



Fouling community of the snow crab *Chionoecetes opilio* in Sydney Bight, Canada: preliminary observations in relation to sampling period and depth/geographical location

Luc SAVOIE¹, Gilles MIRON² and Michel BIRON^{1*}

(1) Centre des pêches du Golfe, Pêches et Océans Canada, C. P. 5030, Moncton, Nouveau-Brunswick, Canada E1C 9B6. * Corresponding author Gilles Miron: Gilles.Miron@umoncton.ca

(2) Département de biologie, Université de Moncton, Moncton, Nouveau-Brunswick, Canada E1A 3E9
Fax : +1 (506) 858-4542

Abstract: We examined the foulers on the exoskeleton of 498 male snow crabs (*Chionoecetes opilio*) sampled off the eastern coast of Cape Breton Island (Sydney Bight). A total of sixteen sessile invertebrate families were identified. The most dominant families belonged to the bryozoans (Alcyonididae and Hippothoidae), the cirripeds (Balanidae) and the polychaetes (Spirorbidae). Crabs hosted different fouling communities in relation to depth/geographical locations and sampling periods. These differences were confirmed by multivariate analyses (e.g., MDS plot, ANOSIM and SIMPER analyses). The fouling communities observed on crabs sampled at depth > 150 m significantly differed from those from < 150 m. These differences were mainly caused by the presence of the bivalve *Anomia* sp. (Anomiidae) and cocoons from the Hirudinae *Johanssonia artica* (Piscicolidae) over 150 m. The fouling communities sampled in September 2001 and October 2002 were significantly different than those sampled during the other periods. The similar fouling communities observed in the Sydney Bight at depths < 150 m may be related to the mobility of the snow crabs in the top 150 m.

Résumé : Communauté d'épibiontes du crabe des neiges *Chionoecetes opilio* au large de Sydney Bight, Canada : observations préliminaires en fonction de la période d'échantillonnage et de la profondeur/région géographique. Nous avons examiné les épibiontes retrouvés sur l'exosquelette de 498 crabes des neiges (*Chionoecetes opilio*) mâles échantillonnés au large des côtes de l'Île-du-Cap Breton (Sydney Bight). Seize familles d'invertébrés sessiles ont été identifiées. Les familles les plus importantes appartenaient aux bryozoaires (Alcyonididae et Hippothoidae), cirripèdes (Balanidae) et polychètes (Spirorbidae). La communauté d'épibiontes observée sur les crabes variait en fonction de la profondeur et de la période d'échantillonnage. Ces variations sont confirmées par des analyses multivariées (e.g. analyses MDS, ANOSIM et SIMPER). La communauté d'épibiontes observée sur les crabes échantillonnés à plus de 150 m était significativement différente de celle des crabes échantillonnés à moins de 150 m. Ces variations étaient principalement causées par la présence du bivalve *Anomia* sp. (Anomiidae) et de cocons de l'Hirudinae *Johanssonia artica* (Piscicolidae) à des profondeurs supérieures à 150 m. Les communautés d'épibiontes observées en septembre 2001 et en octobre 2002 étaient significativement différentes de celles observées lors des autres périodes d'échantillonnage. La similarité des communautés observées dans Sydney Bight aux profondeurs inférieures à 150 m peut être attribuée à la mobilité des crabes dans les premiers 150 m de profondeur.

Keywords: Snow crab • *Chionoecetes opilio* • Fouling community • Distribution • Variability • Atlantic Canada

Reçu le 14 mars 2007 ; accepté après révision le 20 août 2007.

Received 14 March 2007; accepted in revised form 20 August 2007.

Introduction

The snow crab, *Chionoecetes opilio* (O. Fabricius, 1788), is a subarctic species found in the Atlantic Ocean from Northern Labrador to the Gulf of Maine and in the Pacific Ocean (Powles, 1968; Tremblay, 1997). Individuals from the southern Gulf of St. Lawrence (SGSL) bearing a carapace width > 40 mm generally molt once a year and are characterized by a terminal molt (Moriyasu et al., 1987; Conan et al., 1988). The adult males generally prefer muddy habitats over a broad range of depths (20 to 400 m) where low temperatures are observed (–1 to 3°C) (Chassé et al., 2004). The snow crab is considered as a sedentary species (Watson, 1970) but may exhibit seasonal migrations in some areas for molting and mating (Ennis et al., 1990; Sainte-Marie & Hazel, 1992).

The snow crab fishery relies, in part, on the age structure of the stock to define fishery management strategies. Age is estimated from a carapace stage chart that is based on carapace condition. This classification was developed for the SGSL and considers factors such as color, wear,

hardness, and the general abundance of epibionts (Moriyasu et al., 1998).

Epibiosis is a common life-history strategy observed among marine organisms (Wahl, 1989). It involves mutual and commensal relationships between a fouling species and its host with the most critical factor being the availability of a suitable substratum (Moldonado & Uriz, 1992; Parapar et al., 1997) and the presence of various chemical, physical and biological parameters (Wahl, 1989). Decapod crustaceans may provide such a suitable substratum for settlers, and although they may not show a high degree of colonization, most of them support many invertebrates (Parapar et al., 1997; Fernandez et al., 1998). The exoskeleton of snow crabs, once the terminal molt has been completed, offers a microhabitat for epibiotic organisms.

The fouling community may vary in time and geographically. Results from Dick et al. (1998) and Savoie et al. (2007), for instance, showed that the structure of the fouling community differed between regions for two crab species of the genus *Chionoecetes*. The fouling community may thus represent a habitat signature depending on the

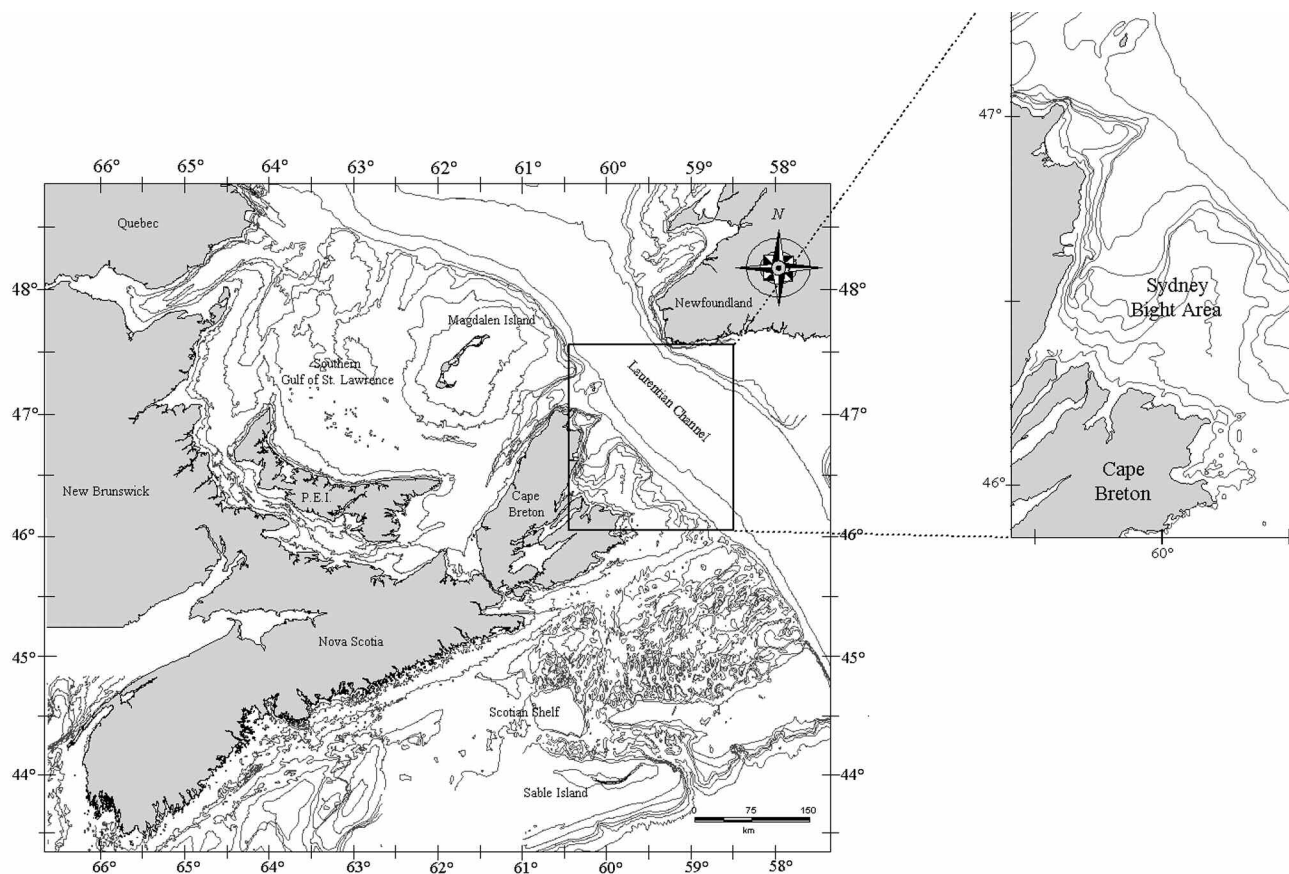


Figure 1. Location of study site.

Figure 1. Localisation du site d'étude.

amount of time a crab spends under a given set of environmental parameters (e.g., depth, temperature) (Key et al., 1997). The colonization of a substratum depends on the abundance of settling larvae, which in turn is a function of the habitat selection behaviour and the season. The evolution of the fouling community also depends on the fouling history and the presence/absence of a dominant species (Osman, 1977).

The aim of this study was to describe the variability of the fouling community observed on the exoskeleton of snow crabs in relation to the sampling periods and depths/geographical locations and provide a comparative data set of foulers to fishery stakeholders.

Material and Methods

Study area

Snow crabs were collected from the Sydney Bight off the eastern coast of Cape Breton Island (Fig. 1). The Sydney

Bight is characterized by a rocky shallow shelf near the coast and an offshore muddy bottom. It is bordered on the east by a 500 m deep trench, the Laurentian Channel. It is an area where cold, muddy substrates occur over a broad range of depths.

Sampling

Crabs were collected with a Bigouden *Nephrops* trawl (Conan et al., 1994) hauled by a 20 m stern-trawler chartered by the Department of Fisheries and Oceans (DFO) for the annual assessment of the snow crab stocks (Biron et al., 2002 & 2003). The fouling community was described using the exoskeleton of 498 adult male snow crabs. Only male crabs were used since the fishery relies on carapace information from males. Crabs were collected in September 2001 (S1) and May (S2), July (S3) and October 2002 (S4). Thirty stations were sampled per sampling period with a maximum of 6 adult crabs (when available) randomly collected per station (Fig. 2). The location of the trawl station within each 10 minute latitude/longitude grid

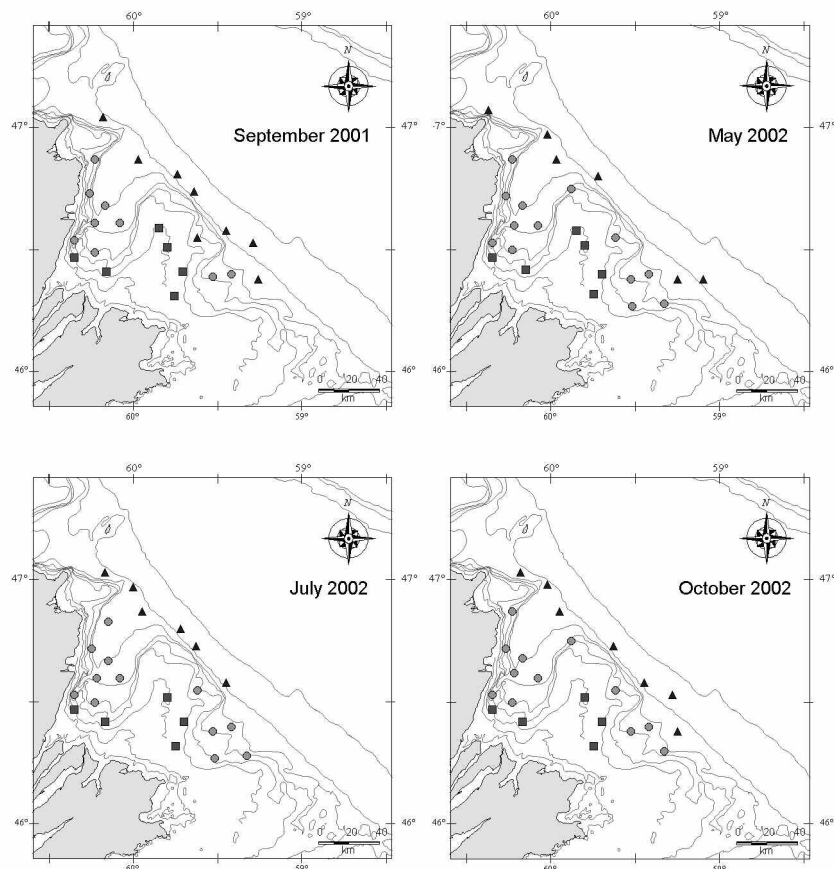


Figure 2. Location of sampling stations for each sampling period (■ < 75 m; ● 75-150 m; ▲ > 150 m).

Figure 2. Répartition des sites d'échantillonnage lors de chaque période d'échantillonnage (■ < 75 m ; ● 75-150 m ; ▲ > 150 m).

was chosen using a systematic random sampling design (Biron et al., 2002 & 2003). The number and location of stations were based on the available depth range and geographical coverage: < 75 m around Smokey Bank (D1), 75 to 150 m in the main fishing area (D2), > 150 m near the slope of the Laurentian Channel (D3) (Fig. 2 and Table 1). At each location, temperature (Minilog® sensor), depth (depth sounders) and position (DGPS system) were taken. Each crab collected was bagged and frozen individually and brought back to the laboratory for analysis.

Laboratory

Carapace width (CW), carapace length (CL) and chela height (CH) were measured in all crabs with a digital vernier caliper (Conan & Comeau, 1986). These parameters were used to insure that crabs reached their terminal molt. Crabs were categorized using the carapace stages from Moriyasu et al. (1998). The dorsal, ventral and limb external surfaces of the carapace were examined for epibiotic coverage on each crab. The type, location and number of foulers were noted. Although foulers were identified to the genus or, whenever possible, to the species, only the family was used in the analyses due to a small number of individuals for certain genera. Counts were made for solitary individuals. Epibiotic families occurring in 10% or less of crabs were considered minor families while the ones occurring in 50% or more were considered major. Abundance determination for colonial animals was made differently depending on the species. For the colonial bryozoans *Alcyonidium* spp., estimated percentage coverage was recorded for each of the crab's external surfaces (dorsal, ventral and side legs). A count of 1 individual was given to *Alcyonidium* spp. in the case of a surface coverage of $\leq 10\%$ (Dick et al., 1998). The estimated percentage coverage was divided by 10 and rounded to the nearest whole number to give the number of individuals in cases where surface coverage exceeded 10%. Each separate colony of bryozoans other than *Alcyonidium* spp. that did not generally form extensive merging colonies was recorded as 1 individual. The identification of certain bryozoan families was confirmed by the Atlantic Reference Centre (ARC), St. Andrews (NB), Canada.

Statistical analysis

Multivariate analyses were used to study the fouling assemblages including multi-dimensional scaling (MDS), analysis of similarities (ANOSIM) and similarity percentages (SIMPER). These analyses were carried out with PRIMER 5©. MDS were based on Bray-Curtis similarities. Data (number of each epibiont per crab) were transformed (fourth root-transformation) to minimize bias from highly abundant families. The ANOSIM significance

test (Clarke, 1993) was used to compare similarities in family compositions between samples. A two-way nested ANOSIM was performed with the transformed data to test differences between the four sampling periods and the three depth/geographical locations. Similarity of percentages analysis (SIMPER) was used to determine which family contributed the most to any dissimilarity among sampling periods and depth/geographical locations (Clarke & Warwick, 1994).

Finally, richness (number of families) was used as a community index. Values were compared among sampling periods and depth/geographical locations using a one-way ANOVA. Data were $\log(1+x)$ -transformed to obtain homogeneity of variances. Multiple pairwise-comparison tests, using least-square means, were performed for post-hoc comparisons after all ANOVAs, using the Tukey test. Homogeneity of variances was tested with the *F*-test and normality of data was evaluated by examining plots of the residuals. If transformation of the data did not lead to homogeneity of variances, no statistical test was conducted. ANOVA and post-hoc comparisons were carried out with SYSTAT 9.0©.

Results

General observations

Sixteen sessile invertebrate families were observed on the exoskeleton of crabs (Table 1). These families were distributed amongst six phyla. Occurrences of each identified family (as well as the genera) are shown in Table 1, where percentages are presented for each sampling period and each depth/geographical location. Overall, no general pattern was observed amongst the minor families. Minor families were more numerous on the exoskeleton of crabs during the summer period (nine in May and eight in July 2002) than during the fall (five in September 2001 and four in October 2002). Four families had major occurrences in each of the sampling periods: Balanidae cirripeds (98.1%), Alcyonididae (92.4%) and Hippothoidae bryozoans (74.1%) and Spirorbidae polychaetes (84.2%). These families were also observed on crabs sampled at each depth/geographical location. Bryozoans from the Aeteidae, Schizoporellidae and Scruporellaridae families appeared more frequently on crabs during the sampling periods in the summer than the ones in the fall. Members of the Celleporidae family appeared more frequently on crabs sampled during the sampling periods in the fall. Occurrences of the Alcyonididae, Hippothoidae, Balanidae and Spirorbidae families decreased from shallow (< 150 m) to deep waters (> 150 m), except for the Alcyonididae family during the May 2002 sampling.

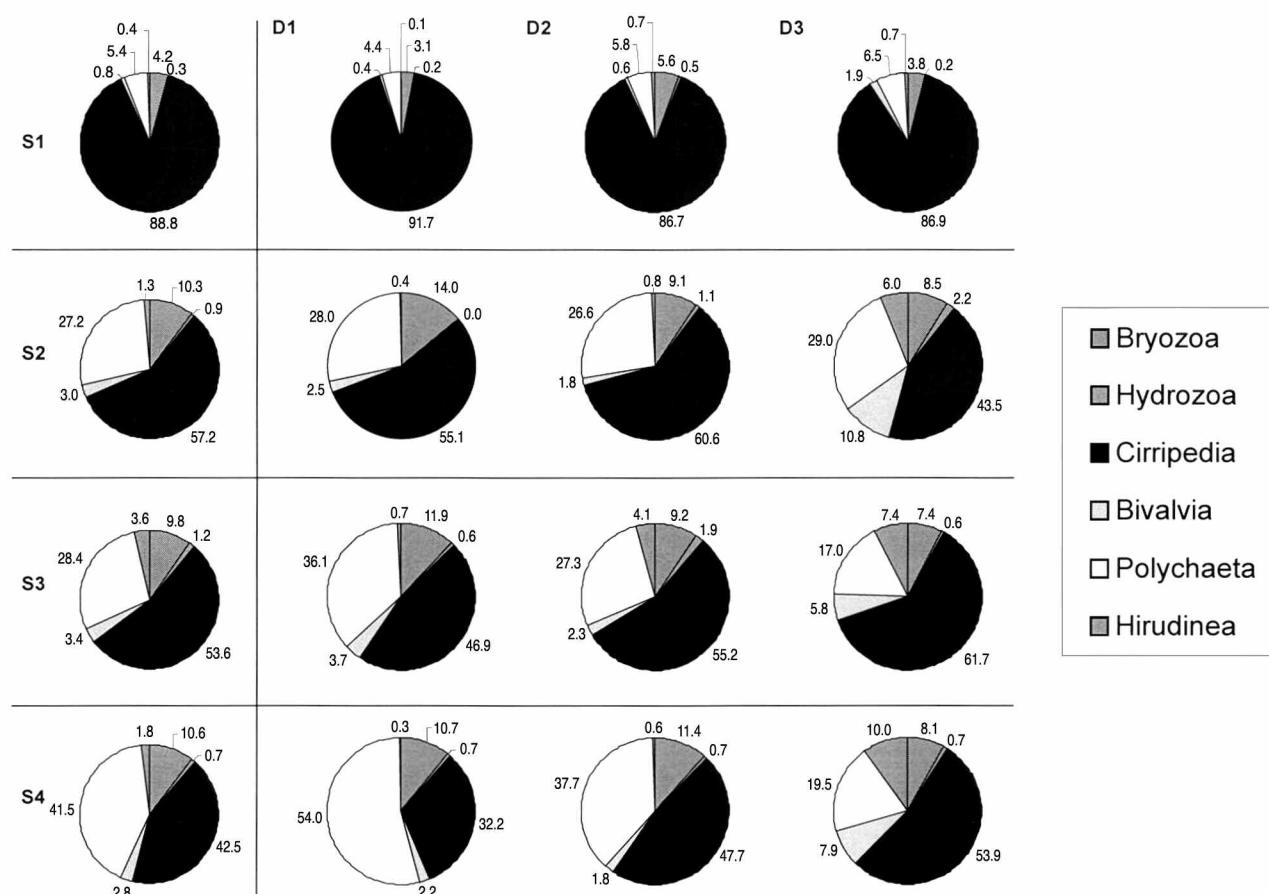


Figure 3. Relative abundance (%) of phyla observed on male snow crabs (*Chionoecetes opilio*) for each depth/geographical location (D1: < 75 m; D2: 75-150 m; D3: >150 m) and sampling period (S1: September 2001; S2: May 2002; S3: July 2002; S4: October 2002). All sampling stations are confounded in pie charts for each sampling period (left column).

Figure 3. Abondance relative (%) des phyla observés sur les crabes des neiges (*Chionoecetes opilio*) mâles à chaque profondeur (D1 : < 75 m ; D2 : 75-150 m ; D3 : > 150 m) et période d'échantillonnage (S1 : septembre 2001 ; S2 : mai 2002 ; S3 : juillet 2002 ; S4 : octobre 2002). Toutes les stations d'échantillonnage sont confondues dans les graphiques pour chaque période d'échantillonnage (colonne de gauche).

The relative abundances for all families (as well as the genera) are presented in Table 2 for each sampling period and depth/geographical location. Differences were mainly limited to three families for the sampling periods: Balanidae, Spirorbidae and Hippothoidae. The Balanidae family was the dominant one. The Spirorbidae family increased steadily from September 2001 to October 2002. Most of the bryozoan families were rare and made no significant difference in the family composition found on the crabs. The Anomidae family (bivalve) increased from shallow to deep waters. The same pattern was observed for cocoons from the Piscicolidae family (Hirudinae). Figure 3 illustrates the variations observed in the relative abundance of the six major phyla.

Temperatures varied with the sampling periods and depth/geographical locations (Table 3). Water temperatures

were usually higher at depth > 150 m compared to those observed at depths < 150 m. Temperatures closest to the water surface (< 75 m) were colder in May 2002 and increased as the year progressed. Temporal variations in water temperatures were less important at depths > 75 m.

Multivariate analyses

Two apparent groups were revealed by the MDS analysis based on the assemblage of the fouling community (Fig. 4). The first group is related to crabs sampled in September 2001 (S1) whereas the second cluster is related to crabs sampled at depths > 150 m (D3). Results from a two-way crossed analysis support that sampling period ($R = 0.115$, $P < 0.001$) and depth/geographical location ($R = 0.08$, $P < 0.001$) significantly affected the fouling community. The pair-wise test showed a similarity in the fouling

Table 2. Relative abundance (%) of foulers on the exoskeleton of *Chionoecetes opilio* for each sampling period and depth/geographical location in Sydney Bight area.

[illegible]

Table 3. Water temperature (mean \pm 95% confidence interval) observed for each depth during the sampling periods.

Tableau 3. Température de l'eau (moyenne \pm int. de conf. à 95%) observée à chaque profondeur pendant les périodes d'échantillonnage.

Sampling period	Depth (m)	Temperature (°C)
September 2001	< 75	2.17 \pm 0.12
	75-150	1.81 \pm 0.13
	> 150	5.18 \pm 0.29
May 2002	< 75	0.15 \pm 0.06
	75-150	1.56 \pm 0.22
	> 150	4.35 \pm 0.78
July 2002	< 75	1.19 \pm 0.15
	75-150	1.84 \pm 0.12
	> 150	5.26 \pm 0.33
October 2002	< 75	2.72 \pm 1.34
	75-150	2.08 \pm 0.12
	> 150	4.45 \pm 0.43

Table 4. Results from pair-wise ANOSIM tests carried out on the similarity of the fouling community between male snow crabs (*Chionoecetes opilio*) sampled for each sampling period and depth.

Tableau 4. Résultats de l'analyse ANOSIM effectuée sur la similarité des communautés d'épibiontes observées sur les crabes échantillonnés à chaque profondeur lors des périodes d'échantillonnage.

Groups (Pairwise Test)	R Statistic	P
Depths/geographical locations		
D1, D2	-0.020	0.775
D1, D3	0.121	< 0.001
D2, D3	0.183	< 0.001
Global Test	0.080	< 0.001
Sampling periods		
S1, S2	0.155	< 0.001
S1, S3	0.181	< 0.001
S1, S4	0.240	< 0.001
S2, S3	-0.002	0.567
S2, S4	0.020	0.047
S3, S4	0.058	< 0.005
Global Test	0.115	< 0.001

communities between crabs sampled in May (S2) and July 2002 (S3) and between crabs sampled in May and October 2002 (S4) (Table 2). The similarity observed on crabs sampled between depths < 75 m (D1) and depths of 75-150 m (D2) was significant, but crabs sampled at depths > 150 m (D3) had fouling assemblages different from crabs

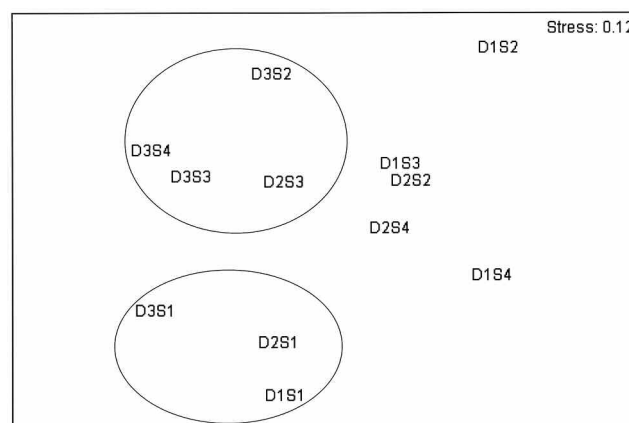


Figure 4. Two dimensional MDS ordination of sampling period-depth/geographical location strata by the Bray-Curtis dissimilarity of the 4th root transformed abundances of all members of each family. D1: < 75 m; D2: 75-150 m; D3: >150 m; S1: September 2001; S2: May 2002; S3: July 2002; S4: October 2002.

Figure 4. Représentation 2D de l'ordination MDS effectuée sur l'abondance des membres de chaque famille en fonction de la profondeur et de la période d'échantillonnage. D1 : < 75 m ; D2 : 75-150 m ; D3 : > 150 m ; S1 : septembre 2001 ; S2 : mai 2002 ; S3 : juillet 2002 ; S4 : octobre 2002.

sampled at the other two depths (Table 4). The absence of a noticeable effect from the sampling periods (other than S1) and depth/geographical locations (other than D3) is clearly evident in Figure 4.

The SIMPER analysis revealed that the Balanidae, Spirorbidae and Hippothoidae families were the main families responsible for the similarity in the fouling community structure for each depth/geographical location and that the Anomidae and Piscicolidae could be responsible for the dissimilarity between deep (D3) and shallow (D1 and D2) waters (Table 5A). For the sampling periods, the families Balanidae, and Spirorbidae were the main families responsible for the similarity in the fouling community structure, but the number of individuals observed from the family Balanidae in September 2001 (S1) is largely responsible for the dissimilarity between the sampling periods (Table 5B).

The ANOVAs carried out on the total abundance of the four major phyla showed that sampling period and depth/geographical location had significant effects on cirripeds and bivalves (Table 6). The abundance of cirripeds was greater on crabs sampled in September 2001 (Fig. 5, Table 7). Cirriped abundances also varied between depths. Bivalves were more abundant on crabs sampled in May 2002. This relationship was due to a large number of individuals found on crabs sampled at depths > 150 m. The Tukey multiple comparison tests did not find any

Table 5. Contribution of families to similarity (%) for the fouling community observed on male snow crabs for each depth (A) and sampling period (B). Contribution to dissimilarity (%) between depths and sampling periods are also shown.

Tableau 5. Contribution de chacune des familles (%) à la similarité des communautés d'épibiontes observées sur les crabes pour chaque profondeur (A) et période d'échantillonnage (B). Les contributions à la dissimilarité (%) entre chaque profondeur et période d'échantillonnage sont également montrées.

A. Depth						
Family	Contribution to similarity (%)			Contribution to dissimilarity (%)		
	< 75 m (D1)	75-150 m (D2)	> 150 m (D3)	D1-D2	D1-D3	D2-D3
Balanidae	69.21	76.32	73.80	58.06	59.76	57.87
Spirorbidae	20.07	13.58	15.33	24.98	20.93	19.81
Hippothoidae	5.90	5.21	2.98	5.82	5.47	5.77
Alcyonididae	3.78	4.28	3.54	3.52	3.09	3.97
Anomidae	0.68	0.33	2.93	2.60	4.38	5.21
Piscicolidae	0.07	0.12	0.07	1.26	2.91	4.09

B. Sampling period										
Family	Contribution to similarity (%)				Contribution to dissimilarity (%)					
	Sept. 2001 (S1)	May 2002 (S2)	July 2002 (S3)	Oct. 2002 (S4)	S1-S2	S1-S3	S1-S4	S2-S3	S2-S4	S3-S4
Balanidae	89.96	73.77	66.38	57.79	71.72	71.64	65.86	44.80	39.82	38.82
Spirorbidae	4.61	17.11	20.67	28.63	14.12	13.55	20.36	28.35	35.55	35.15
Hippothoidae	2.58	5.20	6.24	5.85	4.83	4.32	4.24	8.14	7.70	7.12
Alcyonididae	2.52	3.18	4.55	5.70	3.23	3.18	3.07	4.66	4.77	4.82
Anomidae	0.18	0.52	1.15	1.29	2.42	2.60	2.29	5.34	4.69	5.00
Piscicolidae	0.03	0.11	0.77	0.23	1.35	2.23	1.26	4.33	2.55	3.85

significant differences in regard to the sampling period. The abundance of both polychaetes and bryozoans was a function of the interaction between sampling period and depth/geographical location (Table 6). Polychaetes were more abundant on crabs sampled in October 2002 (Fig. 5, Table 7). This was particularly true for crabs sampled at depths < 75 m. Polychaetes, cirripeds and bryozoans were usually more abundant on crabs sampled in shallow waters. No pattern was observed for bivalves, but they were generally more abundant at depths > 150 m. No statistical analysis was carried out for the Hirudinea and Hydrozoa taxa because of homogeneity problems.

Discussion

Environmental conditions such as salinity, temperature and current regimes usually help define the habitat in which certain species may live or settle in a marine environment (e.g., Crisp, 1974; Key et al., 1997). The similarity between the fouling communities observed on snow crabs sampled in the top 150 m of water may suggest that the Sydney Bight area has homogeneous environmental conditions in this water layer. The area is however known to be a physically complex and dynamic area (McLellan, 1954). Waters from the Gulf of St. Lawrence and the Labrador Current

converge along the slope of the Laurentian Channel to create temperature and salinity gradients. Our results tend to support that the water masses in Sydney Bight vary with depth/geographical location. Water temperatures, for instance, varied from $1.6 \pm 1.9^\circ\text{C}$ in depths < 75 m to $4.9 \pm 1.2^\circ\text{C}$ at depths > 150 m. This variation may be important enough to induce differences in the fouling community near the Laurentian Channel. The higher temperature of the water near the channel could increase the settlement and growth of different species of larvae, increasing the number of species at depth > 150 m (Table 1).

Although the snow crab from the eastern coast of Canada is traditionally described as sedentary (Watson, 1970), recent tagging studies have shown that adult males may wander over great distances. Biron (unpublished data) observed that crabs off the coast of Nova Scotia may travel over 23 km within 3 months. In his study, only 11% of crabs were recaptured within 10 km of the release site on the Scotian Shelf, whereas over 50% of crabs were recaptured within the same distance in the southern Gulf of St. Lawrence. The retention rate for the Sydney Bight area was even lower than the one observed on the Scotian Shelf (Biron, unpublished data). The facts that the majority of crabs from Sydney Bight are actively moving between areas tend to support that they may have shared a common

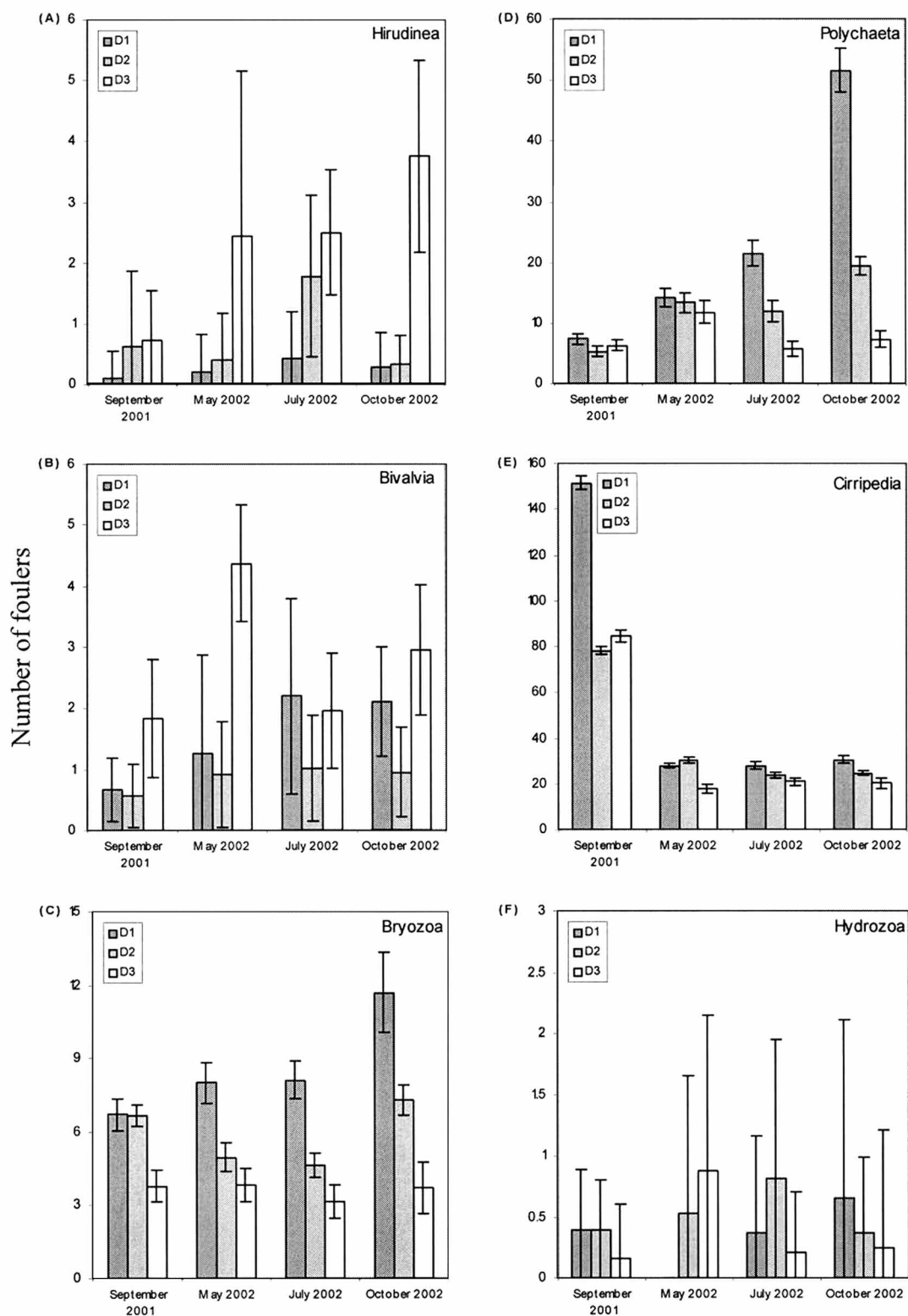


Figure 5. Number of foulders (mean \pm 95% confidence interval) observed on male snow crabs in relation to depth/ geographical location and sampling period.

Figure 5. Nombre d'épibiontes (moyenne \pm intervalle de conf. à 95%) observé sur les crabes des neiges mâles en fonction de la profondeur et de la période d'échantillonnage.

Table 6. Summary of two-way ANOVAs examining the effect of depth and sampling period on the abundance of four major phyla found on male snow crabs.**Tableau 6.** Résumé de l'ANOVA à deux facteurs examinant l'effet de la profondeur et de la période d'échantillonnage sur l'abondance des quatre principaux phyla retrouvés sur les crabes des neiges mâles.

Source of variation	SS	df	MS	F	P
Cirripedia					
Sampling period	34.35	3	11.45	54.58	< 0.001
Depth/Geographical location	4.90	2	2.54	11.69	< 0.001
Sampling period X Depth/ Geographical location	1.63	6	0.27	1.30	0.256
Error	101.94	486	0.21		
Total		497			
Polychaeta					
Sampling period	5.82	3	1.94	7.39	< 0.001
Depth/Geographical location	9.62	2	4.81	18.34	< 0.001
Sampling period X Depth/Geographical location	4.13	6	0.69	2.62	0.016
Error	127.47	486	0.26		
Total		497			
Bivalvia					
Sampling period	0.88	3	0.29	2.89	0.035
Depth/Geographical location	2.69	2	1.34	13.19	< 0.001
Sampling period X Depth/Geographical location	0.59	6	0.10	0.97	0.447
Error	49.50	486	0.10		
Total		497			
Bryozoa					
Sampling period	0.28	3	0.09	0.82	0.481
Depth/Geographical location	5.77	2	2.88	25.63	< 0.001
Sampling period X Depth/Geographical location	1.64	6	0.27	2.43	0.025
Error	54.68	486	0.11		
Total		497			

environment at one point. Crab movements within the top 150 m of water in the Sydney Bight may homogenize the fouling communities found on crabs sampled at these depths. Other studies have also suggested that crabs may wander from one region to another (Brêthes et al., 1987) increasing the similarities between the fouling communities.

The sampling period played a major role in the abundance of each member of the fouling community. A large number of small barnacles were observed on crabs sampled in September 2001. Polychaetes were abundant on crabs sampled in October 2002 while mollusks peaked on crabs sampled during the summer sampling period of 2002. The colonization of a substratum is known to be dependent upon the abundance of settling larvae, which in turn is a function of the time of the year as well as the behaviour of the larvae (Osman, 1977). In the present study, the sampling period and the habitat selection behaviour of some larvae could have played a role in the abundance variations of cirripeds, mollusks and polychaetes on snow crabs. Our results also tend to show that spatial competition

on host may be important between the cirripeds and the polychaetes.

The development of an abundant and diversified fouling community on the exoskeleton should be important for ageing this species because brachyuran crabs do not exhibit many specialized body grooming structures (Bauers, 1981). However, the behaviour of the crab may contribute to the type of foulers observed on its carapace. Burying, for instance, may reduce the incidence of certain foulers (Barnes & Bagenal, 1951; Abello et al., 1990; Becker, 1996). Becker (1996) showed that crabs inhabiting muddy bottoms were significantly less densely colonized than hard-bottom species. This supports the idea that crabs found in different habitats should host different epibiont communities. The low number of hydrozoans found on snow crabs may reflect the burying behaviour of the snow crab (Miller, 1975).

It is difficult to confirm if annual or seasonal changes in the physical environment can cause any important variations in species composition on snow crabs since the host crabs are mobile substrata whose movement is dictated

Table 7. Tukey multiple comparison tests carried out on the abundance of four major phyla found on male snow crabs for each depth (A) and sampling period (B). D1: < 75 m; D2: 75-150 m; D3: >150 m; S1: September 2001; S2: May 2002; S3: July 2002; S4: October 2002.

Tableau 7. Tests de comparaisons multiples (test de Tukey) effectuées sur l'abondance des quatre principaux phyla retrouvés sur les crabes des neiges mâles pour chaque profondeur (A) et période d'échantillonnage (B). D1 : < 75 m; D2 : 75-150 m ; D3 : > 150 m ; S1: septembre 2001 ; S2: mai 2002 ; S3: juillet 2002 ; S4: octobre 2002.

A. Depth				
	Cirripedia	Polychaeta	Bivalvia	Bryozoa
D1 vs D2	0.009	< 0.001	0.022	0.002
D1 vs D3	< 0.001	< 0.001	0.150	< 0.001
D2 vs D3	0.045	0.322	< 0.001	< 0.001

B. Sampling period				
	Cirripedia	Polychaeta	Bivalvia	Bryozoa
S1 vs S2	< 0.001	0.076	0.943	0.510
S1 vs S3	< 0.001	0.040	0.417	0.328
S1 vs S4	< 0.001	< 0.001	0.069	0.972
S2 vs S3	0.187	0.996	0.803	0.992
S2 vs S4	0.447	0.057	0.288	0.340
S3 vs S4	0.965	0.096	0.811	0.207

by the search of a particular range of temperatures (Brêthes et al., 1987; Biron et al., 2000; Dionne et al., 2003) and homogeneous muddy substrata (Powles, 1968). Snow crabs are believed to synchronize their inshore migrations with temperature in order to maintain a stable thermal environment to sustain their locomotory activities (Lovrich et al., 1995). The mobility of the snow crab also confuses the relationship between fouling community and depth. Our study showed differences in the fouling communities between crabs sampled in shallow waters (< 150 m) versus those sampled in deep waters (> 150 m) of the Sydney Bight. Our results, however, failed to discriminate differences in the fouling communities of crabs sampled at depths < 75 m versus those sampled at depths between 75 and 150 m. We recommend using fixed substrata (alive and/or artificial) to eliminate the effect of crab movement to confirm the effect of depth/geographical location and sampling period on the fouling community of the snow crab.

Acknowledgements

We would like to thank the snow crab section (Gulf Fisheries Centre, Moncton, NB, Canada) of the Department of Fisheries and Oceans for their financial support. We also

would like to thank H. Benoît and M. Mallet for their help regarding the statistical analyses. G. Pohle (Atlantic Reference Centre, St. Andrews, NB, Canada) confirmed the identification of some Bryozoan species. We finally wish to thank M. Moriyasu and C. McKindsey for reviewing earlier drafts of the manuscript. Comments from two anonymous reviewers also improved the manuscript.

References

- Abelló P., Villanueva R. & Pili J.M. 1990. Epibiosis in deep-sea crab populations as indicator of biological and behavioral characteristics of the host. *Journal of the Marine Biological Association of the United Kingdom*, **12**: 687-695.
- Barnes H. & Bagenal T.B. 1951. Observations on *Nephrops norvegicus* (L.) and on an epizoic population of *Balanus crenatus* Brug. *Journal of the Marine Biological Association of the United Kingdom*, **30**: 369-380.
- Bauers R.T. 1981. Grooming behavior and morphology in the decapod crustacean. *Journal of Crustacean Biology*, **1**: 153-173.
- Becker K. 1996. Epibiont on carapaces of some malacostracans from the Gulf of Thailand. *Journal of Crustacean Biology*, **16**: 92-104.
- Biron M., Wade E., Moriyasu M., DeGrâce P., Campbell R. & Hébert M. 2000. Assessment of the 1999 snow crab (*Chionoecetes opilio*) fishery off eastern Nova Scotia (Areas 20 to 24). Department of Fisheries and Oceans. *Canadian Stock Assessment Secretariat Research Document*, **2000/017**.
- Biron M., Savoie L., Campbell R., Wade E., Moriyasu M. & DeGrâce P. 2002. Assessment of the 2001 snow crab (*Chionoecetes opilio*) fishery off eastern Nova Scotia (Areas 20 to 24). Department of Fisheries and Oceans. *Canadian Stock Assessment Secretariat Research Document*, **2002/011**.
- Biron M., Savoie L., Sabeau C., Wade E. & Moriyasu M. 2003. Assessment of the 2002 snow crab (*Chionoecetes opilio*) fishery off eastern Nova Scotia (Areas 20 to 24). Department of Fisheries and Oceans. *Canadian Stock Assessment Secretariat Research Document*, **2003/012**.
- Brêthes J.-C., Coulombe F., Lafleur P.-E. & Bouchard R. 1987. Habitat and spatial distribution of early benthic stages of the snow crab *Chionoecetes opilio* O. Fabricius off the north shore of the Gulf of St. Lawrence. *Journal of Crustacean Biology*, **7**: 667-681.
- Chassé J., Drinkwater K.F., Pettipas R.G. & Petrie W.M. 2004. Temperature conditions on the Scotian Shelf and in the Southern Gulf of St. Lawrence in 2003 relevant to snow crab. Department of Fisheries and Oceans. *Canadian Stock Assessment Secretariat Research Document*, **2004/002**.
- Clarke K.R. 1993. Non-parametric multivariate analyses of changes in community structure. *Australian Journal of Ecology*, **18**: 117-143.
- Clarke K.R. & Warwick R.M. 1994. *Changes in marine communities: an approach to statistical analysis and interpretation*. Natural Environment Research Council: Swindon.
- Conan G.Y., Moriyasu M., Comeau M., Mallet P., Cormier R., Chiasson Y. & Chiasson H. 1988. Growth and maturation of

- snow crab (*Chionoecetes opilio*). In: *Proceedings of the international workshop on snow crab biology* (G.S. Jamieson & W.D. McKone eds), pp. 45-66. Canadian Manuscript Report of Fisheries and Aquatic Sciences 2005.
- Conan G.Y. & Comeau M. 1986.** Functional maturity and terminal molt of a male snow crab, *Chionoecetes opilio*. *Canadian Journal of Fisheries and Aquatic Sciences*, **43**:1710-1719.
- Conan G.Y., Comeau M., Gosset C., Robichaud G. & Garaicoechea C. 1994.** The Bigouden nephrops trawl, and the Devismes trawl, two otter trawls efficiently catching benthic stages of snow crab (*Chionoecetes opilio*), and American lobster (*Homarus americanus*). *Canadian Technical Report of Fisheries and Aquatic Sciences*, **1992**.
- Crisp D.J. 1974.** Actors influencing the settlement of marine invertebrate larvae. In: *Chemoreception in marine organism* (P.T. Grant & A.M. Mackie eds), pp. 177-265. Academic Press: London.
- Dick M.H., Donaldson W.E. & Vining I.W. 1998.** Epibionts of the Tanner Crab *Chionoecetes bairdi* in the region of Kodiak Island, Alaska. *Journal of Crustacean Biology*, **18**: 519-528.
- Dionne M., Sainte-Marie B., Bourget E. & Gilbert D. 2003.** Distribution and habitat selection of early benthic stages of snow crab *Chionoecetes opilio*. *Marine Ecology Progress Series*, **259**: 117-128.
- Ennis G.P., Hooper G. & Taylor D.M. 1990.** Changes in the composition of snow crab (*Chionoecetes opilio*) participating in the annual breeding migration in Bonne Bay, Newfoundland. *Canadian Journal of Fisheries and Aquatic Sciences*, **47**: 2242-2249.
- Fernández L., Parapar J., González-Gurriarán E. & Muñio R. 1998.** Epibiosis and ornamental cover patterns of the spider crab *Maja squinado* on the Galician coast, Northwestern Spain: Influence of behavioral and ecological characteristics of the host. *Journal of Crustacean Biology*, **18**: 728-737.
- Key M.M., Volpe J.W., Jeffries W.B. & Voris H.K. 1997.** Barnacle fouling of the blue crab *Callinectes sapidus* at Beaufort, North Carolina. *Journal of Crustacean Biology*, **17**: 424-439.
- Lovrich G.A., Sainte-Marie B. & Smith B.D. 1995.** Depth distribution and seasonal movements of *Chionoecetes opilio* (Brachyura: Majidae) in Baie Sainte-Marguerite, Gulf of Saint Lawrence. *Canadian Journal of Zoology*, **73**: 1712-1726.
- McLellan H.J. 1954.** Temperature-salinity relations and mixing on the Scotian Shelf. *Journal of the Fishery Research Board of Canada*, **11**: 419-430.
- Miller R.J. 1975.** Density of the commercial spider crab, *Chionoecetes opilio*, and calibration of effective area fished per trap using bottom photography. *Journal of the Fishery Research Board of Canada*, **32**: 761-768.
- Moldonado M. & Uriz M.J. 1992.** Relationship between sponges and crabs: patterns of epibiosis on *Inachus aguiarii* (Decapoda: Majidae). *Marine Biology*, **113**: 281-286.
- Moriyasu M., Conan G.Y., Mallet P., Chiasson Y. & Lacroix H. 1987.** Growth at molt, molting season and mating of snow crab (*Chionoecetes opilio*) in relation to functional and morphometric maturity. *International Council for the Exploration of the Sea*, **1987/K**.
- Moriyasu M., Wade E., Sinclair A. & Chiasson Y. 1998.** Snow crab, *Chionoecetes opilio*, stock assessment in the south-western Gulf of St. Lawrence by bottom trawl survey. *Canadian Special Publication of Fisheries and Aquatic Sciences*, **125**.
- Osman R.W. 1977.** The establishment and development of a marine epifaunal community. *Ecological Monographs*, **47**: 37-63.
- Parapar J., Fernández L., González-Gurriarán E. & Muñio R. 1997.** Epibiosis and masking material in the spider crab *Maja squinado* (Decapoda: Majidae) in the Ría de Arousa (Galicia, NW Spain). *Cahiers de Biologie Marine*, **38**: 221-234.
- Powles H. 1968.** Distribution and biology of the spider crab *Chionoecetes opilio* in the Madgallen Shallows, Gulf of St. Lawrence. *Canadian Manuscript Report of Fisheries and Aquatic Sciences*, **997**.
- Sainte-Marie B. & Hazel F. 1992.** Moulting and mating of snow crabs, *Chionoecetes opilio* (O. Frabicius), in shallow waters of the northwestern Gulf of St. Lawrence. *Canadian Journal of Fisheries and Aquatic Sciences*, **49**: 1282-1293.
- Savoie L., Miron G. & Biron M. 2007.** Fouling community of the snow crab *Chionoecetes opilio* in Atlantic Canada. *Journal of Crustacean Biology*, **27**: 30-36.
- Tremblay M.J. 1997.** Snow crab (*Chionoecetes opilio*) distribution limits and abundance trends on the Scotian Shelf. *Journal of Northwest Atlantic Fishery Science*, **21**: 7-22.
- Wahl M. 1989.** Marine epibiosis. I. Fouling and antifouling: some basic aspects. *Marine Ecology Progress Series*, **58**: 175-189.
- Watson J. 1970.** Maturity, mating and egg laying in the spider crab, *Chionoecetes opilio*. *Canadian Journal of Fisheries and Aquatic Sciences*, **27**: 1607-1616.