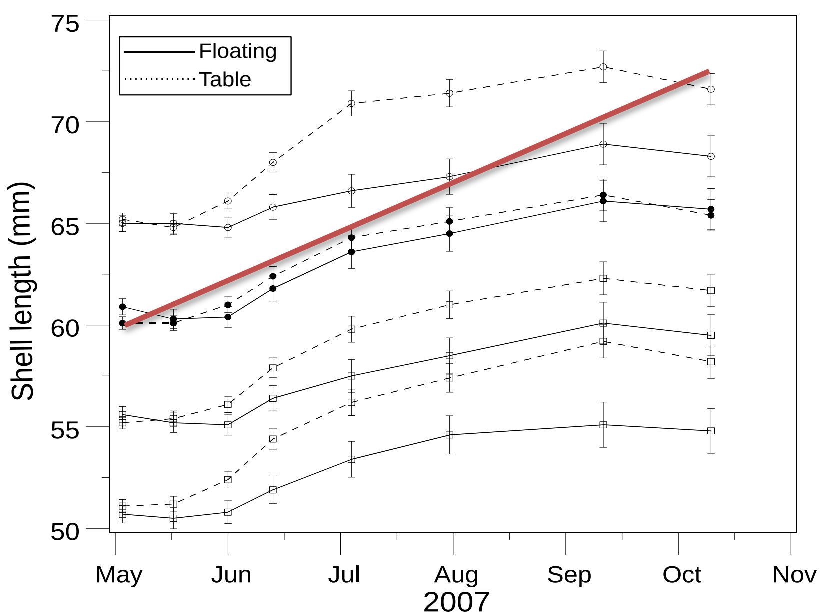

Figure 31 : Graph from an ACRDP report describing production in terms of length of four lots of oysters in two oyster culture devices. The red line shows production measured in this study of the 60-mm experimental lot in Saint-Simon Bay.

L'Étang Ruisseau Bar began production of hatchery seed in 2009, and as of 2012 we did notice the excellent growth of oysters >55 mm in floating bags. The 2015 study represents the first results of a standardized protocol on oysters from hatchery stock. In this context, the average annual growth is approximately 12.5 mm in South Saint-Simon, and with the starting point at 60 mm in the above graph, the line would be higher than the final point of the upper line with an initial average of 65 mm. This annual growth in excess of 12 mm, with percentages of over 85% of market-size oysters, is similar to the growth obtained with glued oysters under the same environmental conditions.

In the commercial context, the value of the stock obtained in a season from this study is mainly related to the number of oysters raised in bags. With each increase of 25 oysters, the value of the stock increases by $10.00 with no sign of slowing down. At a certain currently unknown density, a decrease should be expected in the stock value, because the density will eventually have a significant effect on biological production and the quality of the oysters which will affect the stock of market-sized oysters. The total weight of the oysters in a bag and the ability to adequately monitor biofouling must also be taken into consideration. From a strictly biological standpoint, however, a greater stock value could be anticipated by increasing the number of oysters per bag to 225.

In general, it can be observed that the performance of the 9-mm bag is slightly lower than 14-mm and 18-mm bags; for example, there is a higher percentage of Cocktail oysters (Figure 9), which is explained by the smaller length growth in this mesh. It can also be noted that the oysters in 18-mm mesh bags have a greater weight growth, probably because of more growth of the thickness parameter.

With respect to density, the effects vary widely between the sites except at the Tracadie site where there is a significant association between the density and the linear and weight results. At this culture site, the stocking density of 125 oysters per bag provides the best linear and weight growth. The biofouling level on the floating bags would seem to have been higher in South Saint-Simon and Tabusintac, which could have explained the inconsistency between density and performance. However, even in Tracadie, the best monetary return occurs with a stocking density of 200 oysters per bag as everywhere else.

5. RECOMMENDATIONS

- In order to confirm the results in terms of the main factors in this study, stocking density and type of mesh, redo the study in Tracadie Bay, increasing the replication level at each site and choose two locations to do the monitoring.
- Ensure that the initial lots are more uniform.
- Monitor biofouling closely or select floats that enable the bags to dry well.
- If possible, choose two lots of oysters, 50 mm and 60 mm.

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