Evaluation of spawning period and spat collection of the northernmost population of European oysters (*Ostrea edulis* L.) on the Canadian Atlantic coast

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Abstract

The European oyster (*Ostrea edulis* L.) was introduced in Lockhart Lake (N.B., Canada) at the end of the 1990's. They have since, against expectations, established a self sustaining population in some part of the lake making it the northernmost population of this species along the Canadian Atlantic east coast. As they are able to reproduce naturally, it would be possible to undertake their culture without relying on hatchery reared juveniles. The objectives of this study were to determine the spawning time of the oysters and the most efficient type of spat collectors. In order to determine the spawning time, we took samples of oysters and perform plankton tows in June-September 2004. Six types of collectors were tested, in triplicates, and each type was placed at two different depths at three sites. Spawning occurred in mid-July and spat was observed in early August. A low number of spat had settled on the collectors (from 0 to 468 spat per collector). The number of collected spat seems to be influenced by the type of collector, depth and location in the lake. The most efficient collectors were the Chinese hats ($\overline{X} = 261$ spat per collector) in comparison to the others ($\overline{X} = 7$ spat per collector). The low number of collected spat could be explained by many factors such as an inappropriate collection technique and/or the poor condition of the genitors or larvae. Unfavourable environmental conditions found at the northern limit of *O. edulis* distribution may constrain the energy allocated to larvae. Thus, their capacity to complete their metamorphosis with success is limited, leading to a high mortality rate.

Résumé

L'huître européenne (*Ostrea edulis L.*) a été introduite au Lac Lockhart (NB, Canada) vers la fin des années 1990. Ces huîtres se sont établies dans une partie du lac et représentent aujourd'hui la population la plus nordique située le long de la côte est Atlantique du Canada. Comme elles sont capables de se reproduire naturellement, il pourrait être possible d'entreprendre leur culture sans compter sur la production de juvéniles en écloserie. Les objectifs de cette étude ont été de déterminer la période de ponte et le type de collecteurs le plus efficace pour le captage du naissain. Afin de déterminer la période de ponte, des échantillonnages d'huîtres et des traits de plancton ont été effectués en juin-septembre 2004. Six types de collecteurs ont été testés en triplicatas et chacun d'eux a été placé à deux profondeurs différentes sur trois sites. La période de ponte a eu lieu à la mi-juillet et le naissain a été observé sur les collecteurs au début août. Une faible quantité de naissain s'est fixée sur les collecteurs (de 0 à 468 naissains par collecteur). Le nombre de naissain collecté semble être influencé par le type de collecteur, la profondeur et la position dans le lac. Les collecteurs les plus efficaces ont été les chapeaux chinois ($\overline{X}$ = 261 naissains par collecteur) en comparaison aux autres collecteurs ($\overline{X}$ = 7 naissains par collecteur). Ce faible captage peut être expliqué par une technique de collecte inappropriée, et/ou par la mauvaise condition des géniteurs ou des larves. Les conditions environnementales non favorables retrouvées à la limite de distribution nordique de *O. edulis* peuvent fortement influencer le taux d'énergie alloué aux larves. Ce manque d'énergie pourrait limiter leur capacité à terminer leur métamorphose avec succès, menant ainsi à un taux de mortalité élevé.

Introduction

Rapid growth and the ability of the European oyster (*Ostrea edulis* L.) to live in a wide range of environments has made this species an ideal candidate for mariculture (Ruiz *et al.*, 1992). The first European oysters were introduced in Milford, Connecticut by Loosanoff in 1949, who reported on their initial survival, gametogenesis, and spawning (Loosanoff, 1955, 1962). Following this successful introduction, culture of *O. edulis* has been tried in Eastern Canada, at St Andrews (New Brunswick) and Ellerslie (Prince Edward Islands) in 1957, 1958 and 1959. However, heavy mortalities occurred, apparently associated with low winter water temperatures (Medcof, 1961). Flat oysters were thereafter brought to the Atlantic coast of Nova Scotia in 1970, but the low salinity in Point Pleasant killed the majority of the oysters. Because of the unfavourable conditions in Nova Scotia, the European oyster did not reproduce and their renewal largely depended on hatchery seed production. In the last few years, hatcheries have encountered several technical difficulties in production of healthy spat and the European oyster industry in Nova Scotia has declined (Vercaemer *et al.*, 2003). On the other hand, heavy winter mortalities led to many winterization experiments as far north as Shippagan and New Horton (New Brunswick). Following these experiments, a newly established flat oyster population has been discovered in New Horton (Lockhart Lake) and, because of recent hatchery problems, this population has attracted a great interest as a natural source of seed.

The life cycle of the European oyster contrasts with that of the American oyster (*Crassostrea virginica* Gmelin) in many ways. First, *O. edulis* spawn at temperatures varying from 13 to 16°C (Korringa, 1940; Walne, 1974; Le Dantec & Marteil, 1976; Newkirk *et al.*, 1995), while *C. virginica* spawn at 20°C (Lavoie, 1995). Furthermore, fertilisation of eggs and the development of the trochophore and veliger stages occur in the paleal cavity of the *O. edulis* female for approximately half of the larval period (Loosanoff *et al.*, 1966; Le Dantec &

Marteil, 1976; Newkirk & Haley, 1982; Newkirk *et al.*, 1995). In *C. virginica*, fertilisation occurs in the water column (Lavoie, 1995). The duration of the larval period of *O. edulis* is usually 16 to 24 days (Le Dantec & Marteil, 1976). Early development is rapid, going from the fertilized eggs to the trochophore larvae in just a few hours. In the next two days, the trochophore larvae reaches the veliger stage, but is still brooded for a few days (Le Dantec & Marteil, 1976). Larvae are released from the female at a size of 142 μm-190 μm (Korringa, 1940; Loosanoff *et al.*, 1966; Walne, 1974; Newkirk *et al.*, 1995; Uyan & Aral, 2000), after 8 to 10 days of brooding (Korringa, 1947; Newkirk & Haley, 1982). After a planktonic stage of 8 to 14 days (Le Dantec & Marteil, 1976), larvae settle at a size of 280 μm to 300 μm (Loosanoff *et al.*, 1966; Le Dantec & Marteil, 1976; Uyan & Aral, 2000).

Variations in the recruitment of *O. edulis* may be due to a number of factors such as low temperature during spawning season, quantity and quality of available substrate for spat settlement, spat mortality caused by dredge haul, predation and overfishing (McKelvey *et al.*, 1993). Prediction of spatfall timing is critical to the success of a bivalve culture industry. Thus, this study will evaluate the larval recruitment at Lockhart Lake by comparing spat collection on six types of collectors deployed at three sites and at two depths. In order to predict the spatfall time and, therefore, the best time to install the collectors, plankton tows and direct observation of gonads will be conducted.

Materials and Methods

The study was carried out at Lockhart Lake (N 45.67735°, W 64.74505°) in southeastern New Brunswick (Fig. 1). This salt lake covers an area of approximately 69 hectares and is indirectly influenced by the tide cycles of the Bay of Fundy. The depth of the lake varies between 0.9 to 12.2 m and the bottom is primarily composed of mud. The population of European oysters is mainly found in shallow areas of the northeast part of the lake. This study was conducted between June and September of 2004. Two sampling sites

(A and B) and three spat collection sites (C, D and E) were chosen according to the location of European oysters (Fig. 1). The depth at collection sites range between 3 and 5 m. Sites A and B are situated approximately 9 m from shore and at a depth of 1 to 1.5 m.

Adult oysters collection

A total of 10 oysters were collected by dredging weekly in June and September, and twice a week in July and August. For each collected oyster, length, height and total weight were recorded. Fresh and dry weight of flesh and dry weight of valves were also determined to estimate the condition indices based on the Medcof and Needler (1941) method.

$$\text{Physiological index} = [\text{tissue dry weight} / \text{shell dry weight}] \times 1000$$

$$\text{Commercial index} = [\text{tissue dry weight} / (\text{oyster wet weight} - \text{shell dry weight})] \times 1000$$

In addition, a smear of gonad products was taken from all individuals to identify sex by light microscopy. Observations of the opened oysters were also carried out to determine their reproductive status. A scale of S_1 to S_3 was used to classify each oyster. S_1 is an oyster before spawning, with gametes highly abundant. S_2 is an oyster with eggs or larvae on the gills. The S_2 stage was subdivided in three parts; S_{2A} an oyster with a white milky egg mass on gills, S_{2B} an oyster with a light grey larvae mass on gills corresponding to the trochophore stage and S_{2C}, an oyster with slate grey larvae mass on gills corresponding to the veliger stage. The S_3 stage is an oyster having released its larvae and showing empty gonads. Stages are illustrated in Figure 2.

Environmental parameters

Environmental parameters were monitored to compare the conditions under which spawning and release of larvae occurred. Environmental parameters were recorded at each sampling

date and were collected at the surface and at the bottom of the collection sites, A and B. Temperature (°C), salinity (‰) and dissolved oxygen (mg/L) were recorded using a YSI Model #85-25 FT. Water samples were also collected at these sites to determine suspended matter (mg/L).

Oyster spat collection

Between July 19 and September 14, larvae were sampled at sites C, D and E by towing a plankton net (mesh = 103 μm) for 5 minutes, twice a week. Larvae were conserved in a 50 % alcohol solution and counted later to estimate their density (larvae/m^3). A randomly chosen sub-sample of larvae (n=30) was measured for each sample. On July 27, after the first larvae observed on July 23, six types of collectors were submerged at sites C, D and E. Collectors tested during this study were Chinese hats, Vexar bags full of soft-shell clam shells, onion bags filled with Netron pieces, drain tubes, scallop shell strings and French tubes (Fig. 3). A total of 96 collectors were used in this study. At each of the three collection sites, each type of collector was set at two depths (1.2 and 1.8 m), in triplicate. The only exception was the French tubes which had no replicates. The Chinese hats and drain tubes were coated in a mixture of water, lime, sand and cement to provide a suitable substrate for the larvae (Dijkema & Bol., 1984). Two of the replicates and all French tubes were removed from water on October 27 and brought to the laboratory where the number and size of collected juveniles were recorded. The last replicate was sunk to the bottom to evaluate winter survival rates of the juveniles.

Data analysis

The data was analyzed with SPSS 12.0© for Windows©. All analyses were calculated at a confidence level of $P < 0.05$. As normality and homoscedasticity of variances were not met, logarithm and natural logarithm transformations were performed on data (number of spat per collector) to meet the requirements of the ANOVA. Following these transformations,

normality and homoscedasticity of variances were still not met, so a Poisson regression was used, as this statistical test is more appropriate when data are extremely different. The factors were site, depth and type of collector. A Kruskal-Wallis non-parametric test was used to evaluate spat growth. Factors included were site and depth.

Results

Environmental parameters

Temperature ranged between 10.1 °C at the beginning of June to 19.7 °C in mid-July. Temperature followed the same trends for both sites A and B. Drop in temperature was observed early in August, but temperature reached again the maximum in mid-August. Salinity at the two sampling sites was similar during the study with a maximum of 29.8 ‰ observed in mid-August. Dissolved oxygen concentrations were approximately the same during the sampling period at each site, with a maximum of 11.26 mg/L in mid-June and a minimum of 6.43 mg/L in mid-July. Those results are represented in Figure 4.

Total suspended matter fluctuated continuously throughout the study period, varying from 3.35 mg/L to 21.71 mg/L (Fig. 5). We observed two peaks of suspended matter concentration during the season. The first occurred at site B at the end of July and the second at site A in mid-September. Concentrations of organic and inorganic suspended matter fluctuated between 0.44 mg/L to 4.68 mg/L, and 2.00 mg/L to 21.06 mg/L, respectively during the study. Peaks of organic and inorganic suspended matter were observed at the beginning and the end of July and at the end of July and mid-September, respectively.

Adult oysters

Gametes were observed on June 29 and sex identification was possible from that time until September 2nd. After September 2nd, a mix of spermatozoa and oocytes was observed in the gonads of the same oyster and it became impossible to correctly sex the oysters. A sex ratio male/female of 2:1 was observed. Table 1 shows the morphometric measurements of

these individuals. Females brooding larvae appeared for the first time on July 16 at a temperature of 19°C and remained present until August 17, indicating that spawning took place for a little more than one month. Once spawning occurred, eggs are fertilized on the gills of the oysters and their development starts, going through three different stages, before being released in the water column. At the first stage (S_{2A}), the eggs, then, looked like a white milky mass covering most of the gills (Fig. 2b). These eggs developed into trocophore larvae (stage S_{2B}) and their colour changed to light grey (Fig. 2c) and changed again to slate grey just prior to being released (S_{3C} - Fig. 2d). Table 2 shows the percentage of oysters in these different stages throughout the experiment.

Commercial condition index peaked at the end of June (173.45) and physiological condition index peaked at the beginning of July (67.08). Condition indices began to decrease at the end of July corresponding to the spawning period of the European oysters (Fig. 6). Larvae appeared in the plankton on July 23 at a temperature of 19.5°C and exhibited maximum density on July 30 at 17.6°C. The last larvae were sampled on September 14th at a temperature of 16.6°C. The mean size of free-living larvae was 187 µm with a minimum of 150 µm for newly-liberated larvae and a maximum of 270 µm for mature larvae. In Figure 7, four peaks of high larval density are visible. The main peak of the season occurred at the end of July (40,000 larvae/m^3) and the three others occurred in August (< 20,000 larvae/m^3).

Oyster spat collection

We first examined at the collectors on August 4, and some spat were already present on the Chinese hats. However, data reported here were taken on the collectors removed from water on October 27.

Spat number

The Poisson regression showed that the number of spat was influenced by the position of the site, depth and type of collector. Spat collection at site C was significantly different ($P<0.001$) from site D and E (Table 3). The number of spat collected at 1.8 m was significantly higher ($P=0.0076$) than at 1.2 m. The Chinese hats were the most effective collectors. Specific number and mean size of spat collected in relation to each type of collector are shown in Table 4.

Spat size

The mean size of spat found on the collectors at sites C, D, and E was significantly different ($p<0.001$), with spat size on site E (11.8 mm) being higher than site D (10.5 mm), in turn higher than site C (8.7 mm). Furthermore, at each site, the mean size of the larvae collected at 1.2 m was significantly higher ($p<0.001$) than at 1.8 m. Only Site E exhibited spat larger than 25 mm, with the biggest spat found on the Chinese hats (max. 32 mm).

Discussion

The European oyster lives at a salinity ranging between 23 ‰ and 33 ‰ (Korringa, 1940; Newkirk *et al.*, 1995; Uyan & Aral, 2000) and spawns, in contrast to the American oyster, at temperatures varying between 13°C and 16°C (Korringa, 1940; Walne, 1974; Le Dantec & Marteil, 1976; Newkirk *et al.*, 1995). Spawning generally does not occur below this temperature range without a prolongation of development time (Le Dantec & Marteil, 1976). Temperatures (10°C-20°C) and salinities (26 ‰-30 ‰) recorded during the 2004 growing season at Lockhart Lake allowed *O. edulis* to spawn. However, the presence of eggs on the female oyster gills was only observed at 19°C. Given that oysters were sampled by dredging and that the marginal relief of the lake is generally abrupt, they were possibly taken at different depths. However, since the temperature at 1 and 3 m varied little (± 0.5 °C) during the growing season, this indicates that the oysters indeed spawned at 19°C. Thus, a

delay in the spawning period was observed. Studies have shown that, in *C. virginica*, the initiation of gametogenesis and spawning could occur at different temperatures according to the geographical position (Ruiz *et al.*, 1992) and studies carried out on *O. edulis* demonstrate that timing and duration of gametogenesis could vary and be highly dependant on water temperature and food availability (Wilson & Simons, 1985). It is known that food availability greatly influences the physiological condition of oysters (Frolov & Pankov, 1992). It is also known that carbohydrates (or glycogen) accumulated after the spawning period of the previous season becomes the main source of energy used by adult bivalves (Walne & Mann, 1970; Frolov & Pankov, 1992) during gametogenesis (Fando *et al.*, 1972; Ren & Ross, 2001). As this population is found in its northern distribution limit and water temperature cools quickly at the end of the summer, it is possible that the oysters cannot accumulate enough glycogen during autumn and winter and this could have slowed the gametogenesis processes, and thus explains the delay observed in the spawning period.

At the beginning of summer 2004, it was difficult to differentiate between female and male gametes. According to Lucas (1971), the identification can only be made when differentiation is advanced enough. The sexing of *O. edulis* became even more difficult after spawning since we observed ambisexual individuals. As European oysters are protandric, it is possible, based on histological observations of gonads, to see both sexes in the same section of a gonad (Orton, 1927). Once the spawning occurred in mid-July, a decline in condition indices was observed. This reduction is mainly caused by the use of food reserves and expulsion of gametes during spawning (Paquotte & Moriceau, 1987; Austin *et al.*, 1993). According to Korringa's (1956) classification of commercially acceptable dry meat condition, we observed that very poor oysters were found in Lockhart Lake since more than 70 % of these oysters had a commercial index below 90.

Larvae of European oyster are usually released from the female by the time they reach a length of 143 µm -190 µm (Korringa, 1940; Loosanoff *et al.*, 1966; Walne, 1974; Newkirk *et al.*, 1995; Uyan & Aral, 2000) and they usually set at a length of 280 µm-300 µm (Loosanoff *et al.*, 1966; Le Dantec & Marteil, 1976; Uyan & Aral, 2000). The mean length of larvae during this study was 187 µm and only 40 % of the larvae were higher than the mean length. An exception was observed on August 12 when more larvae larger than the mean length were recorded with a proportion of 67 % and a mean length of 199 µm. The lack of mature larvae with a size close to the usual size at settlement might be explained by various hypotheses. First, it is possible that European oyster larvae in Lockhart Lake set at a smaller size than the usual size at settlement. Boury (1929), cited by Korringa (1940), also found that setting could take place at a size of 270 µm with larvae larger than 270 µm being rare. This would explain the fact that larvae of 270 µm represented the maximum size observed at Lockhart Lake in 2004. Another possibility could be that we did not tow the plankton net deep enough and, during their larval growth, the larvae tend to sink to a greater depth to reach a substrate for settlement. However, this may not be the case since Korringa (1940) demonstrated that the vertical distribution of full-grown *O. edulis* larvae was uniform during daytime. Another plausible hypothesis is that the larvae did not have enough energy to reach the settlement stage and undertake metamorphosis. Viability of newly-liberated larvae in European oysters is correlated with lipid content which is the major reserve of energy (Helm *et al.*, 1973; Holland & Spencer, 1973). In fact, there is a direct correlation between the size of the released larvae and the lipid content of the releasing females (Frolov & Pankov, 1992). The Poisson regression showed that site, depth and type of collector influence the number of spat found on the collectors. However, to have a better understanding about larval dispersion and to know the ideal collection sites, we would need hydrological studies done on this lake. The Poisson regression also demonstrates that spat collection was significantly lower at 1.2 m

than at 1.8 m. Accordingly to Abbe (1981), a better oyster spat collection is frequently observed at a greater depth. This larval behaviour is explained by many authors as a preference for darkened conditions when setting (Ritchie & Menzel, 1969; Shaw *et al.*, 1970), while others suggested that light stimulates larval settlement (Medcof, 1955). With regard to the type of collectors, Dijkema & Bol (1984) indicated that a mixture of sand and lime offer an excellent substrate for larval settlement. Our results showed that Chinese hats were the most effective collectors. The angle at which larvae can set may play a major role in settlement selectivity since other collectors, such as the drain tubes, where limed with the same mixture. The Kruskal-Wallis non-parametric test demonstrates that spat growth rate was different in relation to the location in the lake. According to Dijkema *et al.* (1985), spat that settled in shallow areas had a better growth than the ones in the deeper areas. As a higher number of spat settled in the deeper area, this would indicate that it would be a good practice to raise the collectors after spat settlement to boost the growth of juveniles. Finally, small number of spat collected in 2004 may be explained by several factors. A lot of fouling was found on the collectors at Lockhart Lake and this could have adversely affected the larval settlement (Méthé & Léger, 1993). Predation on larvae may also be an important factor. According to Dame (1996), jellyfish is one of the most common predators of larvae and a great quantity of jellyfish was observed in the summer of 2004 at Lockhart Lake. Another factor may be the physiological condition of the larvae which limit their capacity to set and finish their metamorphosis, as previously discussed.

Conclusion

The environmental conditions in Lockhart Lake seemed to be suitable to maintain a self reproducing European oyster population. Recruitment success of *O. edulis* depends on a series of events such as spawning, settlement and subsequent growth of the small juveniles. The efficiency of spat collection is influenced by fouling and it seems that fouling in Lockhart Lake can be a major factor. Thus, it is necessary that we increase our knowledge of larval population dynamics in order to have a better estimate of the best time to install spat collectors. This would certainly optimise the culture practices of *O. edulis* in this lake.

A better understanding of the state and structure of this population is also important to exclude the possibility of inbreeding that could have a negative effect on larval quality and viability. Larval quality refers to physiological condition, survivorship performance and growth during the growing season (Racotta *et al.*, 2003). The low spat collection recorded in 2004 may be explained by poor larval quality. We need more information on the genetic structure and on the energy reserve of genitors and on the energy allocated to their larvae in order to determine whether these aspects are playing a role in the poor spat collection found in 2004. Finally, once we are successful in collecting spat of *O. edulis* in Lockhart Lake in sufficient numbers, it will be necessary to evaluate the winter survivorship in order to promote a sustainable aquaculture practice.

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Table 1: Length (mm), height (mm) and weight (g) of the European oysters (*Ostrea edulis* L.) collected during the 2004 growing season, at Lockhart Lake,N.B.

	Site A	Site B
Mean length	96.94 ± 11.68	96.97 ± 13.50
Mean height	95.24 ± 9.50	94.76 ± 12.83
Mean weight	115.51 ± 40.43	113.84 ± 48.26
n	108	112

Table 2: Percentage of oysters in each of the 5 stages. S_1-Oyster where gametes are highly abundant; S_{2A} -Oyster with a white milky eggs mass on gills; S_{2B} -Oyster with a light grey larvae mass on gills (trochophora stage); S_{2C} -Oyster with a slate grey larvae mass on gills (veliger stage); S_3 -Oyster with depletion of gonads.

Status	S_1	S_{2A}	S_{2B}	S_{2C}	S_3
May	100	0	0	0	0
June	100	0	0	0	0
July	65.8	5.7	5.7	7.1	15.7
August	41.2	9.8	1.9	5.9	41.2

Table 3: Poisson regression examining the effect of site, depth and type of collector on the number of spat collected.

Constant	Site	Depth	Collector	β	SE β	p
1				5.691	0.033	0.000
	1			-0.378	0.045	0.000
	2			0.071	0.039	0.070
		1		-0.091	0.034	0.008
			1	-5.409	0.268	0.000
			2	-6.949	0.578	0.000
			3	-4.870	0.205	0.000
			4	-2.242	0.061	0.000

Table 4: Mean number (two replicates) and mean size (mm) of spat present on each type of collector, for each site and depth . CH –Chinese hats, SCVB – Vexar bag full of clam shells, OBNP –Onion bags with Netron pieces, DT –Drain tubes, SSS –Scallop shell strings, FT –French tubes.

			Number (N) and size (S) of spat per collector					
Depth (meters)	Site		Type of collector					
			CH	SCVB	OBNP	DT	SSS	FT
	C	N	191 ± 20	16*	1 ± 0	0	2 ± 2	0*
		S	8.8 ± 0.02	8.1 ± 0.47	9.0 ± 0.00	-	10.7 ± 3.00	-
1.2	D	N	291 ± 66	37 ± 1	0	1 ± 0	4 ± 0	0*
		S	11.5 ± 0.02	8.3 ± 0.27	-	18.0 ± 1.00	10.6 ± 0.80	-
	E	N	245 ± 43	41 ± 1	1 ± 0	2 ± 1	0	1*
		S	15.0 ± 0.03	9.6 ± 0.38	10.0 ± 0.00	19.5 ± 1.20	-	5.0 ± 0.00
	C	N	203 ± 1	15*	0	3 ± 2	1 ± 0	1*
		S	8.6 ± 0.02	7.1 ± 0.52	-	13.2 ± 1.20	8.0 ± 0.00	8.0 ± 0.00
1.8	D	N	304 ± 50	33 ± 1	0	5 ± 2	1 ± 0	3*
		S	9.9 ± 0.01	7.8 ± 0.32	-	15.0 ± 1.30	17.0 ± 0.00	6.0 ± 1.20
	E	N	314 ± 206	20 ± 4	0	2 ± 1	1 ± 0	2*
		S	9.6 ± 0.03	10.6 ± 0.45	-	11.5 ± 2.50	20.0 ± 0.00	6.5 ± 0.50

* only one replicate

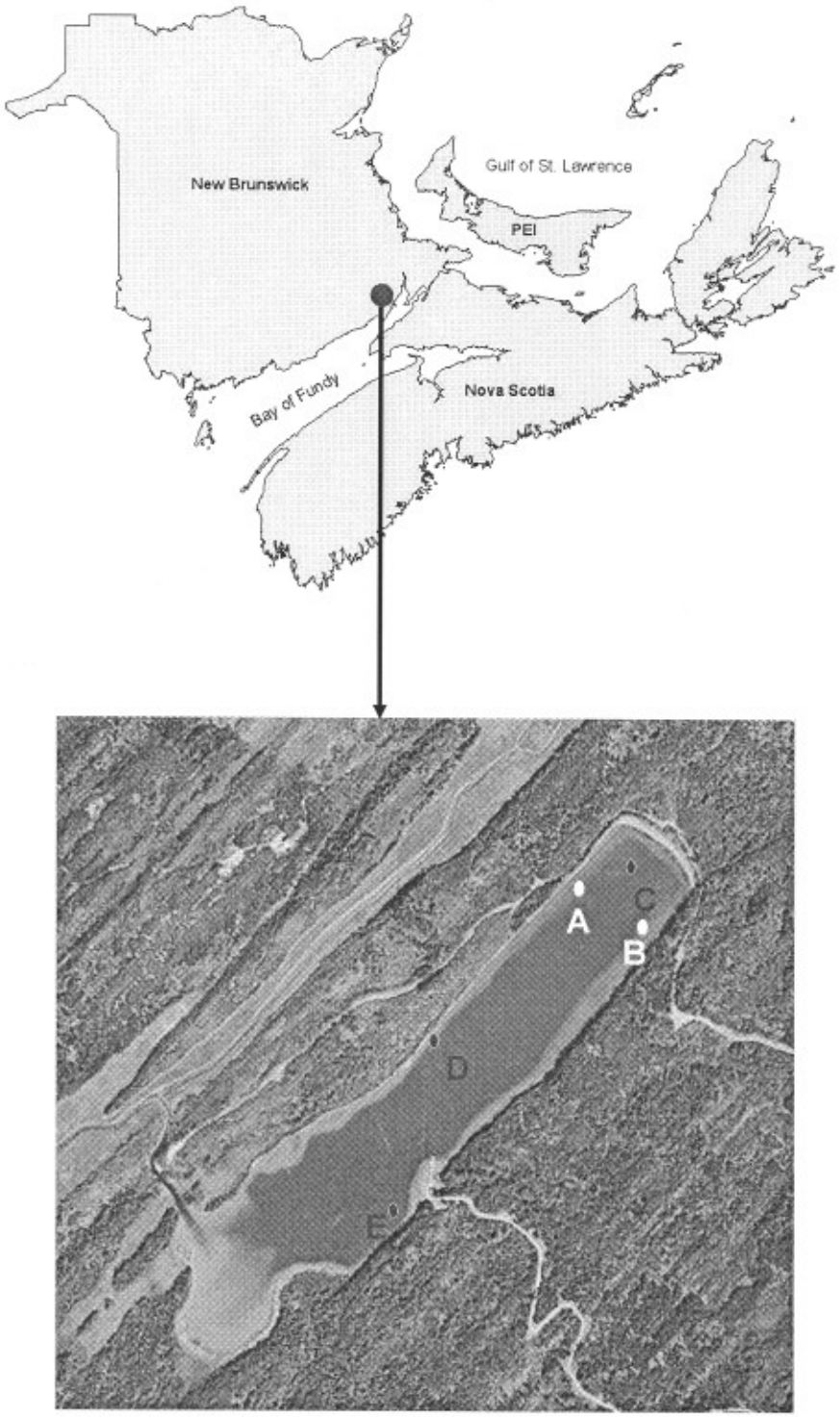


Figure 1. Location of Lockhart Lake in southeastern New Brunswick and position of the sampling (A and B) and spat collection sites (C, D and E).

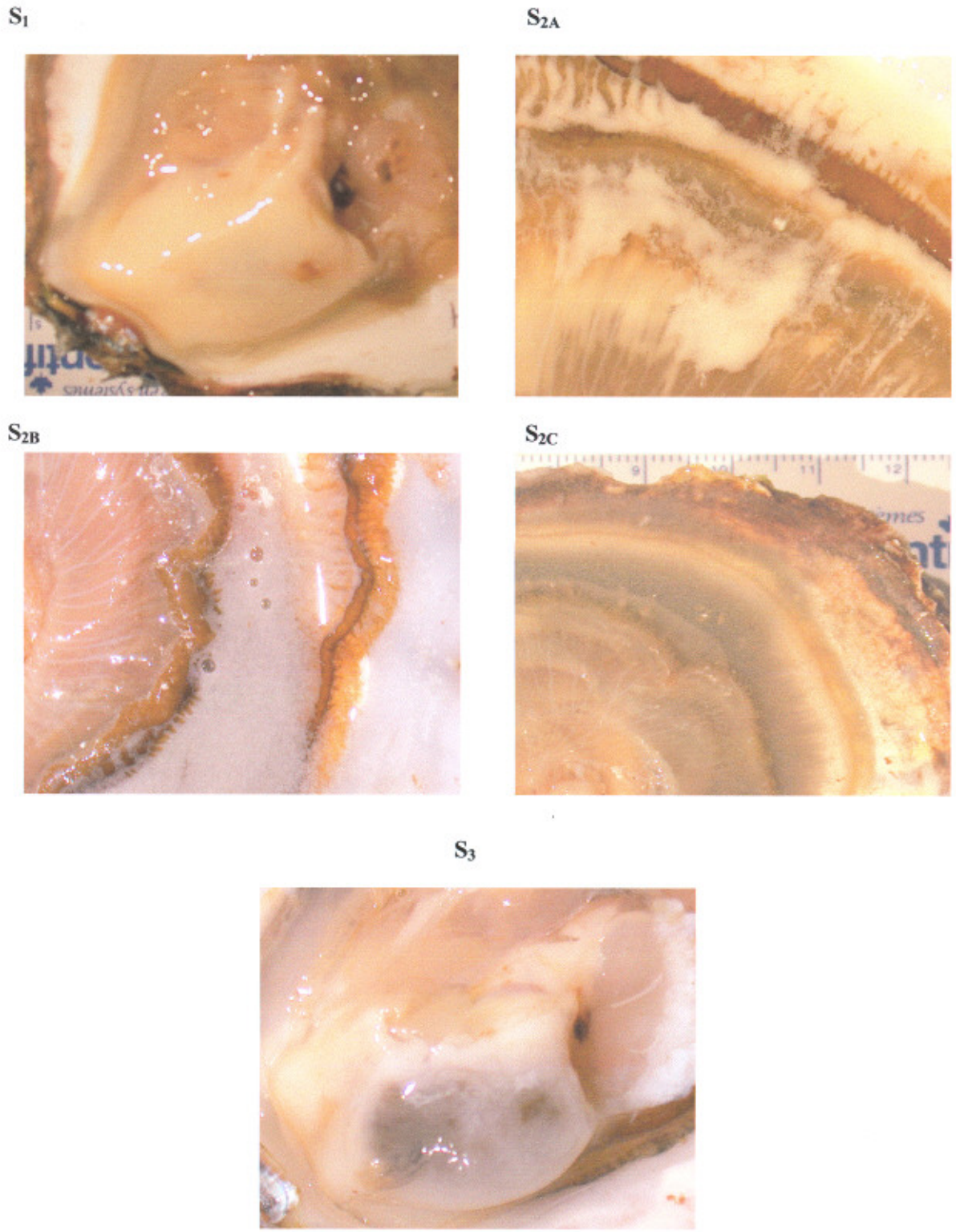
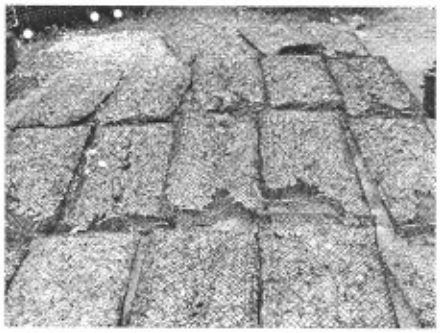


Figure 2. Stages of the reproductive cycle of *Ostrea edulis* L. S_1 - mature gonad, S_{2A} – white milky egg mass on gills, S_{2B} – light grey larvae mass (trochophora) on gills, S_{2C} – slate grey larvae mass (veliger) on gills and S_3 – empty gonad.

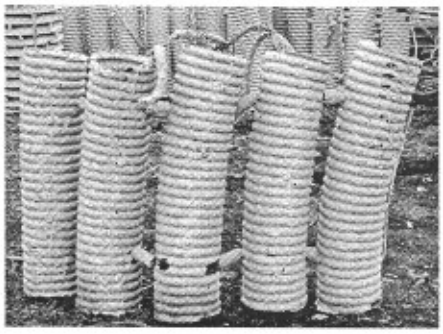
3a

3b

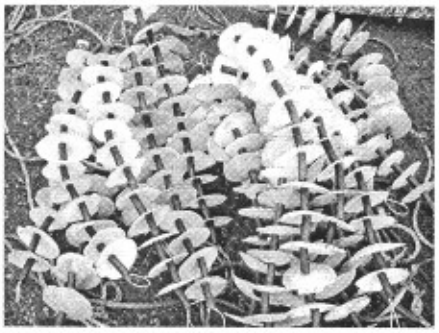


3c

3d



3e



3f

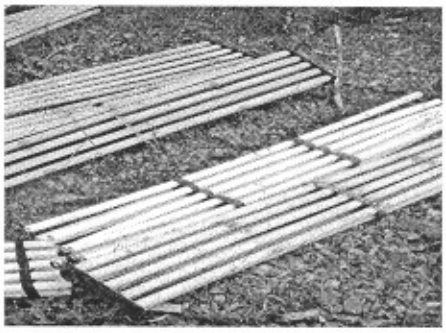


Figure 3. Collector used in this study. 3a – Chinese hats; 3b – Vexar bags full of clam shells; 3c – Onion bags filled with Netron pieces; 3d – Drain tubes; 3e – Scallop shell strings; 3f – French tubes.

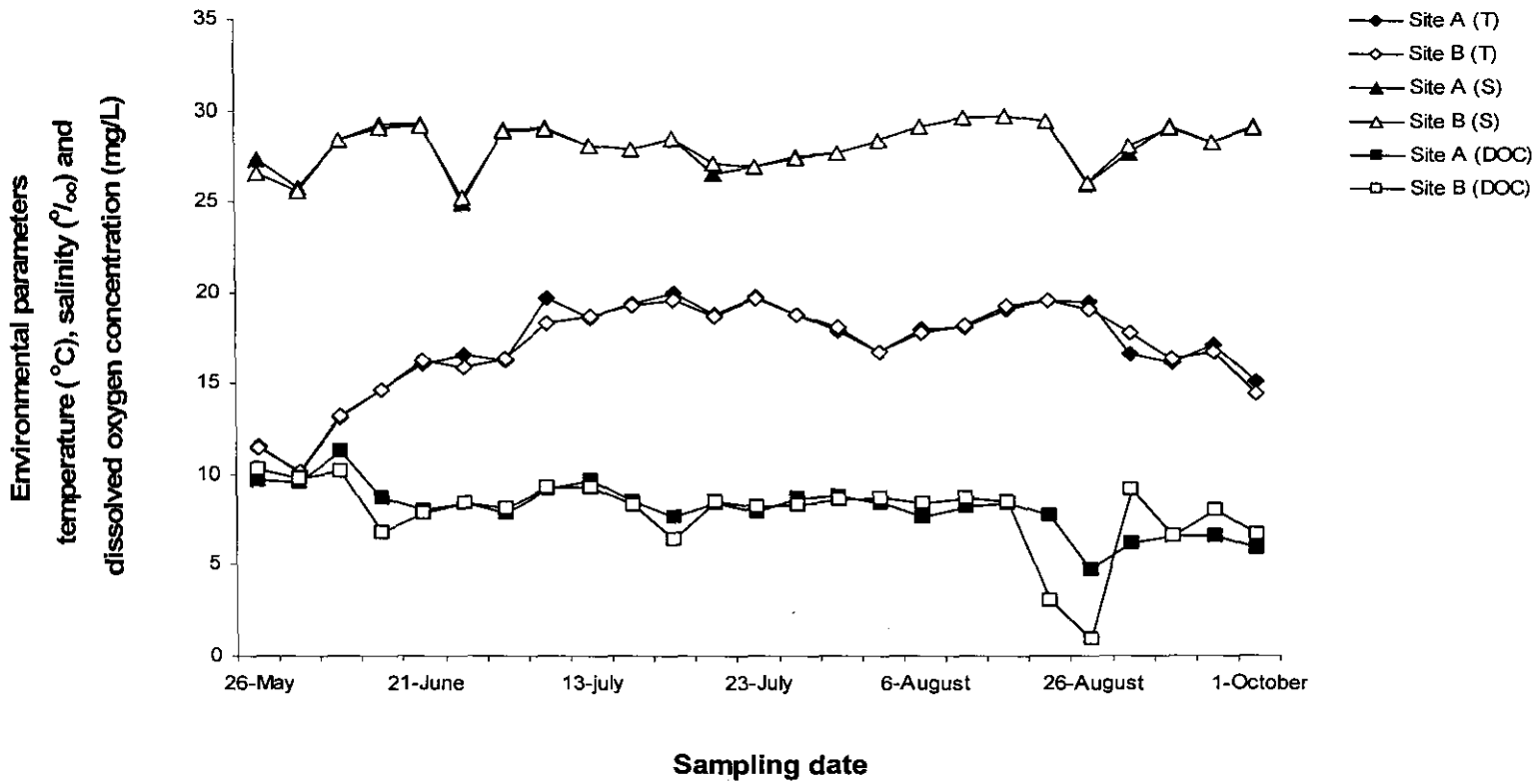


Figure 4. Environmental parameters (temperature (T), salinity (S) and dissolved oxygen concentration (DOC) recorded on site A and B during the sampling season at Lockhart Lake, N.B.

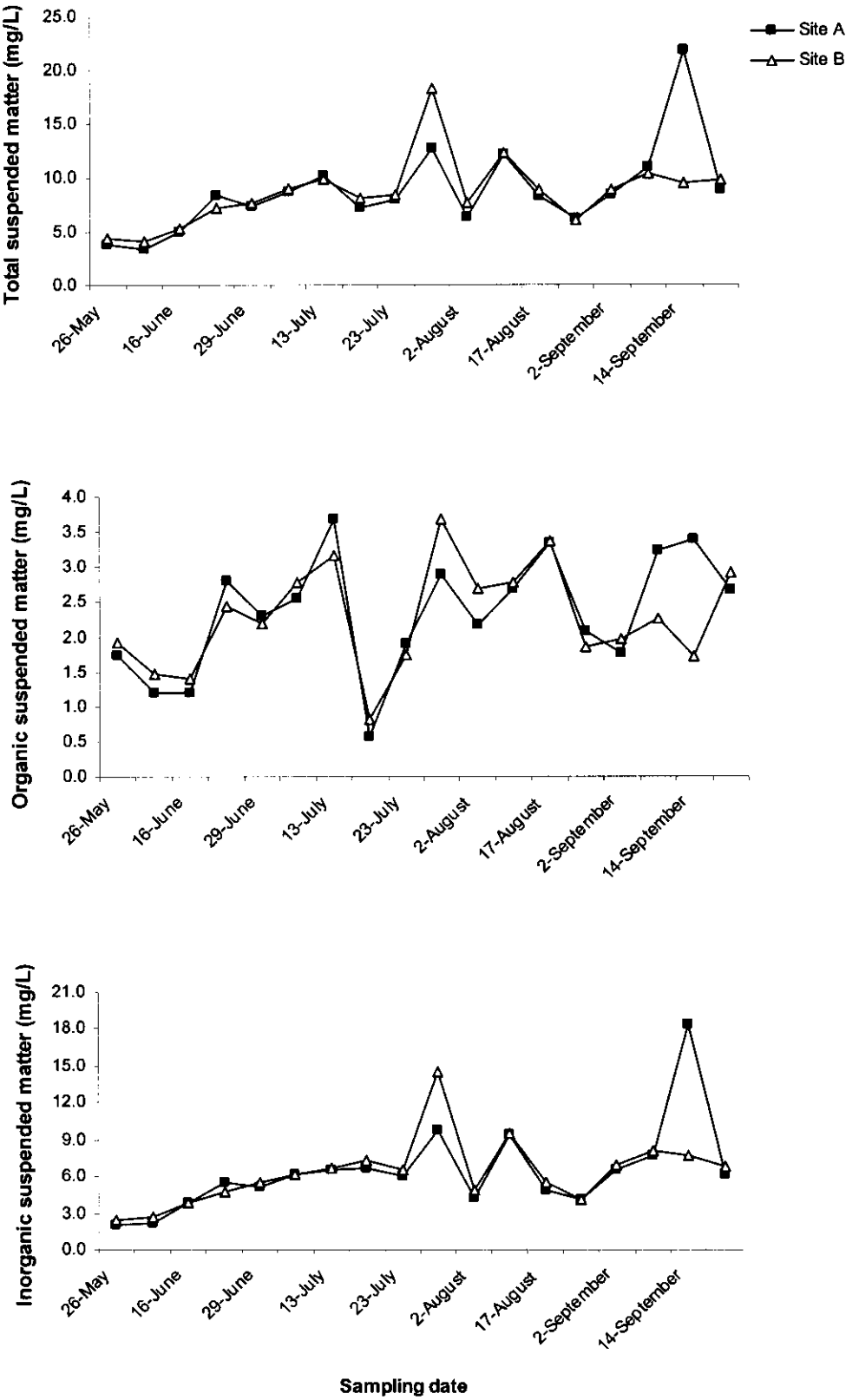


Figure 5. Total, organic and inorganic suspended matter (mg/L) recorded in sites A and B during the sampling season at Lockhart Lake, N.B.

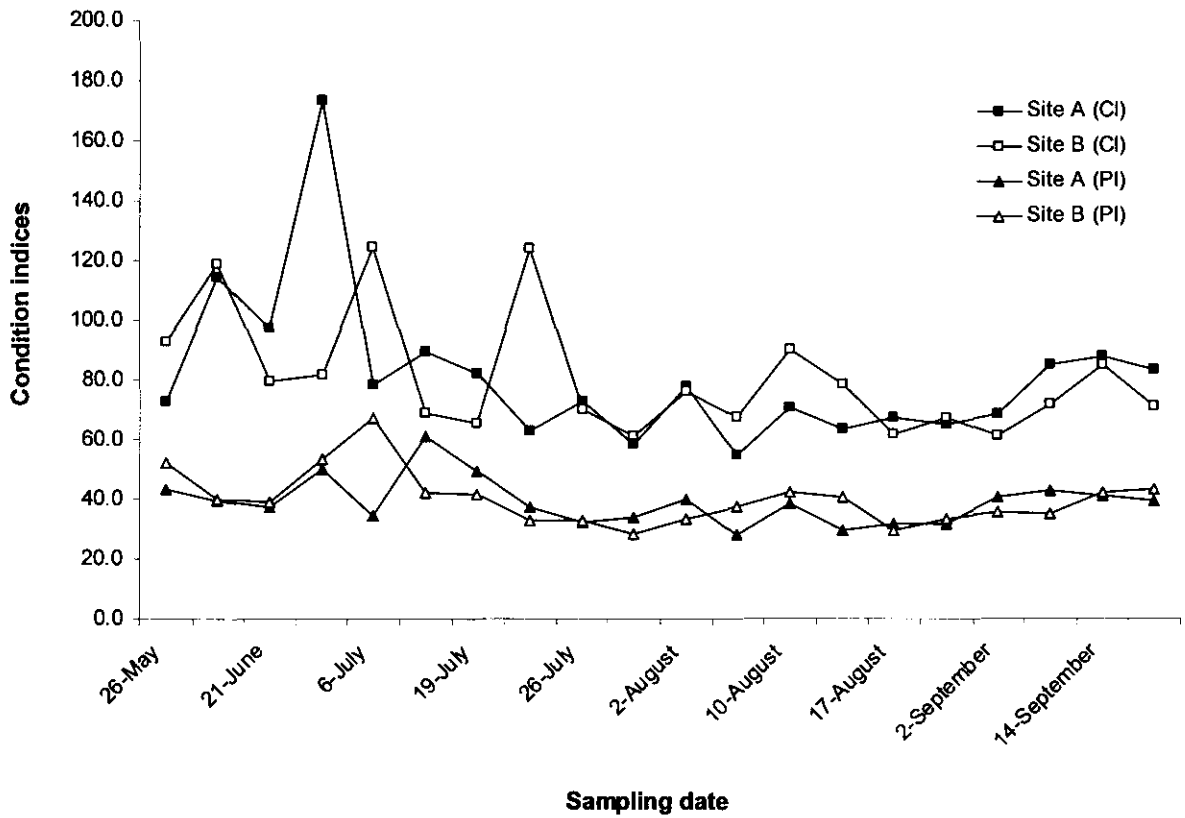


Figure 6. Condition indices (Commercial index = CI, Physiological index = PI) of the oysters collected in sites A and B during the sampling season at Lockhart Lake, N.B.

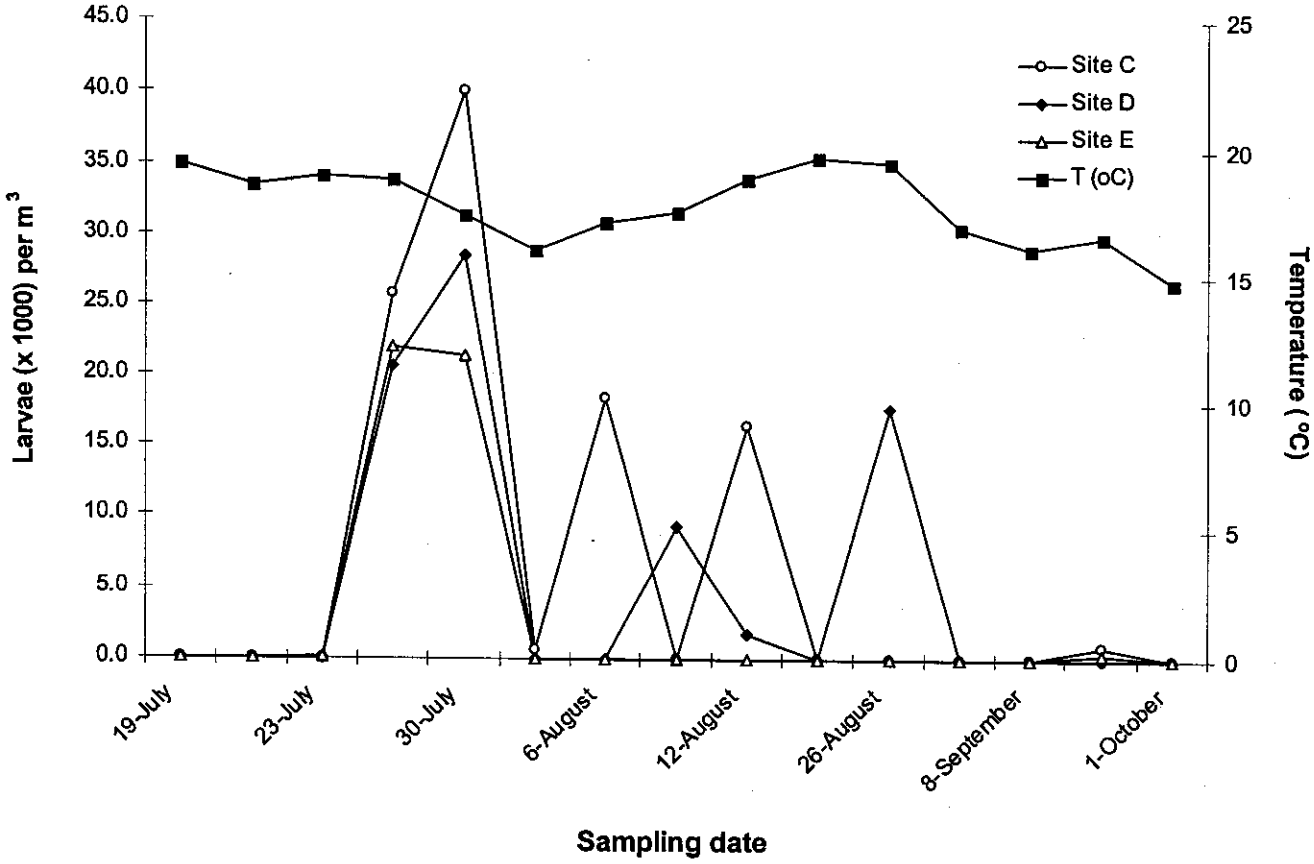


Figure 7. Density of *Ostrea edulis* larvae (per cubic meter) collected at sites C, D and E during the sampling season at Lockhart Lake, N.B.