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# Overview analyses of the Community Aquatic Monitoring Program (CAMP) in the Basin Head Lagoon from 2002 to 2008

# Vue d'ensemble des analyses du Programme de Surveillance de la Communauté Aquatique (PSCA) dans la lagune de Basin Head de 2002 à 2008

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## ABSTRACT

An analysis was conducted of littoral nekton data collected in Basin Head Lagoon, Prince Edward Island (PEI), through the Community Aquatic Monitoring Program (CAMP) for the years 2002 to 2008. The objective was to determine whether a recent decline in abundance of the distinct variant of Irish moss (*Chondrus crispus*) could be explained by, or might be correlated with, changes in fauna. Samples of nearshore fish, crabs and shrimp are obtained monthly, May to September, by beach seine at six stations around the main lagoon. Additional data collected include water temperature, salinity, oxygen content, substrate type and coverage of submerged aquatic vegetation. Abundance and richness of fish and crustaceans were lowest in 2006 followed by increased abundance of certain species (sand shrimp – *Crangon septemspinosa*, mummichog – *Fundulus heteroclitus*, Atlantic silverside – *Menidia menidia*, smooth flounder – *Pleuronectes putnami*, and green crab – *Carcinus maenas*) to their highest levels in the seven years of monitoring. Different community assemblages were found in Basin Head in 2007 and 2008 compared to the earlier years, a pattern driven by higher abundance of sand shrimp in 2007 and 2008, higher abundance of young-of-the-year mummichog in 2008 and fewer fourspine stickleback (*Apeltes quadracus*) in 2007 and 2008. The two last years were also warmer than the three previous years and eelgrass (*Zostera marina*) coverage declined in the last year. Comparison between Basin Head and the other sites sampled in Prince Edward Island showed that Basin Head differed from the other sites primarily by having the highest number of green crab every year since 2004. Increases in green crab abundance may have contributed to the decline in Irish moss.

## RÉSUMÉ

Une analyse a été effectuée sur les données littorales de necton récoltées à Basin Head, Île-du-Prince-Édouard (IPE), entre 2002 et 2008 par le biais du Programme de Surveillance de la Communauté Aquatique (PSCA). L'objectif était de déterminer si le récent déclin de la souche distincte de mousse d'Irlande (*Chondrus crispus*) retrouvée à Basin Head pouvait être expliqué en partie par les changements ou tendances retrouvés dans l'assemblage faunique échantillonné par le PSCA. Le PSCA échantillonne les poissons, crabes et crevettes retrouvés près des côtes avec une seine de plage mensuellement de mai à septembre à six stations autour de la lagune principale. En outre des observations de la température de l'eau, la salinité, le contenu en oxygène dissout, le type de substrat et la couverture de la végétation aquatique submergée sont aussi notées. L'abondance et la richesse en poissons et en crustacés étaient à leur niveau le plus bas en 2006 suivit d'une augmentation dans l'abondance de certaines espèces (crevette de sable - *Crangon septemspinosa*, choquemort - *Fundulus heteroclitus*, capucette d'Atlantique - *Menidia menidia*, plie lisse - *Pleuronectes putnami*, et crabe vert - *Carcinus maenas*) à leurs niveaux les plus élevés durant les sept années de surveillance de ce programme. Différents assemblages de la communauté ont été retrouvés à Basin Head en 2007 et 2008 comparativement aux années précédentes, un patron caractérisé par une abondance accrue de crevette de sable en 2007 et 2008, une abondance accrue de choquemort (jeune-de-l'année) en 2008 et une diminution d'épinoche à quatres épines (*Apeltes quadracus*) en 2007 et 2008. Durant les deux dernière années, les températures de l'eau étaient plus chaudes comparativement aux trois années précédentes et la couverture de zostère marine (*Zostera marina*) a diminué dans la dernière année. Une comparaison entre Basin Head et les autres sites échantillonnés à IPE, a démontré que Basin Head différait des autres sites principalement en ayant la plus grande abondance de crabe vert pour toutes les années depuis 2004. L'augmentation de l'abondance du crabe vert aurait possiblement contribué au déclin de la mousse d'Irlande.

## INTRODUCTION

The *Oceans Act* (Section 32 (d)) commits the Department of Fisheries and Oceans (DFO) to work collaboratively with a range of stakeholders *"to establish marine environmental quality guidelines, objectives and criteria respecting estuaries, coastal waters and marine waters."* In 2003, the Stewardship and Environmental Science Sections that existed at the time in the DFO Gulf Region developed a monitoring program to assist in determining and monitoring the ecological health of estuaries and bays in the southern Gulf of St. Lawrence (sGSL). The outcome was the development of the Community Aquatic Monitoring Program (CAMP). One of the aims of this program was to develop an index of the ecological health of an estuary, bay or coastal shoreline by looking at the diversity and relative abundance of fish and crustacean species. For example, an estuary which has been degraded by human activity may have fewer species and fewer fish in total than one which is relatively healthy and unperturbed by human activity. The species assemblage of a particular estuary may change over time, which could reflect environmental perturbations that need to be addressed. It was recognized at the outset that such questions could only be answered after many years of data collection and observation of trends in the community assemblage. Key objectives of CAMP were: 1) provide an outreach program for the DFO to interact with Environmental Non-Governmental Organizations (ENGOs) to raise awareness of the ecology of estuaries and bays; 2) collect baseline data of coastal species on abundance, diversity and community assemblages for future comparisons; and, 3) test the potential of a community-led program for monitoring coastal health in the sGSL.

To help develop this monitoring program, a pilot project was set up during the summer of 2003 at four sites within three provinces bordering the sGSL. The four pilot sites were Lamèque and Shediac in New Brunswick (NB), Antigonish in Nova Scotia (NS) and Basin Head in Prince Edward Island (PEI). Basin Head was chosen because at the time it was an Area of Interest (AOI) in the Marine Protected Areas (MPA) program under the *Oceans Act.* Basin Head has since officially become a MPA in October 2005.

Measurement of marine environment quality is important in assessing the impact of any type of point or non point source pollution such as agricultural runoff or management measures such as those instituted for protecting and conserving the distinct strain of Irish moss (*Chondrus crispus*) found in Basin Head. Using beach seining techniques in 2003, employees of the DFO Oceans and Science Branch in Moncton (NB), worked with members of local community groups, as well as DFO personnel from the area office in Charlottetown. Prior to the launching of the pilot project in 2003, a preliminary sampling of the fish in the littoral zone of Basin Head Lagoon (Fig. 1) was carried out in September 2002. Since its full inception in 2004, CAMP has extended to over 29 bays and estuaries across the sGSL and has continued to sample Basin Head annually. We now have seven years of data on nekton (animals living in shallow coastal waters) of Basin Head Lagoon. From these seven years, five (2004 to 2008) followed the standardized CAMP protocol in which sampling occurs at six stations monthly from May to September.

The form of Irish moss found in Basin Head lagoon is considered distinct because it does not attach to the bottom but instead is held by byssal threads of mussels. This distinct form is also found almost exclusively in the nonsexual reproductive stage, reproducing by fragmentation. The Basin Head seaweed also has broad flat fronds compared to narrow dichotomous branching fronds of the plant in the open coast (DFO 2009). As early as 1980, decline in this distinct Irish moss bed located in the northeast arm of Basin Head was monitored through different studies (McCurdy 1980, Judson et al. 1987) and aerial photography (Sharp et al. in prep). The change in abundance and condition of this distinctive seaweed in Basin Head led Oceans and Habitat Management section to ask advice from the Science section regarding the potential cause(s) of decline of Irish moss in Basin Head. In response to the science review of the status of Basin Head Marine Protected Area, the scientists involved in CAMP were asked to present results from data collected up until now to determine if changes in the littoral nekton community monitored through CAMP could explain the Irish moss decline.

The objective of this paper is to analyze the CAMP data collected in Basin Head and in particular to determine whether the littoral nekton community showed any changes coincident with the reduction in Irish moss abundance and conditions which might suggest a cause for the reduction.

## METHODS AND MATERIALS

### STUDY SITE

Basin Head lagoon is located on the south side of the north eastern tip of PEI and was selected for CAMP monitoring because at the time it was proposed as the first MPA in the sGSL (Fig. 1). The Basin Head lagoon watershed is relatively small (17.5 $km^2$), surrounded by land and separated from the ocean by a barrier sand dune. The lagoon is comprised of a 0.24 $km^2$ main basin where most of the sampling for CAMP was done, a 2.9 km long northeast arm where the distinct strain of Irish moss is found and a 0.5 km channel leading to the ocean (Sharp et al. 2003). The watershed is used primarily for agriculture (Island Nature Trust 2001). Basin Head lagoon is shallow with a maximum depth of 3.3 m (Sharp et al. 2003). The lagoon also hosts a large population of invasive green crabs (*Carcinus maenas*) (Audet et al. 2003) and a distinct strain of Irish moss, the latter found mainly in the shallow water of the northeast arm (Sharp et al. 2003).

### STATION SELECTION FOR CAMP

The sampling stations were chosen to be distributed throughout the main basin which could easily be accessed by car or boat. Ability to sample by beach seine was also a factor that determined the location of stations. A requirement of CAMP was for each station to contain eelgrass beds or to be favorable habitat for eelgrass. All stations within the Basin Head lagoon shared approximately the same depth, salinity, temperature, substrate type and vegetation. Seven stations were sampled in 2002 and 2003. After 2003, station 7 was dropped from the program because of accessibility and safety problems, and also because CAMP recommended six stations per site to ensure sampling completion within a single day (Thériault et al. 2006).

### COMMUNITY SAMPLING

Monthly daytime sampling was done in September 2002, July to October 2003 and from May to September 2004 to 2008 with the exception of May 2007 when insufficient personnel were available for sampling. Sampling was also done around high tide as much as possible and was not done at extreme low tides. One beach seine haul was done at each of the six stations with a beach seine of 30 m X 2 m, 6 mm mesh size, and a central bag measuring 2 m X 1 m. The net was walked out perpendicular to shore 15 m then 15 m parallel to shore and then back into shore for an area sampled of 225 $m^2$. Once the seine was hauled back to shore, all captured fish and crustaceans were placed in an aerated fish tub. These animals were identified to the closest species or genus, separated by developmental growth stage (young-of-the-year (YOY) or adult), counted and released live back into the water. Young-of-the-year were distinguished from adults by length which was clear at the beginning of the summer (i.e., July) but became difficult by the end of sampling season (i.e. September, October) when the difference in length between YOY and 1 year olds became minimal. The mummichog was identified as a YOY when it measured ≤ 3 cm total length (Fritz and Garside 1975; Kneib and Stiven 1978). The Atlantic silverside was identified as YOY when ≤ 8 cm (Jessop 1983). The stickleback species including blackspotted, threespine, fourspine and ninespine were identified as YOY when ≤ 2 cm (Scott and Scott 1988). The sand shrimp were identified as YOY when ≤ 2 cm in total length (Corey 1981).

## HABITAT CHARACTERIZATION

Environmental data were also collected monthly after each beach seine haul to characterize habitat. Water temperature (ºC), salinity (ppt) and dissolved oxygen (mg / L) were measured with a portable hand held multi probe YSI 85. The YSI probe was submerged at mid-depth in the water column in mid-seine site and the data were recorded once the reading stabilized.

A substrate sample was taken monthly at each station in 2003 and then in September only from 2004 to 2008 to give an indication of organic content, humidity content and the grain size distribution. These different endpoints were calculated in the laboratory after the field season. Humidity content was determined by drying a sub-sample in an oven at 70ºC for 24 hours. Organic content was determined by placing the sediment sample in a muffle furnace at 500ºC for three hours. The grain size was characterized by shaking the sediment in a sieve shaker for 10 minutes. The sediments were fractioned in 2 mm, 1 mm, > 500 µm, > 250 µm, > 125 µm, > 63 µm, < 63 µm.

Submerged aquatic vegetation (SAV) coverage was measured within a 50 X 50 cm quadrat. The quadrat was randomly thrown three times within the area beach seine. The quadrat was divided into four equal subquadrats.  At each throw, each subquadrat was vieed and percent coverage by each SAV type was estimated.. Starting in 2007, a scale from 0 to 5 (0 = no vegetation present and 5 = 100% coverage) was used to estimate the percent coverage by each plant. In 2008, SAV was divided into nine categories which were used to simplify the plant and algae identification by the ENGOs. The nine categories included: 1) eelgrass (*Zostera marina*), 2) widgeon grass (*Ruppia maritima*), 3) green algae (*Ulva lactuca* and *Enteromorpha sp.,* green filamentous sp.), 4) brown filamentous (*Pilayella littoralis*), 5) rockweed (*Fucus* sp. and *Ascophyllum nodosum*), 6) common red seaweed (*Chondrus crispus*, *Polyides rotundus*, *Gracilaria tikvahiae*, *Dasya baillouviana,* red filamentous sp.) 7) common brown seaweed (smooth and rough tangle weed, *Scytosiphon* sp. *Chorda filum*), 8) kelp (*Laminaria* sp.) and 9) invasive species (*Codium fragile*). SAV coverage was not always possible when water was turbid and visibility poor.

## STATISTICAL ANALYSES

### Univariate analyses

Analysis of variance (ANOVA) was used to compare spatial (i.e., among stations) and temporal differences (i.e., among years) in the total abundance of animals and species richness in Basin Head. Data were examined for normality and homoscedasticity by probability plot and $F_{max}$ test, respectively. Data were transformed to $\log_{10}$ when normalization was required. Tukey multiple comparison tests were used when significant differences were found among groups. Significance level was set at p = 0.05. Univariate statistics and descriptive statistics were completed with SYSTAT 11 software ® (2004 SYSTAT Software Inc., Point Richmond, CA, USA). In 2002 the coastal fish and crustacean community was sampled only in September whereas in 2003, the pilot project sampled from July to October therefore these two first years are not comparable to the subsequent five years of data. Detailed statistical analyses were therefore restricted to the 2004 - 2008 data for univariate and multivariate analyses. All data were averaged across months for each station and the six stations were treated as replicates for the univariate statistics.

**Multivariate analyses**

Descriptive multivariate analyses were calculated with PRIMER 6.1.10. software ®. All data were also averaged across months for each station for the multivariate statistics. Data on the total number of animals captured were square root transformed to minimize the effect of the few dominant species and to include the effect of the rare species (Cao et al. 2001).

Transformed abundance data were used to generate a Bray-Curtis similarity matrix. The matrix contains similarity coefficients (S) with values in the range of 0 to 100% between each pair of samples. When S equals 100%, the two samples are totally similar and S = 0 when two samples are completely dissimilar (Clarke and Warwick 2001). The Bray-Curtis similarity matrix was then used to calculate the ANOSIM (analysis of similarity) which depends on the relative order (i.e., ranking) of the similarity coefficients in the Bray-Curtis similarity matrix, rather than their absolute values. The ANOSIM determined whether the fish and crustacean assemblages differed statistically among years and stations. The ANOSIM test statistic, R=Rho, is based on the ratio of the between-group to within-group similarity ranking and ranges from 0 to 1, with the value indicating the degree of dissimilarity (1 = completely dissimilar; 0 = completely similar). Pairwise comparison tests are also calculated which generates an R value and a significance (p) value for each possible pair of comparisons. The importance of the pairwise tests is not so much the significance level, which can be low because of few replicates in each group, but rather the R value which provides an absolute dissimilarity measure among the samples on a scale of 0 (indistinguishable) to 1 (completely dissimilar) (Clarke and Gorley 2001). R values that are equal or over 0.75 indicate that variables are well separated; R value between 0.74 and 0.5 indicated that variables are overlapping but different; R value between 0.49 and 0.25 indicated that the variables are overlapping but somewhat different; R value below 0.25 indicate that variables are overlapping and not different from one another (Clarke and Gorley 2001).

A non-metric Multi-Dimensional Scaling (MDS) plot was used to visualize the spatial relationships between the variables. The ranks of the Bray-Curtis similarity matrix are the only information used to generate an MDS plot. An MDS plot constructs a map of the samples in a specific number of dimensions (2-dimensions or 3-dimensions) which attempts to satisfy all the conditions imposed by the rank similarity matrix. The relative distance between samples is interpreted as a measure of their similarity. Points that are closer together represent samples that are very similar in species composition, and points that are far apart correspond to very different communities. The procedure also reports a stress level which is a measure of accuracy in representation of the MDS. By definition, stress level increases with reduced dimensionality and also with increasing quantity of data. The acceptance level of stress for a 2-D MDS graph is set to $< 0.2$, indicating that the MDS is a good to excellent representation with minimal risk of misinterpretation (Clarke and Gorley 2001).

The BEST routine was used for matching biotic data (abundance data) to environmental patterns. This method involves the following general steps: 1) construct a fixed similarity matrix of the animal assemblage among all stations, 2) construct multiple similarity matrices of the abiotic environmental variables among all stations for each abiotic variable singly, all possible pairs of abiotic variables, all possible triplets and so on until all possible matrices of abiotic environmental data are constructed for all permutations. BIOENV then searches for the abiotic similarity matrix that is the best match with the biotic similarity matrix. The assumption is that the suite of abiotic variables selected best 'explains' the fish pattern found at the stations (Clarke and Ainsworth 1993). The BEST routine is based on the rank correlation computed between the two matrices (e.g., Bray-Curtis similarity matrix for the biotic variables and the normalized Euclidean distance for the abiotic variable). A permutation test to calculate the statistical significance for the BEST test was also performed.

Prior to the BEST analyses, a Draftsman plot which calculates Pearson correlation coefficients between all pairs of variables, was done to test if there were any highly correlated abiotic variables and to verify which variables needed transformation for normality. The Draftsman plot showed that within the nine SAV categories, some of the rare vegetations were highly inter-correlated (e.g., common brown seaweed, kelp, and invasive species). Therefore, we included in the analyses only SAV that were most abundant, which includes: the eelgrass and the green algae, the latter comprising sea lettuce (*Ulva lactuca*), *Enteromorpha* sp. and green filamentous species. The BEST analysis was done with the following environmental data: water temperature, salinity, dissolved oxygen, eelgrass percent cover and green algae percent cover. These environmental variables were selected because they had been collected monthly since 2004. Other environmental variables sampled were not collected in all months (sediment humidity, organic content and grain size) so could not be included in the BEST analysis.

A similarity percentage routine called SIMPER was also used to determine which species contribute the most to the separation between two groups of samples. This routine decomposes average Bray-Curtis similarities between all pairs of samples and calculates the percentage dissimilarity contribution for each species

# RESULTS

## DESCRIPTIVE RESULTS FOR BASIN HEAD

Descriptive statistics were calculated with data from 2002 to 2008. A total of 170,367 fish and crustaceans representing seventeen species were captured in Basin Head between 2002 and 2008. Counts of each species per year, and species Latin and common names, are provided in Table 1. An average total abundance per beach seine haul of 866 (CPUE range: 335 in 2002 to 2,288 in 2008) fish and crustaceans were caught when averaging across years. The large range in yearly total abundance from 2002 to 2008 can be explained by the different sampling effort in those years with six beach seine haul done in 2002, 22 in 2003 and 30 beach seine hauls done from 2004 to 2008. An average species richness of 7.9 species per beach seine haul (range: 6.3 in 2006 to 9.0 in 2003) was caught when averaging across years. Total abundance of all fauna captured doubled between 2007 (34,934) and 2008 (68,651) (Fig. 2). In 2006 total abundance was the lowest of all the years sampled monthly from May to September (2004 to 2008) with only 11,233 individuals captured. In 2004 and 2005, the total abundance was comparable (21,430 in 2004 and 19,908 in 2005). In 2003, only 12,202 fish and crustaceans were captured and in 2002 only 2,009 were captured because of the lower sampling effort in those two years. The total number of taxa captured from 2004 to 2008 was sixteen each year except in 2006 when it was 12. This lower species richness in 2006 corresponds with the lower abundance also found in that same year.

When pooling all years together the most common species captured in Basin Head were: sand shrimp (63.2% of the total abundance of fish and crustaceans), mummichog (15.8%), fourspine stickleback (8.1%), silverside (3.3%), threespine stickleback (2.7%), green crab (2.3%), blackspotted stickleback (1.6%) and ninespine stickleback (1.3%). Species that contributed under 1% of the total abundance were: grass shrimp (0.66%), winter flounder (0.56%), smooth flounder (0.21%), rock crab (0.11%), cunner (0.06%) and sculpin (0.06%). Finally, the rare species which contributed less than 0.02% of the total abundance (< 30 individual captured over seven years) were: pipefish, alewife, tomcod, killifish, mud crab, sand lance, white hake, American eel, grubby and mackerel. Most of the Basin Head littoral nekton community consisted of eight species which together contributed 98.3% of the total abundance (Fig. 3).

## UNIVARIATE STATISTICS FOR BASIN HEAD

Total abundance of animals caught per beach seine haul (YOY + adults) significantly increased in the last two years ($F_{4,25}$ = 7.24; p < 0.01; one-way ANOVA; Fig. 2) with higher numbers caught in 2007 than 2006 (Tukey test, p = 0.03) and higher numbers caught in 2008 than in all previous years except 2007 (Tukey test, p ≤ 0.03). This increase was largely driven by adult sand shrimp ($F_{4,25}$ = 12.95; p < 0.01; Fig. 4) with significantly higher number in 2008 than all the other years except 2007 (Tukey test, p < 0.01). Other species that contributed to the higher total abundance in 2008 were the smooth flounder (YOY + adult) ($F_{4,25}$ = 24.61; p < 0.01) with higher numbers in 2008 than all previous years (Tukey test p < 0.01); the pipefish (YOY + adult) ($F_{4,25}$ = 5.10; p < 0.01) with higher numbers in 2008 than 2004-2006 (p = 0.01) and the green crab (YOY + adult) ($F_{4,25}$ = 3.83; p = 0.02) with higher numbers in 2008 than in 2005 and 2006 (p = 0.01 and 0.04 respectively (Fig. 5).
Total abundance did not differ significantly among the six stations sampled in Basin Head ($F_{5,24}$ = 0.93; p = 0.48; one-way ANOVA using years 2004-2008 as replicates).

Species richness (number of kinds of animals caught per beach seine haul) was significantly lower in 2006 (average 6.3) than all other years except 2007 (average 6.8) ($F_{4,25}$ = 6.68, p < 0.01; Tukey test p < 0.05; Fig. 6). The six stations sampled did not differ significantly in species richness ($F_{5,24}$ = 1.10; p = 0.39; one way ANOVA using years as replicates).

## MULTIVARIATE STATISTICS FOR BASIN HEAD

The temporal changes identified in abundance and species richness in the univariate statistics were also reflected in community structure subjected to Analysis of Similarity (ANOSIM) with the software PRIMER (stations used as replicates with months averaged across stations within each year; data square root transformed to down-weight influence of the most abundant species). Community structure differed significantly in 2008 from all previous years (Global Rho = 0.43; p < 0.01; pairwise multiple comparison Rho values ≥ 0.75; p ≤ 0.01 for all years compared to 2008 except 2007 Rho = 0.49; p = 0.01). As suggested in univariate analyses, the community structure was also different in 2007; pairwise multiple comparison showed some difference between 2007 and 2006 (Rho = 0.33; p ≤ 0.01) and between 2007 and 2005 (Rho = 0.44; p ≤ 0.01). All other pairwise comparisons between years showed small differences (Rho values < 0.25). The differences between the last two years (2007 and 2008) and the three previous years (2004 to 2006) are apparent in the non-metric multi-dimensional scaling plot (nMDS) shown in Figure 7.

ANOSIM testing among the six stations (using years as replicates) showed a weak, marginally significant difference in nekton assemblage (Rho = 0.13; p = 0.04; Fig. 8). The largest difference was between stations 1 (boat launch on the western shore of the lagoon) and 3 (the only site in the northeast arm) (pairwise multiple comparison R = 0.40; p = 0.02). All other station pairwise comparisons were not significant.

The species contributing most to the yearly differences (SIMPER analysis) was the adult sand shrimp which was more abundant in 2007 and 2008 than in previous years ((Table 2; Fig. 4). The second most influential taxon was the YOY mummichog which was also more abundant in 2008 than the previous years. Conversely, adult mummichog showed a considerable decrease in 2008 compared to the other years, especially 2007 which showed the highest abundance of adult mummichog over all five years (Fig. 4). A quality assurance/quality control exercise done at certain CAMP sites showed that volunteers had difficulty discriminating between the two developmental stages (Thériault et al. 2008). Therefore the big difference in the two developmental stages between 2007 and 2008 could be due to not identifying these developmental stage correctly. Another species often contributing to the average dissimilarity between the faunal community in 2008 and other years was the adult fourspine stickleback which was less abundant in 2008 than in 2004 and 2005 (Fig. 4). Though this difference was picked up through the univariate statistics ($F_{4,25}$ = 2.94; p = 0.040), the difference was too small to be identified by the Tukey multiple comparison test (Fig. 4). The adult fourspine stickleback was also less abundant in 2007 and 2006 compared to 2005 and 2004 (Fig. 4). Taken together, these differences suggest a reduction in fourspine stickleback abundance in 2006 which have not since returned to levels observed in 2004 and 2005 (Fig. 4). Another species that often came out as contributing to yearly differences in the SIMPER analyses was the adult silverside which was more abundant in 2007 than in 2005, 2006 and 2008 (Fig. 4). However, the univariate analysis (1-way ANOVA) was not able to show significant yearly differences for the silverside. The last species contributing to dissimilarity in the SIMPER routine was the green crab which was more abundant in 2008 than in 2006 (Table 2).

Adult sand shrimp was also the species that contributed most to the difference in nekton assemblage between station 3 (northeast arm) and other stations (SIMPER analysis; Fig. 8; Table 3). Fewer sand shrimp were caught at station 3 than at any other station. The adult mummichog was the second species contributing the most to the spatial differences. The abundance of adult mummichog was higher at station 3 than at stations 1, 2 and 4 but lower than at stations 5 and 6. The YOY mummichog came out four times as a species contributing to the spatial dissimilarity and was more abundant at station 3 than at stations 1 and 2 but less abundant than at stations 5 and 6 as was the adult mummichog. The adult fourspine stickleback came four out of five times as the third and fourth species contributing to the dissimilarity between the stations. The abundance of adult fourspine stickleback was lower at station 3 compared to station 1 and station 6 but higher compared to station 2 and 4. The adult silverside also came out twice as a species contributing to the dissimilarity between stations 3 vs. station 4 and 5. The average abundance of adult silverside at station 3 was only half the abundance observed at stations 4 and 5 (Table 3). Overall, station 3 had higher abundance of adult and YOY mummichog and lower abundance of adult sand shrimp, fourspine stickleback and silverside compared to some of the other stations.

Of the environmental variables examined for correlation with the nekton assemblages (temperature, salinity and dissolved oxygen of the water, percent eelgrass cover and percent green algae cover), temperature and percent eelgrass cover had the highest correlation (BEST analysis; Rho = 0.42 p = 0.001). Temperature increased slightly over the years with a yearly average temperature of 17.0ºC in 2008 compared to 14.7ºC in 2004 (Fig. 9). A one-way ANOVA showed that water temperature differed significantly among the years ($F_{4,25}$ = 24.27; p < 0.01) but not among the stations ($F_{5,24}$ = 0.17; p = 0.97). Eelgrass cover slightly decreased in 2008 but did not differ significantly among stations (Fig. 10).

## WERE THE CHANGES OBSERVED AT BASIN HEAD ALSO SEEN AT OTHER SITES IN PEI?

Since 2003, CAMP expanded beyond Basin Head with other sites sampled in PEI following the same protocol. In 2004, three sites were sampled through CAMP including Basin Head, Mill River and Trout River. In 2005, the same three sites were sampled and Brudenell-Montague, Murray River and Pinette River were added. In 2006, the same six sites were sampled except that the latter three sites were only sampled from August to September due to insufficient staff. In 2007, the program expanded and Summerside was added to the other six sites and all seven sites were sampled from May to September. In 2008, two new sites were added to the program, Souris and DeSable River (Fig. 11). Data from these sites allowed us to determine whether inter-annual changes observed in Basin Head were unique to that site or were part of a larger geographic trend within the nine sampled sites in PEI. Specifically, the changes observed at Basin Head were:

1. increased total abundance of animals in 2007 and 2008 compared to earlier years;
2. lower total abundance and species richness in 2006;
3. increased total abundance of green crab over the years in Basin Head with the highest abundance captured in 2008;
4. different community structure in 2008 and 2007 compared to the earlier years which was mostly driven by higher abundance of sand shrimp in 2007 and 2008, higher abundance of YOY mummichog in 2008 and fewer fourspine stickleback in 2007 and 2008 compared to 2004 and 2005;
5. increased temperature in Basin Head over the years; and,
6. slight decrease in eelgrass coverage over the years.

To verify if the same temporal changes in total abundance (i.e. increased total abundance in 2007 and 2008 and decreased total in 2006) were seen in other sites, univariate analyses were performed to test for yearly and spatial differences. The first analysis was done with Basin Head, Mill River and Trout River which had full baseline data (i.e. data collected from May to September from 2004 to 2008). Two-way ANOVA indicated a significant yearly difference ($F_{4,75} = 11.41$; $p < 0.01$) but no site difference nor interaction. Mill River and Trout River showed a decreased total abundance in 2006 followed by an increase in 2007 and 2008 to levels somewhat comparable to 2004 and 2005 as opposed to an increase in 2007 and 2008 above all the previous years as seen in Basin Head (Fig. 12). Brudenell-Montague, Murray River and Pinette River had to be analyzed differently because only two months were sampled in 2006. Since all analyses were done by averaging across months, we had to average only August and September every year (2005-2008) to be able to do a yearly comparison for each of these three sites. A two-way ANOVA could not be done between sites and years when including Brudenell-Montague, Murray River, Pinette River and Basin Head due to the interaction. One-way ANOVA were performed for each of those sites individually to test for yearly differences when averaging across months for August and September only. All three sites showed different yearly patterns than Basin Head. Brudenell-Montague showed a significant decrease in total abundance in 2006 as did Basin Head ($F_{3,20} = 5.79$, $p < 0.01$). Pinette River and Murray River showed significant yearly differences ($F_{3,20} = 7.41$, $p = 0.02$; $F_{3,20} = 3.81$, $p = 0.03$, respectively) with higher total abundance in 2006 (Fig. 12). Note that for the latter three sites mentioned above, Figure 12 shows average total abundance in 2005, 2007 and 2008 calculated with all months sampled and 2006 with only August and September data. The other sites sampled through CAMP (Summerside, Souris and DeSable River) could not be subjected to the same type of analysis because they had only been sampled in 2007 and or 2008. Overall, in 2006 a decrease in total abundance was seen in Basin Head, Mill River, Trout River and Brudenell-Montague.

The highest increase in total abundance in 2008 was seen in Basin Head compared to all the other sites (Fig. 12).

The second temporal change observed in Basin Head, lower species richness in 2006, was also observed in Trout River and in Mill River (Fig. 13). However, when analyzing each site individually for yearly differences no significant difference was found for either site (Mill River: $F_{4,25}$ = 1.23, p = 0.32; Trout River: $F_{4,25}$ = 0.46, p = 0.77). Trout River showed a slight species richness decrease in 2006 and also in 2008 and Mill River showed low species richness in 2006 but lower species richness was observed in 2007. Brudenell-Montague, Murray River and Pinette River did not show reduced species richness in 2006 (analysis done with August and September data only; note that Figure 13 shows average species richness in 2005, 2007 and 2008 calculated with all months sampled and 2006 with only August and September data). Brudenell-Montague and Pinette River had significantly higher species richness in 2007 compare to 2008 when comparing data for August and September only ($F_{3,20}$ = 5.54, p < 0.01; $F_{3,20}$ = 3.28, p = 0.04, respectively). Murray River showed no significant difference in species richness among the years when analyzing only August and September data. Therefore, significantly lower species richness in 2006 was only observed in Basin Head, but low species richness was also present in 2006 in Trout River and Mill River but these results were not significant.

Basin Head had higher abundance of green crab than the other CAMP sites sampled in PEI (Fig. 14). Because not all sites were analyzed each year from 2004 to 2008, a one-way ANOVA was performed for Pinette River, Murray River and Brudenell-Montague because these were the only three sites that were sampled for multiple years (2005 to 2008, excluding 2006 since only August and September were sampled). The other sites such as Souris and DeSable were only sampled in 2008 and in Mill River, Trout River and Summerside the green crab were inexistent except for a single green crab captured in Summerside. Only Murray River showed a similar pattern than Basin Head with a significant increase in total abundance of green crab over the years ($F_{2,15}$ = 25.64, p < 0.01) with higher number in 2008 compare to all the other years (Tukey p < 0.01). Pinette River also showed yearly difference ($F_{2,15}$ = 3.89, p < 0.04), but abundance peaked in 2007 and significantly decreased in 2008. No yearly difference was found for Brudnell-Montague.

In total, 3,577 green crab have been captured in Basin Head since 2004 and 1,343 were captured in 2008 alone which is the highest annual total abundance for green crab captured at any PEI CAMP site since we began the program in 2003 (Fig. 14). In 2008, the field crew recorded all green crab as adult and no YOY were recorded as opposed to the previous years in which a certain number of YOY green crab were identified. Other sites in PEI that captured green crab was Brudenell-Montague with 790 green crab captured since 2005 (this site was not sampled in 2004). Souris which only started sampling for CAMP in 2008 captured 659 green crabs in that year. Murray River captured 529 green crab since 2005 and 301 of them were caught in 2008. In Pinette River, 264 green crabs in total were captured since 2005. Finally, the other sites caught smaller numbers of green crab (i.e. DeSable: 24 in 2008, Summerside: 1 in 2008). As for Trout River and Mill River they are still not invaded by the green crab and therefore no green crab have been captured in those two sites since we started sampling CAMP in 2004. These results show that Basin Head is the site with the highest numbers of green crab and that the abundance of this invasive species was highest in 2008 and has increased since 2006 in Basin Head and in some other PEI sites such as Murray River (Fig. 14).

A multivariate analysis was done in PRIMER including all nine sites sampled since 2004 to test if the different community structure seen in Basin Head was also observed in the other sites.

The abundance of each species was square root transformed and each station was averaged across months and years to better represent the data on an MDS plot. A two-way crossed ANOSIM showed high spatial differences among sites (Rho = 0.68; p < 0.01) and lower temporal difference among years (R=0.30, p <0.01). Each site was distinct from each other (MDS plot; Fig 15). High Rho values for the pairwise comparison tests (Rho ≥ 0.70) occurred between Basin Head and all the other sites, such as Pinette (Rho = 0.92, p < 0.01), DeSable River (Rho = 0.91, p < 0.01), Mill River (Rho = 0.81, p < 0.01), Summerside (Rho = 0.79, p < 0.01), Souris (Rho = 0.73, p < 0.01), Murray River (Rho = 0.72, p < 0.01), Brudenell-Montague-Montague (Rho = 0.71, p < 0.01) and Trout River (Rho = 0.71, p < 0.01). The yearly difference combining all the sites together showed that the community assemblage in 2008 differed the most from the community assemblage in 2006 (Rho = 0.52, p < 0.01) and 2005 (Rho = 0.517, p < 0.01) followed by 2004 (Rho = 0.36, p < 0.01) and finally less difference occurred between 2008 and 2007 (R = 0.28, p < 0.01). These results are similar to what was found for the yearly differences in Basin Head. When doing the ANOSIM analyses for each site separately all sites showed yearly differences except Trout River. All of the sites, except Trout River, showed largest community structure differences between 2008 or 2007 and earlier years (2005 or 2006). This demonstrates that inter-annual changes in community assemblage observed at Basin Head were also observed in the other PEI sites sampled by CAMP.

The highest difference among the years, pooling all nine sites together, occurred between 2008 and 2006. Adult sand shrimp and YOY mummichog were more abundant in 2008 than in 2006. As observed in Basin Head, the fourspine stickleback was less abundant in 2007 and 2008 than in 2004 and 2005. In general, the same species as in Basin Head (i.e., sand shrimp) contributed to the differences among the years when pooling all the PEI sites together. On a site-by-site analysis the adult mummichog was most influential in inter-annual changes observed at Mill River and Trout River with highest abundance in 2007 and 2008. Sand shrimp was the second most influential species contributing to the yearly differences in Mill River and Trout River with higher abundance in 2008 than in 2006 and 2007. The YOY mummichog in Mill River and Trout River was more abundant in 2008 than in all other years as was seen in Basin Head. The fourspine stickleback was also more abundant in 2004 and 2005 compared to 2008 and 2007 but did not contribute as much to the yearly difference as it did when doing the analyses for Basin Head alone. As for Brudenell-Montague, Pinette River and Murray River which were analyzed with August and September data only from 2005 to 2008, the species contributing the most to the yearly difference was not always the adult sand shrimp but rather a mixture of adult mummichog, adult silverside, and adult sand shrimp.

In Basin Head, the univariate statistics had shown a significant increase in water temperature since 2005 and highest average temperature was recorded in 2008. It is important to note that monthly sampling was always performed four weeks apart plus or minus a few days and approximately in the same week from year to year. Therefore, inter-annual temperature comparisons could be made. The same analysis was done for each of the PEI sites to verify if water temperature had increased over the years elsewhere. A one-way ANOVA needed to be done since significant interaction was present when analyzing sites and years together. The Brudenell-Montague, Murray River and Pinette River were analyzed only for August and September data from 2005 to 2008. At no sites did we see the same increase in temperature over the years observed in Basin Head (Fig 16). Trout River had no significant difference in temperature over the years and Mill River had a significant increase ($F_{4,25}$ = 9.78, p < 0.01) in temperature from 2004 to 2006 and then a decrease in 2007 and 2008. No significant temperature differences were observed among years at the other sites except in Murray River where highest temperature was recorded in 2006 which then decreased in 2007 and 2008 ($F_{3,20}$

= 8.741, $p < 0.01$). An analysis was done with all sites excluding Souris and DeSable to test for sites difference in the water temperature. This analysis showed a significant difference in water temperature among the sites ($F_{6,167} = 17.53$, $p < 0.01$) with Basin Head showing significantly lower average temperature than all the other sites (Fig. 16).

To verify if eelgrass coverage was lower in Basin Head than elsewhere in PEI, a one-way ANOVA was done to test for differences in eelgrass coverage among the sites. Only the data from 2008 were analyzed. The one-way ANOVA showed that Basin Head had similar percent eelgrass coverage to all the other sites except Trout River which had more eelgrass cover. A yearly comparison was done for Trout River and Mill River which were the only two sites which had a complete set of data sampled since 2004. Neither of these sites showed a significant yearly decrease in the eelgrass cover as we had seen in Basin Head.

## DISCUSSION

The CAMP data indicated changes to the littoral nekton community of Basin Head between 2004 and 2008. Abundance and richness were lowest in 2006 and increased greatly in the subsequent two years. Increased abundance in 2008 was mostly contributed by higher abundance of adult sand shrimp and YOY mummichog present in Basin Head. Analyses of data collected at other CAMP sites in PEI also showed changes in the littoral nekton community. Some of these changes were similar to Basin Head and others were not. Similar changes to Basin Head often occurred in Mill River and Trout River. These latter two sites and Brudenell-Montague showed higher total abundance of animals in 2007 and 2008 compared to the earlier years as seen in Basin Head (Fig. 12). This higher abundance was driven in part by high sand shrimp abundance for some sites but also by mummichog and fourspine stickleback for other sites. It is still unclear to us why such an increase in abundance in 2008 was observed at Basin Head and in some other PEI sites. One possibility is a storm surge that occured on December $27^{th}$ 2004 along the Atlantic coast. This storm resulted in extensive damage to the Basin Head wharf and caused extensive erosion and damage to the coastal area. During that storm water level rose to 1.2 m above the highest tide. Conceivably this storm could have affected either Basin Head lagoon or its nekton in their overwintering location. Overwintering ecology of many species is unknown but at least some species of fish and invertebrates including sand shrimp (Locke et al. 2005) may overwinter in coastal waters inside the lagoon. It is possible that survivors of this event, and their progeny, might have had lowered predation pressure, reduced competition, or increased food or other resources resulting in population growth in 2007 and 2008 in Basin Head, Mill River, Trout River and Brudenell-Montague. Other similar results to Basin Head include the multivariate analyses which demonstrated largest community structure differences between 2007-2008 and earlier years (2005 or 2006). However, the species mostly contributing to the community structure differences was not necessarily the sand shrimp as in Basin Head but other species such as the adult mummichog for Mill River and Trout River and the adult silverside for other sites.

Basin Head differed from other PEI sites in having highest abundance of green crab. Furthermore, Basin Head had a slight decrease in eelgrass cover and a slight increase in water temperature over the years which were not observed elsewhere.

In 2007, a preliminary analysis of CAMP data from 11 sites (i.e. Lameque, Shippagan, St. Louis de Kent, Bouctouche, Scoudouc River, Pictou, Antigonish, Mabou, Mill River, Trout River, Basin Head) was done. These sites were chosen because they had a full dataset, sampling from May to September for 2004 to 2007. These preliminary analyses found differences in the nekton assemblage of Basin Head relative to all but one of the other ten sites (Courtenay and Theriault, unpublished). A clustering routine identified three distinct groups differing in degree of anthropogenic disturbance. Mabou and Basin Head formed a group characterized by the lowest degree of such anthropogenic impacts. SIMPER analysis indicated that the Mabou/Basin Head cluster was characterized by relatively fewer mummichog and more fourspine stickleback and shrimp than the more impacted sites. BEST analysis indicated that the Mabou/Basin Head nekton assemblage was associated with, among other things, lower temperature and more eelgrass coverage than assemblages found at more impacted sites. In the present study, the increase in number of mummichog, decrease in number of fourspine stickleback and decrease in eelgrass coverage in Basin Head might suggest a reduction in environmental quality. However, the biggest change of all, the increase in sand shrimp numbers would suggest the opposite (i.e., healthy, less impacted area) according to our preliminary analysis. CAMP is not at a point yet to deliver definitive information on environmental quality within or among sites but additional analyses are being carried out with land use data to try to see if correlation exists between nekton littoral community structure and land use intensity. Furthermore, five of the six CAMP sampling stations are located around the main lagoon of Basin Head and only one CAMP station is located in the northeast arm where the distinct Irish moss bed occurs. Therefore, our data may not provide a strong signal of changes most affecting the Irish moss bed in the northeast arm.

As mentioned in the ecological assessment of the Irish moss in Basin Head marine protected area (DFO 2009), many factors may be affecting the abundance, structure and distribution of Irish moss. The factors that have been suggested include: macroalgal blooms, eutrophication and environmental quality, water circulation patterns, accumulation of fine particulate matter and increased abundance of green crab. The last factor is of particular interest to us, because we found a significant increase of green crab in the Basin Head lagoon. Studies have shown that green crab prey on blue mussels (Miron et al. 2005). Therefore, the potential negative effects of green crab on Irish moss may be indirect and associated with predation on mussels which is used as an essential and unique organism for the anchoring of the Irish moss (DFO 2009). The reduction of blue mussel in the ecosystem might be expected to reduce the anchoring, stability and recruitment of Irish moss in Basin Head lagoon and therefore might explain its decline in the recent years.

# REFERENCES


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

Cao, Y., D.P. Larsen, and R.St-J. Thorne. 2001. Rare species in multivariate analysis for bioassessment: some considerations. Journal of North American Benthic Society 20: 144-153.

Clarke, K.R. and M. Ainsworth. 1993. A method of linking multivariate community structure to environmental variables. Marine Ecology Progress Series 92: 205-219.

Clarke, K.R. and R.N. Gorley. 2001. PRIMER v5: User Manual/Tutorial. PRIMER-E:Plymouth Ltd. West Hoe, W.K. 91p.

Clarke, K.R. and R.M. Warkick. 2001. Change in marine communities: an approach to statistical analysis and interpretation, 2nd edition. PRIMER-E: Plymouth. 144 p.

Corey, S. 1981. The life history of *Crangon septemspinosa* Say (Decapoda, Caridea) in the shallow sublittoral area of Passamaquoddy Bay, New Brunswick, Canada. Crustaceana. 41: 21-28.

DFO. 2009. Ecological Assessment of Irish Moss (*Chondrus Crispus*) in Basin Head Marine Protected Area. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2009/059.

Fritz, E.S. and E.T. Garside. 1975. Comparison of age composition, growth, and fecundity between two populations each of *Fundulus heteroclitus* and *F. diaphanus* (Pisces : Cyprinodontidae). Canadian Journal of Zoology 53: 361-369.

Island Nature Trust. 2001. Community use of the Basin Head Lagoon, Prince Edward Island. Report prepared by the Island Nature Trust for the Basin Head Lagoon Ecosystem Conservation Committee. 26 p.

Jessop, B.M. 1983. Aspects of the life history of the Atlantic silverside (*Menidia menidia*) of the Annapolis River, Nova Scotia. Canadian Manuscript Report of Fisheries and Aquatic Sciences No. 1694. 41 p.

Judson, D., R. Galland, and P. Howlett. 1987. Basin Head ''giant'' Irish moss biomass survey July-August 1987 and controlled harvest project November 1987. PEI Dept. Fisheries and Aquaculture report. 16 p.

Kneib, R.T. and A.E. Stiven. 1978. Growth, reproduction, and feeding of *Fundulus heteroclitus* (L.) on a North Carolina salt marsh. Journal of Experimental Marine Biology and Ecology 31: 121-140.

Locke, A., G.J. Klassen, R. Bernier, and V. Joseph. 2005. Life history of the sand shrimp, *Crangon septemspinosa* Say, in a southern Gulf of St. Lawrence estuary. Journal of Shellfish Research 24: 603-613.

McCurdy, P. 1980. Investigation of a unique population of *Chondrus crispus* in Basin Head Harbour, Prince Edward Island. Final report contract CS155-0-6302, 08-005 to National Research Council of Canada. 34 p.

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. Journal of Shellfish Research 24: 579-586.

Scott, W.B. and M.G. Scott. 1988. Atlantic fishes of Canada. Canadian Bulletin of Fisheries and Aquatic Sciences 219. 731 p.

Sharp, G., R. Semple, K. Connolly, Martec Ltd., D. Audet, D. Cairns and S. Courtenay. 2003. Ecological assessment of the candidate marine protected area, Basin Head Lagoon. Canadian Manuscript Report of Fisheries and Aquatic Sciences 2641: vii + 70 p.

Sharp, G., R. Semple, H. Vandermeulen, M. Wilson, C. LaRocque, and S. Nebel. (in prep.). The Basin Head *Chondrus crispus* Population Abundance and Distribution 1980 to 2008. DFO CSAS Res. Doc.

Strain, P.M. and P.M. Clement. 1996. Nutrient and dissolved oxygen concentrations in the Letang Inlet, New Brunswick, in the summer of 1994. Canadian Data Report on Fisheries and Aquatic Science 1004, iv + 33 p.

Theriault, M-H, S.C. Courtenay, C. Godin, and W.B. Ritchie. 2006. Evaluation of the Community Aquatic Monitoring Program (CAMP) to assess the health of four coastal areas within the southern Gulf of St. Lawrence with special reference to the impacts of effluent from seafood processing plants. Canadian Technical Report of Fisheries and Aquatic Sciences 2649: vii +60 p.

Thériault, M-H, S.C. Courtenay, and J. Weldon. 2008. Quality Assurance/ Quality Control (QA/QC) program for the Community Aquatic Monitoring Program (CAMP). Canadian Technical Report of Fisheries and Aquatic Sciences 2823: v +29 p.

***Table 1.*** *Sum of fish and crustaceans total abundance (YOY + A) caught in Basin Head by beach seine from 2002 to 2008.*

| Common / Scientific name | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 |
|---|---|---|---|---|---|---|---|
| blackspotted stickleback *Gasterosteus wheatlandi* | 7 | 23 | 458 | 780 | 467 | 352 | 578 |
| threespine stickleback *Gasterosteus aculeatus* | 91 | 577 | 665 | 1182 | 385 | 463 | 1189 |
| fourspine stickleback *Apeltes quadracus* | 428 | 3117 | 3027 | 3508 | 1430 | 1095 | 1177 |
| ninespine stickleback *Pungitius pungitius* | 39 | 205 | 644 | 855 | 64 | 98 | 329 |
| Mummichog *Fundulus heteroclitus* | 561 | 2311 | 3476 | 2829 | 2472 | 9026 | 6288 |
| Killifish *Fundulus diaphanus* | 0 | 0 | 4 | 0 | 0 | 0 | 0 |
| Atlantic silverside *Menidia menidia* | 91 | 692 | 354 | 779 | 374 | 1865 | 1543 |
| Cunner *Tautogolabrus adspersus* | 3 | 18 | 3 | 55 | 0 | 0 | 17 |
| Shorthorn sculpin *Myoxocephalus scorpius* | 0 | 0 | 88 | 5 | 1 | 1 | 1 |
| Grubby *Myoxocephalus aenaeus* | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| Atlantic tomcod *Microgadus tomcod* | 0 | 0 | 14 | 0 | 0 | 0 | 0 |
| white hake *Urophycis tenuis* | 0 | 0 | 0 | 2 | 0 | 1 | 0 |
| Alewife (Gaspereau) *Alosa pseudoharengus* | 24 | 0 | 0 | 0 | 0 | 5 | 0 |
| Atlantic Mackerel *Scomber scombrus* | 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| American Sand Lance *Ammodytes hexapterus* | 0 | 0 | 0 | 2 | 0 | 0 | 1 |
| Pipefish *Syngnathus fuscus* | 0 | 16 | 0 | 0 | 0 | 4 | 10 |
| American Eel *Anguilla rostrata* | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| flounder sp.[1] *Pleuronectes sp.*[1] | 0 | 6 | 0 | 0 | 0 | 0 | 0 |
| smooth flounder *Pleuronectes putnami* | 0 | 29 | 11 | 27 | 6 | 54 | 227 |
| winter flounder *Pseudopleuronectes americanus* | 144 | 139 | 433 | 113 | 105 | 16 | 0 |
| **Total fish** | **1 389** | **7 133** | **9 178** | **10 138** | **5 304** | **12 980** | **11 360** |

***Table 1 (continued).***

| Common / Scientific name | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 |
|---|---|---|---|---|---|---|---|
| grass shrimp<br>*Palaemonetes vulgaris* | 61 | 32 | 781 | 64 | 2 | 155 | 24 |
| sand shrimp<br>*Crangon septemspinosa* | 483 | 4710 | 10731 | 9320 | 5374 | 21157 | 55 911 |
| rock crab<br>*Cancer irroratus* | 6 | 83 | 37 | 19 | 22 | 9 | 9 |
| Mud crab<br>*Xanthidae Family* | 0 | 0 | 0 | 0 | 0 | 0 | 4 |
| green crab<br>*Carcinus maenas* | 70 | 244 | 703 | 367 | 531 | 633 | 1343 |
| **Total crustacean** | **620** | **5 069** | **12 252** | **9 770** | **5 929** | **21 954** | **57 291** |
| **Total (fish+crustaceans)** | **2 009** | **12 202** | **21 430** | **19 908** | **11 233** | **34 934** | **68 651** |
| total beach seine haul | 6 | 22 | 30 | 30 | 30 | 30 | 30 |
| CPUE total[2] | 335 | 508 | 714 | 664 | 374 | 1 164 | 2 288 |

[1] Could not distinguish between the winter flounder and the smooth flounder due to their small size
[2] CPUE = catch per unit effort

***Table 2.*** *SIMPER results indicating the first four species contributing most of the average dissimilarity among the pairwise year comparisons for Basin Head.*

| Pairwise Comparison | Average dissimilarity among groups | Species (A = adult) (YOY = young-of-the-year) | 2008 average abundance | Other year average abundance | Contribution (%) to dissimilarity |
|---|---|---|---|---|---|
| 2008 vs.2007 | 39.31 % | Sand shrimp (A) | 41.77 | 25.22 | 26.34% |
| | | Mummichog (YOY) | 10.51 | 3.41 | 13.24% |
| | | Mummichog (A) | 4.39 | 12.86 | 12.74% |
| | | Silverside (A) | 4.64 | 6.52 | 6.55% |
| | | | | | |
| 2008 vs. 2006 | 51.98% | Sand shrimp (A) | 41.77 | 12.68 | 37.46% |
| | | Mummichog (YOY) | 10.51 | 3.36 | 11.26% |
| | | Mummichog (A) | 4.39 | 5.67 | 5.28% |
| | | Green crab (A) | 6.45 | 3.21 | 4.55% |
| | | | | | |
| 2008 vs. 2005 | 45.13% | Sand shrimp (A) | 41.77 | 17.31 | 31.21% |
| | | Mummichog (YOY) | 10.51 | 4.15 | 10.51% |
| | | Fourspine stickleback (A) | 5.68 | 10.18 | 6.53% |
| | | Mummichog (A) | 4.39 | 7.38 | 5.17% |
| | | | | | |
| 2008 vs. 2004 | 47.67% | Sand shrimp (A) | 41.77 | 18.38 | 28.61% |
| | | Mummichog (YOY) | 10.51 | 1.04 | 11.46% |
| | | Mummichog (A) | 4.39 | 8.52 | 6.67% |
| | | Fourspine stickleback (A) | 5.68 | 9.28 | 5.85% |
| | | | | | |
| 2007 vs. 2006 | 43.65% | Sand shrimp (A) | 25.22 | 12.68 | 24.35% |
| | | Mummichog (A) | 12.87 | 5.67 | 17.09% |
| | | Silverside (A) | 6.52 | 2.37 | 9.24% |
| | | Mummichog (YOY) | 3.41 | 3.36 | 7.09% |
| | | | | | |
| 2007 vs. 2005 | 31.11% | Sand shrimp (A) | 25.22 | 17.31 | 15.24% |
| | | Mummichog (A) | 12.87 | 7.38 | 15.22% |
| | | Silverside (A) | 6.52 | 3.33 | 9.38% |
| | | Fourspine stickleback (A) | 5.36 | 10.18 | 9.33% |

**Table 3.** SIMPER results indicating the first four species contributing most of the average dissimilarity among the pairwise stations comparisons for Basin Head.

| Pairwise Comparison | Average dissimilarity among groups | Species (A = adult) (YOY = young-of-the-year) | Other station average abundance | Station 3 average abundance | Contribution (%) to dissimilarity |
|---|---|---|---|---|---|
| Station 1 vs. 3 | 39.63% | Sand shrimp (A) | 31.92 | 16.39 | 29.99% |
| | | Mummichog (A) | 3.45 | 9.41 | 10.91% |
| | | Fourspine stickleback (A) | 10.56 | 7.13 | 6.91% |
| | | Mummichog (YOY) | 1.39 | 3.59 | 5.43% |
| | | | | | |
| Station 2 vs. 3 | 39.85% | Sand shrimp (A) | 22.79 | 16.39 | 20.34% |
| | | Mummichog (A) | 2.27 | 9.41 | 16.05% |
| | | Fourspine stickleback (A) | 3.76 | 7.13 | 8.26% |
| | | Mummichog (YOY) | 2.80 | 3.59 | 8.03% |
| | | | | | |
| Station 4 vs. 3 | 41.57% | Sand shrimp (A) | 18.75 | 16.39 | 17.94% |
| | | Mummichog (A) | 8.80 | 9.41 | 10.73% |
| | | Fourspine stickleback (A) | 6.71 | 7.13 | 8.79% |
| | | Silverside (A) | 6.30 | 3.03 | 8.79% |
| | | | | | |
| Station 5 vs. 3 | 39.55% | Sand shrimp (A) | 26.88 | 16.39 | 18.97% |
| | | Mummichog (A) | 11.14 | 9.41 | 12.26% |
| | | Mummichog (YOY) | 6.38 | 3.59 | 8.71% |
| | | Silverside (A) | 6.86 | 3.03 | 7.88% |
| | | | | | |
| Station 6 vs. 3 | 34.64% | Sand shrimp (A) | 21.70 | 16.39 | 18.80% |
| | | Mummichog (A) | 11.53 | 8.80 | 12.52% |
| | | Mummichog (YOY) | 9.88 | 2.93 | 11.88% |
| | | Fourspine stickleback (A) | 7.58 | 6.71 | 7.88% |

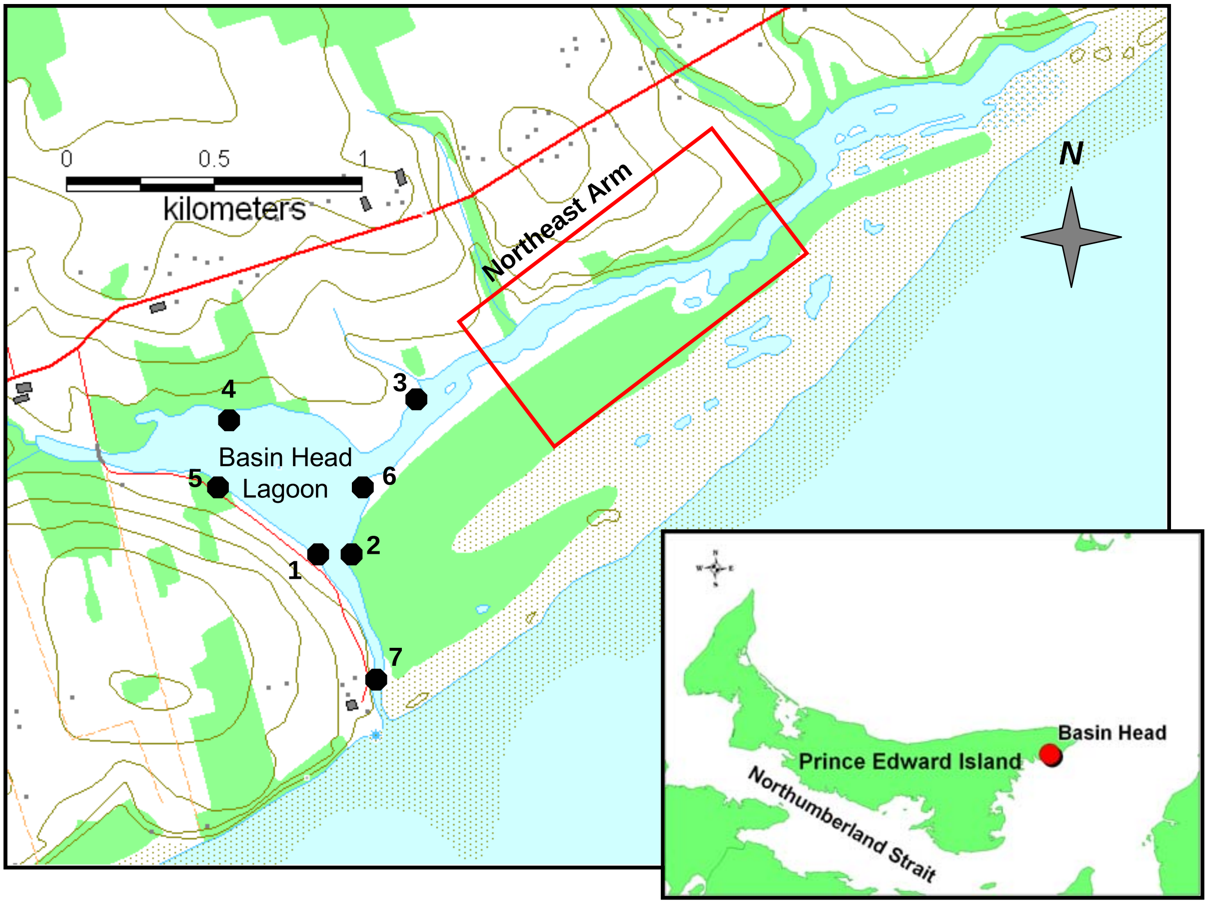


***Figure 1.*** *Map showing the CAMP stations sampled in Basin Head in 2002 to 2008. Starting in 2004 station 7 was dropped but stations 1 to 6 were sampled through 2008. Rectangle indicates the approximate location of the Chondrus crispus bed in the central part of the Northeast Arm of Basin Head.*

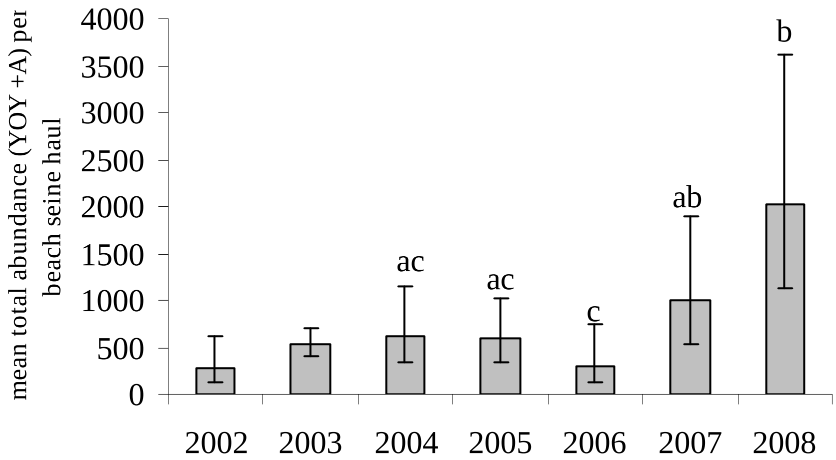


***Figure 2.*** *Mean total abundance (±95% confidence interval) per beach seine haul over the seven years sampled. A one-way ANOVA was performed on the 2004 to 2008 data averaged across months for each year (n = 6 stations sampled per year). Groups sharing common letters are not significantly different (p > 0.05, Tukey test).*

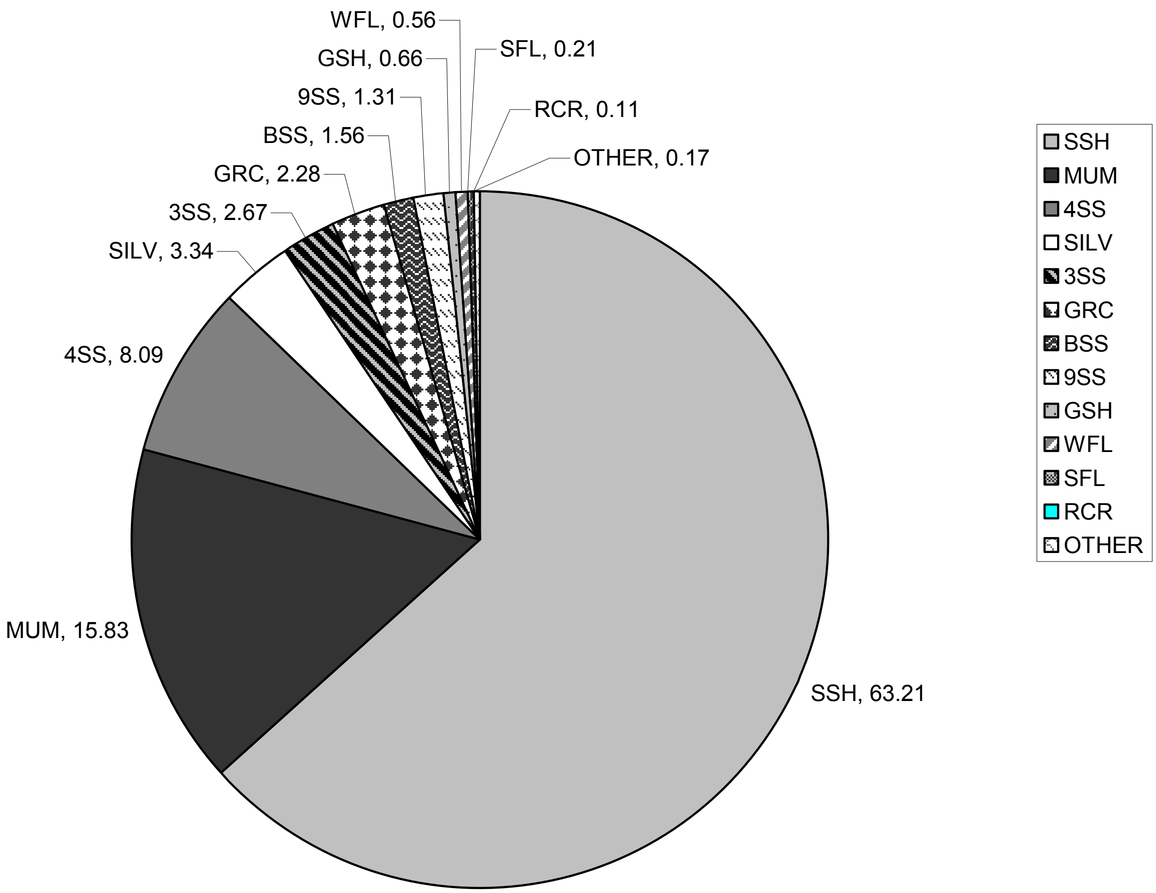


***Figure 3.*** *Pie chart showing the proportion of the twelve most abundant species and the rarer species combined in the "OTHER" category. Calculation of the proportion was done with the sum of each species from 2002-2008. Species acronyms are: SSH = sand shrimp, MUM = mummichog and banded killifish, 4SS = fourspine stickleback, SILV = Atlantic silverside, 3SS = threespine stickleback, GRC = green crab, BSS = blackspotted stickleback, 9SS = ninespine stickleback, GSH = grass shrimp, WFL = winter flounder, SFL = smooth flounder, RCR = rock crab.*

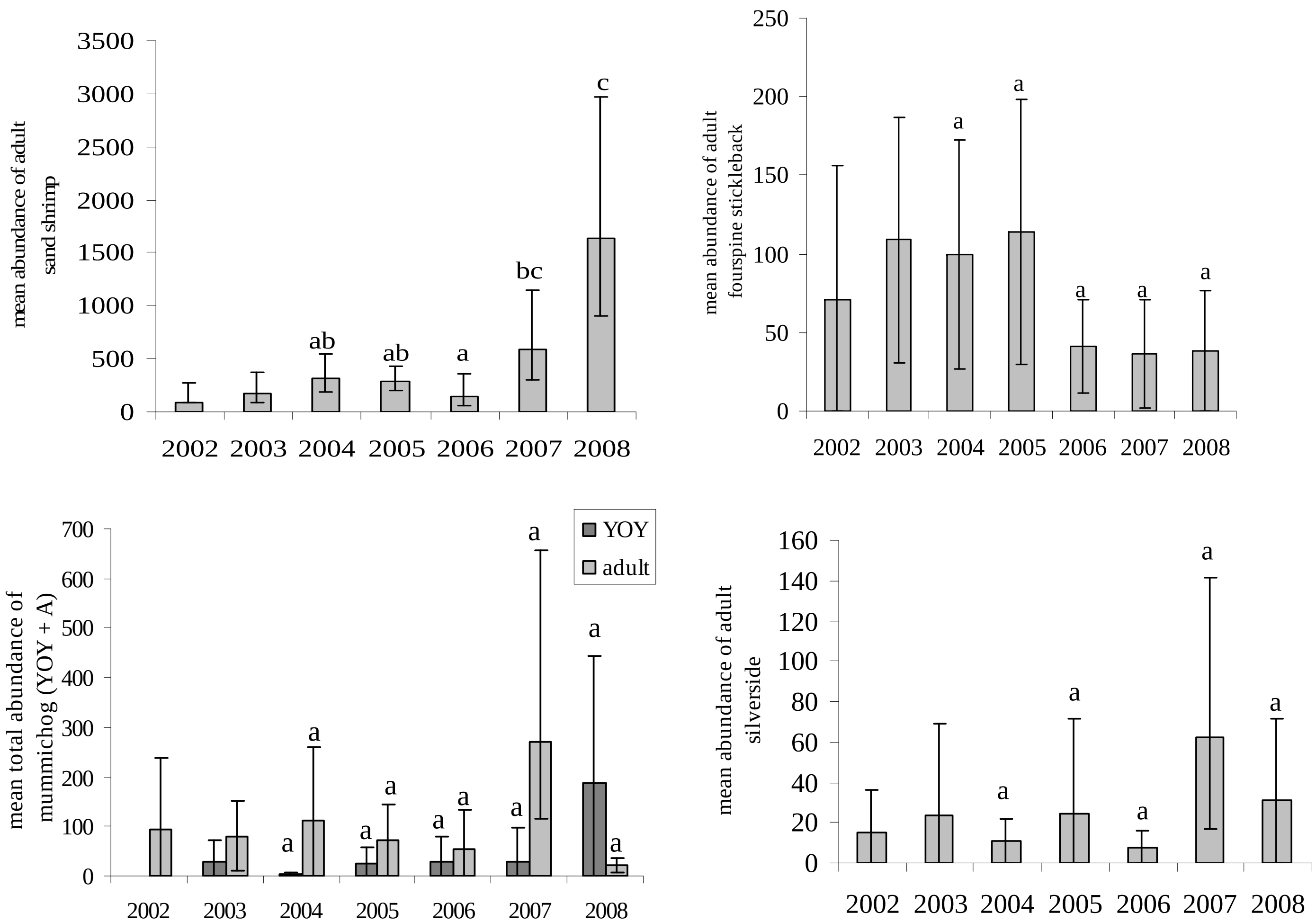


***Figure 4.*** *Mean (± 95 % CI) total abundance of adult sand shrimp (top left panel), adult fourspine stickleback (top right panel), adult and YOY mummichog (lower left panel), and adult silverside (lower right panel) averaged across months for each year (2002 to 2008). Sample size is n = 6 stations for each bar. Groups sharing common letters are not significantly different (p > 0.05, Tukey test). Note: in 2002, adult and YOY mummichog were not separated. Therefore all mummichog captured in 2002 were considered adult.*

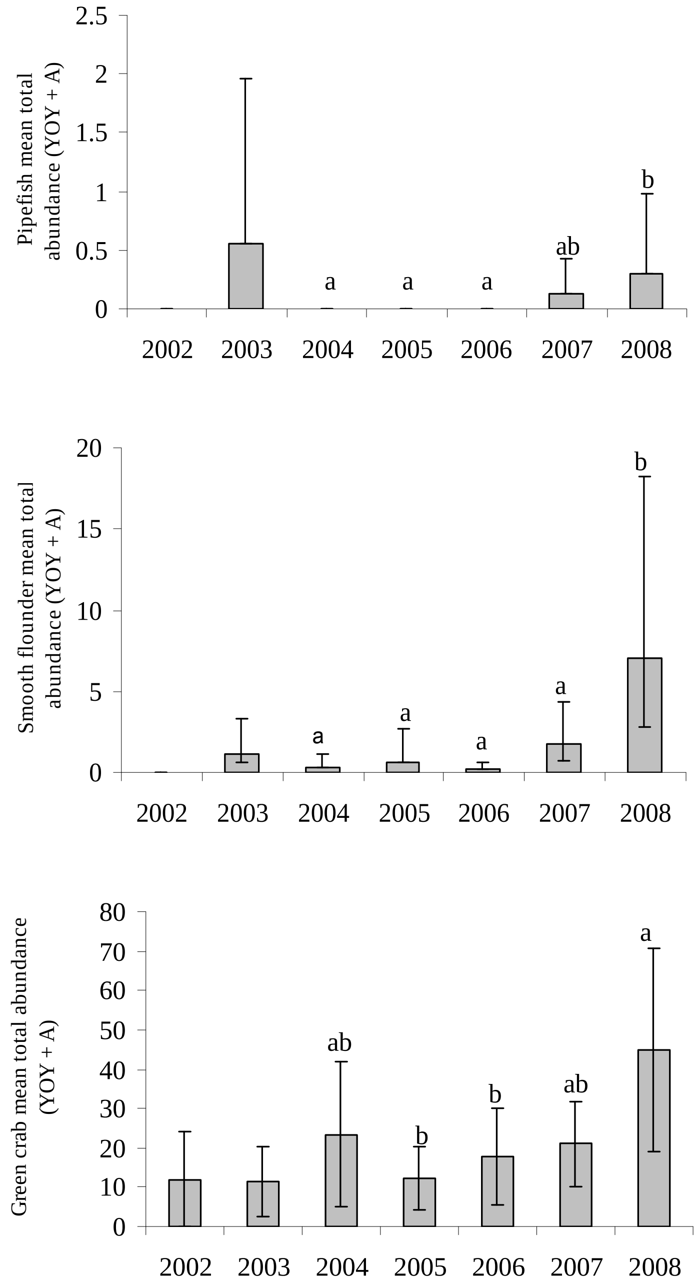


***Figure 5.*** *Mean (± 95 % CI) total abundance of pipefish (upper panel), smooth flounder (middle panel) and green crab (young-of-the-year + adult; lower panel) averaged across months for each year (2002 to 2008). The analyses of variance were done with data from 2004 to 2008 only. Sample size is n = 6 stations for each year. Groups sharing common letters are not significantly different (p > 0.05, Tukey test).*

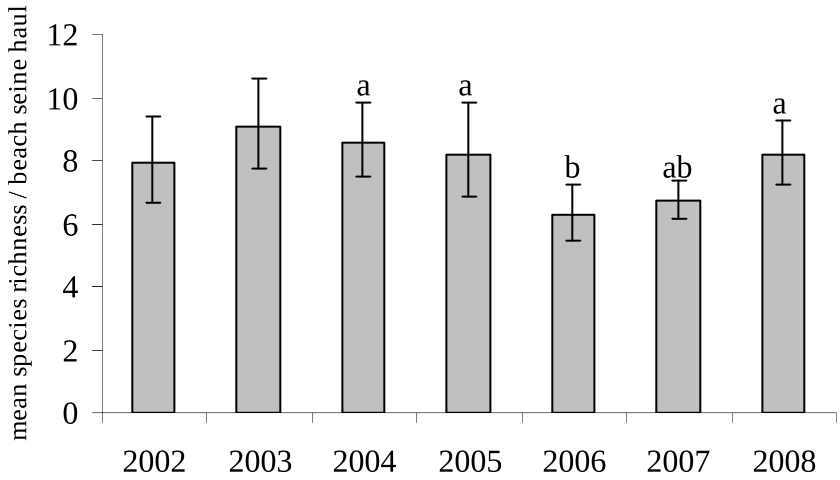


***Figure 6.*** *Mean species richness (± 95% CI) per beach seine haul over the seven years sampled. A one-way ANOVA was performed on the 2004 to 2008 data average across months for each year. Sample size is n = 6 stations for each year. Groups sharing common letters are not significantly different (p > 0.05, Tukey test).*

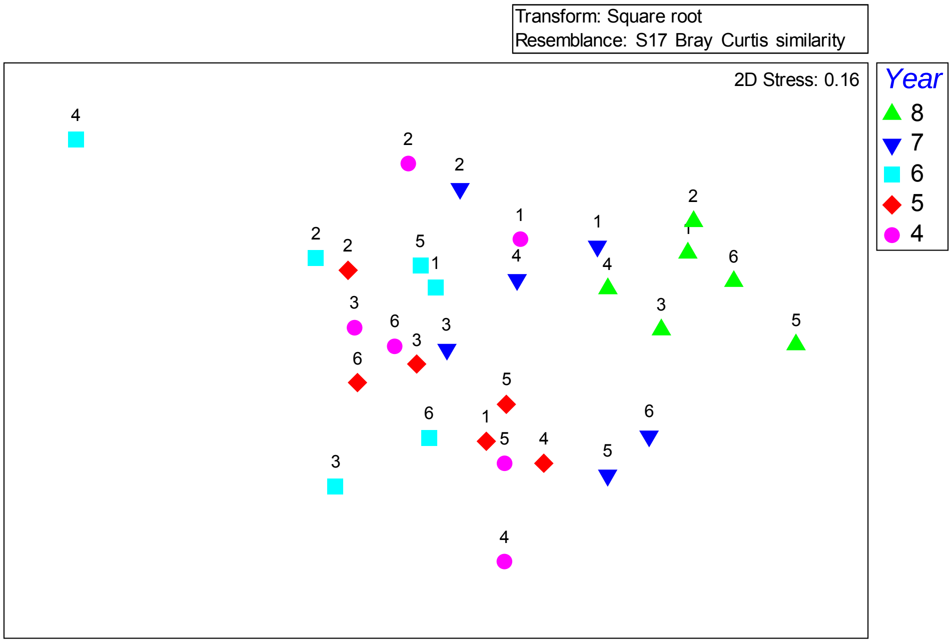


***Figure 7.*** *Multi-dimensional scaling (MDS) plot of the faunal community in Basin Head from 2004 to 2008. The numbers in the figure indicate the station. The abundance of each species was averaged across months for each station and year resulting in 30 points in total in the MDS plot (5 years x 6 stations). Year 8 = 2008, 7 = 2007, 6 = 2006, 5 = 2005, 4 = 2004.*

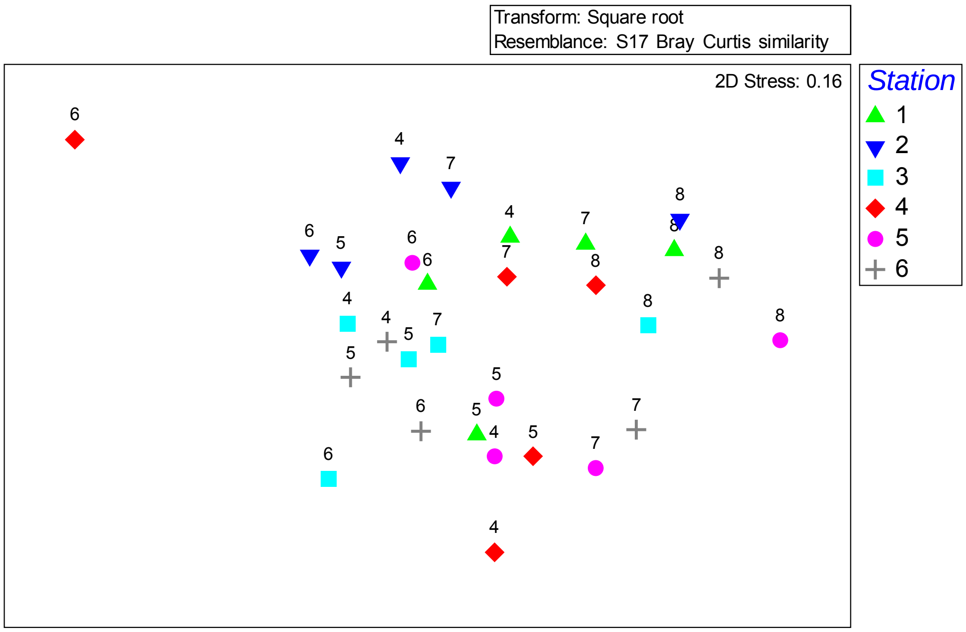


***Figure 8.*** *MDS plot of the faunal community for the 6 stations sampled in Basin Head. The numbers in the figure indicate the year. The abundance of each species was averaged across months for each station and year producing 30 points in total in the MDS plot (5 years x 6 stations).*

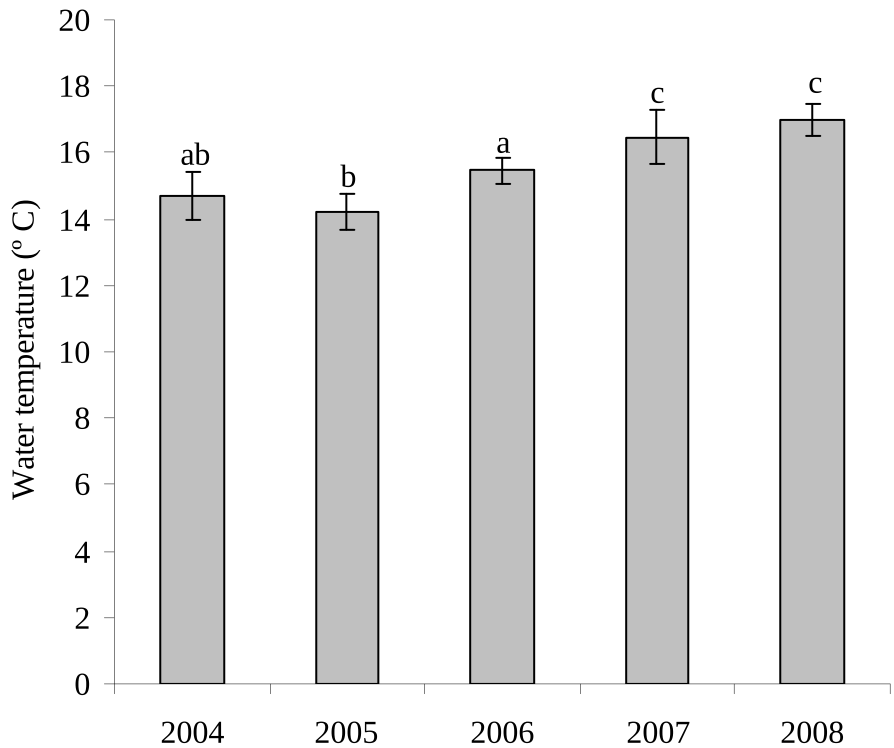


***Figure 9.*** *Mean (± 95% CI) temperature (ºC) in Basin Head averaged across months for each year (2004 to 2008). Sample size is n = 6 stations for each year. Groups sharing common letters are not significantly different (p > 0.05, Tukey test).*

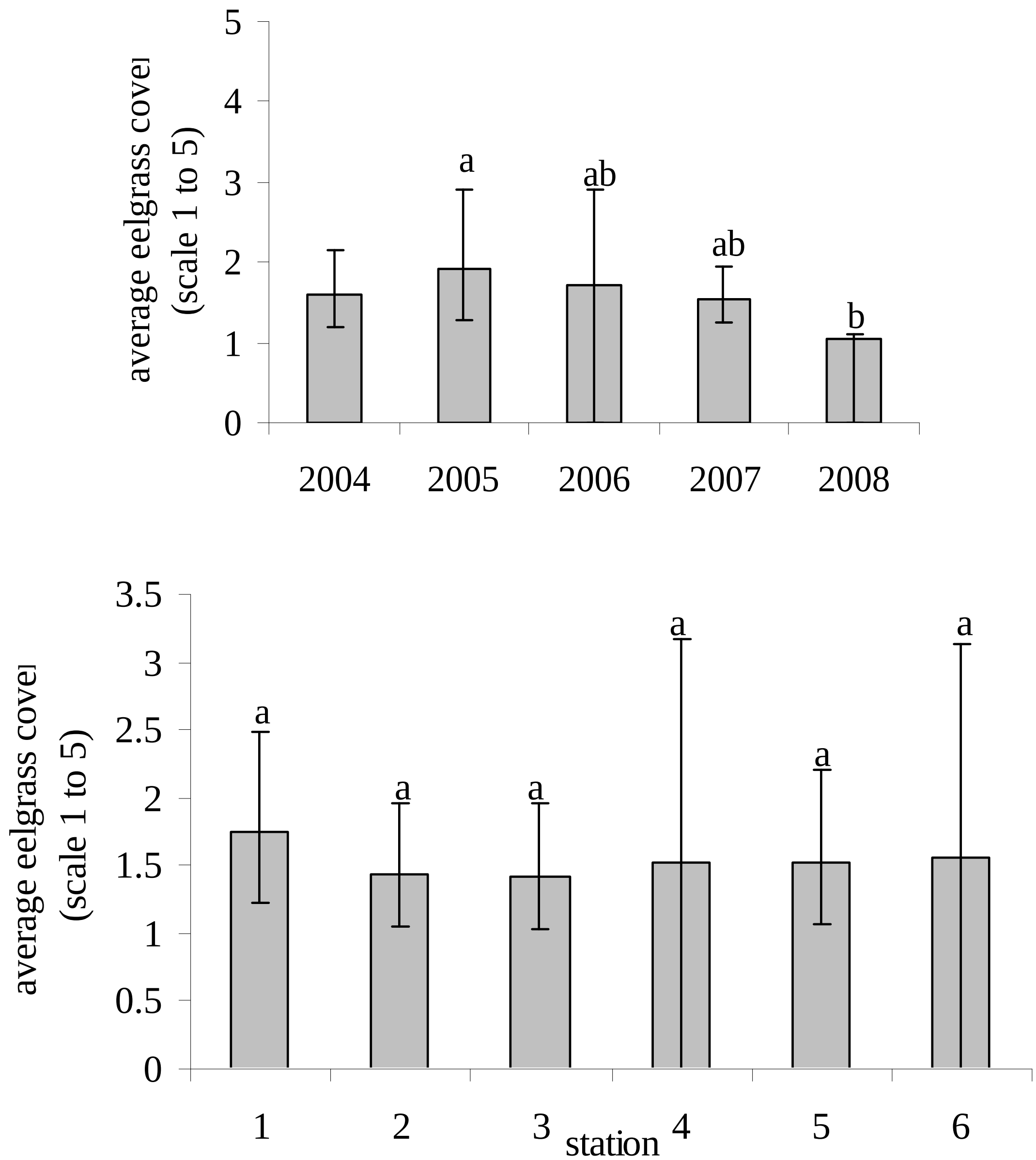


***Figure 10.*** *Bar graphs showing the average (± 95% CI) eelgrass cover for each year (upper panel) and each station (lower panel) sampled from 2004 to 2008 in Basin Head. Replication is n = 6 stations per year for the upper panel and n = 5 years per station for the lower panel. Groups sharing common letters are not significantly different (p > 0.05, Tukey test).*

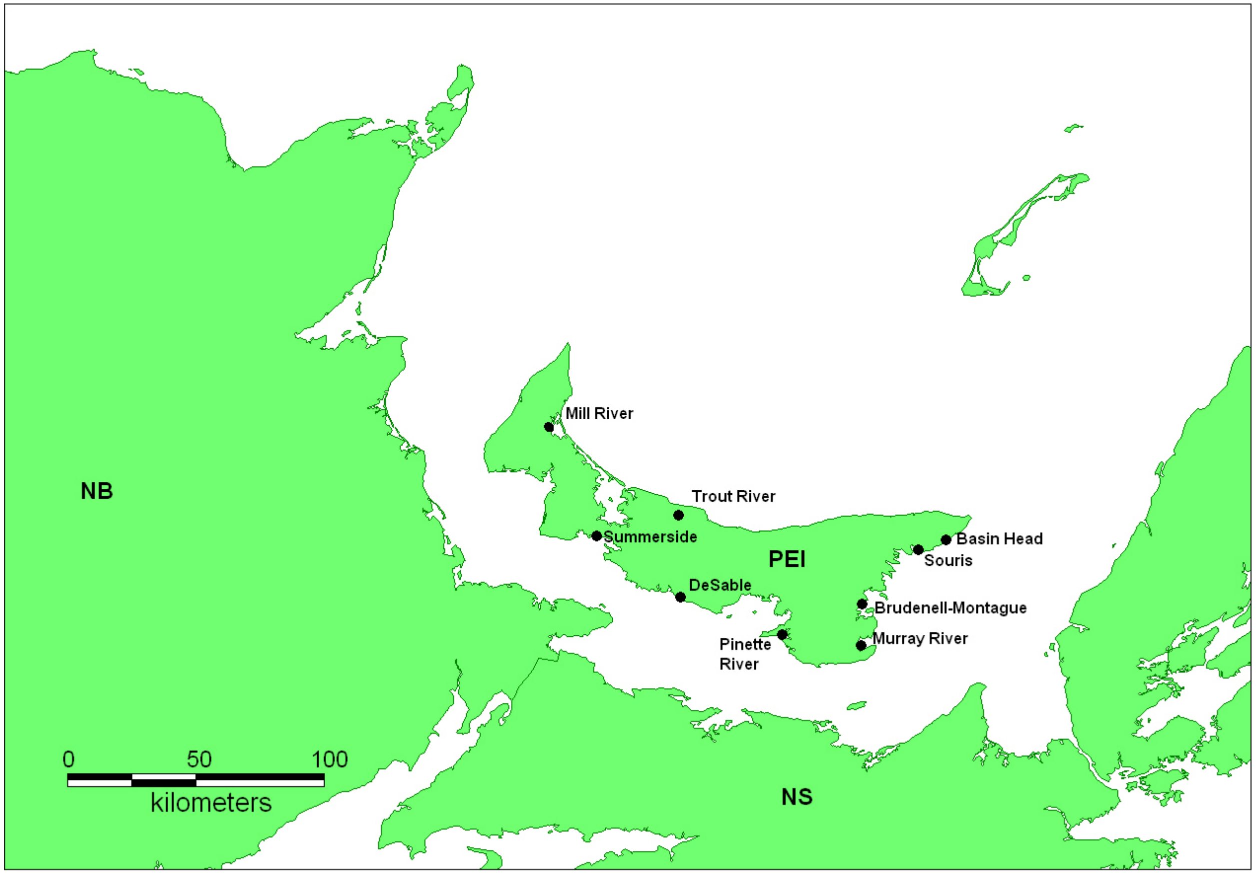


***Figure 11.*** *Map showing the nine sites sampled through CAMP in Prince Edward Island. Basin Head, Mill River and Trout River were sampled since 2004. Brudenell-Montague, Murray River and Pinette River were sampled since 2005. Summerside was sampled starting in 2007 whereas Souris and DeSable were sampled starting in 2008.*

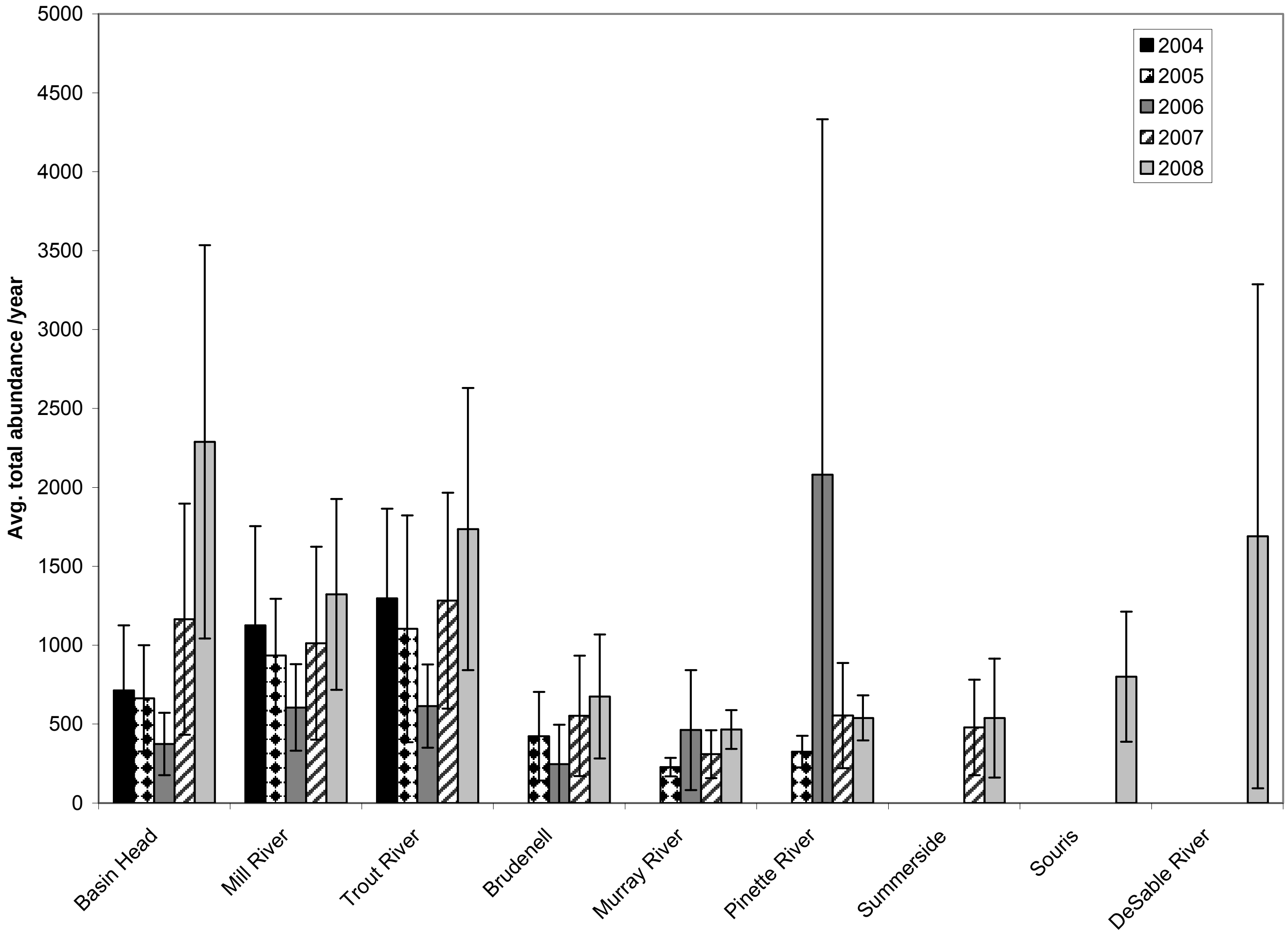


***Figure 12.*** *Bar graph showing the average total abundance (± 95% CI) of animals captured each year in all sites sampled in PEI from 2004 to 2008. Average calculated across months and then across stations (n=6 for all bars). Note: Averages calculated for Brudenell-Montague, Pinette River and Murray River in 2006 were computed using data from August and September only.*

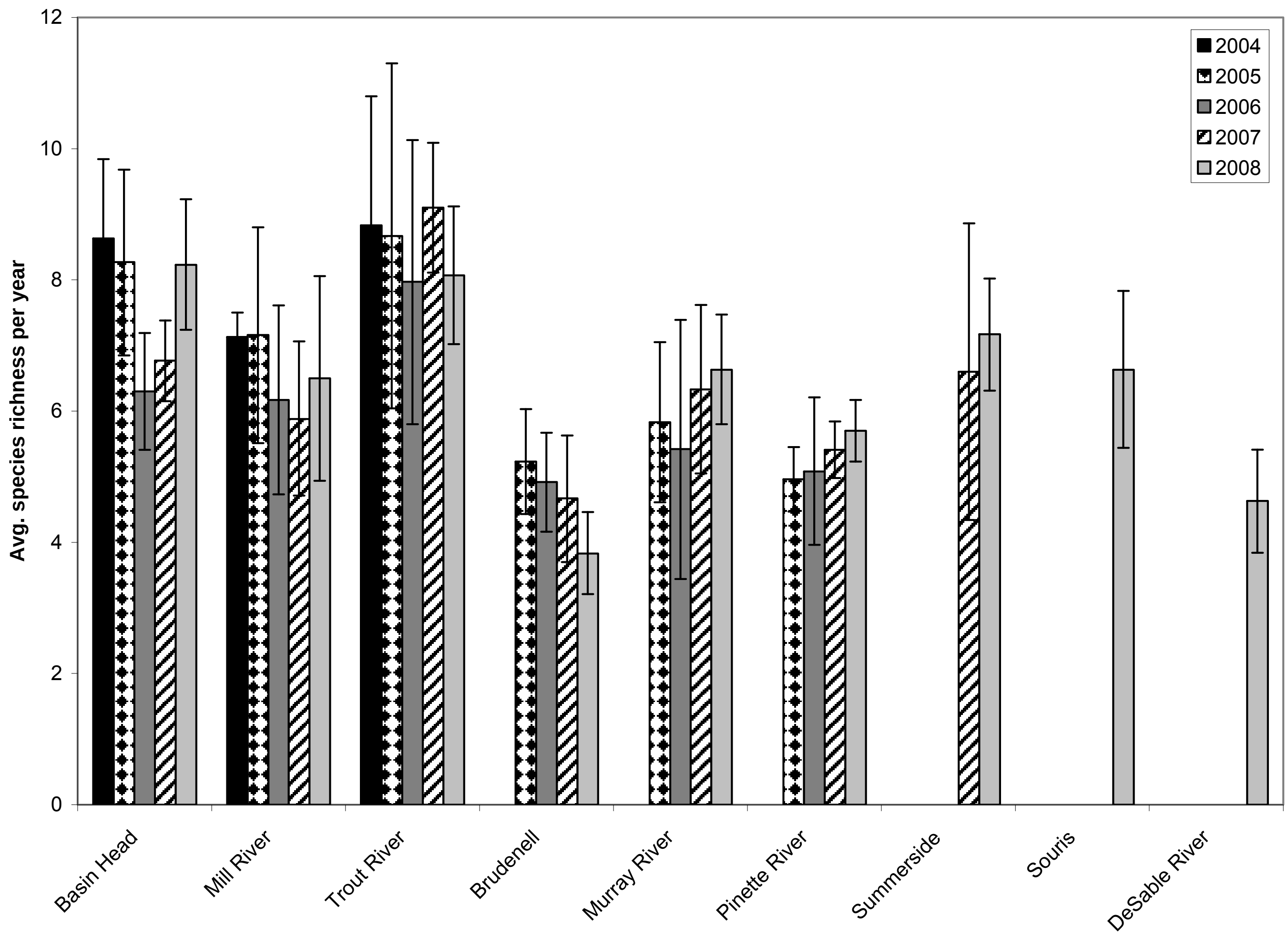


***Figure 13.*** *Bar graph showing the average species richness (± 95% CI) of animals captured each year in all sites sampled in PEI from 2004 to 2008. Average calculated across months and then across stations (n=6 for all bars). Note: averages calculated for Brudenell-Montague, Pinette River and Murray River in 2006 were computed using August and September data only.*

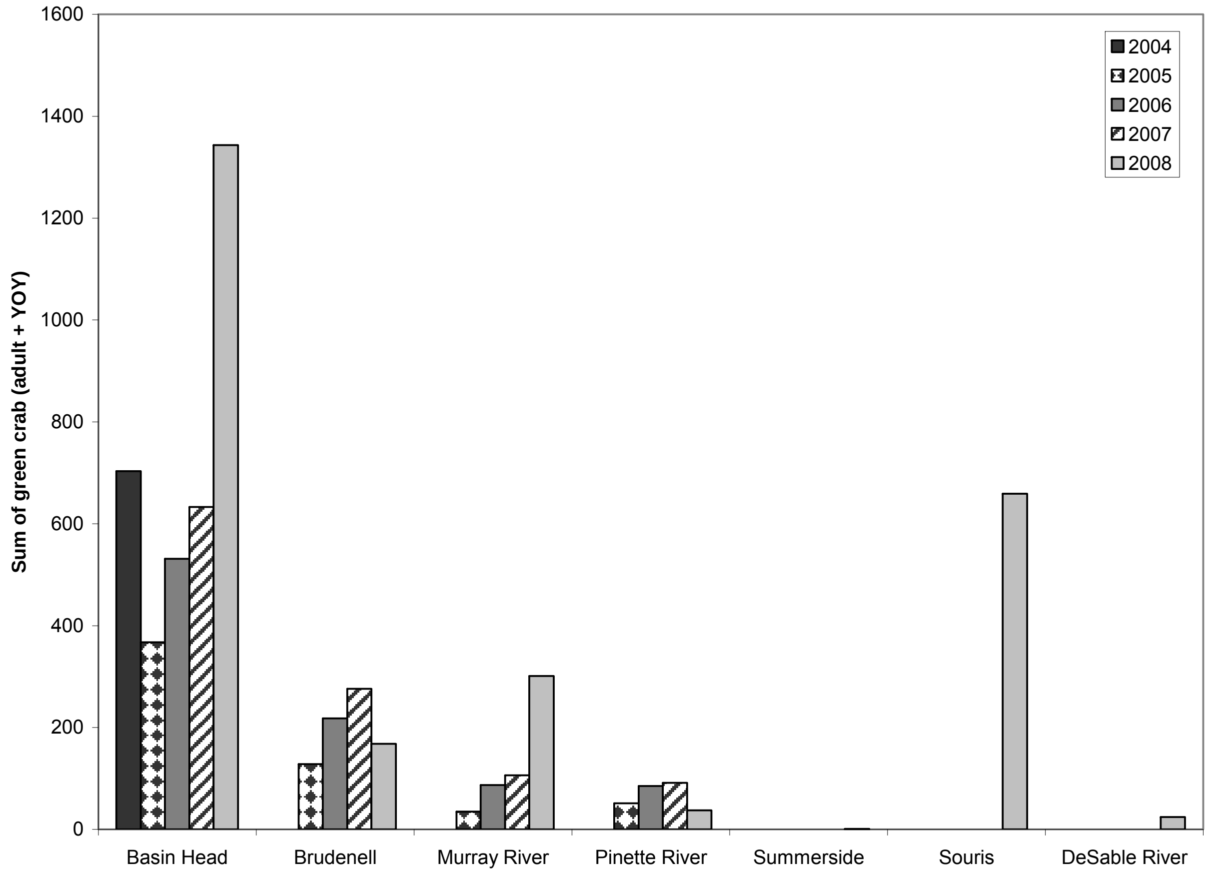


***Figure 14.*** *Bar graph showing the sum of adult + young-of-the-year (YOY) green crab captured in PEI CAMP sites since 2004. Note that Summerside only captured one green crab in 2008 and that Trout River and Mill River are not included in this figure since no green crabs were ever captured in those two sites.*

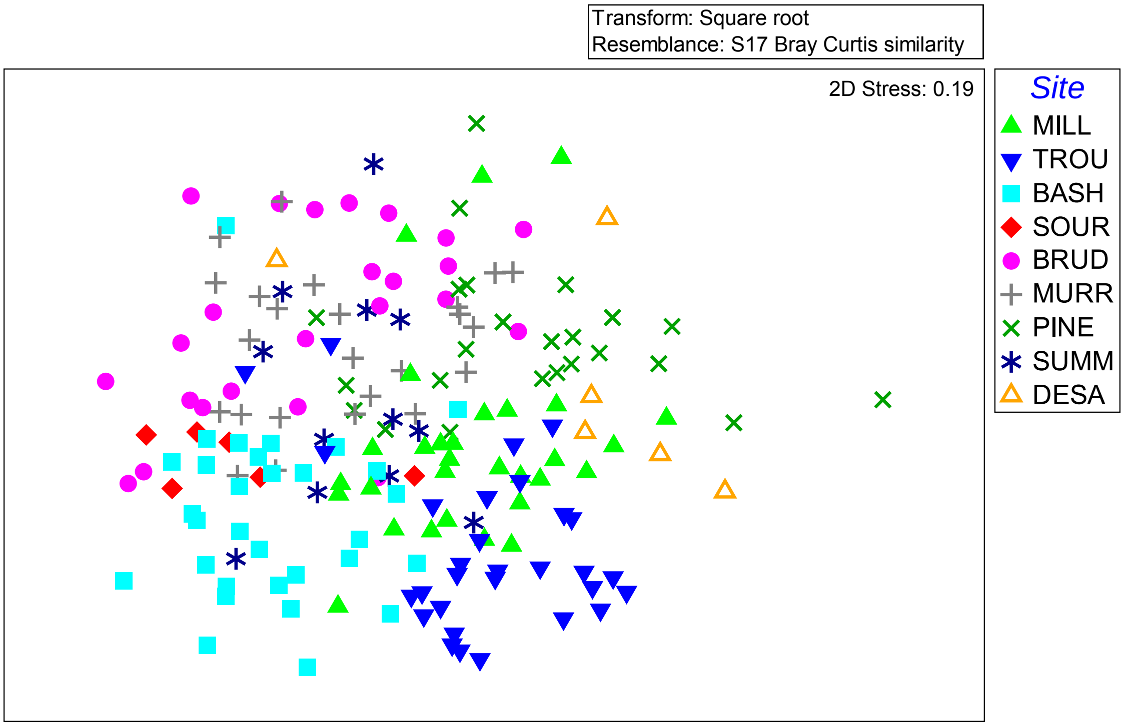


***Figure 15.*** *MDS plot of the faunal community for all nine sites sampled in PEI. The abundance of each species was averaged across months for each station and year producing 30 points (5 years x 6 stations) per site when the site was sampled from May to September from 2004 to 2008.*

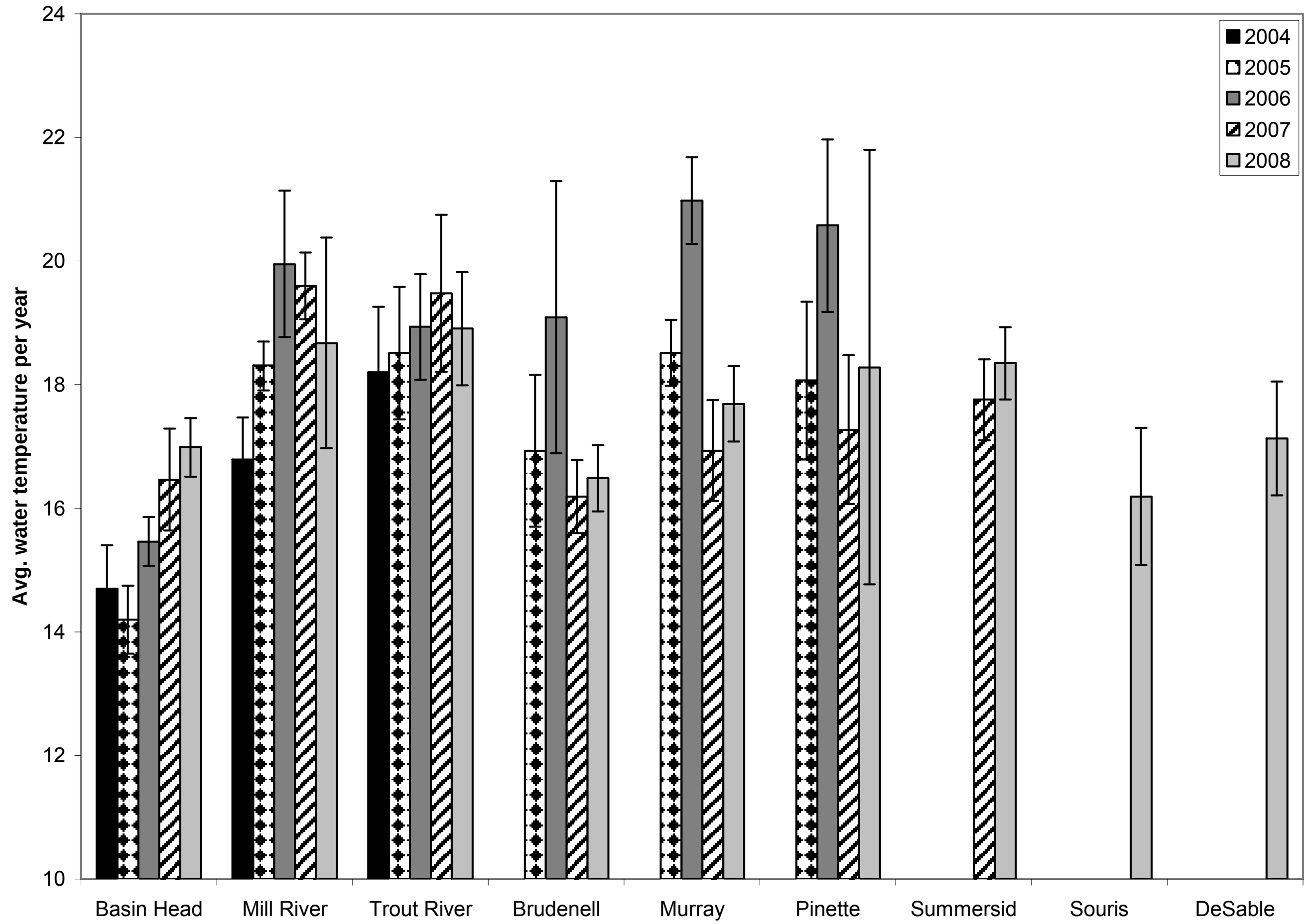


***Figure 16.*** *Bar graph showing the average water temperature (± 95% CI) recorded each year in all sites sampled from 2004 to 2008. Average calculated across months and then across stations (n=6 for all bars). Note: averages for Brudenell-Montague, Pinette River and Murray River in 2006 were calculated using August and September data only.*