Assessment of Green Crab (*Carcinus maenas*) abundance in the Bras d'Or Lake of Cape Breton, N.S.

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ABSTRACT

Vercaemer B., J. Ouellette-Plante, J. T. Johnson and A. McIsaac, 2011. Assessment of Green Crab (*Carcinus maenas*) abundance in the Bras d'Or Lake of Cape Breton, N.S. Can. Tech. Rep. Fish. Aquat. Sci. 2965: vi + 42 p.

The European green crab, *Carcinus maenas*, is a notorious and successful invader worldwide and an ecologically and economically damaging predator of near shore communities. First observed in Atlantic Canada in the early 1950s, green crabs likely arrived in the Bras d'Or Lake in the early 1990s and are now invading new areas such as western Prince Edward Island and southern Newfoundland. Green crab monitoring is one activity of the National Aquatic Invasive Species program initiated by the Department of Fisheries and Oceans (DFO) in 2005. In Nova Scotia, green crab monitoring has been focused in the Bras d'Or Lake, a unique brackish ecosystem, where catch rates seem to have declined over the last decade. Trapping surveys were undertaken in 2008, 2009 and 2010 in several areas of the Bras d'Or Lake where eelgrass surveys have been previously conducted jointly by DFO and the Eskasoni Fish and Wildlife Commission (EFWC). There are variations in catch rates between areas, seasons and years (from 1 to 40 crabs/trap/day) but the data collected do not substantiate an actual decline of green crab abundance in the Bras d'Or Lake.

RÉSUMÉ

Vercaemer B., J. Ouellette-Plante, J. T. Johnson and A. McIsaac, 2011. Assessment of Green Crab (*Carcinus maenas*) abundance in the Bras d'Or Lake of Cape Breton, N.S. Can. Tech. Rep. Fish. Aquat. Sci. 2965: vi + 42 p.

Le crabe vert Européen ou crabe enragé, *Carcinus maenas*, est un envahisseur bien répandu et connu dans le monde entier et un prédateur écologiquement et économiquement dommageable des communautés côtières. Tout d'abord observés dans le Canada atlantique au début des années 1950, les crabes verts sont probablement arrivés dans le lac Bras d'Or au début des années 1990 et envahissent désormais de nouvelles régions telles que l'ouest de l' Île-du-Prince-Edward et le sud de Terre-Neuve. La surveillance du crabe vert est une des activités du programme national des Espèces Aquatiques Envahissantes développé par le Ministère des Pêches et Océans (MPO) en 2005. En Nouvelle-Écosse, la surveillance s'est concentrée dans le lac Bras d'Or, un écosystème unique saumâtre où les taux de capture semblent avoir diminué depuis une dizaine d'années. Des échantillonnages par trappes ont été menés en 2008, 2009 et 2010 dans plusieurs régions du lac Bras d'Or, où des études de distribution des zostères ont déjà été menées conjointement par le MPO et Eskasoni Fish and Wildlife Commission (EFWC). Il y a des variations dans les taux de capture entre les stations d'échantillonnage, les saisons et les années (de 1 à 40 crabes/trappe/jour), mais les données recueillies ne confirment pas une baisse réelle de l'abondance du crabe vert dans le lac Bras d'Or.

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Vercaemer B., J. Ouellette-Plante, J. T. Johnson and A. McIsaac, 2011. Assessment of Green Crab (*Carcinus maenas*) abundance in the Bras d'Or Lake of Cape Breton, N.S. Can. Tech. Rep. Fish. Aquat. Sci. 2965: vi + 42 p.

Qame'k wejiet stoqnamuksit mnjinikej, *Carcinus maenas*, na winsit aqq kisi-kikaji-piskwa't ta'n mu tleyawik msɨt tami wsitqamu'k aqq kaqi-opla'toq ta'n telo'lti'tij wutanl kikjuk pemjajika'simk etekl. Mawi-amskwes nemu'pnik stoqnamuksijik mnjinikejk Mi'kma'kik na'tamiaw 1950ek, aqq etlite'tmumk pejita'new Pitu'poq 1990ek aqq nike' poqji-nmu'jik łtke'snuke'l Epekwitk aqq łpkɨte'snuke'l Ktaqamkuk. Ta'n tel-jikeyuj stoqnamuksit mnjinikej na tel-lukutijik Aquatic Invasive Species etl-lukutijik.

Department of Fisheries and Oceans (DFO) kisite'tmi'tis ula lukwaqney 2005ek aqq ula lukwaqn Nopa Sko'sia etl-lukwasik Pitu'poq, keknue'k tel-salawima'q wsitqamuey, ta'n tett pemi-aji-tke'jik natqa'piemk. Ta'n te'sɨk kisi-natqa'tumk ekitasiksɨp 2008ek, 2009ek aqq 2010ek Pitu'poq ta'n tett ki's DFO aqq Eskasoni Fish and Wildlife Commission (EFWC) kisi-iloqaptmi'tisnl qata'skwl. Kijka' pilu'tek ta'n te'sɨk kisi-natqa'tumk te's tami etl-kwitamemk aqq ta'n teli-punqek aqq te'sipunqek na'sɨk mu ketlewe'nuk pmi-ajitkle'jinew stoqnamuksijik mnjinikejk Pitu'poq.

Introduction

Globalization of biota is increasing at an alarming rate with increasing biological invasions of non indigenous species ((NIS, i.e. species that establish self-sustaining populations outside their native range) (Lodge 1993, Colautti et al. 2006). Invasions (introductions and establishment) of NIS are often unintentional consequences of human activities, such as expanded international trade, which allow NIS to cross natural barriers (Carlton 1989). Technological advances in the transportation of goods and people have increased the rate of NIS introductions. Climate change, which may modify their environmental constraints, may further alter their distribution and impacts (Hellman et al. 2008).

The European green crab (*Carcinus maenas* Linnaeus 1758, Figure 1), a species with high fecundity, high tolerance to a broad range of environmental conditions, and omnivorous feeding behaviour, has spread globally and is listed as one of the top ten most unwanted invasive species in the world (Audet et al. 2003, IMO 2006). Originally from Europe, *C. maenas* (hereafter referred to as green crab) was first recorded on the North American coast in Massassuchetts in 1817 (see Audet et al. 2003), and it has since spread northwards. Green crab was first recorded in Nova Scotia (NS) in the early 1950s (MacPhail 1953), but despite its initial successful spread along the south coast of NS , it was not recorded in northern NS until the 1980s and in Cape Breton Island until 1994 (Audet et al. 2003, Klassen and Locke 2007). In a recent study, Roman (2006) showed that eastern Canadian populations of green crab have higher genetic diversity than those further south in the U.S.A., indicating that multiple invasions have, and may be still occurring in the Maritimes.

Figure 1. The European green crab *Carcinus maenas* (Linnaeus, 1758).

Located in the middle of Cape Breton Island, NS, the Bras d'Or Lake (BDOL) is a series of linked estuarine bodies with small tidal amplitudes relative to those of most of the Atlantic coast (Parker et al. 2007). Because of its brackish water and cold winter temperature, the BDOL was thought to be protected from green crab colonization. Audet et al. (2003) reported sightings in 2000 but the green crabs have probably been present in the BDOL as early as the late 1980s or early 1990s. Green crabs are well-known competitors with native crustaceans and predators of clams, mussels and other bivalves in natural and aquaculture settings (Floyd and Williams 2004, Klassen and Locke 2007 and references within). The presence of green crab in the BDOL is of concern to the commercially important lobster and crab fisheries and to the oyster aquaculture in Atlantic Canada (Miron et al. 2005). Rossong et al. (2006) and Williams et al. (2006) showed that green crabs out compete native juvenile and sub-adult lobsters and can prey on juvenile lobsters. However the populations used were not sympatric, relatively low water temperature (10^oC) may have decreased lobster activity and their experiments were conducted in relatively small tanks where interactions could have been artificially inflated. Furthermore, Davis et al. (1998) showed that even if green crabs are not directly consuming eelgrass (*Zostera marina),* they can damage eelgrass beds and transplants while foraging and digging for food at a threshold density of 4 crabs/m^2. Recently, Malyshev and Quijon (2011) showed evidence of juvenile green crab grazing on eelgrass shoots. Parker et al. (2007) describes eelgrass as a possible keystone species in the BDOL because it provides fish spawning and oyster settling habitat, and important habitat for many fish, invertebrate and waterfowl species. The decline in abundance of two waterfowl species has been associated with the collapse of eelgrass beds in Antigonish Harbour, NS, and was indirectly related to the increase in green crab populations near the study site (Seymour et al. 2002).

With high genetic diversity, aggressive feeding behaviour and their known capacity to physically modify the ecosystem, green crabs are clearly posing ecological and economic threats to the BDOL but their impacts must be assessed more directly. Determining the range of habitats occupied by an invasive species and its relative abundance are important elements for assessing its impact (Grosholz and Ruiz 1996). Tremblay et al. (2006) reported significantly lower green crab catch rates in 2005 compared with 1999/2000 in several subareas of the BDOL, potentially indicating a decline in abundance. The present monitoring study is aimed at documenting green crab abundance, using trap survey protocols development by the Aquatic Invasive Species (AIS) program, at four locations of the BDOL with different habitat characteristics. Four additional stations were sampled in 2009 to better determine their habitat range. This project is part of an ongoing AIS program collaboration between the Department of Fisheries and Oceans (DFO) and the Eskasoni Fish & Wildlife Commission (EFWC).

1. Materials and methods

1.1. Trap survey

Sampling for green crab was conducted in the BDOL from 2008 to 2010. The BDOL is characterized by low salinity (~ 20 psu), a wide temperature range (~-1.5^{o}C - ~25^{o}C) and small tidal amplitude (0.3 m ±0.1 m) (Petrie and Bugden, 2002). Survey sites were selected based on the presence of eel grass established on coverage charts and consideration of local knowledge (Figure 2, Appendix 1 & 2). The Eskasoni, Chapel Island (Potlotek), Wagmatcook and We'koqma'q sites were surveyed each year while Amaguadees, Malagawatch, Gillis Cove and Baddeck were only surveyed in 2009. Eskasoni, Amaguadees and Chapel Island (Potlotek) sites are considered Southern BDOL while the other locations are considered Northern BDOL for this study.

Green crabs were obtained by setting three folding Fukui fish traps (63 x 46 x 23 cm, 1.6 x 1.6 cm mesh) with wide, slit-like openings that are known to target adult green crabs >40 mm carapace width (CW) (Figure 3). Pitfall traps or minnow traps which target juveniles < 25 mm were not used as this study was part of the AIS monitoring conducted nationally and followed a standardized protocol. Bait consisted of about 300 g of herring or mackerel enclosed in a single commercial plastic bait jar, and placed inside each trap. Openings in the sides and lids of the bait jars allowed for bait odors to diffuse.

The three traps were set below the subtidal zone, distributed 10 m apart and at similar depths at each site. Traps were usually deployed in the morning and set overnight (soak time was 24 h). On several occasions at the Eskasoni site, lines of traps were deployed according to a depth gradient. The ground line was secured by a weight at one end of the line and marked by a float at the other end. The trap depth, substrate type, soak time and environmental parameters (salinity, temperature, and oxygen) were recorded at each site. Latitude and longitude were determined using a hand held Global Positioning System (GPS) device. A total of 159 trap samples (477 traps), were obtained over several trapping events conducted and on different habitats at each site to cover a range of environmental characteristics (Tables 1 and 2).

The contents of the trap hauls were processed as follows:

Other taxa than green crab present in the by-catch were recorded and native species were released after sampling. Green crabs were examined individually. Carapace and limb condition, and any injuries were recorded. Crabs designated as damaged included those that were missing, or presenting injuries on, claws, legs, flap or carapace. Carapace and abdomen color were also classified (Appendix 3). Their sex was determined and females were checked for the presence of eggs (ovigerous or egg-bearing females).

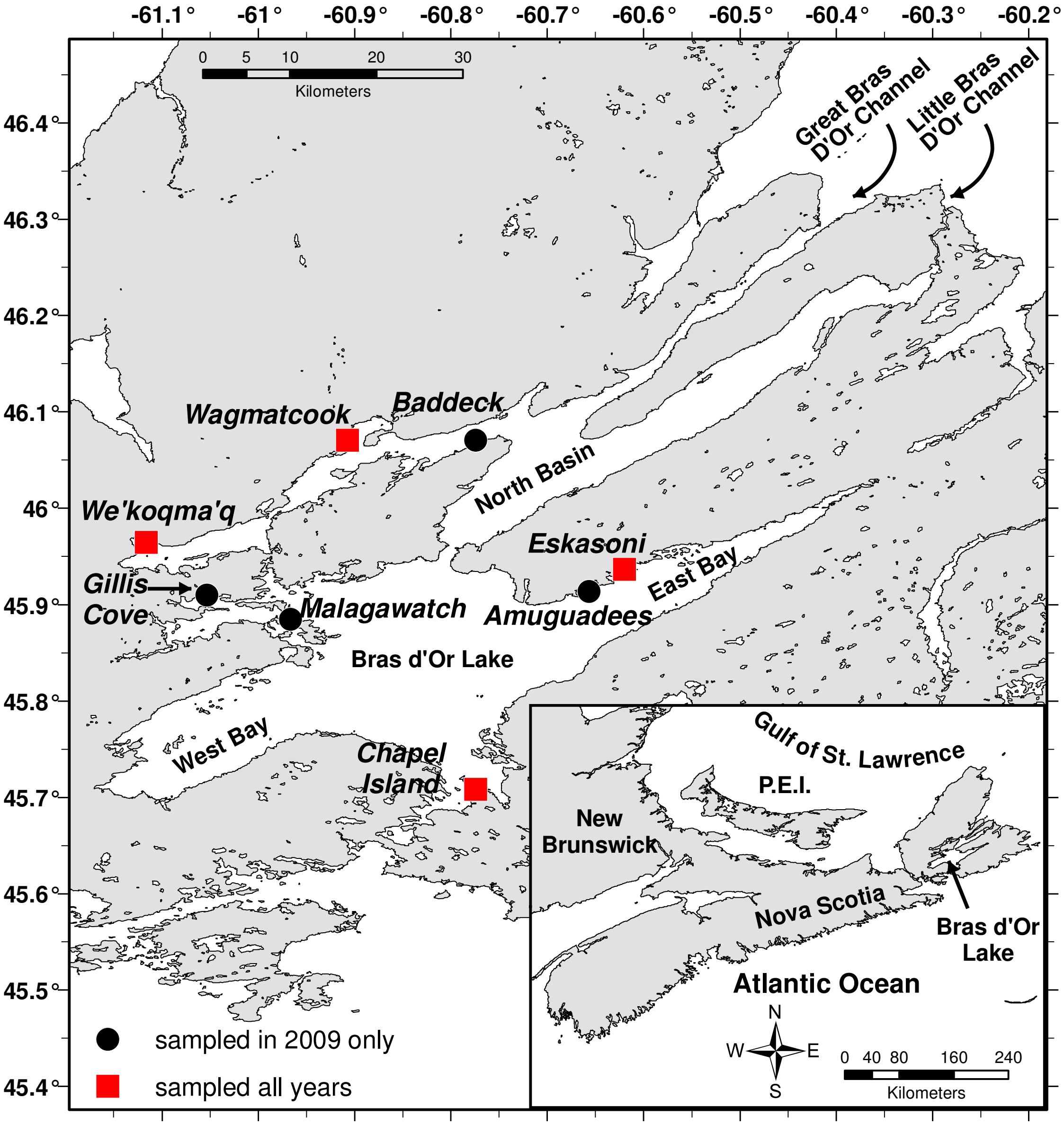

Figure 2. Locations of the 8 trapping sites.

Figure 3. Fukui traps.

Table 1. Dates and locations of the green crab survey conducted in the BDOL. Total number was 159 samples. Each sample consisted of 3 traps set for 24 hours.

Year	Month	Amaguadees	Baddeck	Chapel Island	Eskasoni	Gillis Cove	Malagawatch	Wagmatcook	We'koqma'q
2008	Jul.				2			2	2
	Aug.				2			2	2
	Sept.			4	2			2	2
	Oct.			2	2			2	2
2009	May	2		2	4	2	2		
	Jun		2		12			2	2
	Jul.				8	2		2	2
	Aug.			4	3	2			
	Sept.	2			4			2	2
	Oct.			2	2	2		2	2
2010	May				2				
	Jun			4	6			2	2
	Jul.			2	4			2	2
	Aug.			4	4			2	2
	Sept.			2	2			2	2
	Oct.			2	2			2	2
	Nov.			2					

Table 2. Trap survey effort (number of samples) by benthic habitat type conducted in the BDOL during the study period. Each sample consisted of 3 traps set for 24 hours. EGC=Eelgrass coverage.

Site	Year	Benthic habitat type		
		Continuous EGC	Patchy EGC	Sandy/Rocky
Amaguadees	**2009**		4	
Baddeck	**2009**	1	1	
Chapel Island	**2008**	3	3	
	2009	4	4	
	2010	8	8	
Eskasoni	**2008**	4	4	
	2009	14	11	8
	2010	10	10	
Gillis Cove	**2009**	3	5	
Malagawatch	**2009**	1	1	
Wagmatcook	**2008**	4	4	
	2009	4	4	
	2010	5	5	
We'koqma'q	**2008**	4	4	
	2009	4	4	
	2010	5	5	

Their carapace width (CW) was measured point-to-point (PP)[1] to the nearest mm with a digital caliper). Native rock crabs (*Cancer irroratus*) were measured in the same manner as green crabs. The total green crab catch was weighed and frozen for subsequent analysis.

Age structure of green crab was estimated using the same method as Gillespie et al. (2007) based on following criteria described in Berill (1982) for locations with 5 months of water temperature above 10^{o}C and summarized in Table 3 for 2009. The same criteria were used for crabs caught in 2010 and year classes were adjusted accordingly. Males and females were assigned to different year classes according to their size and carapace's color. As carapace color was not recorded in 2008, age structure could only be determined for the 2009 and 2010 surveys.

Table 3. Age structure criteria based on size of the European green crab (following criteria described Berill (1982) for locations with 5 months of water temperature above 10^{o}C).

Size (mm CW - PP) measured in 2009	Year class (age)	Size (mm CW - PP) measured in 2009
Male		**Female**
<10	2009 (0+)	<10
10-25[a,b]	2008 (1)	10-35 [a,b]
26-40 [a,b]	2007 (2)	36-45 [a,b]
41-55 [a,b]	2006 (3)	46-55 [a,b]
56-70 [a,b]	2005 (4)	56-65 [a,b]
>70	2004 (5+)	>65

[a] if carapace color is red/orange, crab was attributed to next year class
[b] if carapace color is light green, crab was attributed to previous year class

1.2. Trap data analysis

Catch per unit effort (CPUE , i.e. number of green crabs caught per trap per 24h) was modeled as a function of year (2008, 2009, 2010), site (Eskasoni, Chapel Island, Wagmatcook, We'koqma'q) and eelgrass coverage (continuous, patchy) using a 3 way analysis of variance (ANOVA). For Eskasoni, a subset of the 2009 data was analyzed for 3 types of habitat (continuous eelgrass, patchy eelgrass, sandy/rocky). All analyses were performed using Minitab 16.1.

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[1] Carapace width measured point-to-point (PP) is the longest measurement across the carapace including the 5th anterolateral spines (US standard measurement) while notch to-notch (NN) measurement are made with calliper tips placed in the notches between the 4th and 5th spines (Canadian standard measurement).

2. Results and Discussion

A total of 159 samples (n=477 traps) were obtained from 2008 to 2010. Most of the effort was concentrated in Eskasoni where 61 samples of 3 traps each were deployed over the 3 year period. The total number of green crab captured in the 159 samples was 3202 (Appendix 4). The trap surveys were done under a wide range of environmental parameters (Table 4).

Table 4. Ranges of environmental parameters recorded at sampling sites in the Bras d'Or Lakes.

Measured Parameters	Min	Max
Trap depth (m)	1.50	4.25
Temperature (ºC)	7.00	25.50
Salinity (psu)	5.19	21.60
Dissolved oxygen (mg/L)	5.60	15.55

2.1. By-catch and injuries

The catch was comprised primarily of green crabs but there were other species caught as well, such as rock crab (*Cancer irroratus*: 288 individuals), mummichog (*Fundulus heteroclitus*: 22), eel (*Anguilla rostrata*: 2), flat fish (3), perch (*Perca sp.*:1) and cod (*Gadus morhua*: 1). The by-catch was relatively low compared with other locations in Nova Scotia where similar traps were used with comparable soaking times.

The overall frequency of injury was relatively high, 29.8%, compared with 16% the British Columbia study where soak time was also 24 h (Gillespie et al. 2007). Injuries most likely resulted from intra-specific agonistic interactions, before and after trapping. The most common injury (60%) was missing either one leg or one claw only.

2.2. Sex ratio, size and age

Sex ratio:

Overall, most green crabs caught were male (66.8%); and of the females (33.2%), only 1.0% (12 individuals) had eggs (Tables 5 & 6). However, a higher proportion of females (57.5%) were captured in 2008. In 2009 and 2010, the sex ratios were similar to those reported in Tremblay et al. (2006) for the BDOL (73% male green crab) (see Appendix 5). In a recent survey of 33 locations on the Atlantic coast of Nova Scotia, the sex ratios were highly variable between locations, averaging 65.9 % male +/- 18.2 SD (Sephton et al., pers. comm.). Similarly, sex ratios varied between areas surveyed in British Columbia in the summer of 2006 (61.3% to 80.7% male; Gillespie et al. 2007) and between seasons in North Harbour, Newfoundland (54.54%

male in early June to 65.11% at the end of August 2010; K. Matheson, pers. comm.). This skewed sex ratio against females is well known and is an artifact of reproductive behavior. Females avoid males and stay inactive without feeding while bearing eggs (McDonald et al. 2004). The majority of green crabs caught in 2008 were trapped in Eskasoni, especially in July when 77% of the crabs caught were females, which explains the higher proportion of females that year (Appendix 4). This location could be part of a brooding area. It is interesting to note that at Benacadie, at the entrance of East Bay, 8 km south of the Eskasoni site, Cameron (2003) captured 54.9 % male crabs on average in 2001/2002. However, sex ratios were highly variable in her study, ranging from 21.9 to 86.9 % male depending of the sampling date (see Appendix 6) or if females entered the traps first (females will not enter traps when large males are present). In this survey (Table 6) and others in Atlantic Canada, it seems that ovigerous females are usually caught early in the season: 7.2% of the females were ovigerous between late June and mid July in Cameron (2003)'s BDOL study and, in a Prince Edward Island study, the few ovigerous females captured were also caught early in the summer (Audet et al. 2008).

Table 5. Number of male and female green crab and sex ratio (% male)

Year	Male	Female	total	M/F ratio
2008	274	370	644	42.55
2009	1091	438	1529	71.35
2010	774	255	1029	75.22
overall	2139	1063	3202	66.80

Table 6. Ovigerous female green crab (12 individuals) characteristics caught in 3 years of trapping.

Location	Date	Depth (m)	Temp (^oC)	Sal (ppt)	D.O. (mg/L)	Bottom type	CW(mm)	Eggs
Eskasoni	18- Aug-08	2.00	19.40	21.40	7.55	Patchy	35	-
Eskasoni	2-Jun-09	3.00	12.60	20.60	-	Continuous	37	-
Eskasoni	24-Jun-09	2.00	13.00	19.05	9.54	Continuous	52	uneyed
Eskasoni	9-Jul-09	2.25	17.50	18.61	11.45	Continuous	37	eyed
Eskasoni	9-Jul-09	2.00	17.20	18.99	11.095	Patchy	41	eyed
Eskasoni	9-Jul-09	2.50	17.00	19.04	10.96	Sandy/Rocky	40	uneyed
Wagmatcook	11-Jun-09	2.00	12.65	10.50	15.55	Continuous	44	uneyed
Wagmatcook	11-Jun-09	2.50	12.65	10.50	15.55	Continuous	49	uneyed
Wagmatcook	11-Jun-09	3.00	12.65	10.50	15.55	Continuous	32	uneyed
Wagmatcook	20-Jul-09	2.30	18.45	19.46	9.97	Patchy	56	uneyed
Eskasoni	13-Jul-10	2.00	20.50	19.22	9.31	Continuous	43	uneyed
Eskasoni	13-Jul-10	2	20.5	19.22	9.31	Patchy	52	uneyed

Female crabs could have congregated to incubate their eggs in specific locations not sampled in this study. However, more females might enter traps after set-up with cover/shelter (e.g. *Ulva* sp.) or if minnow traps were used as they keep larger crabs from entering (DFO 2011).

Size and Age:

Green crabs ranged in size from 17.1 to 78.0 mm CW, females were smaller than males (Table 7, Figure 4). Counts of the smallest green crabs (<30 mm CW) were low and showed no consistent trend. However in 2008, the mean CW of both male and female green crabs was significantly lower for the BDOL than in 2009 and 2010 ($F_{2,3199}$=220, P<000). The mean sizes of green crab in 2009 and 2010 were slightly larger than the mean sizes Tremblay et al. (2006) reported for the years 1999, 2000 and 2005 (Appendix 5). This could be linked to the different trap designs that were used in these two surveys. However, a few bigger (>90 mm) male green crabs were caught in the earlier surveys (Appendix 5). Using the same trap design in British Columbia, size distribution ranged from 32 to 98 mm and 29 to 76 mm CW for males and females, respectively, which represented three year classes (Behrens-Yamada and Gillespie 2008). However, in the BDOL of Nova Scotia where water temperatures are lower, the size distribution of green crabs caught in 2009 and 2010 represented five year classes (Figure 5).

Table 7. Range of carapace width measured point to point (CW) by species and sex.

Species	Sex	Carapace width (mm)	
		Min	Max
Green crab	**F**	17.1	78.0
	M	18.9	78.0
Rock crab	**F**	48.5	89.0
	M	37.2	113.0

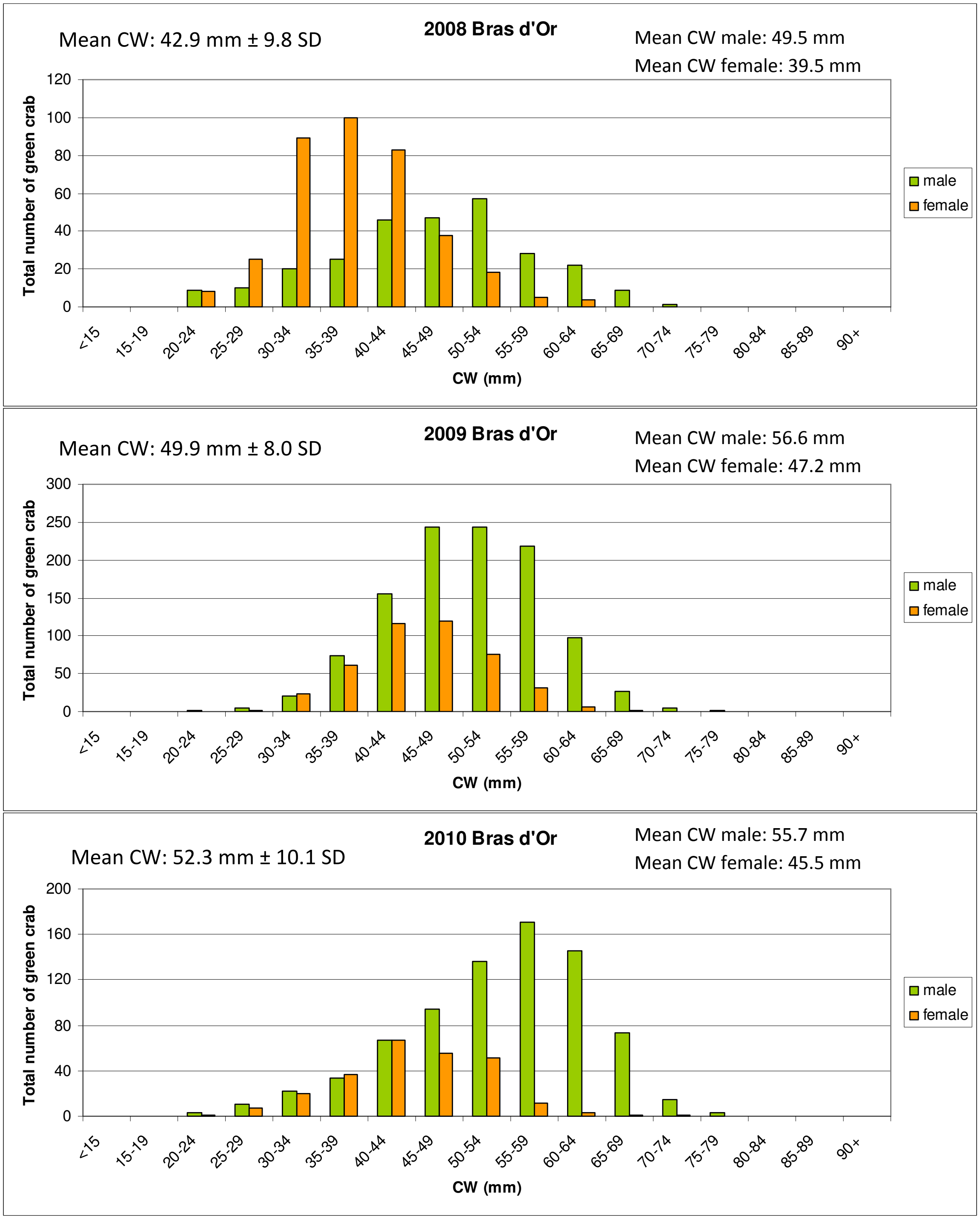


Figure 4. Size frequency distributions of male and female green crab captured in the Bras d'Or lake between 2008 and 2010.

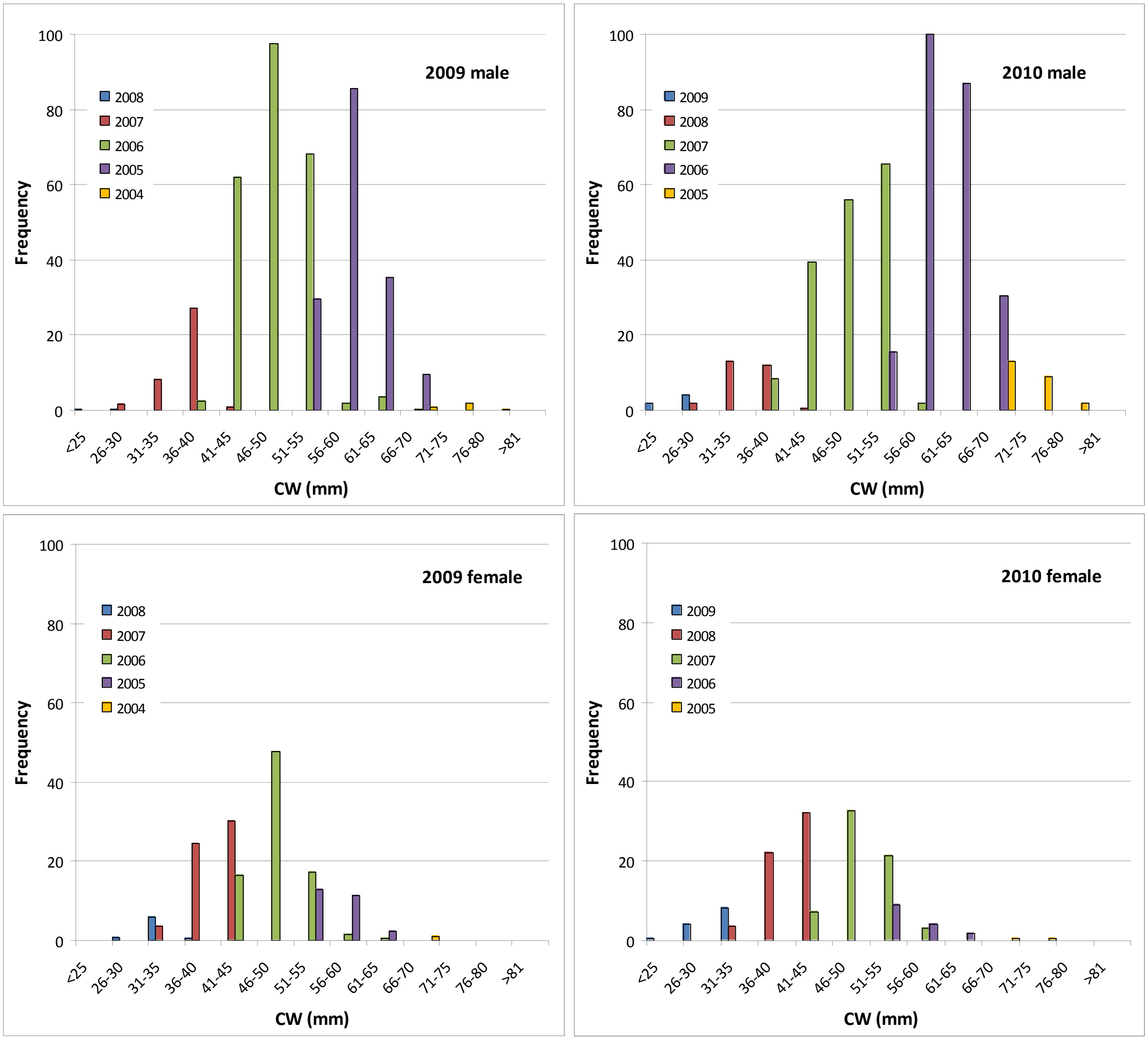


Figure 5. Carapace width measured point to point (CW) by year class (2004-2009) for green crabs collected in the BDOL survey in 2009 and 2010.

2.3. Distribution in space and time

Catch rates can be calculated per sample of 3 traps for comparison with earlier studies or per single trap (i.e. CPUE) (Table 8 and Figure 6). The green crab count frequency expressed as CPUE (number of crabs caught $trap^{-1}$ day^{-1}) indicated that the data were not normally distributed (Appendix 7). After log_e transformation, data were closer to normal distribution and therefore log_e transformed data were used in subsequent analyses of variance (Appendix 7).

Table 8. Summary of sampling in BDOL (all sites combined): Total catch (number of green crab caught), effort (number of traps), catch rate per sample of 3 traps and CPUE (number of crabs caught $trap^{-1}$ day^{-1}) by year and sex.

Sampling year	Sex	Grand Total	Trapping effort	Catch rate per sample of 3 traps	CPUE
2008	F	370	90	12.333	4.111
	M	274	90	9.133	3.044
	total	**644**	**90**	**21.466**	**7.155**
2009	F	438	219	6.000	2.000
	M	1091	219	14.945	4.981
	total	**1529**	219	**20.945**	**6.981**
2010	F	255	168	4.553	1.518
	M	774	168	13.821	4.607
	total	**1055**	**168**	**18.839**	**6.279**
Grand total		**3202**	**477**		

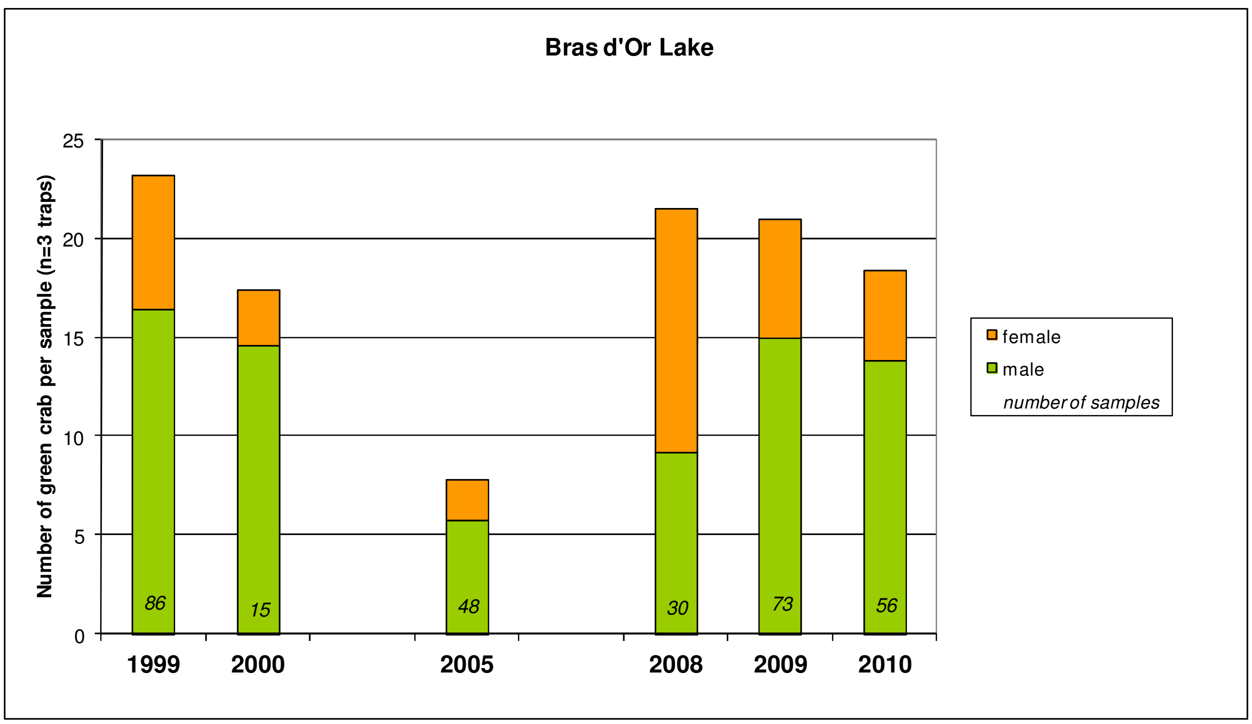


Figure 6. Mean catch rate (number of green crab caught per sample of 3 traps) by survey year in the BDOL. Data from 1999, 2000 and 2005 are from Tremblay et al. (2006) and Tremblay, pers. comm., using modified eel traps soaked for 3h.

The ANOVA for the 2008-2010 data indicated no significant effect due to year but the effect of location was significant (Appendix 7). Catch rates in this study (~20 crabs per sample of 3 traps) were similar to the catch rates in 1999/2000 rates (Figure 6) but the later were determined using a different protocol (Tremblay et al. 2006).

Northern BDOL:

Catch rates in Gillis Cove and Baddeck were low compared to the rest of the locations in 2009 and to the rates documented in the same areas in 1999 (Appendix 4 and Figure 7). The higher catch rate observed in Malagawatch in May 2009 was similar to some of the records in Wagmatcook and We'koqma'q (Appendix 4 and Figures 7 & 8). The catch rates at these last two locations were usually low (<5 crabs $trap^{-1}$ day^{-1}) but there was high and inconsistent inter-annual variability. For instance, at both sites in 2009, July was a month with high catch rate while, in 2010, the catch rates were the highest in September. Overall, the observed catch rates in Northern BDOL seemed to be higher in 2008-2010 than the catch rates documented in 1999 in Tremblay et al. (2006), even when taking into account the fact that the traps were soaked for 24 h (this study) instead of 3 h (1999 study).

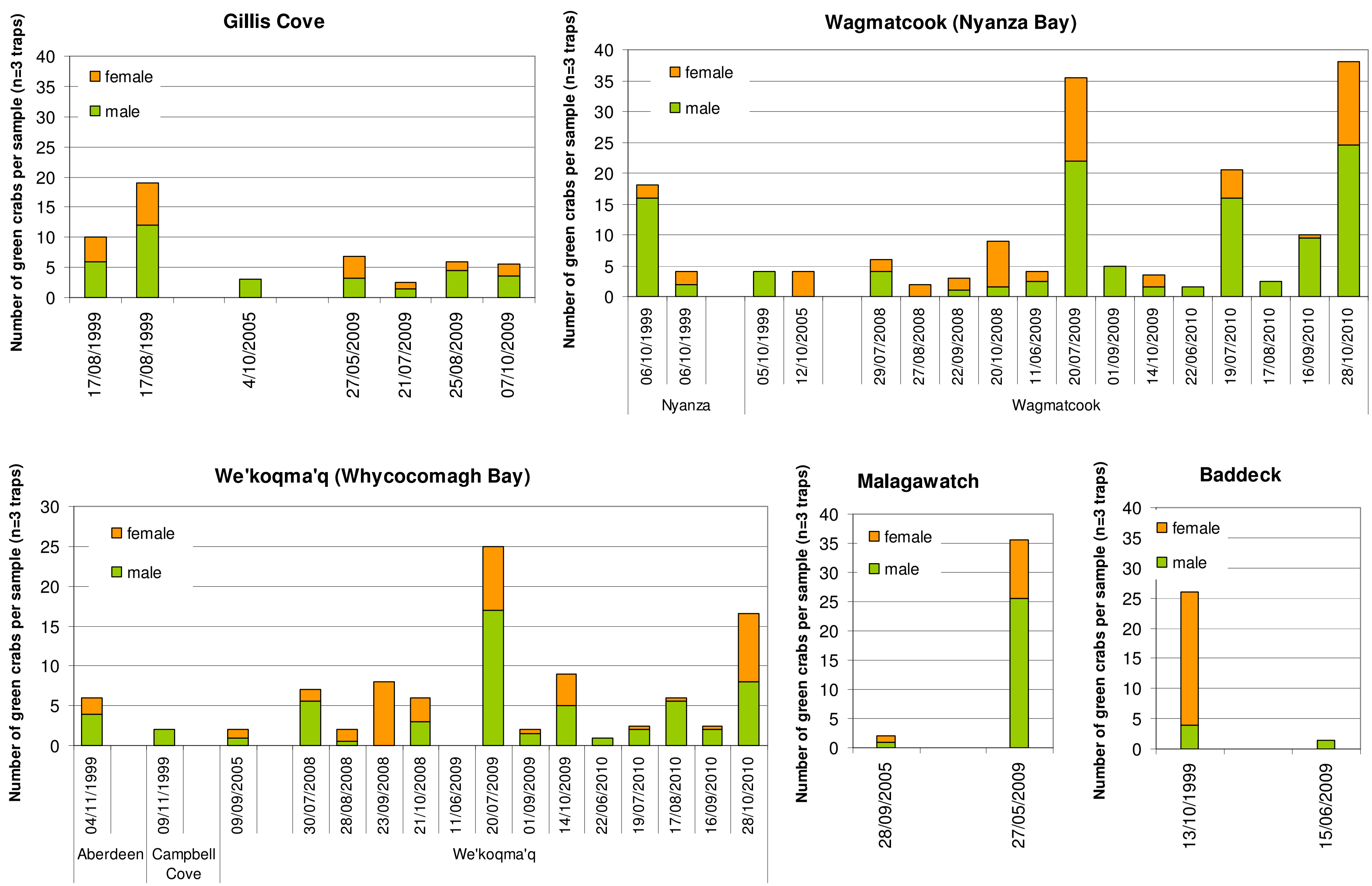
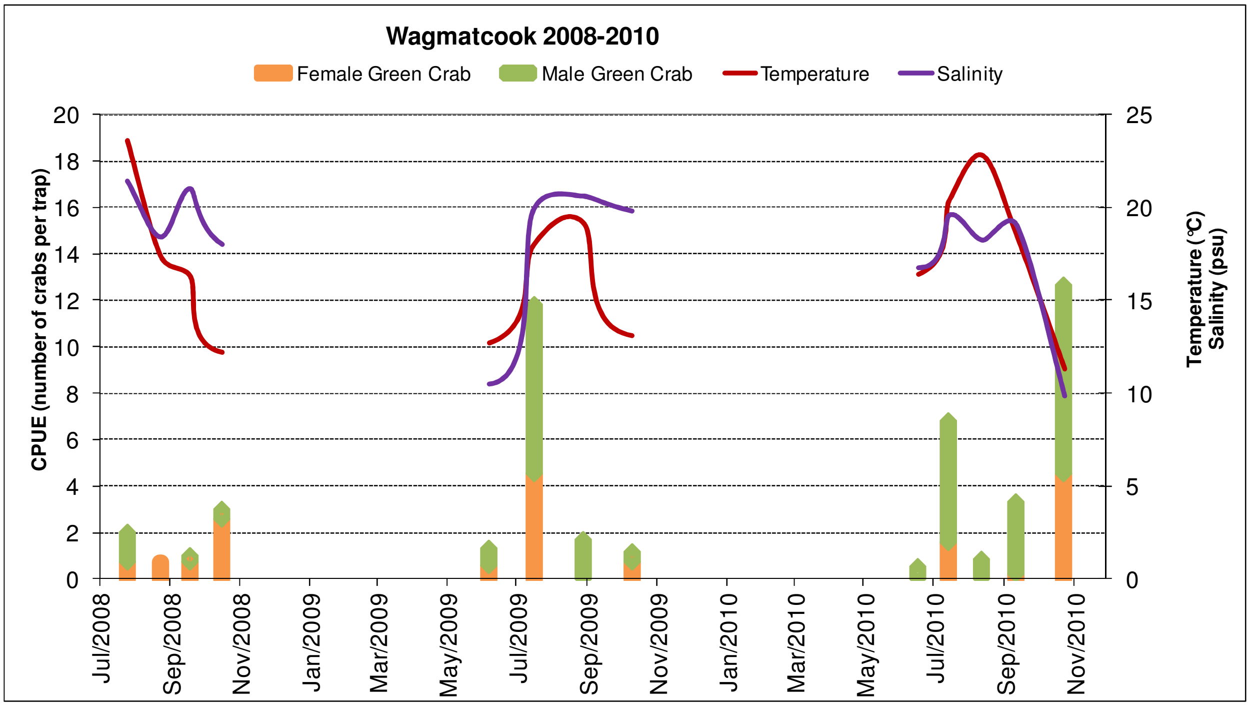


Figure 7. Number of green crabs per sample (n=3 traps) per location surveyed in Northern BDOL in 2008, 2009 and 2010. Data from 1999 and 2005 are from Tremblay et al. (2006).



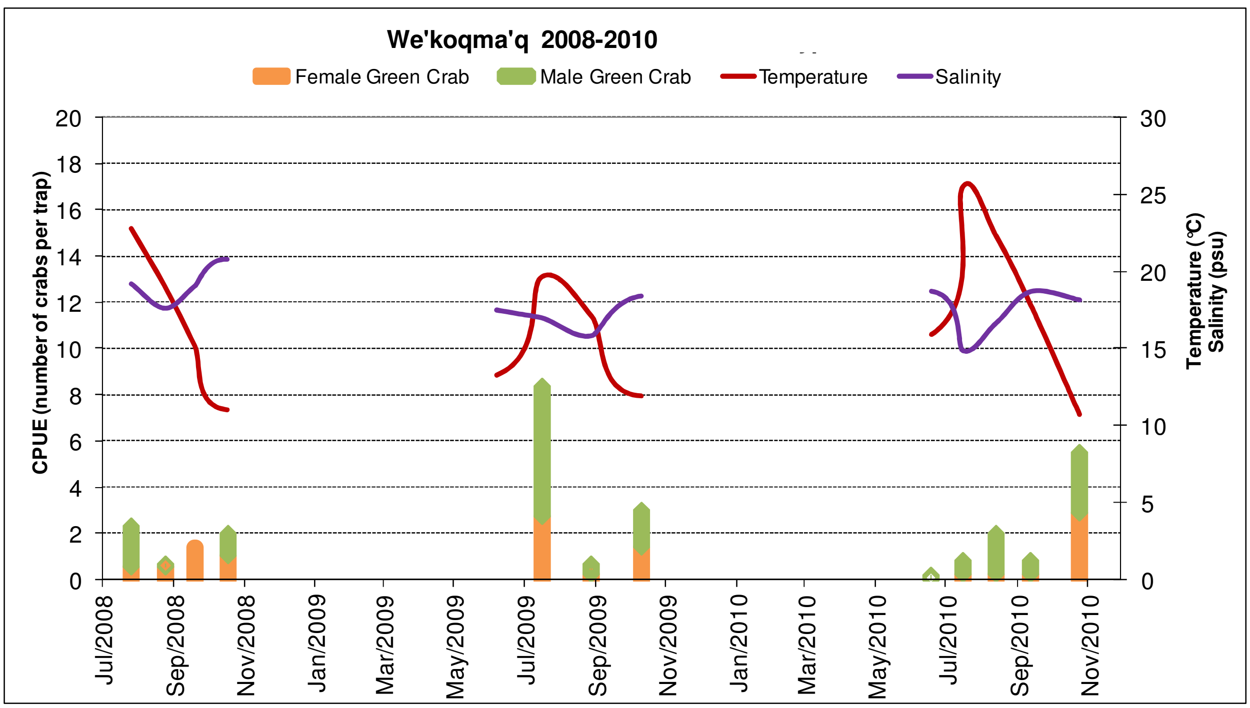


Figure 8. Catch rate (CPUE or number of green crabs caught trap^{-1} day^{-1}),), temperature and salinity recorded at each sampling date in Wagmatcook and We'koqma'q between 2008 and 2010.

Southern BDOL:

In southern BDOL, Amaguadees Pond is one of the many "nursery" barachois ponds around the Lake. It is a shallow lagoon formed by a sand bar located 5 kilometres north of Benacadie Pond where Cameron and Metaxas (2005) found a large number of green crab larvae and adult green crabs (Appendix 6). However salinity is very low in Amaguadees and varied from 5.2 to 6.1 psu between May and September 2009. Only 2 crabs were trapped once in September, out of two deployments of 6 traps each. Adult crabs may be temporally present in these semi-enclosed barachois but at low abundance as the salinities approach the low end of their tolerance range. The highest daily green crab catch rate (123.5 crabs in 3 traps in 24 h or 41.17 crabs $trap^{-1}$ day^{-1}) was recorded in 2009 in Chapel Island where the same highest rate (124 in 3 traps in 3 h) was recorded for the same location in 1999 (Tremblay et al. 2006) , ~10 years after their introduction (Figures 9 & 10). However, it is important to note that both trap type (modified eel trap) and soak time (3 h) were different from the present study. In Eskasoni and Chapel Island, where temperatures are similar to Northern BDOL but where salinities are less variable, catch rates were higher than in Northern BDOL, 5 to 15 crabs $trap^{-1}$ day^{-1}, and also exhibited peaks early in the summer in some years, to 35-40 crabs $trap^{-1}$ day^{-1} (in July 2008 in Eskasoni and in May 2009 in Chapel Island).

Trap effectiveness of modified eel trap and Fukui traps has not been studied or reported and this makes comparison and assessment of trend in abundance difficult. Miller (1990), in a review on effectiveness of crab and lobster traps, reported maximum catch at 5 to 12h soak time for two *Cancer* sp. however the trap design used in the experimental fishing was different from this survey or Tremblay et al. (2006)'s survey. Anecdotal reports have indicated a decrease in green crab abundance in the BDOL between the years 2000 and 2010 but also a recent increase in the last couple of years along with an increase in winter water temperature. Nevertheless, the present survey suggests that the abundance of green crab at the locations surveyed between 2008 and 2010 in the BDOL is highly variable both spatially and temporally.

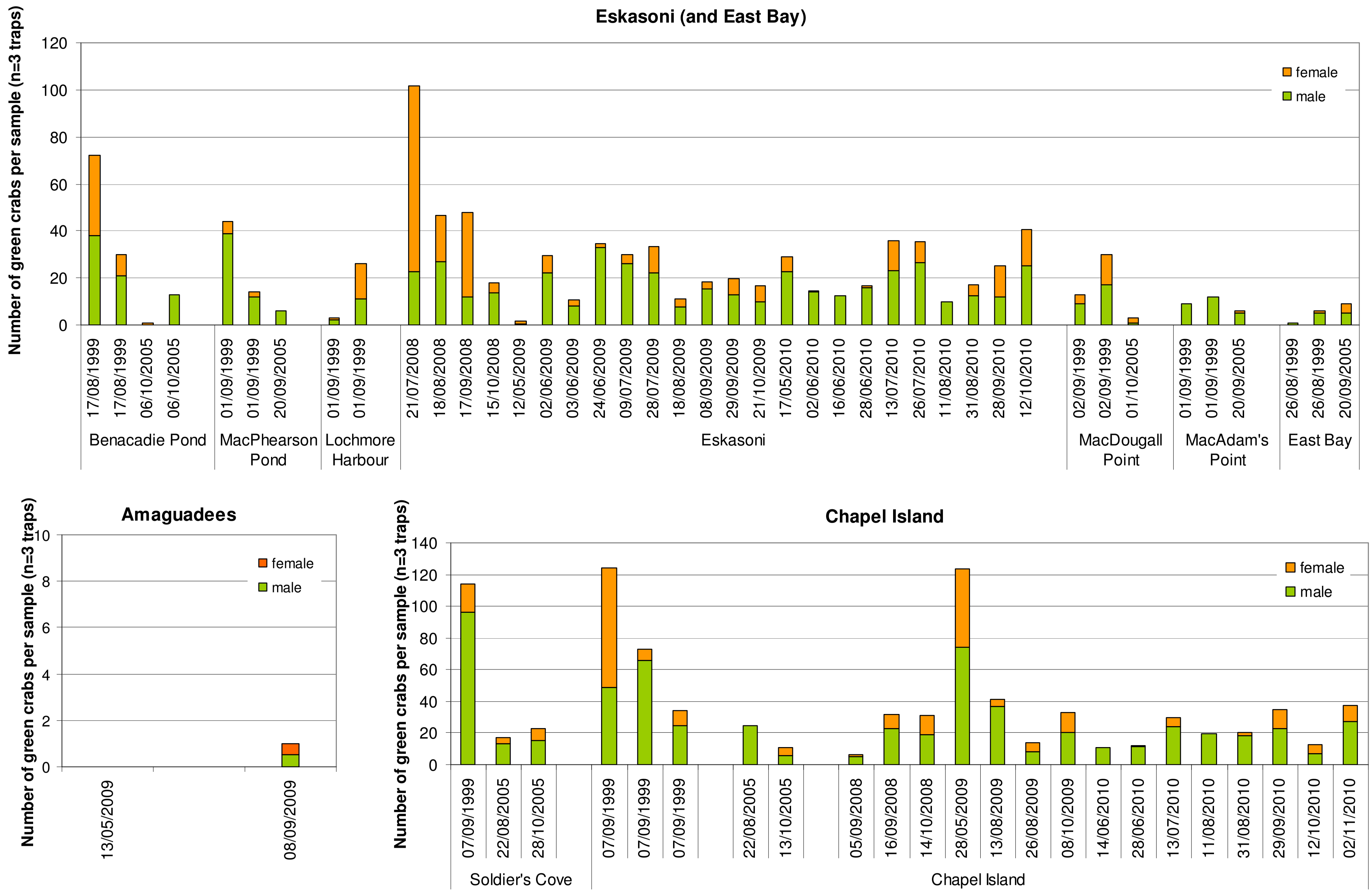
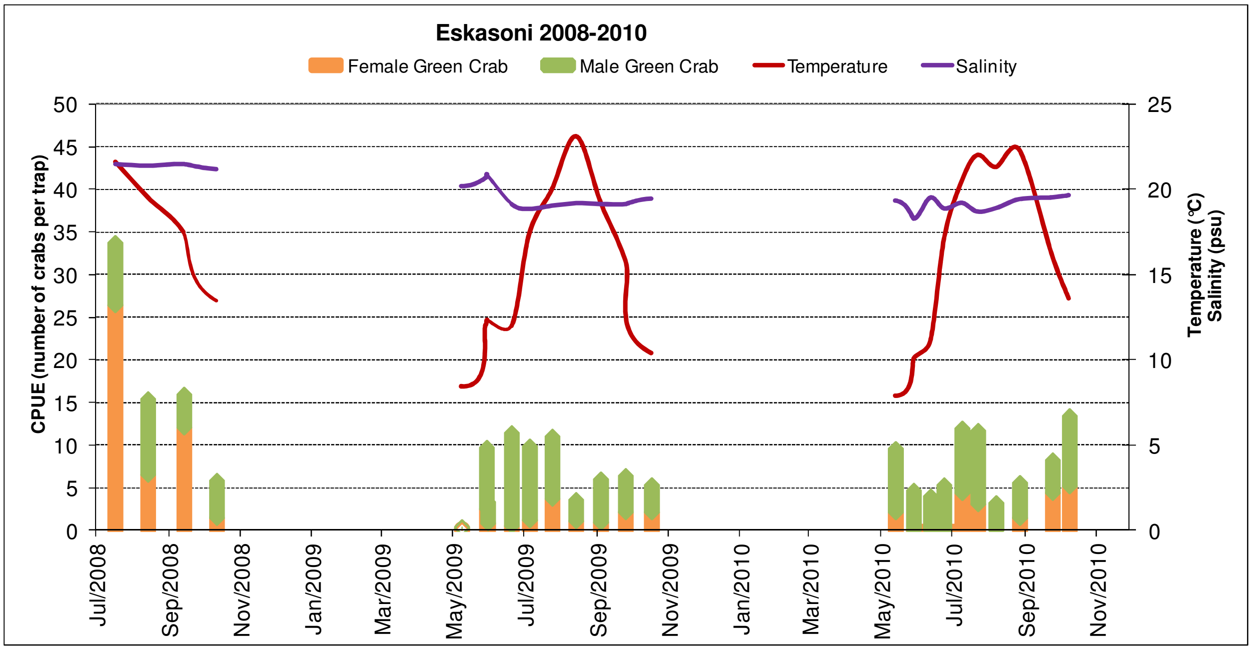


Figure 9. Number of green crabs per sample (n=3 traps) per location surveyed in Southern BDOL in 2008, 2009 and 2010. Data from 1999 and 2005 are from Tremblay et al. (2006).



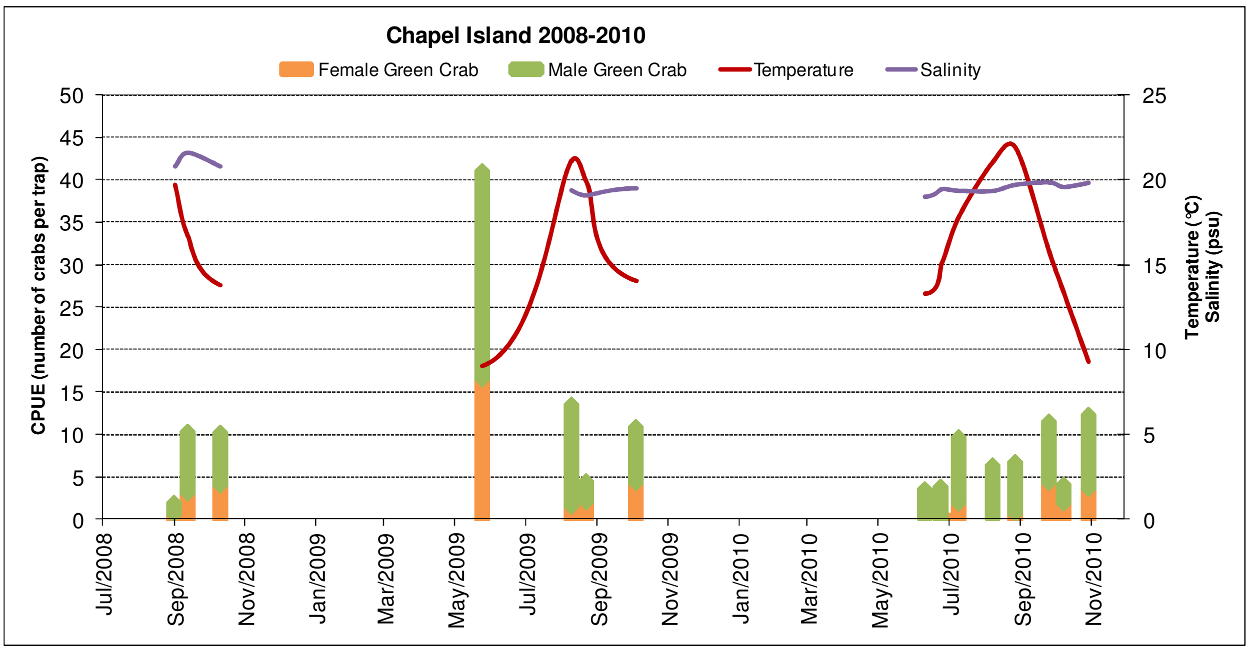


Figure 10. Catch rate (CPUE number of green crabs caught trap^{-1} day^{-1}), temperature and salinity recorded at each sampling date in Eskasoni and Chapel Island between 2008 and 2010.

Catch rates from this BDOL survey were low compared with the most recent invasion of green crabs in Newfoundland (DFO 2011) where they were first reported in 2007. Follow-up studies suggested that green crab were likely present since 2003 or 2004 (DFO 2011). In Newfoundland, using Fukui traps soaked for 24 hours, CPUE varied from a mean of 101.5 ± 44.25 SD (n=12 traps) in June to 48.25 ± 32.69 SD crabs $trap^{-1}$ day^{-1} in August 2010, seven to eight years after introduction, at North Harbour, Placentia Bay, where salinities reached 28.8 and 31.7 psu respectively (K. Matheson, pers. comm.). Lower CPUE was found in waters of similar salinities on the Atlantic shore of Nova Scotia, decades after the introduction of green crabs (i.e. average of 30.90 crabs $trap^{-1}$ day^{-1} in the summer of 2011, D. Sephton, pers. comm.). However, catch rates varied greatly from 5.33 to 340.33 crabs $trap^{-1}$ day^{-1} among locations.

In the BDOL, CPUE values also varied but did not reach the extreme values reported in Atlantic NS or Newfoundland. The low salinities of the BDOL, even though within their environmental range, may possibly impede the development of large green crab populations. It is unclear if green crab abundance will stabilize over the next decade. After 30 years of green crab establishment on the Eastern shore of NS (Audet et al. 2003), CPUE values remain relatively high even in brackish areas (e.g. 24.33 to 29.33 crabs $trap^{-1}$ day^{-1} (n=3 traps) in Cole Harbour in the summer of 2010 at a salinity of 18.4 (D. Sephton, pers. comm.). In contrast, these CPUE values reported in Atlantic Canada are clearly higher than those reported for the west coast of Canada. Using the same Fukui traps and soak time, catch rate varied with location, from 0.37 (n=112) (Clayoquot Sound) to 1.93 crabs $trap^{-1}$ day^{-1} (n=144) (Barkley Sound) with the highest catch rate recorded as 2.28 crabs $trap^{-1}$ day^{-1} (n=120) in July 2006 at Pipestem Inlet, Barkley Sound, 7 years after the first report of green crab (Gillespie et al. 2007). Predation by large native crab species seems to provide biotic resistance to green crab populations in northeastern Pacific (Jensen et al. 2007).

2.4. Habitat differences

In the BDOL, reported CPUE values varied between locations and eelgrass coverage. Boxplots of the total number of green crab per sample indicate some differences in CPUE according to eelgrass coverage (“Continuous” vs. “Patchy”) (Figure 11A). However, the ANOVA resulted in no significant effect of eelgrass coverage type as it varies among sites and years (Appendix 7). Nonetheless, when using the subset data where three types of habitat were investigated in Eskasoni from June 2 to July 7, 2009, habitat type had a significant effect (P=0.017) and there were more green crabs caught in “Continuous” than “Patchy” than ”Sandy/Rocky” habitats (Figure 12 A). However, overall in the BDOL 2008-2010 survey, there were similar numbers of green crabs caught in traps deployed in “Continuous” (mean CPUE = 6.623) and “Patchy”

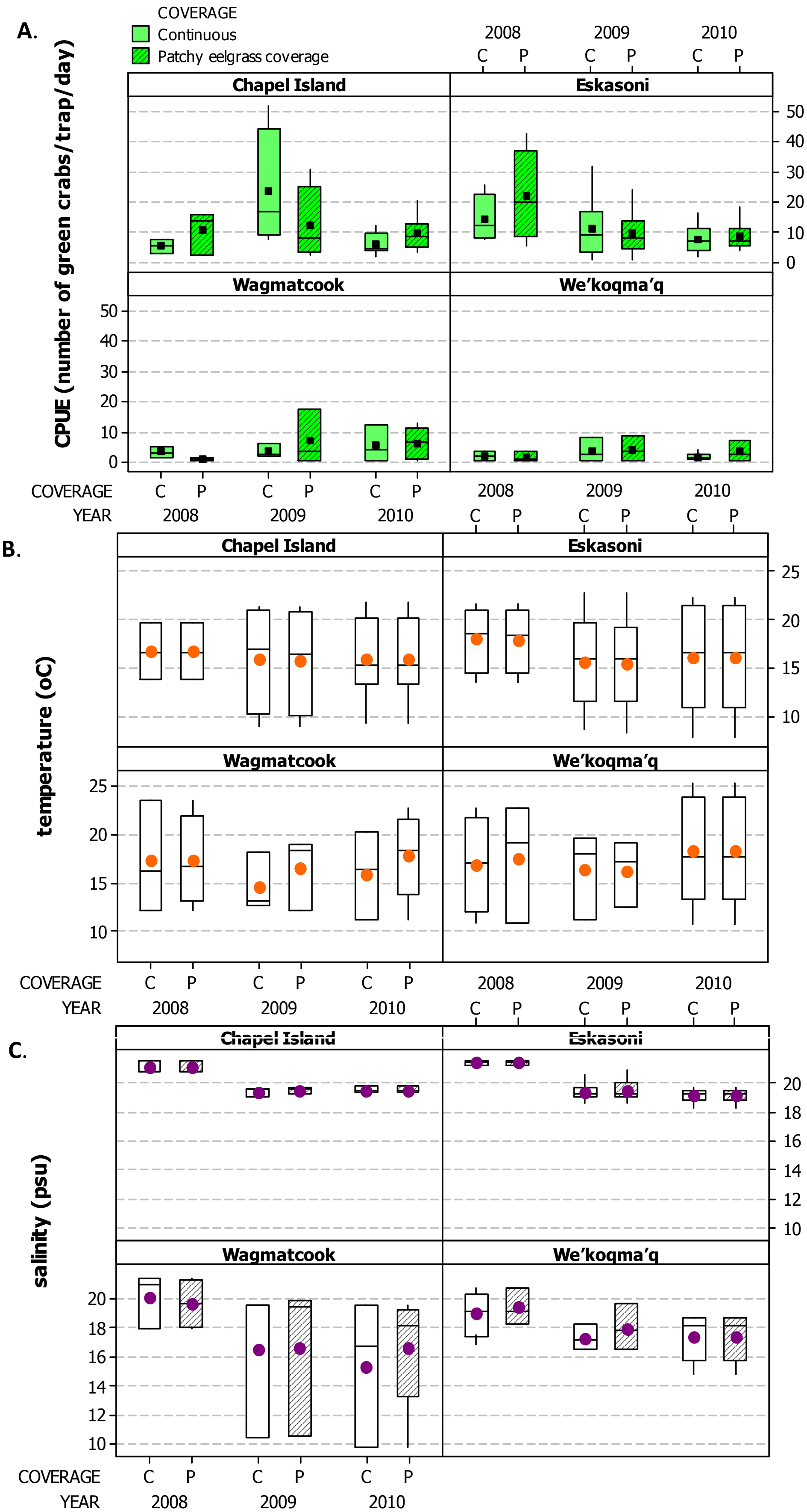


Figure 11. Box plots of CPUE, temperature and salinity by site, year and eelgrass coverage type.

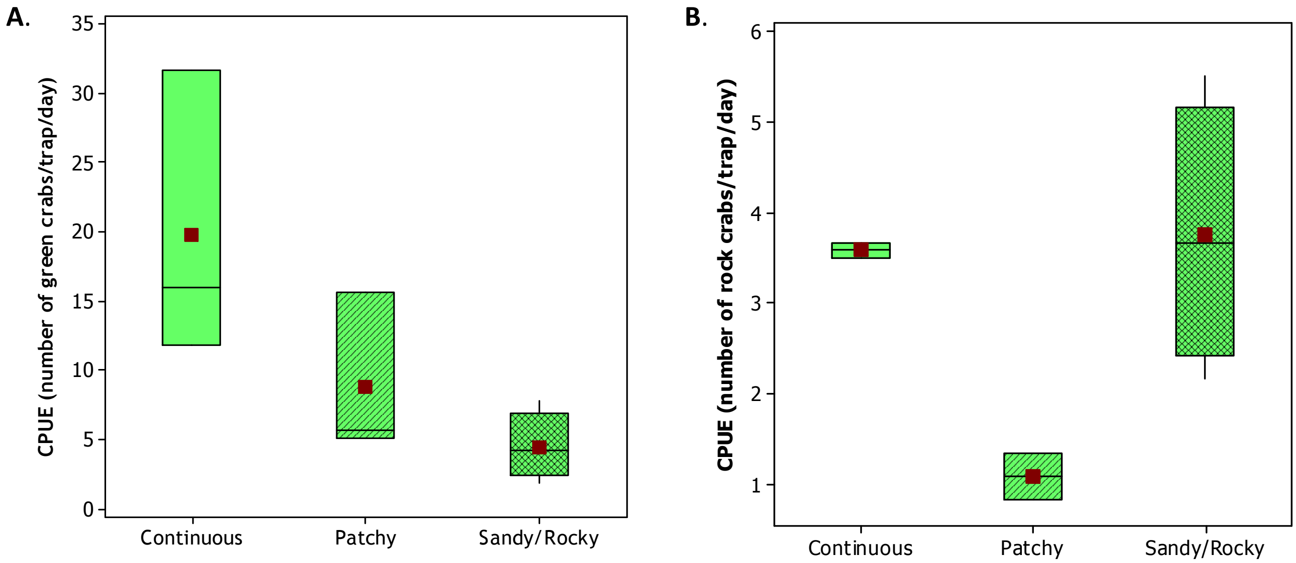


Figure 12. Box plots of catch rate of green crab (A) and rock crab (B) by habitat type in Eskasoni from June 2 to July 9, 2009. Note difference in scales.

(mean CPUE = 7.045) eelgrass coverage habitats, more than in the "Sandy/Rocky" habitat (mean CPUE = 4.500) where there were fewer but on average larger, predominantly male, green crabs (Table 9, Figure 13 C). There were also more peaks in green crab abundance (as previously described) in areas with "Patchy" eelgrass coverage in Wagmatcook, Eskasoni and Chapel Island (with the exception of 2009 at Chapel Island) (Appendix 4). In Eskasoni, there were more crabs caught on habitat with "Continuous" eelgrass coverage in 2009 but not in 2008 and 2010 (Table 10), similarly to Chapel Island. Overall, in Chapel Island and We'koqma'q, there was no difference in the number of green crabs caught between the two type of eelgrass coverage (Table 11).

Table 9. Summary of trapping effort in BDOL (all sites combined): Total catch (number of crabs caught), effort (number of traps) and CPUE (number of crabs. $trap^{-1}.day^{-1}$) by sex and habitat. CPUE values are displayed in brackets. Rock crab data are shown for 2009 only, when the majority of rock crabs were caught. ECG = Eelgrass coverage.

Sampling year	Species	Sex	Continuous EGC	Patchy EGC	Sandy/Rocky
2008	Green Crab	traps	45	45	
		F	140 (3.111)	230 (5.111)	
		M	128 (2.844)	146 (3.244)	
		Total	**268 (5.955)**	**376 (8.355)**	
2009		traps	102	93	24
	Green Crab	F	250 (2.451)	175 (1.882)	13 (0.542)
		M	580 (5.686)	416 (4.473)	95 (3.958)
		Total	**830 (8.137)**	**591(6.355)**	**108 (4.500)**
	Rock Crab	F	4 (0.039)	4 (0.043)	7 (0.292)
		M	109 (1.069)	30 (0.322)	83 (3.458)
		Total	**113 (1.108)**	**34 (0.366)**	**90 (3.750)**
2010	Green Crab	traps	84	84	
		F	116 (1.381)	139 (1.655)	
		M	316 (3.762)	458 (5.452)	
		Total	**432 (5.143)**	**597 (7.107)**	

Table 10. Total catch (number of crabs caught), trapping effort (number of traps in brackets) by habitat type and sex and sex ratio (in %) in Eskasoni. EGC = Eelgrass coverage.

Eskasoni	Continuous EGC			Patchy EGC			Sandy/Rocky			Total
Green crab	F	M	*total*	F	M	*total*	F	M	*total*	
2008	89	80	*169*	189	70	*259*				428
	53%	*47%*	*(12)*	*73%*	*27%*	*(12)*				
2009	112	334	*446*	72	196	*268*	13	95	108	822
	25%	*75%*	*(42)*	*27%*	*73%*	*(33)*	*12%*	*88%*	*(24)*	
2010	55	168	*223*	70	180	*250*				473
	25%	*75%*	*(30)*	*28%*	*72%*	*(30)*				
Total	**256**	**582**	***838***	**331**	**446**	***777***	**13**	**95**	**108**	**1723**
Rock crab	F	M		F	M		F	M		
2008	2	18	*20*		1	*1*				21
2009		89	*89*	2	20	*22*	7	83		201
2010		8	*8*		12	*12*				20
Total	**2**	**115**	***117***	**2**	**33**	***35***	**7**	**83**		**242**

A.

B.

C.

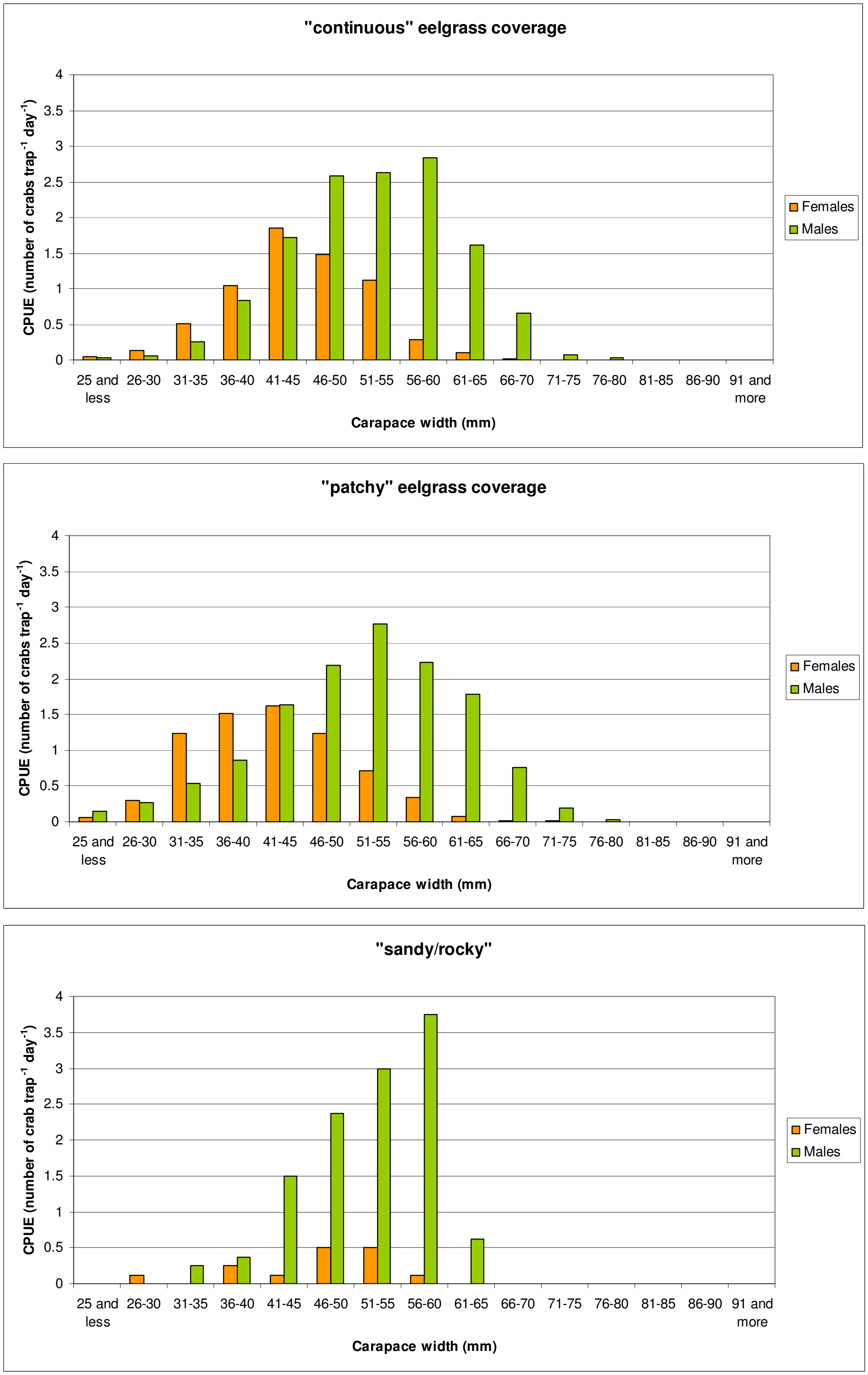


Figure 13. Size frequency of green crabs caught in different habitats (2008 to 2010 combined).

Table 11. Summary of trapping effort at each location surveyed. Total catch (number of crabs caught) by sex and type of eel grass coverage area. EGC = eelgrass coverage.

Chapel Island	Continuous EGC			Patchy ECG			Total
Green crab	F	M	*total*	F	M	*total*	
2008	15	30	*45*	30	63	*93*	138
2009	95	184	*279*	50	94	*144*	423
2010	29	105	*134*	44	177	*221*	355
Total	139	319	*458*	124	334	*458*	916
Rock crab	F	M	*total*	F	M	*total*	
2008				1	3	*4*	4
2009	1	13	*14*				14
2010		2	*2*				2
Total	1	15	*16*	1	3	*4*	20
Wagmatcook	Continuous			Patchy			Total
Green crab	F	M	*total*	F	M	*total*	
2008	21	9	*30*	6	4	*10*	40
2009	19	13	*32*	15	49	*64*	96
2010	24	26	*50*	13	82	*95*	145
Total	64	48	*112*	34	135	*169*	281
Rock crab	F	M	*total*	F	M	*total*	
2009	3	4	*7*	2	7	*9*	16
2010	0	0	*0*	2	2	*4*	4
Total	3	4	*7*	4	9	*13*	20
We'koqma'q	Continuous			Patchy			Total
Green crab	F	M	*total*	F	M	*total*	
2008	15	9	*24*	5	9	*14*	38
2009	11	23	*34*	14	24	*38*	72
2010	8	17	*25*	12	19	*31*	56
Total	34	49	*83*	31	52	*83*	166

Of a total of 288 rock crabs caught in this survey, 201 (or 69.8%) were found in Eskasoni in 2009 where 99 traps, out of a total of 477, were deployed (20.75% of total trapping effort) (Table 10). They were mostly males and caught on either continuous eel grass coverage or sandy/rocky habitat (Figure 12 B).

2.5. Depth differences

Mean CPUE of green crab decreases as depth increases while rock crabs were proportionally more abundant as the depth increased (Figure 14). In the BDOL in areas of lower salinity, including shallow subtidal habitat < 3m, green crab may outcompete the native rock crab (Breen and Metaxas, 2009), while at depth >3m, reduced prey abundance (e.g. shellfish) might be the limiting factor for both species.

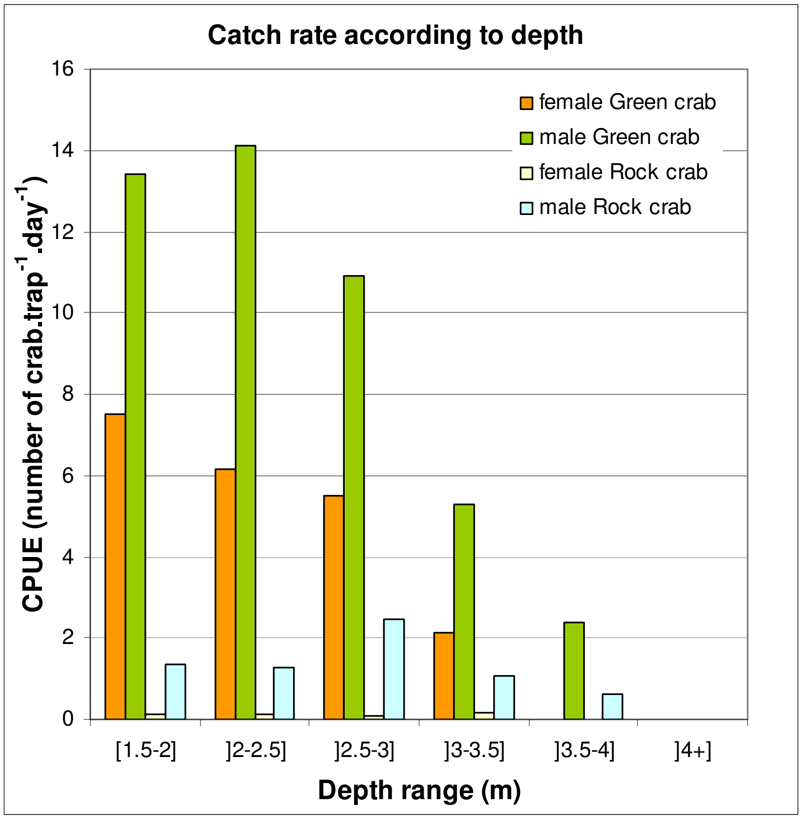


Figure 14. CPUE by depth for green crab and rock crab.

2.6. Salinity and temperature differences

Salinity, among other biotic factors, may determine the distribution of a species in estuarine or brackish systems. Green crab abundance seemed to be restricted where wide seasonal range of salinities occurred, such as in Wagmatcook and We'koqma'q (Figure 11 C) and salinity was a significant factor (P=0.020) to explain differences in CPUE (Appendix 7). Suboptimal salinity (<20 psu) has been shown to delay larval development (Anger et al. 1998) and even short exposure to low salinities typical of the surface waters of BDOL are detrimental to the survival of early larval stages of green crab (Bravo et al. 2007).

Summer temperature however did not vary significantly between sites (Figure 11 B) during the 2008-2010 survey. However inter-annual differences in green crab abundance can be influenced by temperature and the abundance of green crab can decrease significantly as cold winters reduce survival and delay settlement and larval development (Breen and Metaxas 2009). In the BDOL, winter water temperatures <0^{o}C lasted for ~ 2 months in 2005 while, with a warmer winter and minimal ice coverage in 2006, green crabs increased in abundance by 10-fold at Benacadie (Breen and Metaxas 2009). Winter temperatures in the years 2008, 2009 and 2010 were not particularly cold in the BDOL and the abundance estimated by catch rates, and the variability between sites, reported in this survey following the standard AIS protocol, provide credible baseline data for future AIS green crab surveys.

Concluding remarks

A national risk assessment flagged the European green crab as an ecologically and economically high risk species on both coasts of Canada (Therriault et al. 2008). Green crab have been present since the late 1980s-early 1990s in the BDOL and the 2008 to 2010 trapping survey indicated the presence of firmly established populations. As catch rates using traps are a function of abundance and catchability of the target species, it is important to standardize surveys by controlling trap design, depth and soak time and by recording important environmental parameters such as temperature, salinity, bottom type and tidal cycle. As decapods feeding activity typically peaks at twilight or night, it is important that soak time includes these periods. In addition, it is essential to better understand the effectiveness and "saturation" of the trap design used in the standardized surveys. Biological factors such as molting and reproductive status and the presence of prey source and predators are also important to record if possible. In the current BDOL study, some of the most important factors such as trap design, soak time and depth were controlled and catch rates recorded for the different sites surveyed in the BDOL can therefore be used as a coarse indicator (or index) of abundance. During the survey period (2008-2010), there was no indication of an increase or decrease in abundance at the sites surveyed in the BDOL and abundance varied significantly with site, salinity and depth. To assess trends in green crab abundance in the next decades, future surveys must use the standard protocol established by the AIS green crab working group (National AIS monitoring protocol) and focus on areas including the sites already surveyed. Only then can we assess if the apparent decline in green crab abundance between 1999, 2000 and 2005 as reported in Tremblay et al. (2006) was indeed related to increased predation and/or periods of sporadic colder winter temperature. If winter temperature increases, it is unlikely that the green crab will be extirpated from the BDOL and eradication attempts at this scale will not likely be successful. Catch rates will only decrease with intense and concentrated trapping, reducing the average size of green crabs, and eventually, after three years, the size of the population (DFO 2011). Targeted removal of ovigerous green crab could be an effective method to control populations of green crab. Sustained bait fisheries or well-developed management practices are more likely to be successful in reducing destruction of eelgrass beds and predation on shellfish aquaculture or harvesting sites in the BDOL, than on the Atlantic coast of NS or in Newfoundland where green crabs are currently more abundant. The BDOL is a unique and fragile ecosystem (in Nilsson and Grelsson 1995 *sensus)*, currently under many pressures, including invasive species such as the oyster disease MSX and green crabs, and it has recently received designation as a UNESCO Biosphere Reserve. Continuous monitoring is thus crucial to assess abundance and impacts of green crab and for early detection of new invasive species.

ACKNOWLEDGEMENTS

We would like to acknowledge Shauna Gould and Piel Paul for their enthusiastic help in trapping and measuring green crabs. Special thanks to Barbara Sylliboy for the Mikma'q translation, to John Tremblay for providing data from previous surveys and to Dawn Sephton and Cynthia McKenzie who reviewed the report. This survey was funded under the DFO's Aquatic Invasive Species monitoring program.

References

Anger, K., E. Spivak and T. Luppi. 1998. Effects of reduced salinities on development and bioenergetics of early larval shore crab, *Carcinus maenas*. J. Exp. Mar. Biol. Ecol. 220: 287-304.

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

Audet, D., G. Miron and M. Moriyasu, 2008. Biological characteristics of a newly established green crab (*Carcinus maenas*) population in the southern Gulf of St. Lawrence, Canada. Journal of Shellfish Research 27(2):427-441.

Behrens Yamada, S. and G.E. Gillespie. 2008. "Will the European green crab (*Carcinus maenas*) persist in the Pacific Northwest?" ICES J. Mar. Sci. 65: 725-729.

Berrill, M. 1982. The life cycle of the green crab *Carcinus maenas* at the northern end of its range. J. Crustacean Biol. 2: 31-39.

Bravo, M.A., B. Cameron and A. Metaxas. 2007. Salinity tolerance in the early larval stages of *Carcinus maenas* (Decapoda, Brachyura), a recent invader of the Bras d'Or lakes, Nova Scotia, Canada. *Crustaceana* 80: 475-490.

Breen, E. and A. Metaxas. 2009. Overlap in the distributions between indigenous and non-indigenous decapods in a brackish micro-tidal system. Aquatic Biol. 8: 1-13.

Cameron, E.H. 2003. Recruitment of the invasive green crab, *Carcinus maenas*, in Nova Scotia. Thesis (M.Sc.) Dalhousie University, Halifax, Man. 93 p.

Cameron, B. and A. Metaxas. 2005. Invasive green crab, *Carcinus maenas*, on the Atlantic coast and in the Bras d'Or Lakes of Nova Scotia, Canada: larval supply and recruitment. J. Mar. Biol. Assoc. U.K. 85: 847-855.

Carlton, J.T. 1989. Man's role in changing the face of the ocean: biological invasions and implications for conservation of near-shore environments. Conserv. Biol. 3: 265-273.

Colautti, R.I., S.A. Bailey, C.D.A. van Overdijk, K. Admunsen and H.J. MacIsaac. 2006. Characterised and projected costs of nonindigenous species in Canada. Biological Invasions 8: 45-59.

Davis, R.C., F.T. Short and D.M. Burdick. 1998. Quantifying the effects of green crab damage to eelgrass transplants. Restoration Ecol. 6: 297-302.

DFO. 2011. Ecological Assessment of the Invasive European Green Crab (*Carcinus maenas*) in

Newfoundland 2007-2009. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2010/033.

Floyd, T. and J. Williams. 2004. Impact of green crab (*Carcinus maenas* L.) predation on a population of soft-shell clams (*Mya arenaria* L.) in the southern Gulf of St. Lawrence. J. Shellfish Res. 23: 457-462.

Gillespie, G.E., Phillips, A.C., Paltzat, D.L., and Therriault, T.W. 2007. Status of the European green crab, *Carcinus maenas*, in British Columbia - 2006. Can. Tech. Rep. Fish. Aquat. Sci. 2700: vii + 39 p.

Grosholz, E.D. and G.M. Ruiz. 1996. Predicting the impact of introduced marine species: lessons from the multiple invasions of the European green crab *Carcinus maenas.* Biol. Cons.78: 59-66.

Hellmann J.J., J.E. Byers, B.G. Bierwagen, J.S. Dukes. 2008. Five potential consequences of climate change for invasive species. Conserv. Biol. 22:534–43.

International Maritime Organization (IMO). 2006. Global Ballast Water Management Programme. Ten of the Most Unwanted. Online at http://globallast.imo.org/poster4_english.pdf.

Jensen, G.C., P.S. McDonald and D.A. Armstrong. 2007. Biotic resistance to green crab, *Carcinus maenas*, in California bays. Mar. Biol. 151:2231–2243

Klassen, G. and A. Locke. 2007. A biological synopsis of the European green crab, *Carcinus maenas*. Can. Manuscr. Rep. Fish. Aquat. Sci. no. 2818: vii+75pp.

Lodge, D.M. 1993. Biological invasions: lessons for ecology. Trends Ecol. Evolut. 8: 133-137.

McDonald, P.S., G.C. Jensen and D.A. Armstrong. 2004. Between a rock and a hard place: The ecology of ovigerous green crab, *Carcinus maenas* (L.), with emphasis on implications for monitoring and control efforts. J. Shellfish Res. 23: 657.

MacPhail, J.S. 1953. Abundance and distribution of the green crab – a clam predator. In: Needler, A.W.H. Fisheries Research Board of Canada, Report of the Atlantic Biological Station for 1953. p. 33-34.

Malyshev, A. and P.A. Quijón. 2011. Disruption of essential habitat by a coastal invader: new evidence of the effects of green crabs on eelgrass beds. ICES Journal of Marine Science, 68: 1852–1856.

Miller, R.J. 1990. Effectiveness of crab and lobster traps. Canadian Journal of Fisheries and Aquatic Science, 47, 1228-1251.

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. Shellfish Res. 24: 579-586.

Nilsson, C. and G. Grelsson. 1995. The Fragility of Ecosystems: A Review. J. Appl. Ecol. 32: 677-692.

Parker, M., M. Westhead, P. Doherty and J. Naug. 2007. Ecosystem Overview and Assessment Report for the Bras d'Or Lakes, Nova Scotia. Can. Manuscr. Rep. Fish. Aquat. Sci. no. 2789: xvii+223pp.

Petrie, B. and G. Bugden 2002. The physical oceanography of the Bras d’Or Lakes. Proc. N. S. Inst. Sci. 42: 9-36.

Roman, J. 2006. Diluting the founder effect: cryptic invasions expand a marine invader's range. Proc. R. Soc. Lond. [Biol.] 273: 2453-2459.

Rossong, M.A., P.J. Williams, M. Comeau, S.C. Mitchell and J. Apaloo. 2006. Agonistic interactions between the invasive green crab, *Carcinus maenas* (Linnaeus) and juvenile American lobster, *Homarus americanus* (Milne Edwards). J. Exp. Mar. Biol. Ecol. 329: 281-288.

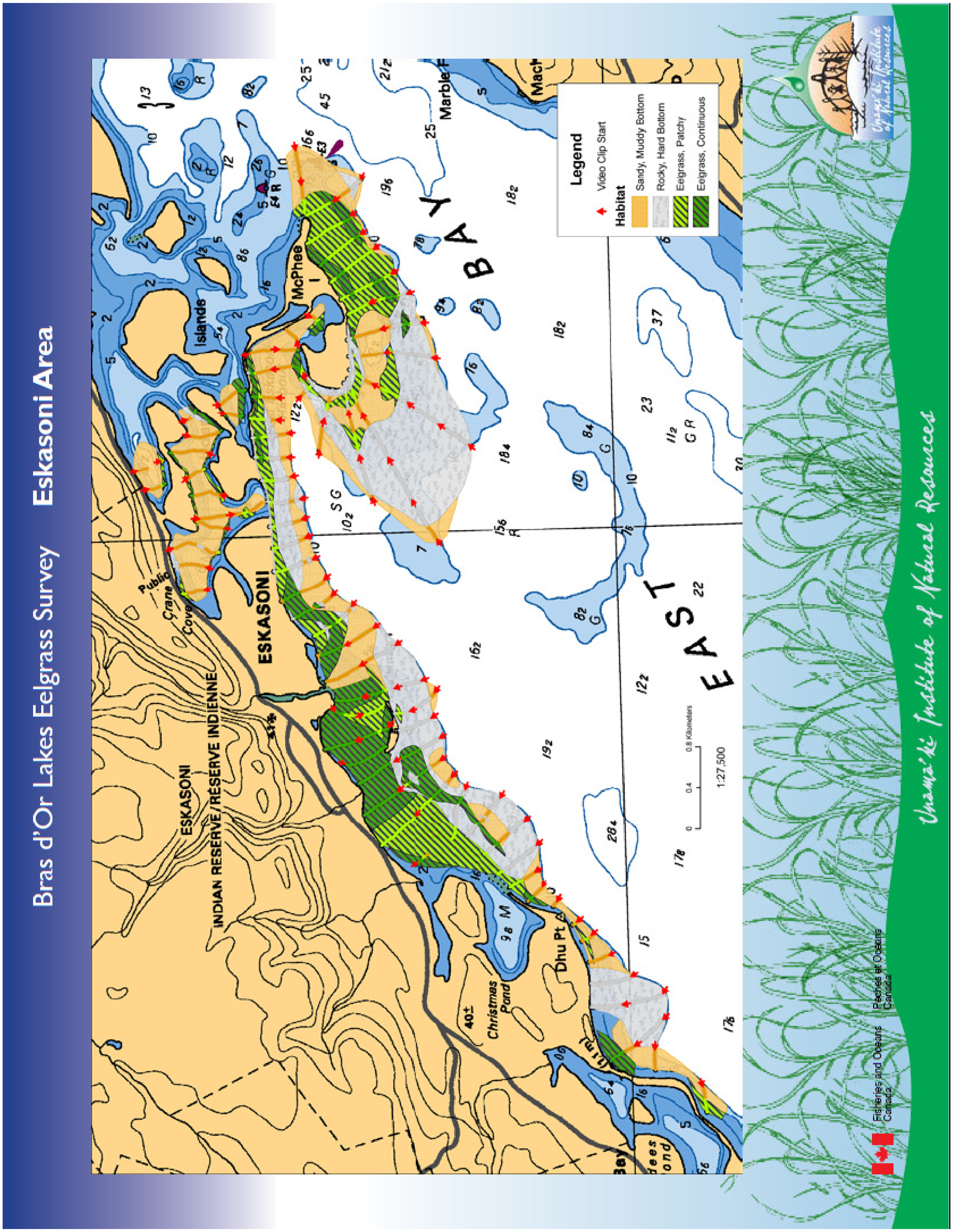
Seymour, N.R, A.G. Miller and D.J. Garbary. 2002. Decline of Canada geese (*Branta canadensis*) and common goldeneye (*Bucephala clangula*) associated with a collapse of eelgrass (*Zostera marina*) in a Nova Scotia estuary. Helgol. Mar. Res. 56: 198-202.

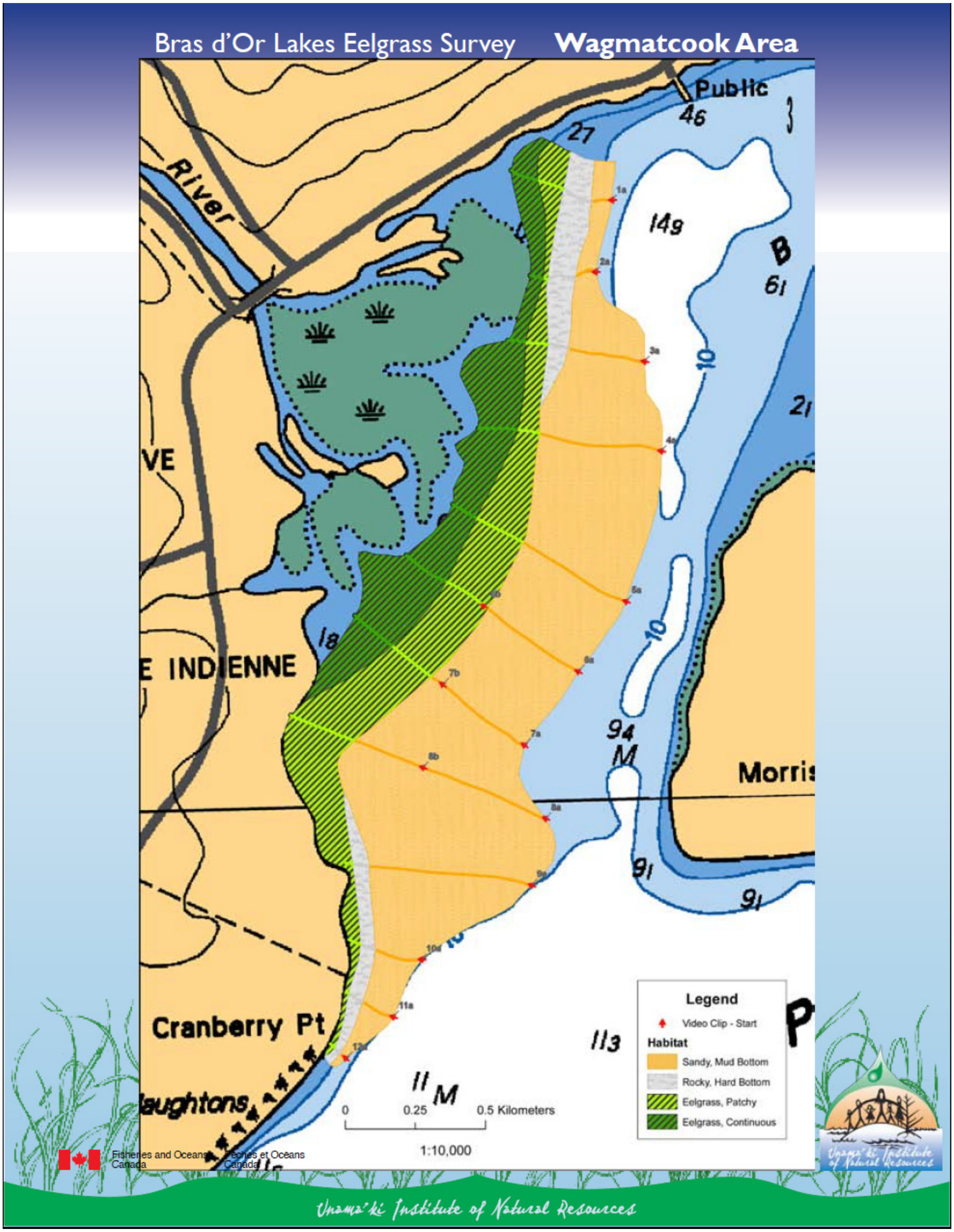
Therriault, T.W.; Herborg, L.M.; Locke, A.; McKindsey, C.W. 2008. Risk assessment for European green crab (*Carcinus maenas*) in Canadian waters. Can. Sci. Advis. Sec. Res. Doc. 2008/042.

Tremblay, M.J., A. Thompson and T. Paul. 2006. Recent trends in the abundance of the invasive green crab (*Carcinus maenas*) in Bras d’Or Lakes and eastern Nova Scotia based on trap surveys. Can. Tech. Rep. Fish. Aquat. Sci. Tech. Rep. 2673: 32 p.

Williams, P.J., T. Floyd and M. Rossong. 2006. Agonistic interactions between invasive green crabs, *Carcinus maenas* (Linnaeus), and sub-adult American lobsters, *Homarus americanus* (Milne Edwards). J. Exp. Mar. Biol. Ecol. 329: 66-74.

Appendix 1. Bras d'Or Lakes near shore survey maps.

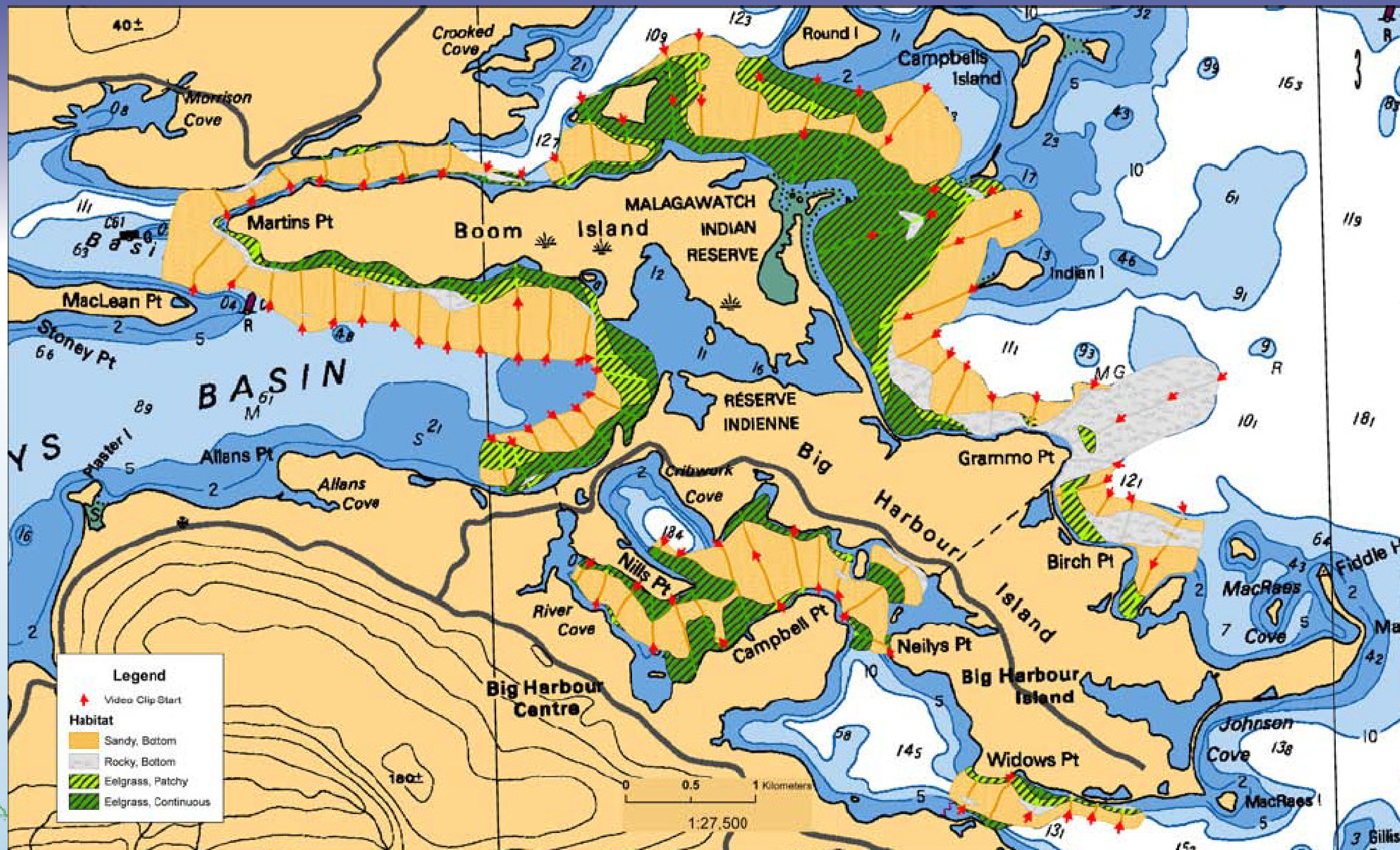




Bras d'Or Lakes Eelgrass Survey
Wagmatcook Area
Public
River
E INDIENNE
Cranberry Pt
Morris
Legend
Video Clip - Start
Habitat
Sandy, Mud Bottom
Rocky, Hard Bottom
Eelgrass, Patchy
Eelgrass, Continuous
0 0.25 0.5 Kilometers
1:10,000
Fisheries and Oceans Canada
Pêches et Océans Canada
Unama'ki Institute of Natural Resources


Bras d'Or Lakes Eelgrass Survey
We'koqma'q Area
WHYCOCOMAGH
MAGH
RESERVE
ERVE INDIENNE
Indian Island
IR
Pooles
Pond
Legend
Video Clip Start
Habitat
Sandy, Mud Bottom
Rocky, Hard Bottom
Eelgrass, Patchy
Eelgrass, Continuous
Worm Field
0
0.25
0.5 Kilometers
1:15,000
Fisheries and Oceans Canada
Pêches et Océans Canada
Unama'ki Institute of Natural Resources

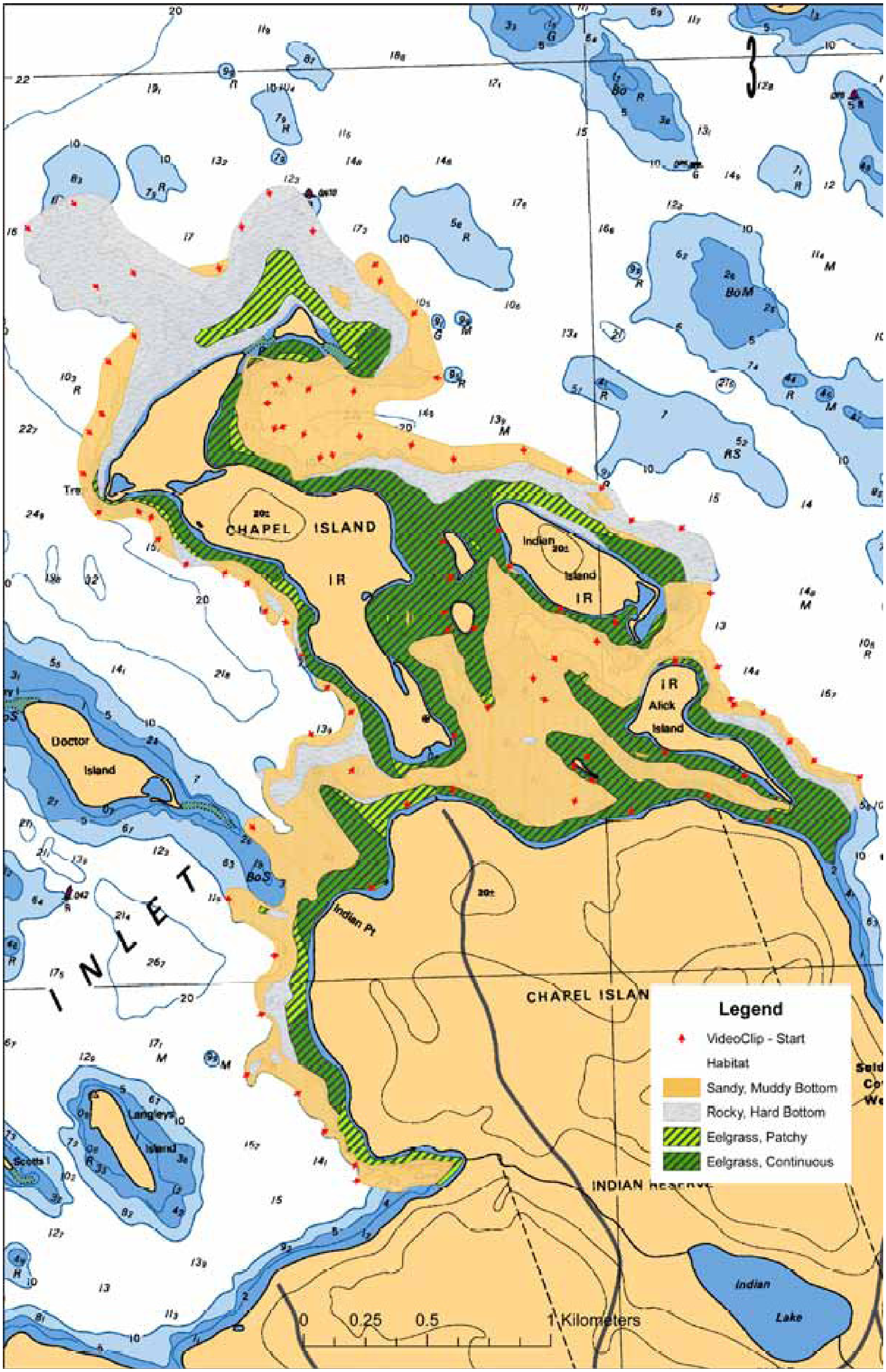
Bras d'Or Lakes Eelgrass Survey **Malagawatch Area**



Fisheries and Oceans Canada | Pêches et Océans Canada

Unama'ki Institute of Natural Resources

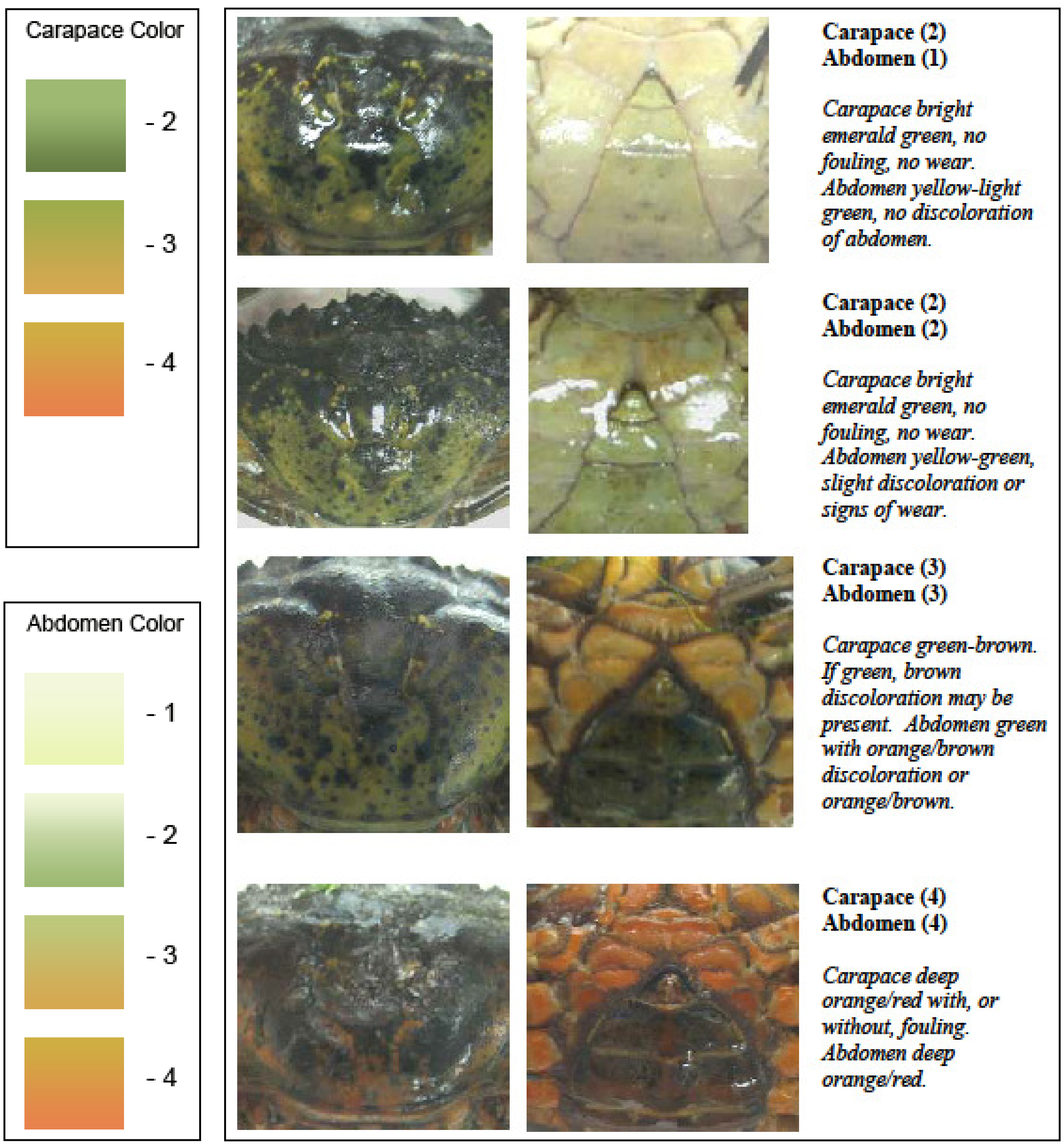
Bras d'Or Lakes Nearshore Bottom-Type Map: **Potlotek**



Appendix 2. GPS coordinates of trapping locations.

Station	GPS coordinates (decimal degrees)	
	Latitude	Longitude
Amuguadees	45.914	-60.657
Baddeck	46.071	-60.775
Chapel Island	45.709	-60.775
Eskasoni	45.937	-60.620
Gillis Cove	45.910	-61.054
Malagawatch	45.885	-60.967
Wagmatcook	46.071	-60.908
Waycobah	45.965	-61.117

Appendix 3. Color code reference and examples.



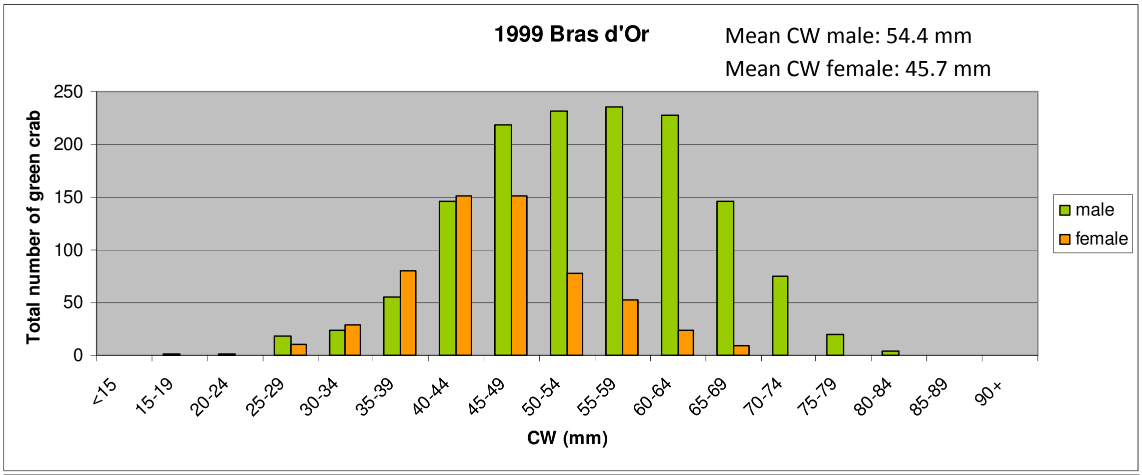
Appendix 4. Summary of green crab (GC) trapping: Total catch by location, sampling date, habitat and sex and number of trap (#).

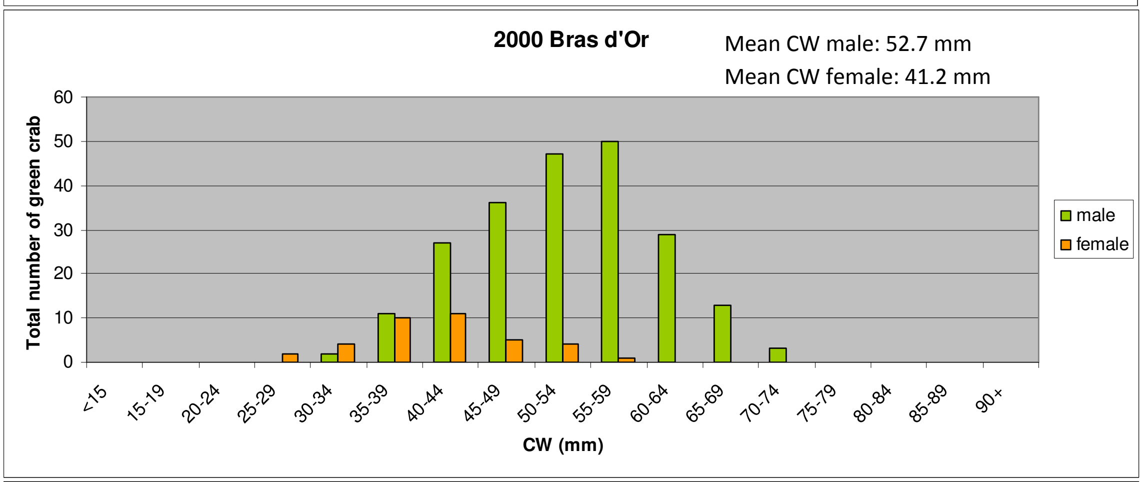
		Continuous			Patchy			Sandy/Rocky			Total number of	
Location	Date In	F	M		F	M		F	M		GC	traps
	2008			#			#			#		#
Chapel Island	5-Sep-08	3	4	3		6	3				13	6
	16-Sep-08	5	11	3	13	34	3				63	6
	14-Oct-08	7	15	3	17	23	3				62	6
Eskasoni	21-Jul-08	48	28	3	110	17	3				203	6
	18-Aug-08	18	21	3	21	33	3				93	6
	17-Sep-08	18	15	3	54	9	3				96	6
	15-Oct-08	5	16	3	4	11	3				36	6
Wagmatcook	29-Jul-08	4	5	3		3	3				12	6
	27-Aug-08			3	4		3				4	6
	22-Sep-08	4	1	3		1	3				6	6
	20-Oct-08	13	3	3	2		3				18	6
We’koqma’q	30-Jul-08	1	3	3	2	8	3				14	6
	28-Aug-08		1	3	3		3				4	6
	23-Sep-08	8		3			3				8	6
	21-Oct-08	6	5	3		1	3				12	6
	2009											
Amuguadees	13-May-09			3			3				0	6
	8-Sep-09			3	1	1	3				2	6
Baddeck	15-Jun-09		1	3			3				1	6
Chapel Island	28-May-09	62	94	3	37	54	3				247	6
	13-Aug-09	7	56	3	2	17	3				82	6
	26-Aug-09	9	13	3	3	3	3				28	6
	8-Oct-09	17	21	3	8	20	3				66	6
Eskasoni	12-May-09	2		6	2	2	6				6	12
	2-Jun-09	22	49	6				8	39	6	118	12
	3-Jun-09				8	23	6	2	9	6	42	12
	24-Jun-09	5	90	3	1	16	3		26	6	138	12
	9-Jul-09	8	40	3	3	44	3	3	21	6	119	12
	28-Jul-09	62	90	9	22	50	3				224	12
	18-Aug-09	7	26	6	10	23	3				66	9
	8-Sep-09	2	25	3	4	6	3				37	6
	29-Sep-09	3	6	3	10	20	3				39	6
	21-Oct-09	1	8	3	12	12	3				33	6
Gillis Cove	27-May-09			3	7	7	3				14	6
	21-Jul-09	2		3		3	3				5	6
	25-Aug-09	1	8	3	2	1	3				12	6
	7-Oct-09	1	4	3	3	3	3				11	6
Malagawatch	27-May-09	9	13	3	11	38	3				71	6
Wagmatcook	11-Jun-09	3	3	3		2	3				8	6
	20-Jul-09	12	7	3	15	37	3				71	6
	1-Sep-09			3		10	3				10	6
	14-Oct-09	4	3	3			3				7	6
We’koqma’q	11-Jun-09			3			3				0	6
	20-Jul-09	5	19	3	11	15	3				50	6
	1-Sep-09		2	3	1	1	**3**				4	6
	14-Oct-09	6	2	3	2	8	3				18	6

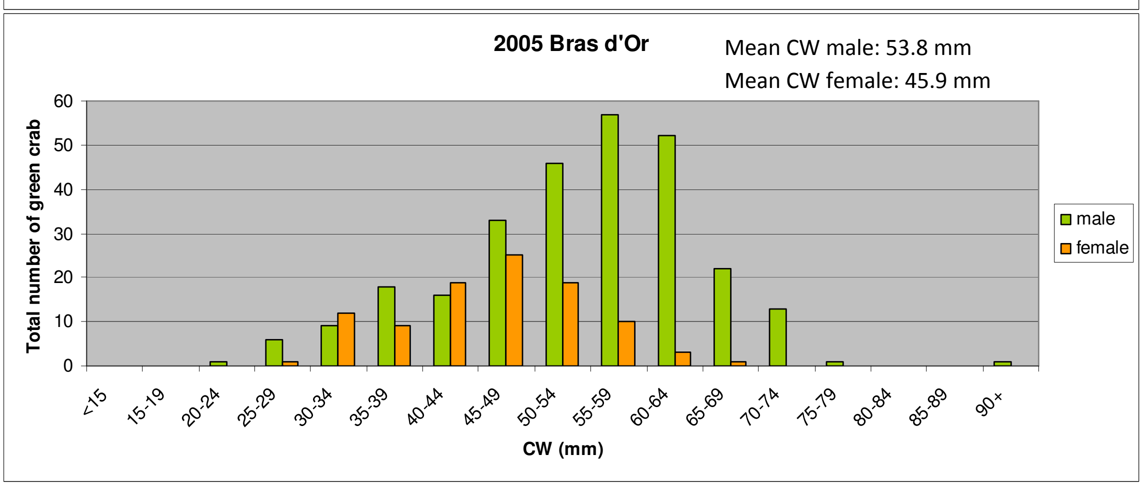
Appendix 4. Continued.

		Continuous			Patchy			Sandy/Rocky			Total GC	Number of traps
Location	Date In	F	M		F	M		F	M			
	2010			#			#			#		#
Chapel Island	14-Jun-10		13	3		9	3				22	6
	28-Jun-10	1	12	3		11	3				24	6
	13-Jul-10	8	24	3	3	24	3				59	6
	11-Aug-10		15	3		24	3				39	6
	31-Aug-10	2	9	3	2	28	3				41	6
	28-Sep-10	5	5	3	20	40	3				70	6
	12-Oct-10	4	1	3	7	13	3				25	6
	2-Nov-10	9	26	3	12	28	3				75	6
Eskasoni	17-May-10	7	24	3	6	21	3				58	6
	2-Jun-10		4	3	1	24	3				29	6
	16-Jun-10		14	3		11	3				25	6
	28-Jun-10		17	3	1	15	3				33	6
	13-Jul-10	5	18	3	21	28	3				72	6
	26-Jul-10	11	37	3	7	16	3				71	6
	11-Aug-10		4	3		16	3				20	6
	31-Aug-10	4	14	3	5	11	3				34	6
	28-Sep-10	19	18	3	7	6	3				50	6
	12-Oct-10	9	18	3	22	32	3				81	6
Wagmatcook	22-Jun-10		1	3		2	3				3	6
	19-Jul-10	3	9	3	6	23	3				41	6
	17-Aug-10			3		5	3				5	6
	16-Sep-10			3	1	19	3				20	6
	28-Oct-10	21	16	3	6	33	3				76	6
We'koqma'q	22-Jun-10		1	3			3				1	6
	19-Jul-10		4	3	1		3				5	6
	17-Aug-10	1	3	3		8	3				12	6
	16-Sep-10	1	3	3		1	3				5	6
	28-Oct-10	6	6	3	11	10	3				33	6
Total		506	1024		544	1018		13	95		3202	477

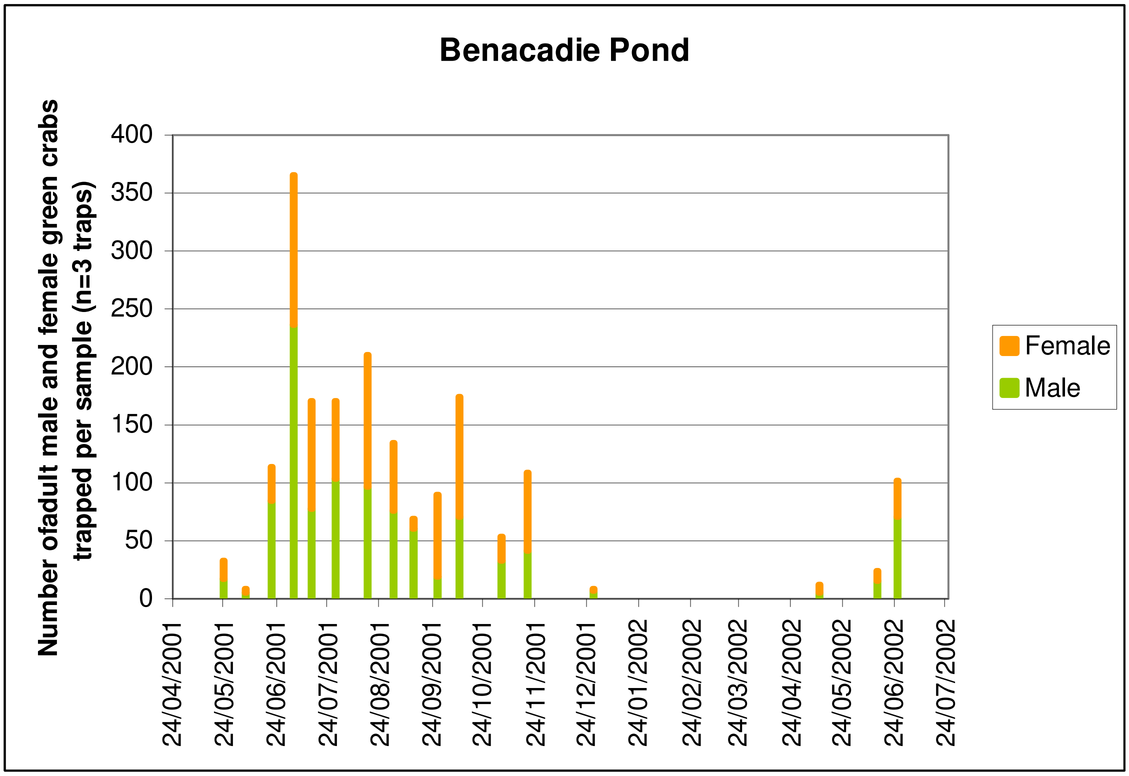
Appendix 5. Size frequency distributions of male and female adult green crab captured in the BDOL. Data between 1999 and 2005 from Tremblay et al. (2006).



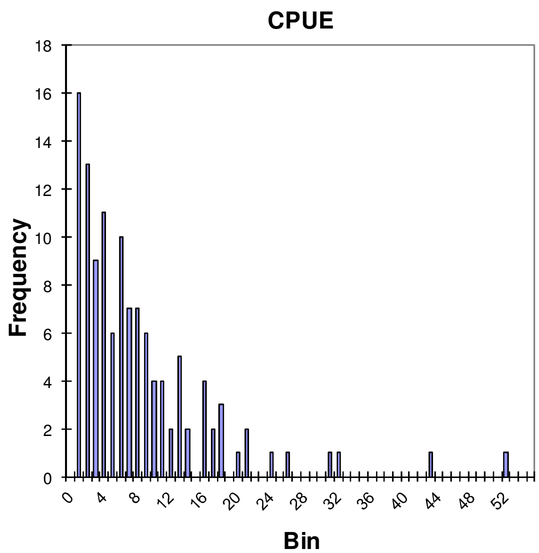


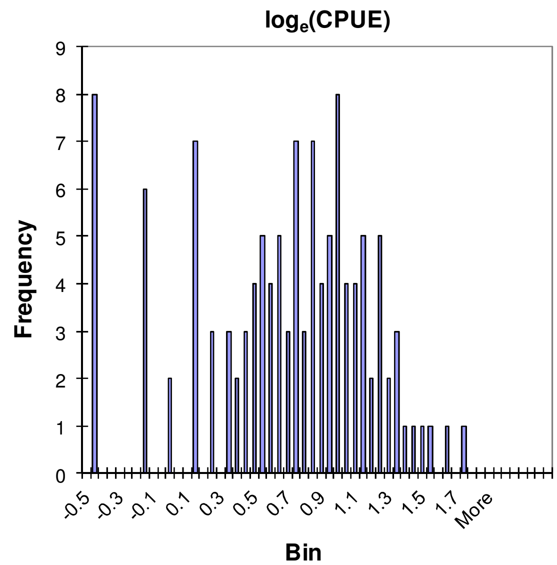


Appendix 6. Number of adults captured per sample at Benacadie, BDOL.
Data from Cameron and Metaxas (2005) and Cameron (2003) from May to June 2002.



Appendix 7. CPUE analysis of variance.

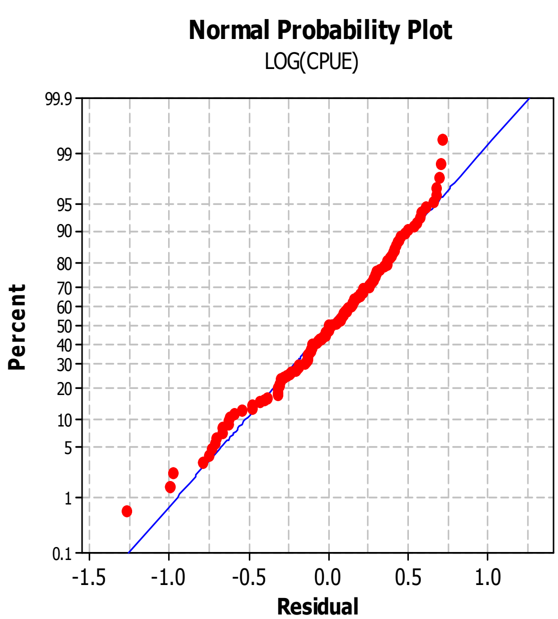


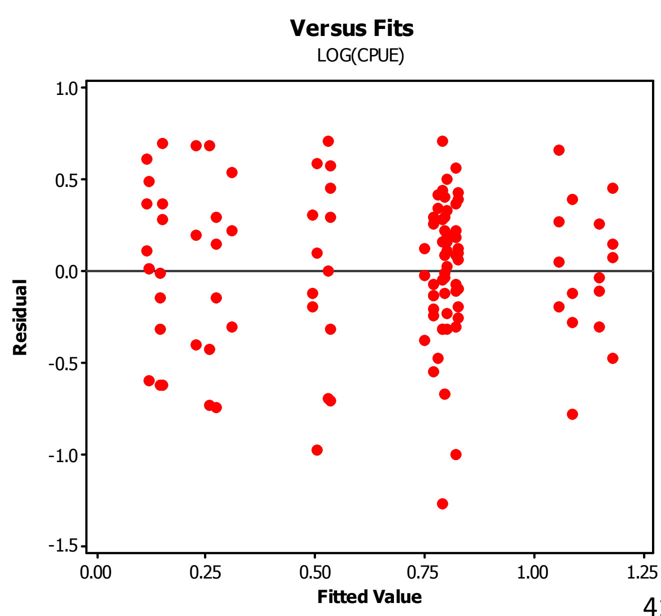


Results for: BDOL all years

General Linear Model: LOG(CPUE) versus LOCATION, YEAR, COVERAGE

```
Factor    Type   Levels  Values
LOCATION  fixed       4  Chapel Island, Eskasoni, Wagmatcook, We'koqma'q
YEAR      fixed       3  2008, 2009, 2010
COVERAGE  fixed       2  C, P
Analysis of Variance for LOG(CPUE), using Adjusted SS for Tests
Source          DF   Seq SS   Adj SS  Adj MS      F      P
LOCATION         3   9.4342   9.7243  3.2414  17.47  0.000
YEAR             2   0.1446   0.1723  0.0862   0.46  0.630
COVERAGE         1   0.0300   0.0295  0.0295   0.16  0.691
LOCATION*YEAR    6   2.0025   2.0025  0.3338   1.80  0.106
Error          107  19.8480  19.8480  0.1855
Total          119  31.4593
S = 0.430692   R-Sq = 36.91%   R-Sq(adj) = 29.83%
Unusual Observations for LOG(CPUE)
Obs  LOG(CPUE)      Fit   SE Fit  Residual  St Resid
 37   -0.47712  0.79039  0.10891  -1.26752     -3.04 R
 46   -0.17609  0.82185  0.10891  -0.99794     -2.39 R
103   -0.47712  0.50346  0.16006  -0.98058     -2.45 R
R denotes an observation with a large standardized residual.
```





General Linear Model: LOG(CPUE) versus COVERAGE

Factor	Type	Levels	Values
COVERAGE	fixed	2	C, P

Analysis of Variance for LOG(CPUE), using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
COVERAGE	1	0.0250	0.0193	0.0193	0.08	0.781
temp	1	0.0443	0.0161	0.0161	0.07	0.799
sal	1	1.3666	1.3666	1.3666	5.53	0.020
Error	114	28.1841	28.1841	0.2472		
Total	117	29.6201				

Results for: Eskasoni 2009
General Linear Model: LOG(CPUE) versus COVERAGE

Factor	Type	Levels	Values
COVERAGE	fixed	3	C, P, RS

Analysis of Variance for LOG(CPUE), using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
COVERAGE	2	0.86905	0.86905	0.43453	7.63	0.017
Error	7	0.39842	0.39842	0.05692		
Total	9	1.26747				

S = 0.238572   R-Sq = 68.57%   R-Sq(adj) = 59.58%