Abundance and function of rock crabs (*Cancer irroratus*) in longline mussel (*Mytilus edulis*) farms

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by

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ABSTRACT

Mallet, J.-F., A.R. LeBlanc, M.Ouellette, and L.A. Comeau. 2009. Abundance and function of rock crabs (*Cancer irroratus*) in longline mussel (*Mytilus edulis*) farms. Can. Tech. Rep. Fish. Aquat. Sci. 2862: viii + 53 p.

This document reports on the relationship between crabs and suspended mussel (*Mytilus edulis*) culture in Prince Edward Island, Canada. Rock crabs (*Cancer irroratus*) were attracted to mussel leases when suspended socks (sleeves) touched the estuarine bottom. Crabs were shown to clean mussel socks of fouling organisms and debris. Ten crabs could reduce the weight of fouling and debris to about half the weight obtained in the absence of crabs. They also reduced the abundance of an invasive tunicate, *Styela clava*, which attached to mussel shells. This effect was detected at times when *S. clava* abundance on socks was relatively low. Rock crab abundances in the mussel leases declined from spring to fall, an observation that could be attributed to a seasonal migration or to the directed rock crab fishery. In one estuarine system the investigation focussed on the green crab, *Carcinus maenas*. As reported for the rock crab, the green crab had a significant cleansing effect, except with respect to an established invasive tunicate, *Ciona intestinalis*.

RÉSUMÉ

Mallet, J.-F., A.R. LeBlanc, M.Ouellette, and L.A. Comeau. 2009. Abundance and function of rock crabs (*Cancer irroratus*) in longline mussel (*Mytilus edulis*) farms. Can. Tech. Rep. Fish. Aquat. Sci. 2862: viii + 53 p.

Ce rapport porte sur la relation entre les crabes et la culture en suspension de la moule bleue (*Mytilus edulis*) à l'Île du Prince Édouard, Canada. Le crabe commun (*Cancer irroratus*) était attiré vers les sites de culture de moules quand les boudins suspendus touchaient le fond marin. Il a été démontré que les crabes nettoient les boudins des salissures et des déchets. Dix crabes étaient capables de réduire le poids des salissures et des déchets d'environ la moitié du poids cumulé en l'absence de crabe. Ils réduisaient aussi l'abondance d'un tunicier envahissant, *Styela clava*, qui s'attachent aux moules. Cet effet a été démontré quand l'abondance de *S. clava* sur les boudins était relativement faible. L'abondance du crabe commun sur les sites de culture diminuait du printemps à l'automne, une observation qui peut être attribuée à une migration saisonnière ou à la pêche dirigée au crabe commun. Dans un des estuaires, l'étude portait principalement sur le crabe vert, *Carcinus maenas*. Comme pour le crabe commun, le crabe vert

a eu un effet nettoyant significatif, sauf dans le cas d'un tunicier envahissant établi, *Ciona intestinalis*.

INTRODUCTION

Mussel socks are often covered in a dense assemblage of fouling organisms such as algae, polychaetes, gastropods, caprellids, tunicates, barnacles and other mussels (LeBlanc *et al.* 2003). Fouling organisms are known to restrict water flow and food availability for cultured shellfish in enclosed systems (Lodeiros and Himmelman 1996). The rock crab is known to consume a wide variety of organisms (Ojeda and Dearborn 1991) including many of the species found on mussel socks. Hidu *et al.* (1981) placed rock crabs in oyster trays and found that the rock crabs fed selectively on small mussels, thereby reducing the degree of mussel spat fouling, and maximized the water flow through the meshed trays by moving oysters around and preventing silt accumulation. In contrast, untreated cages were covered in a densely matted layer of mussels, and silt accumulated on the trays' bottoms. The rock crabs use cues such as prey odour, emanating for example from broken or dying mussels, to locate their prey (Salierno *et al.* 2003). Many mussels fall off the socks or are broken through manipulations of the socks. Broken mussels likely die attached to the sock or fall to the bottom; therefore, aquaculture leases are thought to provide a considerable food supply to the nearby rock crab populations.

One common husbandry method employed by growers to reduce epifauna is to temporarily lower their crops onto the bottom. It seems that this practice allows rock crabs to climb onto the crops and predate upon the fouling organisms, including undesirable mussel spat (see Scarratt and Lowe 1972). By narrowing the size distribution of mussels contained in a sock, rock crabs are thought to reduce the labour associated in cleaning the mussels destined for the market. For these reasons, mussel growers consider a high abundance of rock crab in the vicinity of their leases to be critical to the profitability of their enterprises. LeBlanc *et al.* (2003) examined fouling on mussel socks in the summer and fall in relation to the sinking of the mussel lines. They found that sinking the lines to allow rock crabs to climb on socks had no significant effect on fouling. However, rock crab abundance was not quantified in this study, raising the possibility that the absence of an effect was due to low crab abundance at the treatment site. Therefore, the effectiveness of rock crabs in cleaning mussel socks remains to be tested experimentally.

For a number of years, concerns have been raised by mussel growers about the possible impacts of the rock crab fishery within mussel cultivation areas. On the North shore of PEI, where most mussel aquaculture occurs, the lobster fishing season is between May 1 and June 30 and the rock crab fishery begins shortly thereafter and finishes at the end of October. One prevailing assumption has been that baited traps used in the directed rock crab fishery increasingly lure rock crabs away from the aquaculture sites, thereby reducing the proximate population of crabs available to clean the socks and thus negatively affecting farm productivity. Baited lobster traps also attract and catch rock crabs, however mussel growers are less concerned by this fishery because its season is shorter (2 months) than the directed rock crab fishery's (4 months). By experimentally testing this assumption, it should be possible to establish the scientific foundation necessary to improve rock crab fishery management measures and ensure that both industries are capable of realizing their full potential.

An additional risk factor for rock crab abundance that needs to be considered is competition for habitat and food in several areas of Prince Edward Island (PEI) by the green crab (*Carcinus maenas*), a recently detected invasive species. The green crab is known to be an aggressive and voracious predator. Its infestation may disrupt the established dynamics thought to exist between the rock crab and mussel aquaculture (Audet *et al*. 2003). The green crab might have a negative effect on mussel productivity in two ways: first, it selectively eats large, and thus commercially important, mussels (Miron *et al.* 2005); second, it may displace the rock crab. The green crab is known to be less effective than the rock crab in controlling tunicate fouling on shellfish (Carver *et al*. 2003). Therefore, these two crab species may clean fouling organisms from mussel socks with differing efficiencies. The effect of the green crab on mussel socks needs to be tested experimentally.

In light of this information, the Federal Department of Fisheries and Oceans (DFO) and the mussel industry proposed a collaborative effort to evaluate the dynamics of the rock crab and green crab in relation to aquaculture sites. The specific objectives of this project are listed below.

PROJECT OBJECTIVES

The objectives of this project were divided into two phases. The first phase focuses on the presence of rock crabs on mussel leases while the second phase focuses on the effectiveness of the rock crab and the green crab in cleaning mussel socks.

Phase I objectives

The objectives of phase I were:

- to determine whether rock crabs are effectively attracted to mussel socks on longlines.
- to determine whether there is a decline in the abundance of rock crab in mussel farms during the ice-free season.

Phase II objectives

The objectives of phase II were:

- to verify the widespread assertion that rock crabs are beneficial to mussel longline productivity by evaluating its effectiveness in cleaning mussel socks.
- to verify whether the green crab has a similar beneficial effect on mussel socks.

PHASE I: ROCK CRAB ABUNDANCE IN MUSSEL FARMING AREAS.

METHODOLOGY

MONITORING: ABUNDANCE ON LEASES

Two aquaculture leases per bay were selected at random and monitored during the ice-free seasons of 2005 and 2006. These surveys took place in four bays of Prince Edward Island's North shore, a region of the Island where a relatively small rock crab fishery and a large mussel industry coexist. The rock crab fishing areas are identical to the lobster fishing areas (LFA) and the north shore of PEI corresponds to LFA24 (Figure 1). The locations of the included bays were Lennox Island (Malpeque Bay), Marchwater (Malpeque Bay), New London and Rustico (Figure 1). Rustico Bay was considered a control site because there is no rock crab fishery. The sampling was conducted on an approximately monthly basis from April to November. Details of the sampling schedule are presented in Table 1 and Table 2.

These surveys consisted of 25m transects positioned directly under longlines (Figure 2); specific longlines were chosen randomly within the bays. Rock crabs were hand-collected by scuba-divers along transects. Two divers swam on either side of the transect collecting all rock crabs found within a 1.5 m reach (transect area: 2 divers ×1.5 m wide × 25 m length = 75 m^2). The crabs were brought to the surface where they were measured, sexed and immediately returned to the sea. The status of the line—"touching the bottom" or "off-bottom"—was also noted.

Carapace widths (CW), measured between the two most posterior notches on the anterolateral border, were recorded to the nearest millimetre (Krouse 1972). Starting in 2006, carapace condition was classified as soft shell (soft or "crispy", perfectly clean), new shell (hard, clean and white abdomen, no epiphytes) and old shell (very hard, dull colour, yellowish abdomen, sometimes covered with epiphytes). Missing legs or claws (chelipeds) and ovigerous females (carrying external eggs) were also noted.

After collecting all crabs along the transects, the divers randomly chose ten mussel socks on the same line and collected all crabs present. In 2005, crabs from triplicate bottom transects were collected (total socks samples: 3 lines/lease × 10 socks/line × 2 leases/bay × 4 bays). To reduce variability in the data while maintaining a tractable sampling program, in 2006, the number of lines sampled in each lease was increased to five and sampling in Rustico Bay was discontinued, reducing the number of bays sampled to three (total socks samples: 5 lines/lease × 10 socks/line × 2 leases/bay × 3 bays). Sampling in Rustico was discontinued because of time constraints and too few crabs were found. During the course of this two year study, a total of 5936 rock crabs (2005: n = 2312; 2006: n = 3624) were measured from a total of 257 bottom transects and 2600 mussel socks.

Statistical analyses

The number of crabs per transect, and the number of crabs per mussel sock, were analysed separately. The data were analyzed with a mixed negative-binomial regression. The number of crabs per transect and per mussel sock was regressed against the date, and the year was added as a random factor. The lease nested within the bay was also used as a random factor. The log of the transect area (75 m^2) and the log of the number of socks sampled (10) were used as offsets in the corresponding analysis. Because the same leases where sampled each time, a repeated-measures model with an autoregressive covariance (AR1) structure was used. The autoregressive structure implies that sampling dates that are further apart are less correlated to each other than dates closer together. The data were analyzed with PROC GLIMMIX (SAS v9.1.3).

MONITORING: CULTURED VS. UNCULTURED AREAS

To determine the effect of mussel leases on local rock crab abundances, bay-wide surveys were conducted at Rustico (30 August 2005), Lennox Island (28 April 2006) and New London (28 June 2006 and 17 August 2006) (Figure 1). Transects were positioned directly under mussel lines (inside leases) and outside the leased areas; specific longlines as well as sites located in non-leased areas were chosen randomly within the bays. Crabs were collected and measured as described in the previous section. A detailed description of sampling is presented in Table 1 and Table 2.

In addition, a Lennox Island grower who rotates the cultured and uncultured areas of his leases on a yearly basis allowed us to compare the rock crab densities of the cultured and empty areas of his two mussel leases. This was done using transects positioned under full and empty longlines in the cultured and empty parts of his leases, respectively.

Statistical analyses

Crab density data are expressed as mean ± standard error (SE). The number of crabs per transect inside cultured leases was compared with those outside the lease area using a negative binomial regression model that is analogous to a one-way (Lennox Island and Rustico data) and two-way (New London data) ANOVA. The results are presented in an analysis of deviance table that compares the null model (model with no factors) to the model with the factors included. The *p*-value is based on the Chi-squared distribution with one degree of freedom. The glm.nb function of the MASS library (Venables and Ripley, 2002) of the statistical computing language R (R Development Core Team, 2008) was used. Each bay was analyzed separately, using the area of the lease (inside vs. outside) as a fixed factor. In New London, the date was also added as a factor. The same type of analysis was used to compare the cultured and empty portions of the leases in Lennox Island. In this case, the status of the leases (cultured vs. empty) and the lease were the fixed factors. Non-significant factors ($p > 0.05$) were removed and the models were refitted with only significant factors included. The log of the transect area (75 m^2) was used as an offset to obtain estimates of the mean number of crabs/m^2.

TRAPPING STUDY

Commercial rock crab traps (i.e., Japanese style crab pots; 91 cm bottom diameter, 45 mm mesh size (Figure 3C), were deployed inside, on the perimeter (border) and outside two leases at Lennox Island and Marchwater ([1 inside + 1 border + 1 outside] x 2 lines x 2 leases x 2 bays = 24 traps). Three traps were set 75 m apart on the inside-border-outside gradient of a lease, forming a perpendicular line to the lease. Another set of three traps was deployed at least 100 m parallel to the first line of traps in the same lease (Figure 3). This was repeated on two leases in Lennox Island (Figure 3A) while in Marchwater, four parallel lines (at least 100m apart) of 3 traps were deployed on one lease (Figure 3B). Drummond-Davis *et al.* (1982) determined that rock crabs were attracted to cages within 50 m. Therefore, we determined that cages set 75 m apart would be independent from one another. This cage deployment (Figure 3A and B) was repeated three times in the two bays (June/July, September and October 2007). The escape mechanisms of each trap were blocked to ensure that crabs of all sizes were captured. Traps were baited with frozen herring and deployed for approximately 24 hours. The soak-times of the traps were noted and their positions were recorded using a GPS. All crabs in each crab trap were measured and sexed prior to release. Carapace conditions were also noted. The catch-per-unit effort (CPUE) was calculated using the total catch divided by the soak-time for each trap.

Statistical analyses

The effect of the location of the trap on CPUE was compared using a mixed analysis of variance with location (inside, border, outside) as a fixed effect and date and bay as random effects.

The size of crabs caught in traps was compared to the size of crabs collected by scuba that were susceptible to be caught in a trap. To determine which crabs were susceptible to be caught by traps, the height/width ratio relationship developed by Shotton (1973) was used. Because crabs generally walk sideways and the traps used have a mesh size of 45 mm, the height/width shows that a crab with a height of 45 mm should have a width of 67 mm. Therefore any crab over 67 mm could have been retained by a trap. To compare the size of trap-caught crabs and scuba-caught crabs, a mixed analysis of variance was done with the type of collection (trap vs scuba) as a fixed factor and the bay (Lennox Island vs Marchwater) as a random factor Both mixed models were compared to the one-way models with only the location of the trap or the type of collection as the fixed factor. The functions lme and gls from the nlme package of R, version 2.7.1 (The R Foundation for Statistical Computing) were used to perform the analyses.

RESULTS

MONITORING: ABUNDANCE ON LEASES

Abundance: General

The abundance of rock crabs underneath the mussel lines and on the mussel socks decreased from spring to fall (Table 3). The rate of decrease was similar for all bays studied (Table 3). Leases within the bay accounted for most of the variability in the data (Table 3). This suggests that there are spatial differences in the crab distribution inside these bays. The average rock crab abundances observed underneath mussel lines in 2005 and 2006 in PEI bays ranged from 0.04 to 1.60 crabs/m^2 (Table 4) and the average number of rock crabs per mussel sock ranged from 0 to 3.45 (Table 5). New London Bay had the highest rock crab abundance (beneath mussel lines) of all the studied bays (1.60 crabs/m^2; Figure 4D). Lennox Island had the largest numbers of rock crabs on the mussel socks (3.45 crabs/sock; Figure 5A). A similar bottom rock crab density of 0.5 crabs/m^2 was observed in a Nova Scotia kelp bed by Drummond-Davis and colleagues (1982).

Mussel socks are generally suspended in the water column (off bottom) from a longline. However, the ends of these socks sometimes touch the bottom as a result of manipulations by the grower, added weight due to accumulating epifauna, or the lowering of tides. Since the mussel lines sampled in this study were randomly chosen and that line status frequently changed throughout the grow-out season, this variable was impossible to control or predict. Of the 257 lines surveyed in 2005 and 2006, 58% were classified as "off-bottom" and 42% as "touching the bottom". The line status had an obvious effect on the abundance of rock crabs on the mussel socks (Table 3). In fact, the abundance of rock crabs on the bottom sometimes more than doubled when the mussel socks were touching the bottom (Figure 4).

Average width and width distribution

The results from 2005 and 2006 showed that males from beneath the mussel lines and from the mussel socks had an identical average width of 74 mm. Females from beneath mussel lines and from mussel socks had average widths of 63 mm and 65 mm, respectively. Width ranges from the two crab sources were similar for both sexes (Table 4 and Table 5). More commercial-sized male crabs (CW ≥ 102 mm) were observed underneath mussel lines than on mussel socks. The percentage of commercial-sized male rock crabs dropped during the fishery period in both crab sources (Table 4 and Table 5).

Width distributions for male rock crabs changed throughout the season (Figure 6). The width distributions from the bottom transect and the mussel socks both exhibited a similar pattern of variation. Before the directed fishery, the size distributions for male rock crabs were somewhat symmetrical (Figure 6 A and D). During the rock crab fishery, these size distributions tended to become skewed toward the left (i.e., negatively skewed), illustrating a drop in size (Figure 6 B and E). After the rock crab fishing season, the size distributions were skewed to the right (i.e., positively skewed), illustrating a size increase (Figure 6 C and F). Large-sized males (CW ≥ 80 mm) appeared to return to the mussel leases after the conclusion of the rock crab fishery (Figure 6 C). Very little change in the size distributions of female rock crabs was observed throughout the season (Table 6). The drop in the size of male rock crabs on the mussel leases during the fishery again supports the observations made by the mussel growers, who suggested that the crabs were drawn off their mussel leases during the directed crab fishery.

Sex ratios

Similar to previous reports (Scarratt and Lowe 1972, Drummond-Davis *et al*. 1982 and Carroll 1982), the male/female sex ratios of crabs measured in this study were generally biased in favour of males (Table 6). Male/female sex ratios diminished throughout the fishing season, with more female crabs appearing as the season progressed. Our results also show that fewer females were found on the mussel socks than underneath the mussel lines at any given time (Table 4 and Table 5).

Width-class-frequency charts for the rock crabs found underneath the mussel lines and on the mussel socks show that most crabs found were in the 60–69mm width class, and that there were very few females larger than 80 mm (Figure 7. Within this 60–69mm width class, the sex ratio approached 1:1 (Figure 8). Figure 6 and Figure 7 also show that the size distributions of crabs found on the bottom and on mussel socks were very similar.

Ovigerous females

Table 7 shows that 4.5% of females found on the bottom before and during the fishery were ovigerous (carrying eggs). All the egg-bearing females were found in June and July, and none were found after the rock crab fisherym, in November. The width range of berried females was 50–100 mm. Similar width ranges were reported by Krouse (1972), and Campbell and Eagles (1983). Less than 1% of the females found on mussel socks before and during the fishery were ovigerous.

Moulting and crab condition (missing legs or claws)

Most of the rocks crabs measured in this study were classified as new shell (clean and hard shell, Table 8). The highest percentage of soft-shelled females was found after the rock crab fishery. Most male crabs had new shells all through the ice-free season.

Table 9 shows that less than 10% of the rock crabs measured had missing legs or claws at any given time. The percentage of completely intact crabs tended to be even higher among rock crabs found on mussel socks, an observation that is not surprising given that crabs need all their legs and claws to climb on the mussel socks.

MONITORING: CULTURED VS. UNCULTURED AREAS

Our data shows that mussel leases have an obvious effect on rock crab distributions at New London and Lennox Island (Table 10 A and Figure 9) but not in Rustico. At New London, the date also had an effect on the number of crabs/m² (Table 10 A). There was no significant interaction between the factors; therefore, there were more crabs on leases at all dates (Table 10 A). There were over 25 times more crabs on the leases (0.27 ± 0.06 crabs/m^2) than outside the leases (0.01 ± 0.00 crabs/m^2). Within individual leases, the attraction was strongest when mussels were present (Table 10 B): the mean crab density was 0.13 ± 0.02 crabs/m^2 in the cultivated parts of the leases compared to 0.02 ± 0.00 crabs/m^2 in the uncultivated parts (Figure 10).

On 30 August 2005 in Rustico Bay, very few rock crabs were found on the leases (Figure 9 C). In the off-lease area, all the crabs were found at 2 out of the 6 stations therefore the variability between transects was large. Furthermore, the crabs found around the leases were very inactive, almost to the point of being moribund. The transects where the crabs were found were located near the mouth of Rustico bay, approximately 2 km away from the lease area. The crabs at these stations were also livelier than the ones found around the leases.

TRAPPING STUDY

Neither the bay nor the date had a significant effect on the CPUE therefore the one-way model was used. The positioning of the traps relative to the lease ($F_{2,69}$ = 1.14, p = 0.32) did not have an impact on the CPUE (Figure 11).

A comparison of the size distributions of male rock crabs between those caught along scuba transects and those collected in traps shows that crabs caught by the traps were generally larger ($F_{1,2265}$ = 1552, p < 0.001, Figure 12). The mean CW of crabs caught by scuba and susceptible to be caught by trap (> 67 mm) was 81 mm. This mean only includes crabs caught in Lennox Island and Marchwater to be able to compare with the crabs caught in traps. The trap caught crabs averaged a CW of 96 mm.

PHASE II: THE EFFECT OF THE ROCK CRAB (*CANCER IRRORATUS*) AND GREEN CRAB (*CARCINUS MAENAS*) ON THE PRODUCTIVITY OF MUSSEL SOCKS IN THE BAYS OF PRINCE EDWARD ISLAND.

METHODOLGY

STUDY 2006

Set-up

The experiment was conducted on a mussel lease at Lennox Island, PEI. Vexar tubes (38.1 cm x 2.44 m, 1.27 cm mesh) were placed over mussel socks (Figure 13). Vinyl hoops (38.1-cm diameter) were attached on the outside of the tubes to make them more rigid and prevent them from coming into contact with the mussels. The hoops were positioned at points approximately one-third and two-thirds along the length of the tube. Two different types of tubes were used: "closed" (closed at both ends to exclude predators) and "open" (open at both ends to test for cage effects) (Schmidt and Warner 1984 and Steele 1996). The closed tubes had a round piece of vexar (same diameter and mesh size as the tubes) at the bottom, while the open tubes had a third vinyl hoop at the bottom to keep them open. The tubes were tied to the longline with ropes. The tops of the closed tubes were zipped with tie wraps after being placed over the mussel socks. The tubes were installed on 17 November 2005 by lifting the mussel socks out of water with a boom and slipping the tubes on. Ten tubes (five open and five closed) were installed on each of six lines. Five mussel socks without tubes were also present on each line for a total of 15 socks per line ((5 open tubes + 5 closed tubes + 5 no tubes) x 6 lines = 90 socks). The type of tube (open, closed, none) was assigned randomly to the socks. The mussel lines with the experimental set-up were overwintered by lowering them below ice level.

Experiment

The six lines were subjected to two different treatments: exposure to crabs and no exposure. The no-exposure treatment group was created by buoying up the lines so that the socks would never touch the sea bottom, thus preventing crabs from travelling up the mussel socks. In the exposure treatment group, crab travel on the socks was enabled by allowing the mussel socks to touch the sea bottom for some amount of time. This is accomplished naturally as the growing mussels put increasing weight on the lines. After a week or two, mussel growers added buoys to the lines to lift them off the bottom. Three lines (exposure treatment) were left where they had been originally installed the previous fall. The other three lines (non-exposure treatment) were moved a few meters in the spring (4 May 2006) to a harvested area of the lease, where they were kept off the bottom for the duration of the experiment. This spatial separation was established to make it easier for the mussel growers to access the lines and keep them buoyed up.

Sampling

Samples were collected on 18–20 September 2006. The tubes were removed and the mussel socks were weighed and measured. A 30-cm section of the sock was collected and transported to the lab. This section was weighed, after which mussels were separated from the remaining epifauna and debris (shells, mud and sock material). The mussels were weighed and counted and the lengths of ten randomly selected mussels were recorded. The remainder of the sock was weighed and frozen. Later, these samples were sorted, and all fouling animals were identified to the lowest taxonomic group possible, counted, dried and weighed. From the 90 sock-sections (15 socks/line × 3 lines/treatment × 2 treatments) in the experiment, only two were not sampled because their cages fell off during the course of the experiment.

Statistical analyses

Mixed effects analysis of variances were applied to determine the effect of cage type (closed, open, no cage), crab exposure status (touching or not touching) and intra-treatment line segments (random factor) on the total weight of 30-cm sections, the weight of mussels per 30 cm, the weight of epifauna + waste per 30 cm and the dry weight of epifauna per 30 cm. Only the significant factors ($p < 0.05$) were retained in the analysis. Weights were log transformed to normalize the data and to equalize the variance of the residuals when necessary. The functions lme and gls from the nlme package of R, version 2.7.1 (The R Foundation for Statistical Computing) were used to perform the analyses.

STUDY 2007

Set-up

There proved to be too many uncontrolled variables in the 2006 epifauna experiment. Therefore the set up of experiment was changed in 2007. The tubes used in 2007 were the same as those used in 2006, except that only closed-bottom tubes were used. The bottoms were closed using a round piece of vexar and all tops were zipped closed over mussel socks with hog rings. The tubes were installed over the mussel socks as described for 2006. Fifteen tubes were installed on each of three lines in each of three PEI bays: Lennox Island, Marchwater and Brudenell.

Experiment

In 2007, the density of crabs on the mussel socks was controlled. Before the tubes were closed, crabs, collected by scuba divers, were placed inside the tubes at five different densities (0, 1, 3, 5 and 10 crabs/tube), and randomly distributed among tubes. There were three replicates of each crab density per line, yielding at total of 135 sample tubes (5 densities × 3 replicates × 3 lines × 3 bays). The experiments were conducted twice in each bay, with the duration of each experiment running from 12 to 16 days. The Lennox Island experiments were conducted on 13–25 July and 6–18 September, 2007. Experiments at Brudenell were conducted from 18 July to 1 August and 13–25 September 2007. Marchwater experiments were performed on 10–22 August and 2–18 October 2007. The rock crab (*Cancer irroratus*) was used for Lennox Island and Marchwater experiments, while the green crab (*Carcinus maenas*) was used at Brudenell, the only bay where green crab is present used in this study.

Sampling

The tubes containing the mussel socks were brought into the boat where the tube was removed. Crabs in each tube were counted to determine survival. A 30-cm section of mussel sock was collected, placed in a mesh bag and brought to the lab. The entire section was weighed, after which the mussels were separated from the remaining epifauna (including mussel spat), mud and sock material, and the weight of each component was determined separately. The fouling epifauna was later segregated from the remainder, dried and weighed. At Brudenell, the invasive tunicate, *Ciona intestinalis*, was also sorted and weighed separately. In Marchwater, *Styela clava*, another invasive tunicate, was dried and weighed separately from the other epifauna species.

Statistical analyses

A mixed multiple regression model was used to analyse the effect of crab density on the weight of all remaining material (epifauna + waste), the dry weight of epifauna, the weight of *C. intestinalis* (Brudenell), and the dry weight of *S. clava* (Marchwater). The factors included in the model were date, surviving crab density, and bay; the latter was also confounded with the crab species. Random intercepts were fit for the time and line within a bay. Weights were log transformed to normalize the data and equalize the variance of the residuals. R, version 2.7.1 (The R Foundation for Statistical Computing) was used to perform regression analyses.

RESULTS

STUDY 2006

The cage type/treatment combinations had significantly different effects on the total weight, the weight of the mussels and the weight of epifauna + waste (Table 11). The socks in the no-cage or open-cage groups of the no-crab exposure treatment had the highest total weights and mussel weights (Figure 14 A and B). The total weights of these two groups were similar as was the weight of the mussels, which comprised 84% of the total weight of the socks. The socks in the crab-exposure treatment (no-cage and open-cage groups) had the lowest epifauna + waste weights, and those with no cage and no crab exposure had the highest epifauna + waste weights (Figure 14 C). Only cage type had an effect on the dry weight of epifauna (Table 11). Socks with cages (open or closed) had less epifauna than socks with no cages (Figure 14 D).

STUDY 2007

Crabs had a significant effect on the weight of the epifauna + waste (Table 12 A) and epifauna-only category (Table 12 B), as evidenced by the significance of the crab-density factor ($p < 0.001$). Neither the interaction between crab density and bay, nor that between crab density and time was significant. Therefore, the rate of reduction (slope) was the same between bays on both dates (-0.04 g/crab, Figure 15 and -0.06 g/crab, Figure 16). The fact that the bays are associated with different species of crabs indicates that the two species had the same effect on the epifauna. However, the initial weights of the epifauna + waste and the epifaunal-only categories were different between bays and date (Table 12). In the case of epifauna + waste, the random factors (line and date) were not significant; thus, they were removed from the model. The random date factor was significant for the dry weight of epifauna.

The green crab had no effect ($p = 0.06$) on the wet weight of *C. intestinalis* (Table 13 A). The initial weight of *C. intestinalis* was much higher in September than in June (Figure 17 A). In fact, the June data was not included in the analysis because too few tunicates were present.

Tests for effect of rock crabs on *S. clava* were not performed for Lennox Island because the numbers of *S. clava* there were very low. In Marchwater, the rock crab significantly reduced the weight of *S. clava* (Table 13 B). In this case, there was a significant interaction between crab density and date, indicating that the rate of reduction was different in June and September, being higher in June when tunicate weights were lower (Figure 17 B).

DISCUSSION

THE ATTRACTION OF CRABS TO MUSSEL LEASES

Our results show that crabs are indeed attracted to mussel leases. These results are in agreement with the findings of D'Amours *et al*. (2008) as well as with studies carried out on mussel rafts in Spain with other brachyuran species (Romero *et al.* 1982, Gonzalez-Gurriaran 1986, Freire and Gonzalez-Gurriaran 1995).

The observed aggregation effect is likely due to the fact that aquaculture leases provide a considerable food supply to the rock crab. On the mussel farms, many mussels fall off the socks or are broken through manipulations of the socks. The rock crab is a scavenging predator that uses cues such as prey odour (e.g., emitted by broken or dying mussels) to locate its prey (Salierno *et al.* 2003). Epifauna found on socks are also a source of food for rock crabs. The mussel farms are also thought to provide refuge or shelter to rock crabs by adding complexity to the bottom (Romero *et al.* 1982 and D'Amours *et al.* 2008). Throughout this study, scuba divers observed many rock crabs and lobsters on and under the longline's anchor blocks.

Exceptionally, on one occasion, most crabs collected in Rustico Bay were found about 2 km off leases. According to diver observations made that day, the water was considerably cooler and clearer at the mouth of the bay than inside the bay. Rock crabs reportedly prefer cooler water temperatures and are known to migrate in the summer months to colder, deeper water (Shotton 1973, Stehlik 1991, Gendron and Cyr 1994). The moribund state of the crabs on that day and the historical hypoxic events in Rustico Bay led us to believe that, in addition to warmer water, an environmental phenomenon beyond the scope of this study was affecting the rock crab distribution towards the end of the summer when waters were at their warmest. We do not have temperatures for Rustico Bay in 2005 but in 2004 maximum average daily water temperature (22.8 °C, unpublished data) was reached on 2 August. By 30 August 2004, average daily temperature was 21 °C. Temperatures were likely similar in 2005.

The abundance of crabs on mussel leases was at times twice as high when mussel socks touched the bottom. This is because the mussel socks must contact the bottom for crabs to gain access to them. Under these conditions, crabs can easily climb onto the socks and prey on the food source offered by mussel socks. The effect of line status (touching or not touching the bottom) on crab abundance was less striking during the later periods (i.e., during and after the rock crab fishery), possibly due to the availability of food elsewhere. These findings are consistent with the observation that food or prey availability can affect foraging and crab population density in a given habitat (Salierno *et al*. 2003).

The widths of crabs found on socks and on the bottom were similar. This is true for both sexes. In general, these results show that the size of rock crabs observed by growers is an accurate reflection of the population found on the bottom of the mussel lease. Few large crabs were found on the socks. In addition, the abundance of these large crabs decreases throughout the season. Growers have observed that larger crabs have more difficulty traveling and staying on mussel socks. Therefore, large crabs targeted by the rock crab directed fishery may not participate in the cleaning of mussel socks. These crabs would be more likely to be lured away by baited traps.

The size of females found on leases did not vary throughout the season, however their numbers varied. Early in the season, sex ratios favour males. The number of male rock crabs decreased throughout the season while the number of females was relatively stable. Our data do not allow us to draw conclusions about the underlying cause of this male bias, but it could be due to more males hatching and settling, the longer lifespan of males and/or males being easier for divers to find because of their larger size (Scarratt and Lowe 1972). Carroll (1982) found that annual peaks in the percentage of females corresponded to annual maximum water temperatures. However, we did not find a peak in the number of females. The scarcity of females larger than ~90 mm suggests a terminal moult (Scarratt and Lowe 1972).

No ovigerous females were found after July. Female rock crabs begin releasing their eggs in June. Larvae occur in the water between mid-June and mid-September (DFO, 2008). Very few egg bearing females were found on the socks. This is almost certainly due, at least in part, to the difficulty of climbing caused by the added weight (2.2–45.2 g wet weight; Campbell and Eagles 1983) and awkwardness of the large egg mass. This result could also be explained by more reclusive behaviour on the part of egg-bearing females to protect their eggs.

Soft-shelled females were common in the fall suggesting that female moult occurs sometime late in the fall, after egg release. Reilly and Saila (1978) observed that females larger than 60 mm appeared to be moulting in November and December. Males larger than 80 mm have been reported to moult primarily from January to March (Krouse 1972, Reilly and Saila 1978), but no clear moulting season for males was observed during our two years of sampling.

EFFECT OF THE DIRECTED ROCK CRAB FISHERY

Overall, our results substantiate the observations made by the mussel growers, who had suggested that crab abundance on mussel leases drops during and after the rock crab fishery. However, this study does not enable us to pinpoint the cause of this drop in abundance. It could be that baited traps used in the fishery lure rock crabs away from the aquaculture sites. The radius of effectiveness of a baited trap can be highly variable, reflecting differences in tidal and other currents that affect the distribution of chemosensory stimuli that attract scavengers in marine environments (Sainte-Marie and Hargrave 1987). Drummond-Davis *et al*. (1982) suggested that rock crabs on a kelp bed could be attracted to a baited trap from a distance of up to 50 m. The drop in abundance could also be due to a natural behaviour of rock crabs in response to the rising temperatures or other physical or chemical parameters in the environment during and after the fishing season; the drop-off in crab abundance observed in Rustico Bay in late summer (30 August 05) is likely an example of this. Rebach (1987) and Carroll (1982) have both shown that rock crabs can exhibit natural movements that reflect responses to seasonal cues to complete moulting and reproductive activities. Additional studies have also shown that rock crabs migrate offshore in the summer months (Shotton 1973, Stehlik *et al.* 1991, Gendron and Cyr 1994).

The crabs caught in the traps were larger than the ones caught by scuba, even when removing crabs potentially too small to be caught in a trap from the analysis. The design of this trapping study does not enable us to deduce whether the catch composition is different for the two sampling methods because bigger crabs are attracted to the baited traps from a radius that extends beyond the mussel leases, or simply because these crabs sense the presence of divers from a distance and hide or flee, thus making them harder for divers to catch.

Only ~ 10% of the crabs collected on leases were of commercial size. This led us to question whether the sampling method had an effect on catch composition, or whether these populations are simply significantly smaller in size (i.e., juveniles). Total rock crab landings, rock crab by-catch in the lobster fishery and the catch per unit effort (CPUE; kg/trap/day) in LFA24 are all lower than in the other lobster fishing areas, except LFA26B (DFO 2002 and 2008). There are less rock crab license holders in LFA24 but this fact does not influence the CPUE although it would influence the total landings. Lower landings in this area can be due to many different factors such as a smaller crabs making the rock crab fishery less feasible than other fisheries, or less effective reporting (even though fishers are required to keep logbooks). Not much is known about the rock crab populations in the southern Gulf of St. Lawrence. The only available information is stock status reports for which data are collected from fishery-based activities and the data from this study.

THE EFFECT OF ROCK CRAB AND GREEN CRAB ON EPIFAUNA

This study shows that crabs have a cleansing effect on mussel socks. However, it does not show whether they consume the epifauna or simply dislodge it as they move about on the socks. Crabs are opportunist feeders (Elner 1981 and Hudon and Lamarche 1989), meaning that what they feed on depends on what is present in their environment. Numerous studies have shown that rock crabs eat mollusks, polychaetes, arthropods and many other phyla (Scrarrat and Lowe 1972, Drummond-Davis *et al.* 1982, Hudon and Lamarche 1989, Gendron and Fradette 1995, Stehlik 1993 and Miron *et al.* 2005). The green crab has a similar diet, feeding mainly on bivalves, gastropods, polychaetes and arthropods (Ropes 1967, Elner 1981, Ropes 1988, Klassen and Locke 2007). The epifauna in PEI is composed mostly of polychaetes, gastropods, barnacles and ascidians (Ellis *et al.* 2002 and LeBlanc *et al.* 2003); therefore, it is highly likely that crabs clean mussel socks by consuming the epifauna. In fact, crabs have been used as a method to control biofouling in various aquaculture farms (Hidu *et al.* 1981, Enright *et al.* 1993, Carver *et al.* 2003, LeBlanc *et al.* 2003).

The 2006 experiment did not provide clear answers to the question: What effect does the presence of crabs have on the productivity of mussel socks? This uncertainty arises because the experimental design did not provide information on the density of crabs to which socks were exposed. It was also unclear whether socks in the no-exposure group were truly inaccessible to crabs as crabs are able to climb on the scope lines and make their way to the socks (pers. obs.). Another issue with this design was that the presence of cages appeared to reduce the recruitment of epifauna to the mussel socks, more so than the presence of crabs. However, crabs did apparently help to clean the socks of waste. Consistent with the interpretation that crab exposure reduced waste on socks, the weight of epifauna alone was not different between socks with no exposure to crabs and those exposed to crabs, but the weight of epifauna + waste was lower on socks exposed to crabs. This suggests that there was less waste on socks exposed to crabs. The mussel socks that were not exposed to crabs were kept in the water column during the growing season. Because there is more food at the top of the water column, these mussels were exposed to more food, which could explain the higher weights of mussels on theses socks. However, if this were true, the mussels from the closed cages in this treatment would also have been heavier than mussels on the crab-exposed socks, which was not the case. In 2007, the experimental design was modified to take crab density into account.

The relationship between epifauna biomass and crab density in this study was log-linear over the range of densities used. One would expect that the reduction of epifauna would reach a limit as crab density increased. In studies with the blue crab, crabs engaged in antagonistic behaviours more often at high densities, thereby reducing foraging and feeding (Mansour and Lipcius 1991, Clark *et al.* 1999, Griffen and Byers 2006). However, even if crabs do not feed on the epifauna, regardless of the reason, their movements on socks may be enough to dislodge epifauna. In either case, they still contribute to cleaning the mussel socks.

Rocks crabs were also efficient at reducing the biomass of *S. clava*, an invasive tunicate that is the cause of many problems for the mussel aquaculture industry. They were more efficient when *S. clava* biomass was low, but they may still play a role in reducing the impacts of this tunicate species. Another invasive tunicate, *C. intestinalis*, is also present in PEI waters. Due to time constraints, we only investigated the effect of the green crab on *C. intestinalis,* and found that it had no effect on the biomass of this tunicate. This is in agreement with a study by Carver *et al* (2003) that showed that green crabs do not significantly consume *C. intestinalis*. However, they showed that the rock crab did consume up to 11 individual *C. intestinalis*/day. They also found that crabs with a CW < 80 mm were responsible for consuming the majority of tunicates. The mean CW of crabs found on mussel socks was 70 mm (this study), suggesting that rock crabs could have a significant impact on the biomass of *C. intestinalis*. However, this hypothesis needs further investigation.

Another potential benefit to the presence of crabs on mussel socks is their positive effect on mussel-attachment strength. Although it was not systematically studied here, we observed that mussels with no crab exposure fell off longlines more readily than did those exposed to crabs. Mussel growers have also observed this effect of crabs on mussels. Studies have shown that the presence of predators, namely starfish and crabs, increases mussel attachment on wild mussel beds (Dolmer 1998 and Leonard *et al.* 1999). Leonard et al. (1999) found that mussels living in an area where crab predation was high required 140% more force to be dislodged than mussels living in a low predation area. When mussels from the low predation area were outplanted to the high predation area, they required more strength to be removed from the bed than mussels from the high predation area outplanted to the low predation site. The higher attachment strength was a result of an increase in the number of byssal threads and was a defense mechanism induced by the presence of crabs.

Epifauna biomass reduction did not vary between dates. This is probably due to the design of the experiment: by introducing fixed numbers of crabs into the enclosures, crab densities were constrained to a constant level between dates. In reality, crab abundances vary during the season and its effect on mussel socks most likely does also. In spring, when rock crabs are more abundant, predation pressure is high. But during this period, epifauna biomass is generally low. Because mussel socks are usually put into the water in fall (spring in a few areas), no settlement has yet occurred. Even though socks are not fouled, mussel growers still expose the socks to crabs. This practice increases mussel attachment, which in turn, reduces mussel fall-off. By summer, rock crab abundance has decreased, but may still be high enough to impact socks.

During this period, rock crabs can consume epifauna as well as increase mussel attachment, which is at its lowest in summer (Carrington 2002, Lachance *et al.* 2008.). In the fall, female crabs are moulting and mating occurs. Crabs in pre-moult and moulting stages, as well as mating pairs, do not feed. However, crabs are still found on socks, and thus are able to clean them. Overall, rock crabs as well as green crabs are beneficial to mussel aquaculture, cleaning socks of epifauna and possibly reducing mussel fall-off. Consequently, the yield of mussel socks is increased by their presence.

CONCLUSION

To summarize, we found that crabs are indeed attracted to mussel leases, especially when mussel socks touch the bottom. This situation provides access to socks by making it possible for crabs to climb on them. Smaller crabs are more common on the socks than larger ones. Smaller crabs are more able to move on socks than the larger ones therefore mussel socks may not be an important food source for these large crabs. We also found that the crabs caught in traps are larger than the crabs found on leases. It could be because larger crabs are attracted to baited traps from longer distances than the smaller ones; however the design of this study does not permit us to confirm this hypothesis.

Crab abundances decline throughout the season and increases again in the fall. Unfortunately, we were not able to determine if this was due to the rock crab fishery or to a natural movement by crabs due to environmental conditions.

The rock crab and the green crab are effective at cleaning mussel socks of fouling organisms. They are not, however, as effective at reducing invasive tunicate abundances. The rock crab did reduce the number of clubbed tunicate on mussel socks but only at the beginning of the summer when tunicate abundances are the lowest. The green crab did not reduce the numbers of vase tunicate present on mussel socks. Crabs are useful to mussel growers by reducing the number of epifauna which in turn possibly increases mussel growth by reducing competition for food. The reduction of epifauna biomass also eases the harvesting and processing of mussel socks. These benefits together help increase the productivity of mussel leases.

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LITERATURE CITED

Audet, D., D.S. Davis, G. Miron, M. Moriyasu, K. Benhalima and R. Campbell. 2003. Geographical expansion of a nonindigenous crab, Carcinus maenas (L.), alogn the Nova Scotian shore into the southeastern Gulf of St. Lawrence, Canada. J. Shellfish Res. 22:255-262.

Campbell, A. and M.D. Eagles. 1983. Size at Maturity and Fecundity of Rock Crabs, *Cancer irroratus*, From the Bay of Fundy and Southwestern Nova Scotia. Fishery Bulletin 81: 357-362

Carrington, E. 2002. Seasonal variation in the attachment strength of blue mussels: Causes and consequences. Limnol. Oceanogr. 47: 1723-1733.

Carroll, J.C. 1982. Seasonal Abundance, Size Composition, and Growth of Rock Crab, *Cancer antennarius* Stimpson, Off Central California. J. Crustacean Biol, 2: 549-561

Carver, C. E., A. Chisolm and A. L. Mallet. 2003. Strategies to mitigate the impact of *Ciona intestinalis* (L.) biofouling on shellfish production. J. Shell. Res. 23: 621-631.

Clark. M. E., T. G. Wolcott, D. L. Wolcott and A. H. Hines. 1999. Intraspecific interference among foraging blue crabs *Callinectes sapidus*: interactive effects of predator density and prey patch distribution. Mar. Ecol. Prog. Ser. 178: 69-78.

D'Amours, O., P. Archambault, C.W. McKindsey and L.E. Johnson. 2008. Local enhancement of epibenthic macrofauna by aquaculture activities. Mar. Ecol. Prog. Ser. 371: 73-84

DFO. 2002. Southern Gulf of St. Lawrence rock crab (Lobster fishing areas 23, 24, 25, 26A and 26B). Sci. Stock Status Report C3-04(2002).

MPO. 2008. Évaluation de la pêche du crabe commun (Cancer irroratus) dans les zones de pêche du homard (ZPH) 23, 24, 25, 26A et 26B, dans le sud du golfe du Saint-Laurent, de 2000 à 2006. Secr. Can.de consult. Sci. du MPO, Avis sci. 2008/022.

Dolmer, P. 1998. The interactions between bed structure of *Mytilus edulis* L. and the predator *Asterias rubens* L. J. Exp. Mar. Biol. Ecol. 228: 137-150.

Drummond-Davis, N.C., K.H. Mann and R.A. Pottle. 1982. Estimates of Population Density and Feeding Habits of Rock Crab, *Cancer irroratus*, in a Kelp Bed in Nova Scotia. Can. J. Fish. Aquat. Sci. 39: 636-639

Ellis, K. D. J. Giberson and J. Davidson. 2002. Marine organisms associated with mussel socks on Prince Edward Island: A manual for mussel growers. Charlottetown: Document Publishing Centre. 55 pp.

Elner, R.W. 1981. Diet of green crab Carcinus maenus (L.) from Port Hebert, southwestern Nova Scotia. J. Shell. Res. 1:89-94.

Enright, C. T., R. W. Elner, A. Griswold and E. M. Borgese. 1993. Evaluation of crabs as control agents for Biofouling in suspended culture of European oysters. World Aquac. 24: 49-51.

Freire, J. and E. Gonzalez-Gurriaran. 1995. Feeding ecology of the velvet swimming crab *Necora puber* in mussel raft areas of the Ria de Arousa (Galicia, NW Spain). Mar. Ecol. Prog. Ser. 119 :139-154.

Gendron, L. and C. Cyr. 1994. Distribution bathymétrique et saisonnière du crabe commun (*Cancer irroratus*) au large d'Anse-à-Beaufils, Québec. Rapp. tech. can. sci. halieut. aquat. 2014: ix + 53 p.

Gendron, L. and P. Fradette. 1995. Revue des interactions entre le crabe commun (*Cancer irroratus*) et le homard américain (*Homarus americanus*), dans le contexte du développement d'une pêche au crabe commun au Québec. Rapp. Manus. Can. Sci. Halieut. Aquat. 2306: vii + 47 p.

Gonzalez-Gurriaran, E. 1986. Seasonal changes of benthic megafauna in the Ria-de-Muro-E-Noia (Galicia, Northwest Spain) 2. Decapod Crustaceans (Brachyura). Mar. Biol. 92: 201-210.

Griffen, B. D. and J. E. Byers. 2006. Intraguild predation reduces redundancy of predator species in multiple predator assemblage. J. Animal Ecol. 75: 959-966.

Hidu, H. C. Conary and S. R. Chapman. 1981. Suspended culture of oysters: Biological fouling control. Aquaculture 22: 189-192.

Hudon, C. and G. Lamarche. 1989. Niche segregation between American lobster *Homarus americanus* and rock crab *Cancer irroratus*. Mar. Ecol. Prog. Ser. 52:155-168.

Klassen, G. and A. Locke. 2007. A biological synopsis of the European green crab, *Carcinus maenas*. Can. Manuscr. Rep. Fish. Aquat. Sci. 2818: vii + 75 pp.

Krouse, J.S. 1972. Some Life History Aspects of the Rock Crab, *Cancer irroratus*, in the Gulf of Maine. J. Fish. Res. Bd. Canada 29: 1479-1482.

Lachance, A. A., B. Myrand, R. Tremblay, V. Koutitonsky and E. Carrington. 2008. Biotic and abiotic factors influencing attachment strength of blue mussels *Mytilus edulis* in suspended culture. Aquatic Biol. 2: 119-129.

LeBlanc, A. R., T. Landry and G. Miron. 2003. Identification of fouling organisms covering mussel lines and impact of a common defouling method on the abundance of foulers in Tracadie Bay, Prince Edward Island. Can. Tech. Rep. Fish. Aquat. Sci. 2477: vii + 18 p.

Leonard, G. H., M. D. Bertness and P. O. Yund. 1999. Crab predation, waterborne cues, and inducible defenses in the blue mussel, *Mytilus edulis*. Ecology 80: 1-14.

Lodeiros, C.J.M. and J.H. Himmelman. 1996. Influence of fouling on the growth and survival of the tropical scallop, *Euvolva (Pecten) ziczac* (L. 1758) in suspended culture. Aquacult. Res. 27: 749-756.

Mansour, R. A. and R. N. Lipcius. 1991. Density-dependent foraging and mutual interference in blue crabs preying upon infaunal clams. Mar. Ecol. Prog. Ser. 72: 239-246.

Miron, G., D. Audet, T. Landry and M. Moriyasu. 2005. Predation potential of the invasive green crab (*Carcinus maenas*) and other common predators on commercial bivalve species found on Prince Edward Island. J. Shell. Res. 24: 579-586.

Ojeda, F.P. and J.H. Dearborn. 1991. Feeding ecology of benthic mobile predators: experimental analyses of their influence in rocky subtidal communities of the Gulf of Maine. J. Exp. Mar. Biol. Ecol. 149:13-44.

Pinheiro, J., D. Bates, S. DebRoy, D. Sarkar and the R Core team (2008). nlme: Linear and Nonlinear Mixed Effects Models. R package version 3.1-90.

R Development Core Team (2008). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. ISBN 3-900051-07-0, URL http://www.R-project.org.

Rebach, S. 1987. Entrainment of seasonal and nonseasonal rhythms by the rock crab *Cancer irroratus*. J. Crust. Biol. 7: 581-594

Reilly, P. N. and S. B. Saila. 1978. Biology and Ecology of the Rock Crab, *Cancer irroratus* Say, 1817, In Southern New England Waters (Decapoda, Brachyura). Crustaceana, 34: 121-140

Romero, P., E. Gonzalez-Gurriaran, E. Penas. 1982. Influence of mussel rafts on spatial and seasonal abundance of crabs in the Ria de Arousa, Northwest Spain. Mar. Biol. 72: 201-210.

Ropes, J. W. 1967. The feeding habits of the green crab, *Carcinus maenus* (L.). Fish. Bull. 67: 183-203.

Ropes, J. W. 1988. The food habits of five crab species at Pettaquamscutt River, Rhode Island. Fish. Bull. 87: 197-204.

Sainte-Marie, B. and B. T. Hargrave. 1987. Estimation of scavenger abundance and distance of attraction to bait. Mar. Biol. 94: 431-443

Salierno, J.D., S. Rebach, M.C. Christman. 2003. The effects of interspecific competition and prey odor on foraging behaviour in the rock crab, *Cancer irroratus* (Say). J. of Exp. Mar. Biol. Ecol. 287: 249-260

Scarratt, D.J., R. Lowe. 1972. Biology of the rock crab (*Cancer irroratus*) in Northumberland Straight. J. Fish. Res. Bd. Canada. 29: 161-166.

Schmidt, G. H. and G.F. Warner. 1984. Effects of caging on the development of a sessile epifaunal community. Mar. Ecol. Prog. Ser. 15:251-263.

Shotton, L.R. 1973. Biology of the rock crab, *Cancer irroratus* say, in the coastal waters of Virginia. Thesis (MSc.). Department of Marine Science, University of Virginia. 73p.

Steele, M. A. 1996. Effects of predators on reef fishes: separating cage artifacts from effects of predation. J. Exp. Mar. Biol. Ecol. 198:249-267.

Stehlik, L. L., C. L. MacKenzie Jr. and W. W. Morse. 1991. Distribution and abundance of four brachyuran crabs on the Northwest Atlantic Shelf. Fish. Bull. U.S. 89: 473-492.

Stehlik, L. L. 1993. Diets of the brachyuran crabs *Cancer irroratus*, *C. borealis* and *Ovalipes ocellatus* in the New York Bight. J. Crustacean Biol. 13: 723-735.

Venables, W. N. and Ripley, B. D. 2002 Modern Applied Statistics with S. Fourth Edition. Springer, New York. ISBN 0-387-95457-0.

Table 1. Details of the dive surveys carried out in 2005 in PEI.

Date	Bay	Lease	Status	Number of transects
27 April	Lennox Island	SUR-0200-L	Cultured	2
2 May	Rustico	SUR-0549A-L	Cultured	2
		SUR-0550A-L	Cultured	1
3 May	New London	SUR-0503A-L	Cultured	3
		SUR-0510-L	Cultured	3
4 May	Marchwater	SUR-0526-L	Cultured	3
		SUR-0559A-L	Cultured	3
15 June	Marchwater	SUR-0526-L	Cultured	3
		SUR-0559A-L	Cultured	3
27 June	Marchwater	SUR-0526-L	Cultured	3
		SUR-0559A-L	Cultured	3
28 June	New London	SUR-0503A-L	Cultured	3
		SUR-0510-L	Cultured	3
	Rustico	SUR-0549A-L	Cultured	3
		SUR-0550A-L	Cultured	3
30 June	Lennox Island	SUR-0200-L	Cultured	3
		SUR-0540-L	Cultured	3
20 July	Marchwater	SUR-0526-L	Cultured	3
		SUR-0559A-L	Cultured	3
21 July	New London	SUR-0503A-L	Cultured	3
		SUR-0510-L	Cultured	3
	Rustico	SUR-0549A-L	Cultured	3
		SUR-0550A-L	Cultured	3
28 July	Lennox Island	SUR-0200-L	Cultured	3
		SUR-0200-L	Empty	3
		SUR-0536-L	Cultured	3
		SUR-0536-L	Empty	3
30 August	Rustico	SUR-0548AB-L	Cultured	3
		SUR-0552-L	Cultured	3
		Off lease	Off lease	6
4 October	New London	SUR-0503A-L	Cultured	3
		SUR-0510-L	Cultured	3
5 October	Lennox Island	SUR-0200-L	Cultured	3
		SUR-0540-L	Cultured	3
	Marchwater	SUR-0526-L	Cultured	3
		SUR-0559A-L	Cultured	3
6 October	Rustico	SUR-0549A-L	Cultured	3
		SUR-0550A-L	Cultured	3
2 November	Rustico	SUR-0549A-L	Cultured	3
		SUR-0550A-L	Cultured	3
4 November	New London	SUR-0503A-L	Cultured	3
		SUR-0510-L	Cultured	3
9 November	Lennox Island	SUR-0200-L	Cultured	3
		SUR-0540-L	Cultured	3
15 November	Marchwater	SUR-0614-L	Cultured	3

Table 2. Details of dive surveys in 2006 in PEI.

Date	Bay	Lease	Status	Number of transects
28 April	Lennox Island	SUR-0200-L	Cultured	5
		SUR-0536-L	Cultured	5
		Off lease	Off lease	3
25 May	Lennox Island	SUR-0200-L	Cultured	5
		SUR-0536-L	Cultured	5
1 June	Marchwater	SUR-0526-L	Cultured	5
		SUR-0559A-L	Cultured	5
2 June	New London	SUR-0503A-L	Cultured	5
		SUR-0510-L	Cultured	5
27 June	Lennox Island	SUR-0200-L	Cultured	5
		SUR-0536-L	Cultured	5
28 June	New London	SUR-0503A-L	Cultured	5
		SUR-0514-L	Cultured	5
		Off lease	Off lease	4
13 July	Marchwater	SUR-0526-L	Cultured	5
		SUR-0559A-L	Cultured	5
16 August	Lennox Island	SUR-0200-L	Cultured	5
		SUR-0536-L	Cultured	5
17 August	New London	SUR-0503A-L	Cultured	5
		SUR-0510-L	Cultured	5
18 August	New London	Off lease	Off lease	8
23 August	Marchwater	SUR-0526-L	Cultured	5
		SUR-0559A-L	Cultured	5
		SUR-0510-L	Cultured	5
4 October	New London	SUR-0503A-L	Cultured	5
		SUR-0510-L	Cultured	5
16 October	Lennox Island	SUR-0200-L	Cultured	5
		SUR-0536-L	Cultured	5
		SUR-0536-L	Empty	1
17 October	Marchwater	SUR-0526-L	Cultured	5
		SUR-0559A-L	Cultured	5
1 November	New London	SUR-0510-L	Cultured	5

Table 3. Regression parameters and significance of factors in the relationship ($\ln Y = a + b_1X_1 + b_2X_2 + b_3X_3$) between date ($X_1$), bay ($X_2$) and line status ($X_3$) and the number of crabs per transect (Y) underneath mussel socks and the number of crabs on 10 socks (Y). Crabs were collected in 4 bays in PEI in 2005 and 2006. Significant p levels are in bold face.

	Transects				**Socks**			
				Least square means				
Effect	***Estimate***	***SE***			***Estimate***	***SE***		
Intercept	-0.6864	0.6315			-0.6960	0.6618		
Date	-0.0043	0.0012			-0.0043	0.0020		
				Type III tests of fixed effects				
Effect	***Num df***	***Den df***	***F***	***p***	***Num df***	***Den df***	***F***	***p***
Date	1	206	11.49	**<0.001**	1	206	4.58	**0.034**
Bay	2	5	0.20	0.826	2	5	0.09	0.915
Status	1	206	12.65	**<0.001**	1	206	60.11	**<0.001**
				Covariance parameters				
Parameter	***Estimate***	***SE***	**Subject**		***Estimate***	***SE***	**Subject**	
Intercept	0.8938	1.4701	Lease(Bay)		0.5815	0.7305	Lease(Bay)	
Year	0.0103	0.0606	Lease(Bay)		0	0.1937	Lease(Bay)	
Variance	0.6731	0.1910			1.4330	0.1733		
AR(1)	0.3439	0.1865	Lease(Bay)		0.3245	0.0762	Lease(Bay)	
Scale	0.0161	.			0.8217	.		

Table 4. Average width, width range and commercial size (%) of male and female rock crabs underneath mussel lines before, during and after the directed rock crab fishery in Lennox Island, Marchwater, New London and Rustico Bay, 2005 and 2006.

			Before				During				After				Total			
Sex	**Year**	**Bay**	**n**	**Avg. width (mm)**	**Width range (mm)**	**Legal size (%)**	**n**	**Avg. width (mm)**	**Width range (mm)**	**Legal size (%)**	**n**	**Avg. width (mm)**	**Width range (mm)**	**Legal size (%)**	**n**	**Avg. width (mm)**	**Width range (mm)**	**Legal size (%)**
Male	**2005**	Lennox Island	171	79	37-111	7.6	71	76	27-108	5.6	30	78	35-104	6.7	**272**	**78**	**27-111**	**7.0**
		Marchwater	109	86	45-120	13.8	70	78	32-108	4.3	9	72	28-102	11.1	**188**	**82**	**28-120**	**10.1**
		New London	259	80	20-128	14.3	118	75	18-116	18.6	36	79	36-119	19.4	**413**	**78**	**18-128**	**16.0**
		Rustico	192	79	41-112	4.2	127	73	32-119	5.5	27	77	40-103	3.7	**346**	**76**	**32-119**	**4.6**
		Total 2005	**731**	**80**	**20-128**	**10.0**	**386**	**75**	**18-119**	**9.3**	**102**	**77**	**28-119**	**10.8**	**1219**	**78**	**18-128**	**9.8**
	2006	Lennox Island	402	74	27-116	10.0	87	69	38-105	1.1	56	72	48-111	8.9	**545**	**73**	**27-116**	**8.4**
		Marchwater	141	76	29-108	12.1	225	66	28-109	1.8	103	77	35-114	3.9	**469**	**71**	**28-114**	**5.3**
		New London	506	75	23-126	17.2	432	67	22-119	11.3	101	83	18-118	28.7	**1039**	**72**	**18-126**	**15.9**
		Total 2006	**1049**	**75**	**23-126**	**13.7**	**744**	**67**	**18-119**	**7.3**	**260**	**78**	**18-118**	**14.6**	**2053**	**72**	**18-126**	**11.5**
	2005-2006	**Grand total**	**1780**	**77**	**20-128**	**12.2**	**1130**	**69**	**18-119**	**8.0**	**362**	**78**	**18-119**	**13.5**	**3272**	**74**	**18-128**	**10.9**
Female	**2005**	Lennox Island	42	70	47-78	n/a	22	68	43-80	n/a	42	71	31-88	n/a	**106**	**70**	**31-88**	**n/a**
		Marchwater	13	62	34-80	n/a	19	63	40-78	n/a	7	64	37-77	n/a	**39**	**63**	**34-80**	**n/a**
		New London	88	65	46-82	n/a	82	61	28-77	n/a	20	59	30-77	n/a	**190**	**63**	**28-82**	**n/a**
		Rustico	79	68	43-81	n/a	61	64	40-82	n/a	11	63	43-78	n/a	**151**	**66**	**40-82**	**n/a**
		Total 2005	**222**	**67**	**34-82**	**n/a**	**184**	**63**	**28-82**	**n/a**	**80**	**66**	**30-88**	**n/a**	**486**	**65**	**28-88**	**n/a**
	2006	Lennox Island	95	61	28-92	n/a	56	65	48-84	n/a	26	69	58-78	n/a	**177**	**64**	**28-92**	**n/a**
		Marchwater	47	56	28-79	n/a	80	57	34-79	n/a	40	66	42-79	n/a	**167**	**59**	**28-79**	**n/a**
		New London	314	62	27-100	n/a	181	61	32-83	n/a	17	62	50-72	n/a	**512**	**61**	**27-100**	**n/a**
		Total 2006	**456**	**61**	**27-100**	**n/a**	**317**	**61**	**32-84**	**n/a**	**83**	**66**	**42-79**	**n/a**	**856**	**61**	**27-100**	**n/a**
	2005-2006	**Grand total**	**678**	**63**	**27-100**	**n/a**	**501**	**62**	**28-84**	**n/a**	**163**	**66**	**30-88**	**n/a**	**1342**	**63**	**27-100**	**n/a**

*Legal size ≥ 102 mm CW (males only)

Table 5. Average width, width range and commercial size (%) of male and female rock crabs on mussel socks before, during and after the directed rock crab fishery in Lennox Island, Marchwater, New London and Rustico Bay, 2005 and 2006.

			Before				During				After				Total			
Sex	**Year**	**Bay**	**n**	**Avg. width (mm)**	**Width range (mm)**	**Legal size (%)**	**n**	**Avg. width (mm)**	**Width range (mm)**	**Legal size (%)**	**n**	**Avg. width (mm)**	**Width range (mm)**	**Legal size (%)**	**n**	**Avg. width (mm)**	**Width range (mm)**	**Legal size (%)**
Male	**2005**	Lennox Island	62	76	33-109	4.8	58	75	27-103	1.7	10	82	55-105	10.0	**130**	**76**	**27-109**	**3.8**
		Marchwater	54	82	43-122	13.0	26	79	34-106	3.8	0	n/a	n/a	n/a	**80**	**81**	**34-122**	**10.0**
		New London	71	78	35-144	14.1	20	78	39-120	20.0	5	53	42-68	0	**96**	**76**	**35-120**	**14.6**
		Rustico	37	77	42-115	8.1	37	71	23-113	10.8	3	98	94-104	33.3	**77**	**75**	**23-115**	**10.4**
		Total 2005	**224**	**78**	**33-122**	**10.3**	**141**	**75**	**23-120**	**7.1**	**18**	**77**	**42-105**	**11.1**	**383**	**77**	**23-122**	**9.1**
	2006	Lennox Island	78	74	45-111	9.0	83	67	44-106	1.2	13	70	50-92	0	**174**	**71**	**44-111**	**4.6**
		Marchwater	22	82	34-105	13.6	74	65	42-101	0	27	75	36-108	11.1	**123**	**70**	**34-108**	**4.9**
		New London	72	79	36-112	13.9	60	71	46-119	10.0	8	94	66-107	12.5	**140**	**77**	**36-119**	**12.1**
		Total 2006	**172**	**77**	**34-112**	**11.6**	**217**	**68**	**42-119**	**3.2**	**48**	**77**	**36-108**	**8.3**	**437**	**72**	**34-119**	**7.1**
	2005-2006	**Grand total**	**396**	**78**	**33-122**	**10.9**	**358**	**71**	**23-120**	**4.5**	**66**	**77**	**36-108**	**9.1**	**820**	**74**	**23-122**	**8.0**
Female	**2005**	Lennox Island	29	68	52-80	n/a	31	66	52-77	n/a	14	69	59-79	n/a	**74**	**67**	**52-80**	**n/a**
		Marchwater	26	66	48-78	n/a	23	64	52-79	n/a	0	n/a	n/a	n/a	**49**	**65**	**48-79**	**n/a**
		New London	27	67	48-84	n/a	13	69	52-104	n/a	2	63	55-71	n/a	**42**	**68**	**48-104**	**n/a**
		Rustico	21	70	38-84	n/a	37	67	44-82	n/a	1	67	n/a	n/a	**59**	**68**	**38-84**	**n/a**
		Total 2005	**103**	**68**	**38-84**	**n/a**	**104**	**66**	**44-104**	**n/a**	**17**	**68**	**55-79**	**n/a**	**224**	**67**	**38-104**	**n/a**
	2006	Lennox Island	39	64	41-78	n/a	68	63	35-84	n/a	13	70	60-82	n/a	**120**	**64**	**35-84**	**n/a**
		Marchwater	10	61	46-72	n/a	47	60	34-77	n/a	17	64	43-80	n/a	**74**	**61**	**34-80**	**n/a**
		New London	30	63	51-77	n/a	47	61	43-83	n/a	7	86	68-97	n/a	**84**	**64**	**43-97**	**n/a**
		Total 2006	**79**	**64**	**41-78**	n/a	**162**	**61**	**34-84**	n/a	**37**	**70**	**43-97**	n/a	**278**	**63**	**34-97**	**n/a**
	2005-2006	**Grand total**	**182**	**66**	**38-84**	**n/a**	**266**	**63**	**34-104**	**n/a**	**54**	**70**	**43-97**	**n/a**	**502**	**65**	**34-104**	**n/a**

* Legal size ≥ 102 mm CW (males only)

Table 6. Average number of male (♂) and female (♀) rock crab and the sex ratio (male : female) underneath mussel lines (A) and on mussel socks (B) during the sampling season in Lennox Island, Marchwater, New London and Rustico Bay, 2005 and 2006.

A		***May***			***June***			***July***			***Aug***			***Oct***			***Nov***		
Year	**Bay**	♂	♀	♂:♀	♂	♀	♂:♀	♂	♀	♂:♀	♂	♀	♂:♀	♂	♀	♂:♀	♂	♀	♂:♀
2005	Lennox Island	0.34	0.08	4.1:1	0.21	0.05	4.1:1	0.12	0.04	3.3:1				0.04	0.01	3.0:1	0.07	0.09	0.7:1
	Marchwater	0.04	0.01	6.3:1	0.10	0.02	6.7:1	0.10	0.03	3.3:1				0.05	0.01	4.8:1	0.04	0.03	1.3:1
	New London	0.27	0.05	5.1:1	0.30	0.14	2.1:1	0.13	0.13	1.0:1				0.13	0.06	2.4:1	0.08	0.04	1.8:1
	Rustico	0.25	0.10	2.5:1	0.30	0.12	2.4:1	0.18	0.07	2.6:1				0.10	0.06	1.6:1	0.06	0.02	2.5:1
2006	Lennox Island	0.20	0.40	5.1:1	0.23	0.08	2.9:1				0.12	0.07	1.6:1	0.07	0.03	2.2:1			
	Marchwater	0.19	0.06	3.0:1				0.20	0.05	3.9:1	0.10	0.05	1.8:1	0.14	0.05	2.6:1			
	New London	0.57	0.30	1.9:1	0.11	0.12	0.9:1				0.33	0.15	2.2:1	0.25	0.09	2.7:1	0.27	0.05	5.9:1

B		***May***			***June***			***July***			***Aug***			***Oct***			***Nov***		
Year	**Bay**	♂	♀	♂:♀	♂	♀	♂:♀	♂	♀	♂:♀	♂	♀	♂:♀	♂	♀	♂:♀	♂	♀	♂:♀
2005	Lennox Island	0.13	0.06	2.1:1	0.07	0.03	2.2:1	0.11	0.05	2.3:1				0.02	0.02	1.0:1	0.02	0.03	0.7:1
	Marchwater	<0.01	<0.01	1:1	0.02	0.03	0.8:1	0.05	0.04	1.3:1				0.01	0.01	0.7:1	0	0	0
	New London	0.07	0.04	1.5:1	0.09	0.02	5.9:1	0.04	0.03	1.4:1				<0.01	0.0		0.01	<0.01	2.5
	Rustico	0	0	0	0.08	0.05	1.8:1	0.05	0.05	0.9:1				0.02	0.02	0.9:1	<0.01	<0.01	3
2006	Lennox Island	<0.01	0		0.08	0.05	1.6:1				0.11	0.09	1.2:1	0.02	0.02	1.0:1			
	Marchwater	0.03	0.01	2.2:1	0.04	0.03	1.5:1				0.06	0.04	1.6:1	0.04	0.02	1.6:1			
	New London	0.06	0.01	4.8:1	0.04	0.03	1.4:1				0.05	0.04	1.3:1	0.03	0.03	1.2:1	0.02	0.02	1.1:1

Table 7. Number, percentage and width range of ovigerous female rock crabs underneath mussel lines and on mussel socks before and during the rock crab fishery, 2005 and 2006.

	Year	Total female n	# ovigerous	%	Width range (mm)
Bottom	2005	406	26	6.4	52-77
	2006	773	27	3.5	50-100
	Total	**1179**	**53**	**4.5**	**50-100**
Mussel socks	2005	207	4	1.9	63-72
	2006	241	0	n/a	n/a
	Total	**448**	**4**	**0.9**	**63-72**

* No ovigerous females were found after the fishery.

Table 8. Shell condition (%) of rock crabs underneath mussel lines and on mussel socks before, during and after the rock crab fishery, 2006.

		Male				**Female**			
Rock crab source	**Rock crab fishery**	**n**	**Soft shell (%)**	**New shell (%)**	**Old shell (%)**	**n**	**Soft shell (%)**	**New shell (%)**	**Old shell (%)**
Bottom	Before	972	2.7	92.5	4.8	451	3.5	86.5	10.0
	During	744	2.7	88.8	8.5	317	3.8	89.6	6.6
	After	260	6.9	68.5	24.6	83	8.4	90.4	1.2
	Total	**1976**	**3.2**	**88.0**	**8.8**	**851**	**4.1**	**88.0**	**7.9**
Mussel socks	Before	158	5.1	93.0	1.9	78	6.4	91.0	2.6
	During	217	1.4	94.9	1.4	161	4.3	92.5	3.1
	After	48	4.2	81.3	14.6	37	18.9	75.7	5.4
	Total	**423**	**3.1**	**92.7**	**4.3**	**276**	**6.9**	**89.9**	**3.3**

* Shell condition observations were noted after the first sampling date in 2006.

Table 9. Leg and claw condition (%) of rock crabs underneath mussel lines and on mussel socks before and during the rock crab fishery, 2006.

Rock crab source	Year	Rock crab fishery	n	# of missing legs or claws 0 (%)	1 (%)	2 (%)	>2 (%)
Bottom	**2005**	Before	953	92.9	5.4	1.4	0.4
		During	570	92.5	6.1	0.9	0.5
		After	182	92.9	3.8	2.2	1.1
		Total 2005	**1705**	**92.7**	**5.5**	**1.3**	**0.5**
	2006	Before	1505	95.7	3.0	0.9	0.3
		During	1061	93.7	4.0	1.4	0.9
		After	343	93.9	4.1	1.7	0.3
		Total 2006	**2909**	**94.8**	**3.5**	**1.2**	**0.6**
		Grand total	**4614**	**94.0**	**4.2**	**1.2**	**0.4**
Mussel socks	**2005**	Before	373	93.6	3.5	1.6	1.3
		During	203	93.6	4.9	1.0	0.5
		After	31	96.8	3.2	0	0
		Total 2005	**607**	**93.7**	**4.0**	**1.3**	**1.0**
	2006	Before	251	97.2	2.0	0.4	0.4
		During	379	95.8	2.9	1.3	0
		After	85	97.6	2.4	0	0
		Total 2006	**715**	**96.5**	**2.5**	**0.8**	**0.1**
		Grand total	**1322**	**95.2**	**3.2**	**1.1**	**0.5**

Table 10. Analysis of deviance table of the mean number of crabs collected (A) inside and outside mussel leases and (B) on the cultured and empty portions of leases in PEI between 2005 and 2006. Only significant factors were kept in the models.

Analysis of deviance table

A – Inside vs Outside leases

Source of variation	**df**	**Deviance**	**Residual df**	**Residual deviance**	**p(>|Chi|)**
Lennox Island					
Null			12	24.6148	
Area (inside or outside)	1	10.5707	11	14.0441	0.001
New London					
Null			31	70.567	
Area (inside or outside)	1	31.222	30	39.345	<0.001
Date	1	4.393	29	34.952	0.036
Rustico					
Null			8	10.3028	
Area (inside or outside)	1	1.0310	7	9.2718	0.310

B- Cultivated vs empty area of lease

Source of variation	**df**	**Deviance**	**Residual df**	**Residual deviance**	**p(>|Chi|)**
Null			11	42.954	
Status (cultured or empty)	1	31.728	10	11.226	<0.001

Table 11. Analysis of variance table of the effect of cage type and treatment on mussel socks in Lennox Island in the 2006 growing season. Significant p levels are in boldface

Analysis of Variance Tables

A-Weight of 30 cm section (log+1)

	Df	***F***	***p***
Cage type	2	2.77	0.068
Treatment	1	8.41	**0.005**
Cage type:Treatment	2	8.95	**<0.001**
Residuals	82		

B-Weight of mussels on 30 cm section (log + 1)

	Df	***F***	***p***
Cage type	2	3.04	0.054
Treatment	1	9.23	**0.003**
Cage type:Treatment	2	9.82	**<0.001**
Line(Treatment)	4	3.00	**0.024**
Residuals	78		

C-Weight of epifauna +waste on 30 cm section

	Df	***F***	***p***
Cage type	2	5.09	**0.008**
Treatment	1	21.78	**<0.001**
Cage type:Treatment	2	6.43	**0.003**
Residuals	82		

D-Dry weight of epifauna on 30 cm section (log+1)

	Df	***F***	***p***
Cage	2	10.92	**<0.001**
Residuals	77		

Table 12. Regression parameters and significance of factors in the relationship ($\ln Y = a + b_1X_1 + b_2X_2 + b_3X_3$) between rock crab(*Cancer irroratus*) and green crab (*Carcinus maenas*) densities (X_1), date (X_2) and bay (X_3) and mussel sock epifauna (Y) in PEI bays in the 2007 growing season.

A-Epifauna + waste (log weight)

	Coefficients		ANOVA			
Effect	***Estimate***	***SE***	***Num Df***	***Den Df***	***F***	***p***
Intercept	5.33	0.05	1	114	96281.05	<0.001
Crab density	-0.04	0.01	1	114	57.00	<0.001
Bay			2	114	124.08	<0.001
Date			1	114	69.81	<0.001
Bay:date			2	114	45.45	<0.001

B- Epifauna (log dry weight)

	Coefficients		ANOVA			
Effect	***Estimate***	***SE***	***Num Df***	***Den Df***	***F***	***p***
Intercept	3.41	0.23	1	110	806.03	<0.001
Crab density	-0.06	0.01	1	110	45.26	<0.001
Bay			2	0	11.73	na
Date			1	110	6.79	0.01

Table 13. Regression parameters and significance of factors in the relationship ($\ln Y = a + b_1X_1 + b_2X_2$) between A: the green crab (*Carcinus maenas*) density (X_1) on the vase tunicate (*Ciona intestinalis*) (Y) and B: the effect of the rock crab (*Cancer irroratus*) density (X_1) and date (X_2) on the clubbed tunicate (*Styela clava*) (Y) in PEI bays in the 2007 growing season.

A-Brudenell-*Carcinus maenas*

***Ciona intestinalis* (log wet weight)**

Effects	***Coefficient***	***SE***	***t-value***	***p***
Intercept	6.12	0.08	75.65	<0.001
Crab density	-0.03	0.01	-2.03	0.06

B-Marchwater-*Cancer irroratus*

***Styela clava* (log dry weight)**

				ANOVA		
Effects	***Coefficient***	***SE***	***Num DF***	***Den Df***	***F***	***p***
Intercept	2.99	0.24	1	36	960.31	<0.001
Crab density	-0.16	0.04	1	36	10.22	0.003
Date			1	36	107.96	<0.001
Density:date			1	36	10.64	0.002

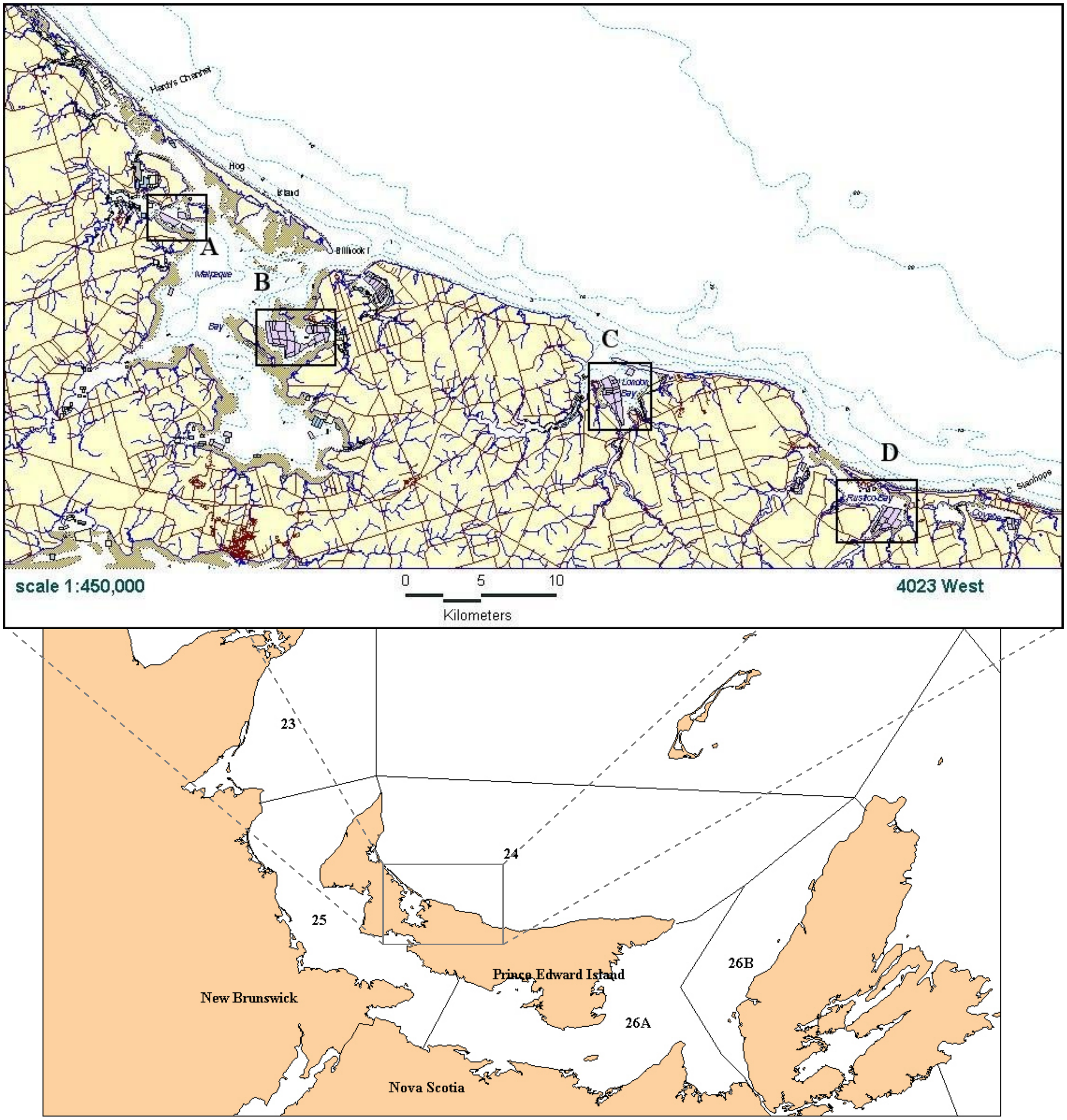


Figure 1. Map of the Atlantic Provinces showing the lobster fishing areas (LFAs). The inset shows where the sampling for the study occurred: Lennox Island (A), Marchwater (B), New London (C) and Rustico (D).

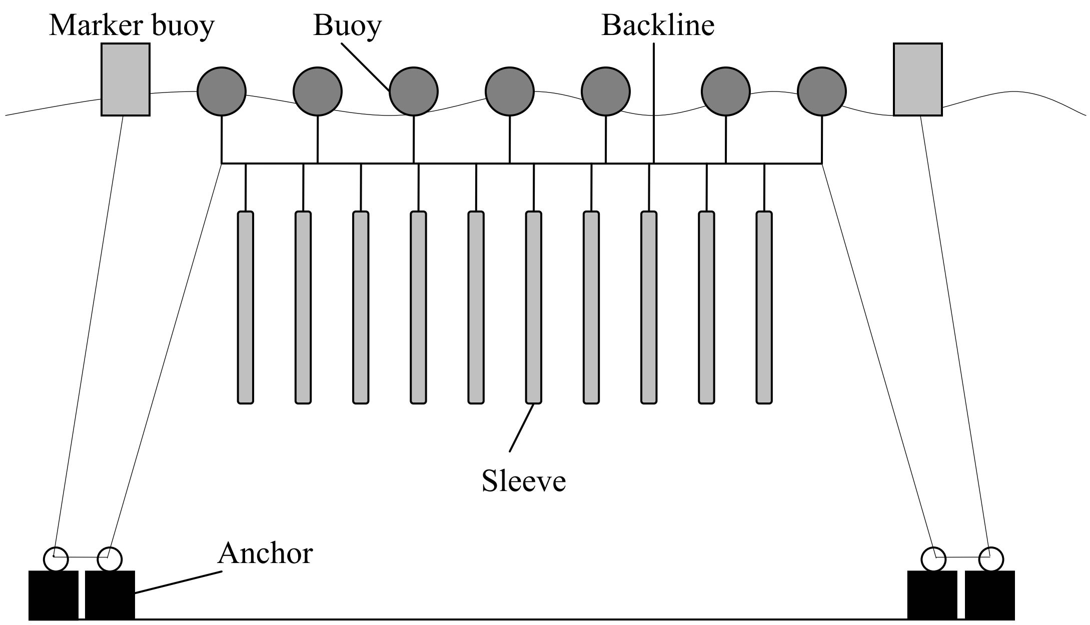


Figure 2. Diagram showing the set up of a mussel long line system.

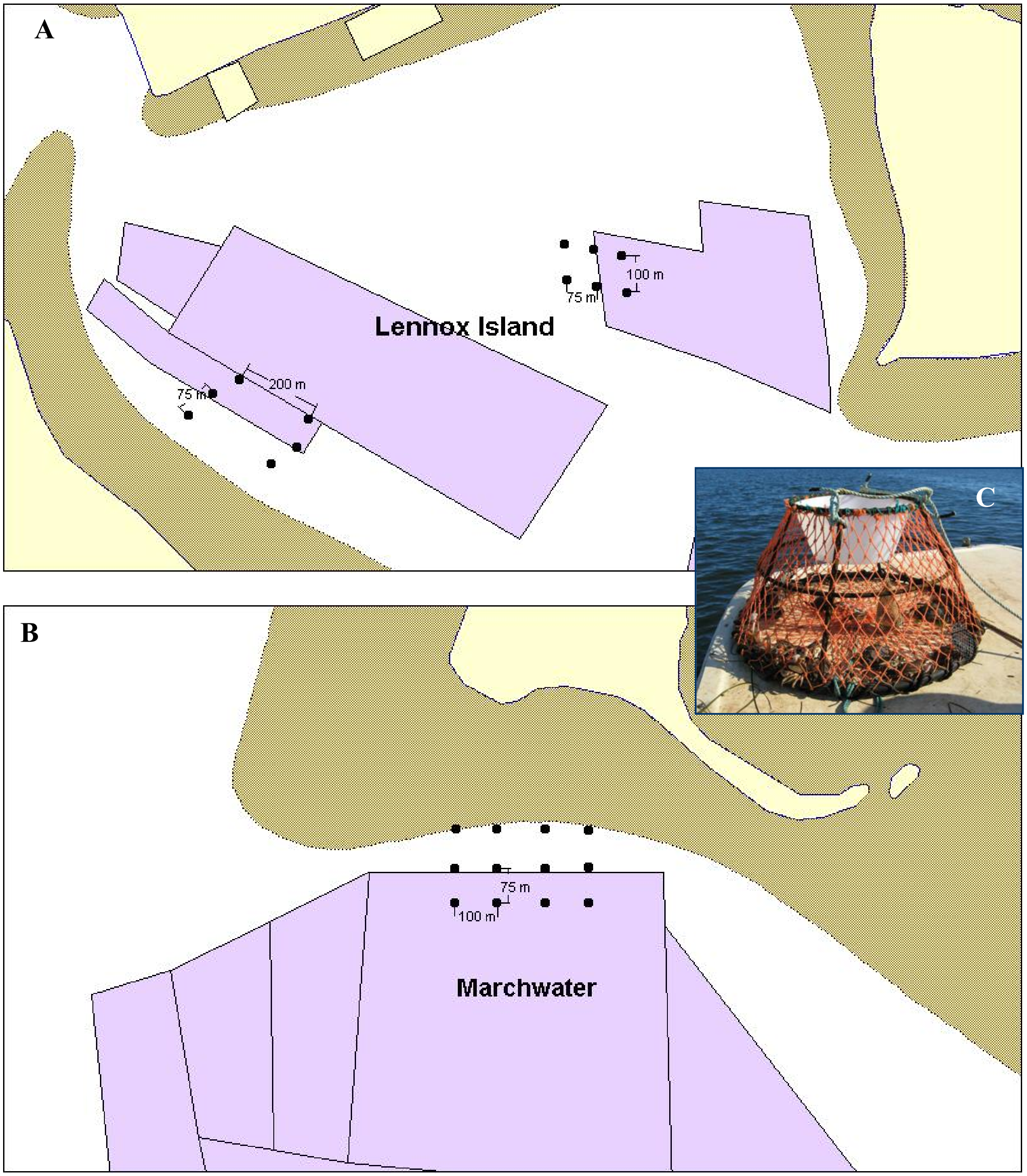


Figure 3. Location of trap deployments inside, on the border and outside leases in Lennox Island (A) and Marchwater (B) and a picture of a commercial rock crab trap; Japanese style crab pot (C).

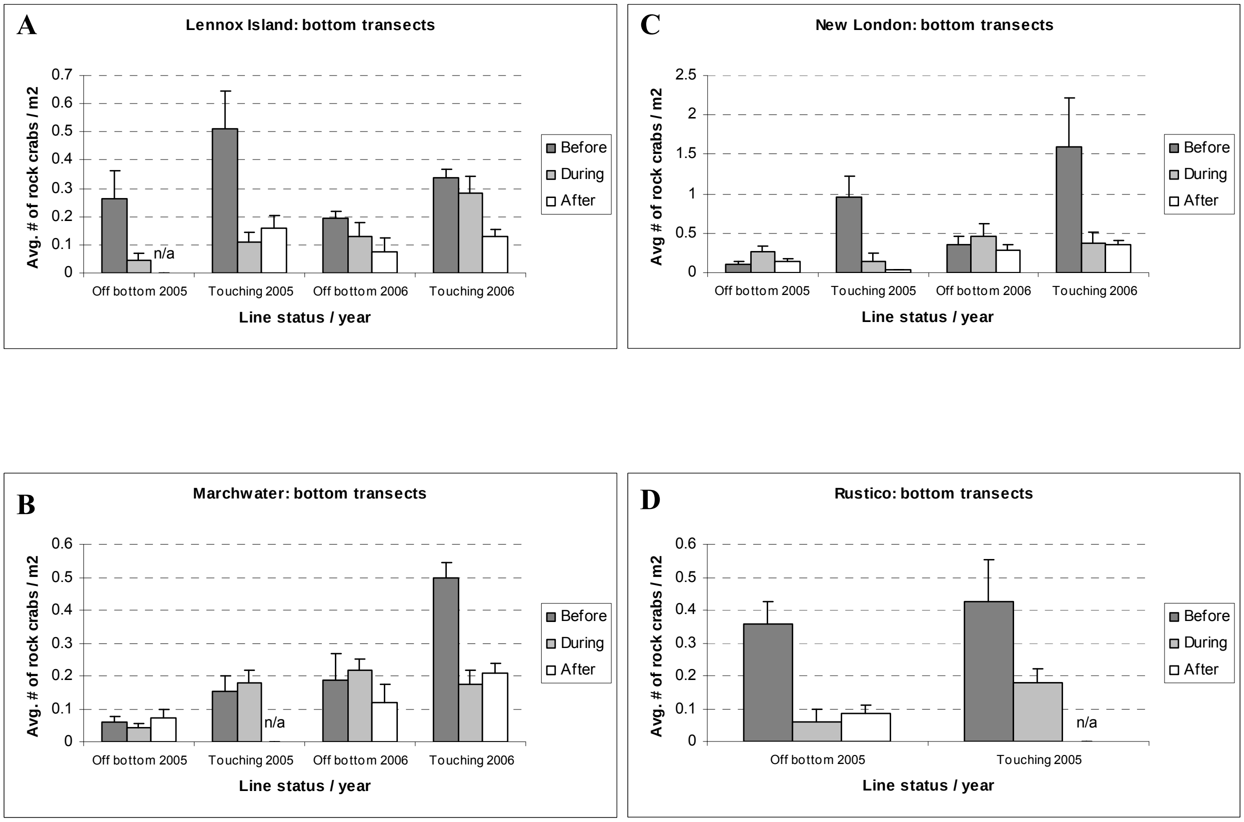


Figure 4. Average rock crab abundance underneath mussel lines (lines off bottom vs. lines touching the bottom) before, during and after the rock crab fishery in Lennox Island (A), Marchwater (B), New London (C) and Rustico (D), 2005 and 2006. Error bars represent the standard errors (± SE).

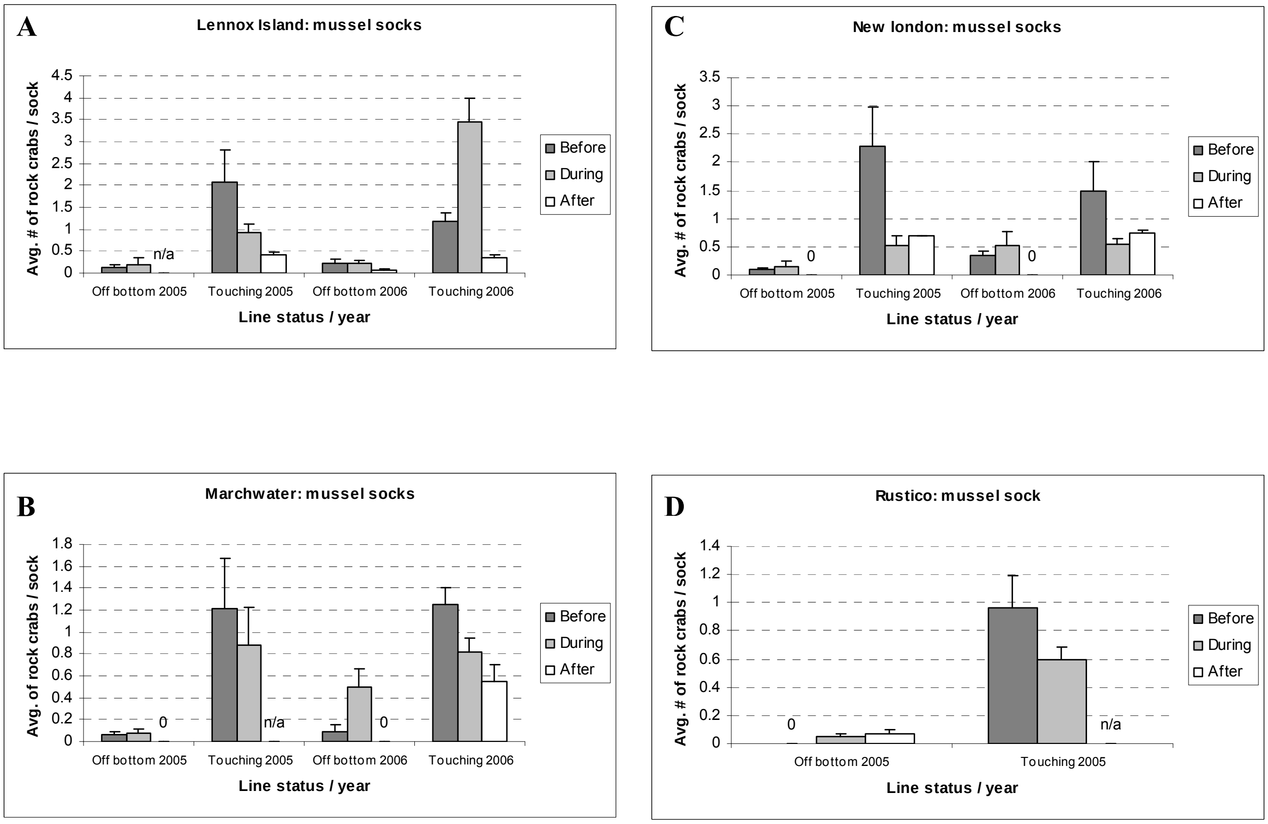


Figure 5. Average rock crab abundance on mussel socks (lines off bottom vs. lines touching the bottom) before, during and after the rock crab fishery in Lennox Island (A), Marchwater (B), New London (C) and in Rustico Bay (D) in 2005 and 2006. Error bars represent the standard errors (± SE).

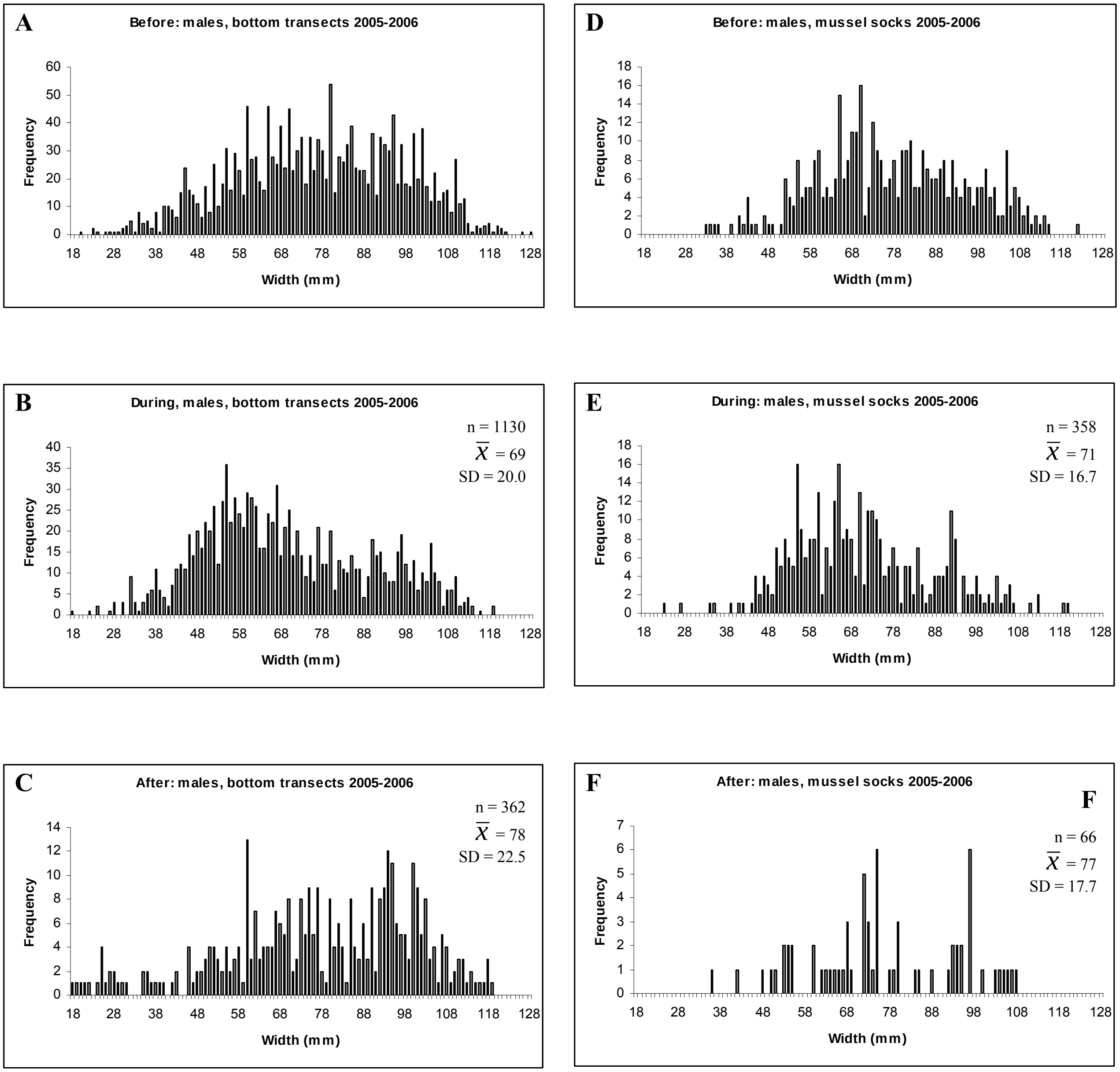


Figure 6. Width-frequency distributions of male rock crabs collected underneath mussel lines (A, B and C) and on mussel socks (D, E, and F) before, during and after the rock fishery in LFA 24, 2005 and 2006.

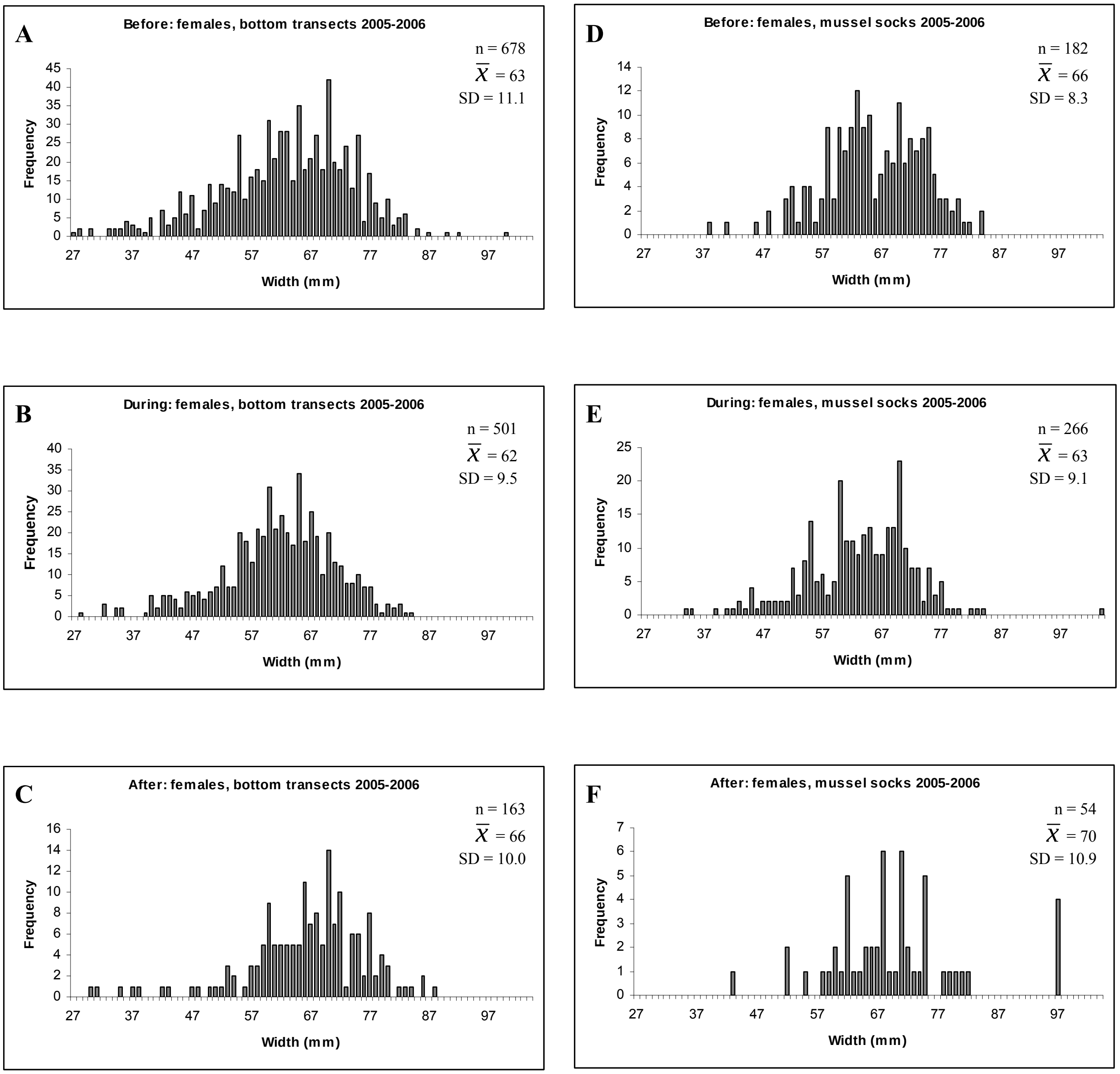


Figure 7. Width-frequency distributions of female rock crabs collected underneath mussel lines (A, B and C) and on mussel socks (D, E, and F) before, during and after the rock fishery in LFA 24, 2005 and 2006.

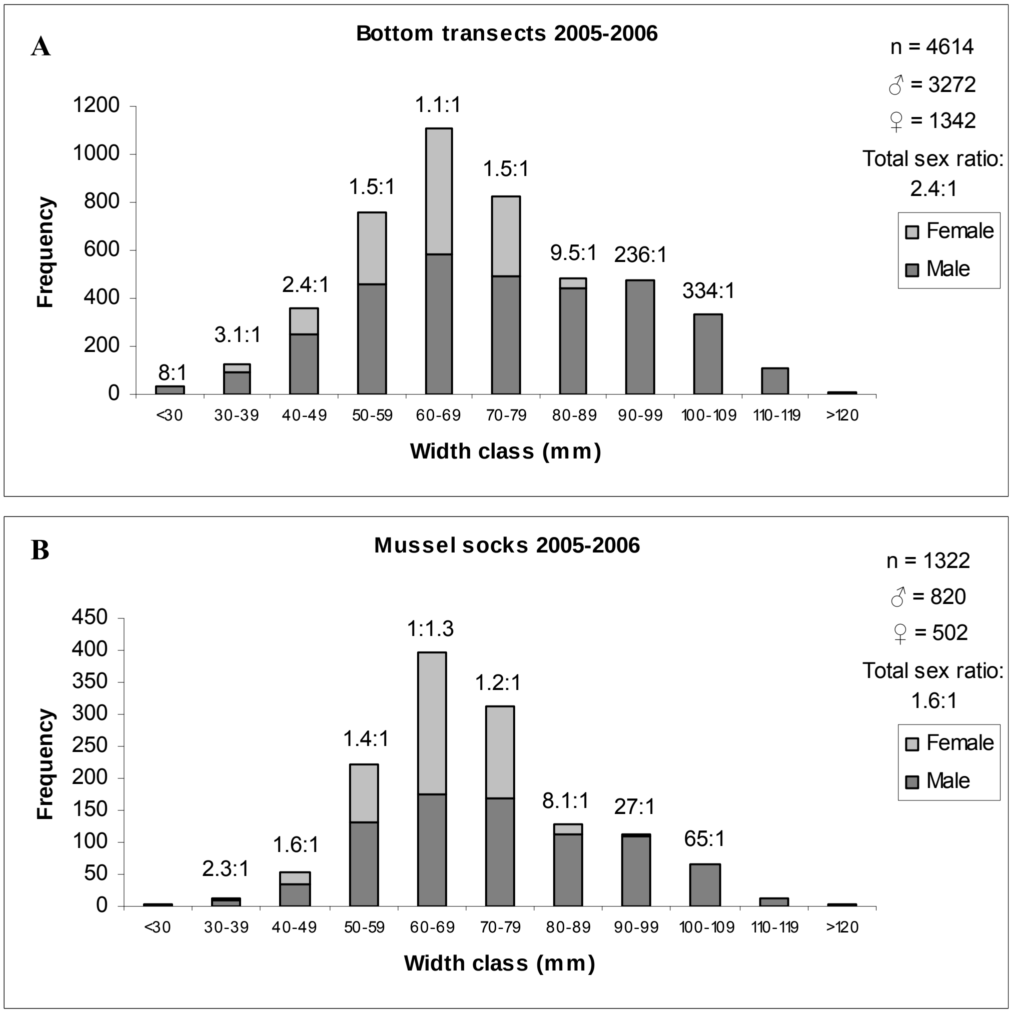


Figure 8. Width class-frequency distributions of rock crabs collected underneath mussel lines (A) and on mussel socks (B) in LFA 24, 2005 and 2006. Male:female sex ratios for each width class are indicated on top of each column.

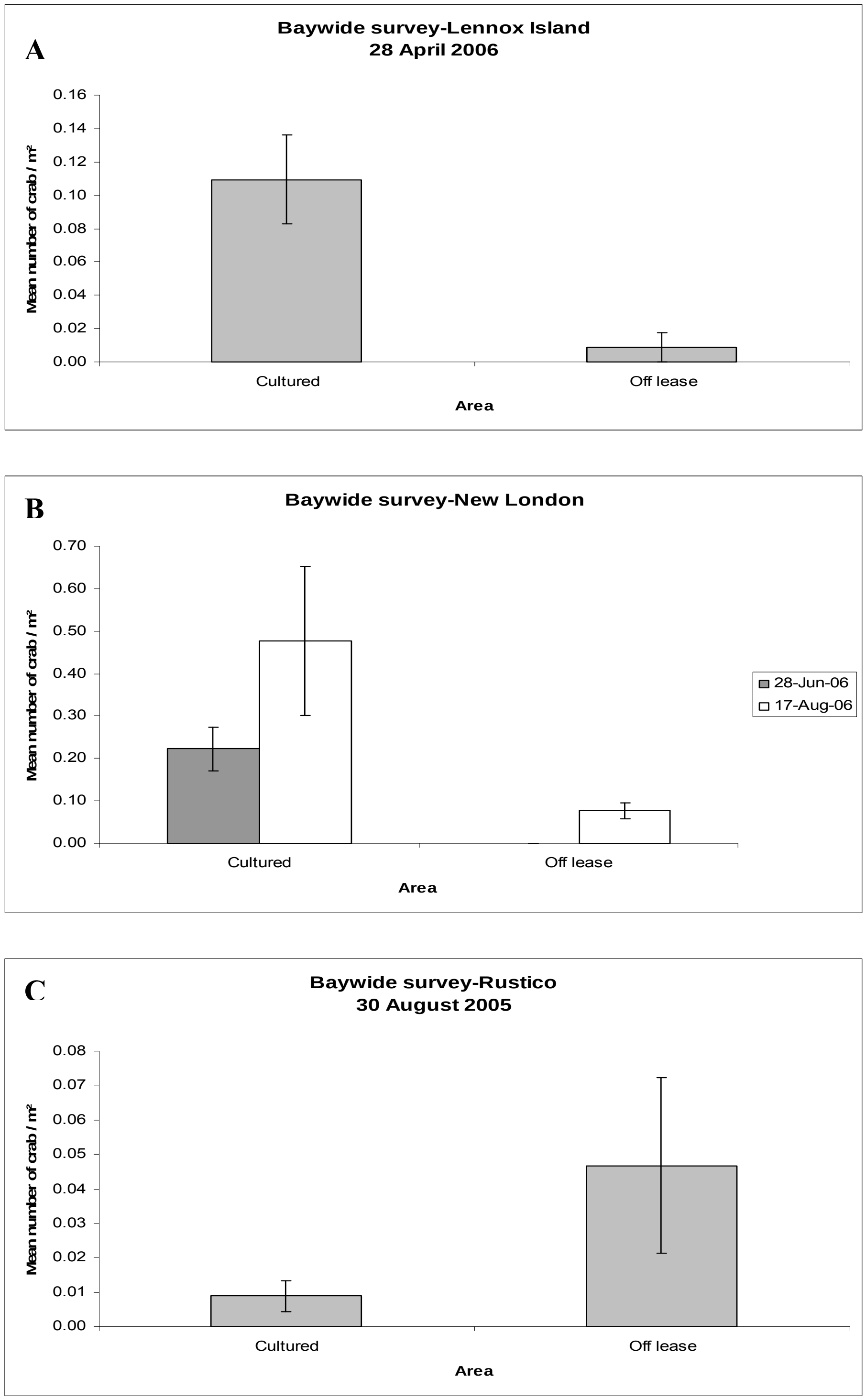


Figure 9. Average rock crab abundance on mussel leases and in off-lease areas in Lennox Island (A), New London Bay (B) and Rustico (C). Error bars represent the standard errors (± SE).

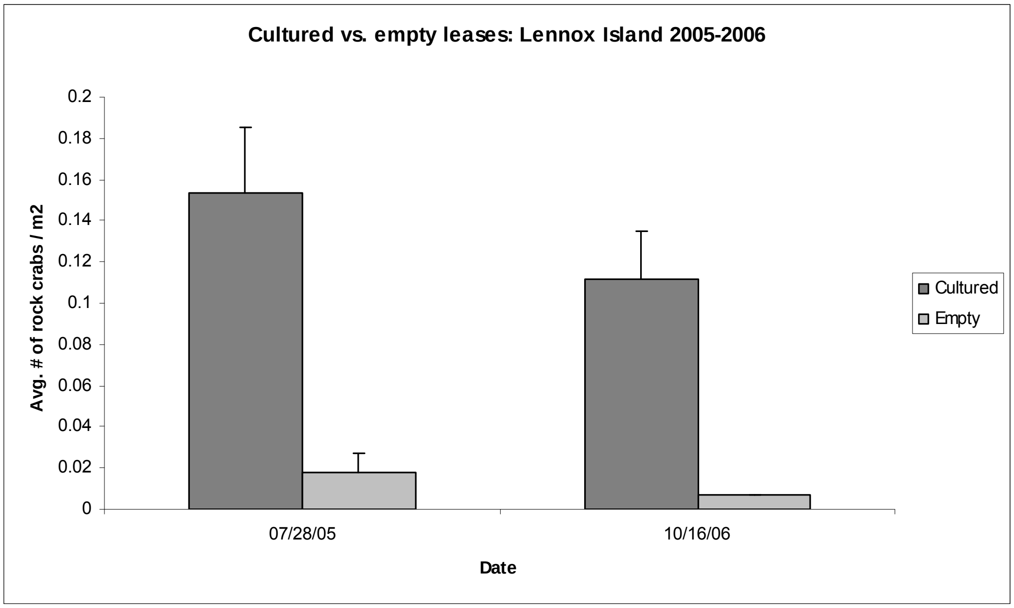
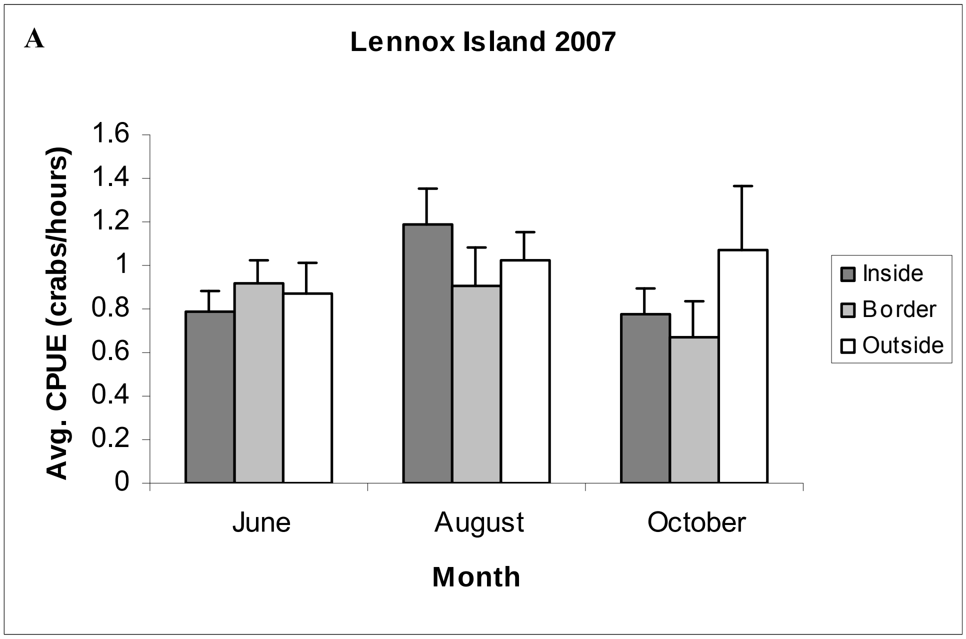


Figure 10. Average rock crab abundance on cultured mussel leases and empty leases in Lennox Island Bay. Data from 2006 are presented on the figure, however they were not included in the statistical analyses because only 1 transect was done on the empty part of the leases. Error bars represent the standard errors (± SE).



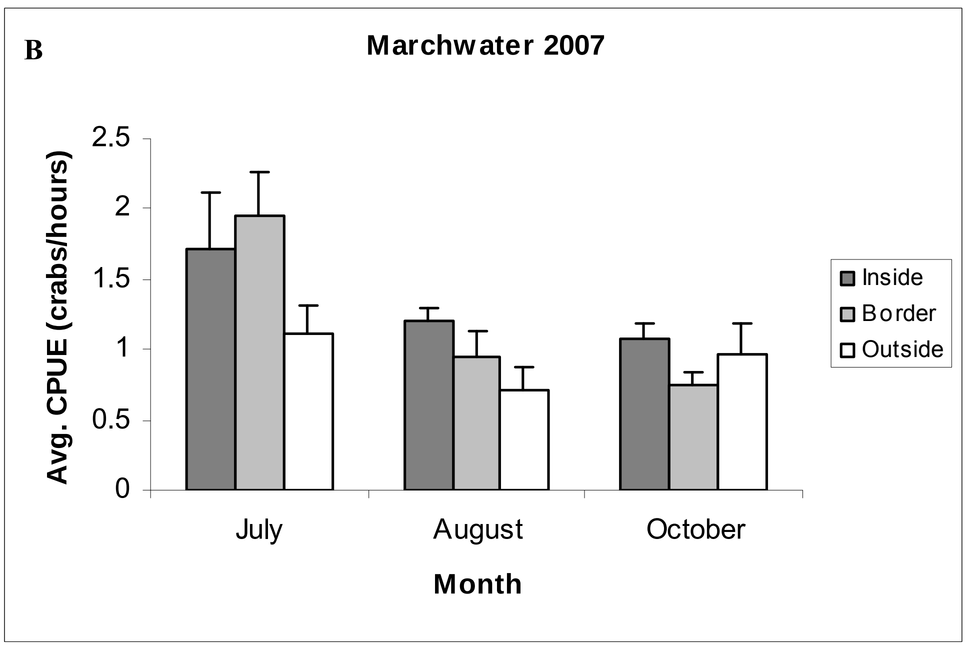


Figure 11. Average catch per units of effort (CPUE) inside, on the border and outside a mussel lease in Lennox Island (A) and in Marchwater (B) in July, August and October. Error bars represent the standard errors (± SE).

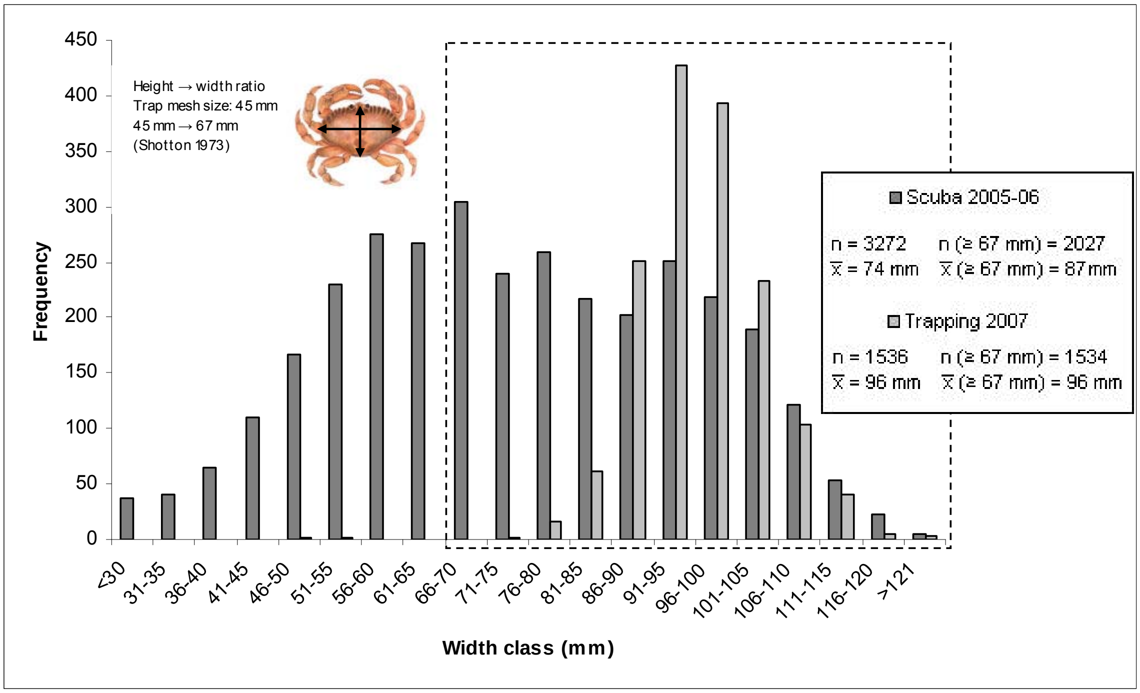


Figure 12. Width class-frequency distributions of male rock crabs collected with the scuba transects method and trapping method. The square represents the size classes that are likely to be retained in the experimental traps (no escape mechanism).

Figure 13. Picture showing vexar tubes over mussel socks.

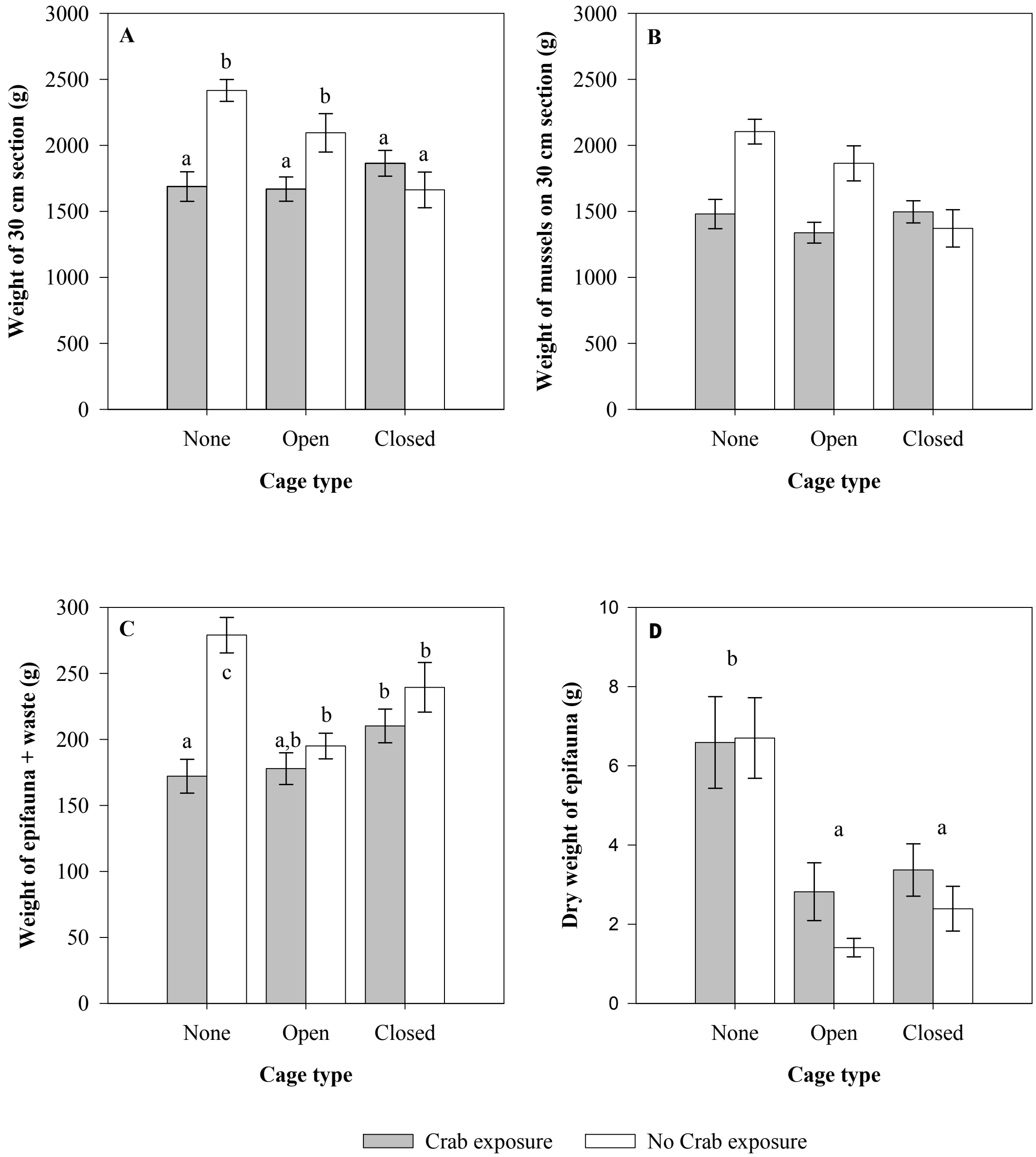


Figure 14. Weights of total, mussel, epifauna+waste and dried epifauna on 30-cm sections of mussel socks with different cage types and two experimental treatments, crab exposure and no crab exposure, in Lennox Island during the growing season of 2006.

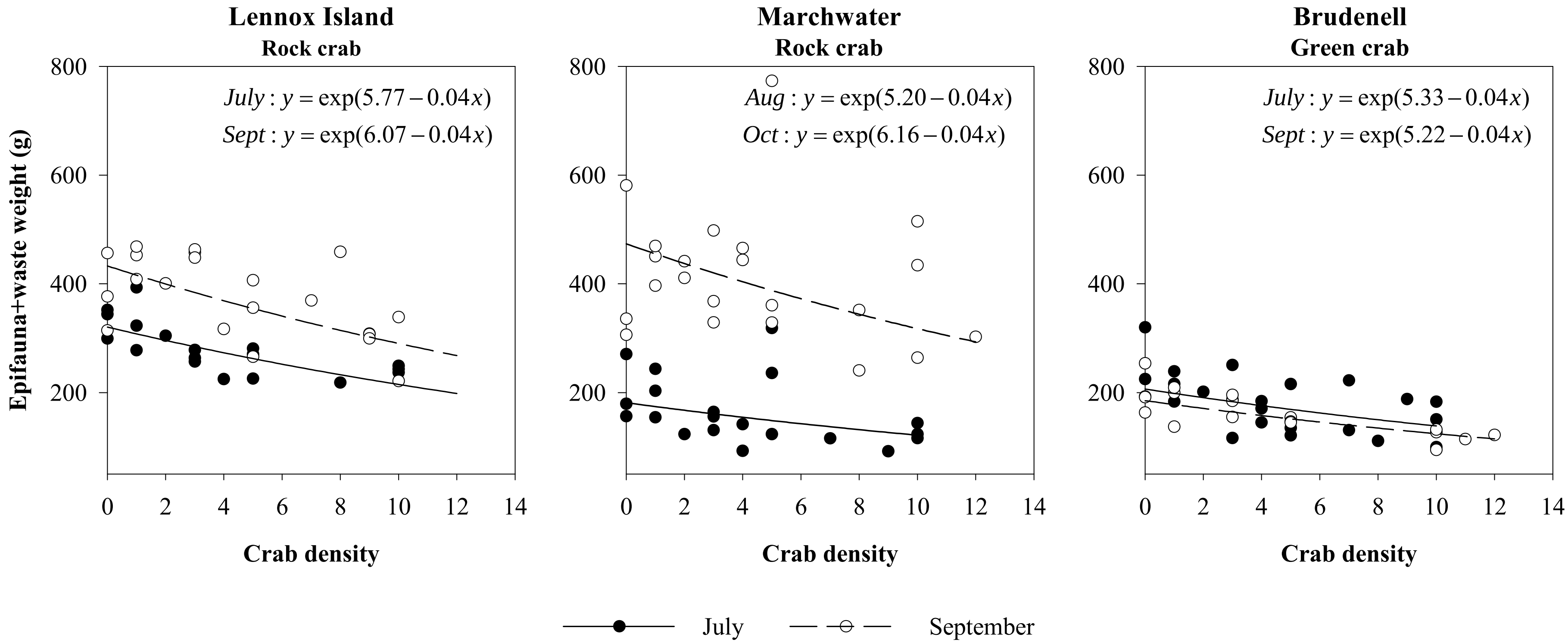


Figure 15. The weight of the epifauna+waste from mussel socks placed in cages with different crab densities in PEI bays in the 2007 growing season. The Marchwater epifauna includes *Styela clava*.

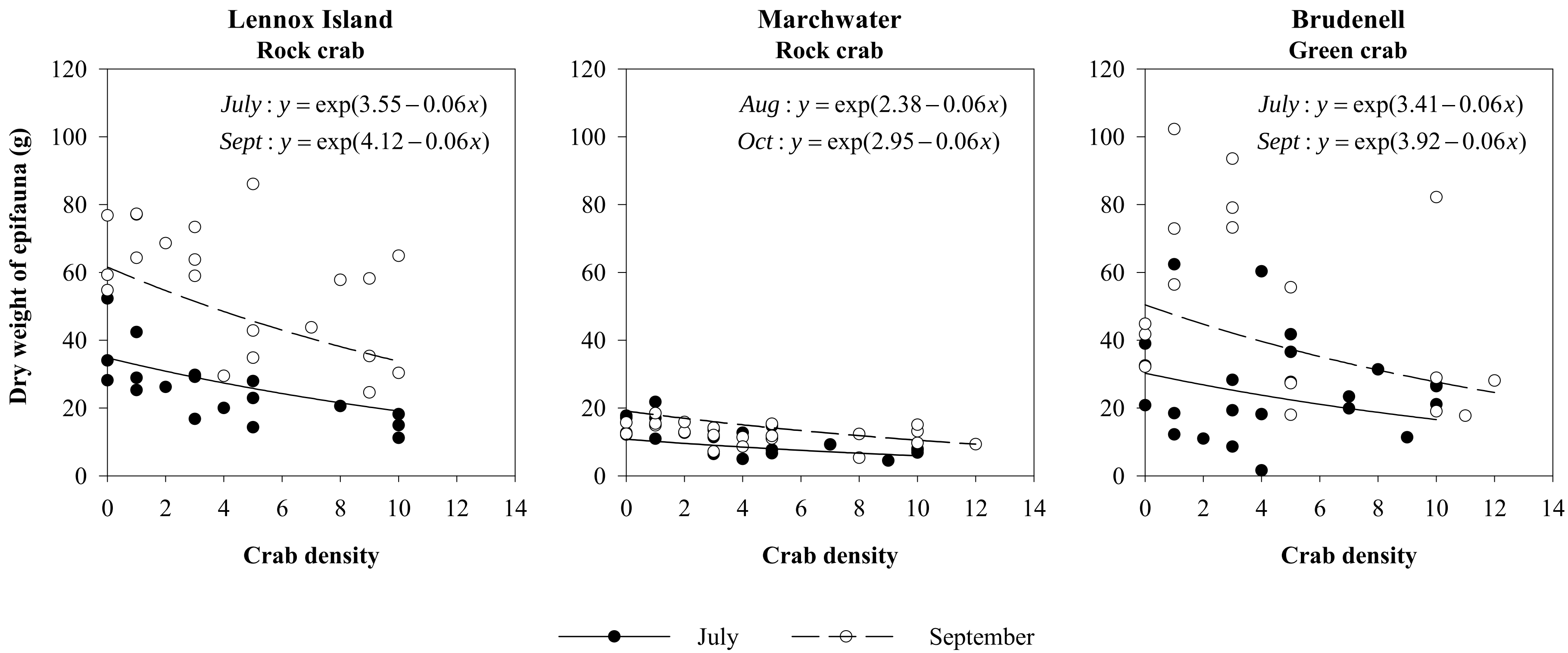


Figure 16. The dry weight of the epifauna from mussel socks placed in cages with different crab densities in PEI bays in the 2007 growing season

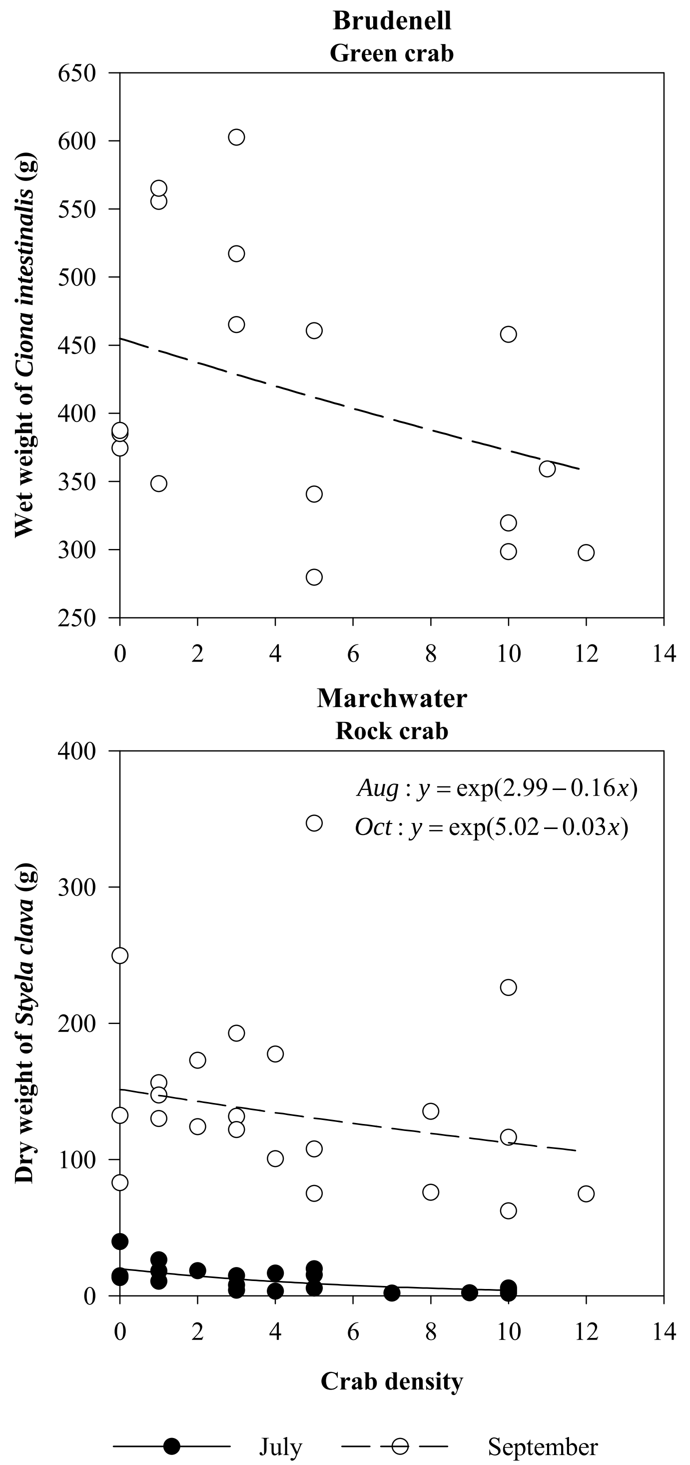


Figure 17. The wet weight of *Ciona intestinalis* in Brudenell River and the dry weight of *Styela clava* in Marchwater from mussel socks placed in cages with different crab densities in PEI bays