

Spatial and temporal trends in paralytic shellfish poisoning levels in the soft-shell clam, *Mya arenaria*, along the southwestern coast of New Brunswick in the Bay of Fundy

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by

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ABSTRACT

Hamer, A., Martin, J.L., Robinson, S., Page, F., Hill, B., Powell, F. and Justason, A. 2012. Spatial and temporal trends in paralytic shellfish poisoning levels in the soft shell clam, *Mya arenaria*, along the southwestern coast of New Brunswick in the Bay of Fundy. Can. Tech. Rep. Fish. Aquat. Sci. 2982: viii +97p.

Shellfish in the Bay of Fundy have historically been known to accumulate paralytic shellfish (PSP) toxins while filter-feeding on the phytoplankton species, *Alexandrium fundyense*. Due to implications for public health, a shellfish monitoring programme was initiated in the Bay of Fundy in 1943 and continues today. The purpose of this particular study was to summarize the impacts of PSP toxins on soft-shell clam, *Mya arenaria*, resources along the southwest coast of New Brunswick in the Bay of Fundy through examination of the temporal and spatial trends in the dataset from 1943-2010.

All sites were positively correlated with one another to varying degrees with the summer season having the highest toxin concentrations. The longest periods of closures were at Crow Harbour, Lepreau Basin and Ross Island Thoroughfare. There were cyclical periods in which toxicity was higher and during those years, the durations of closures were longer. The periods of higher toxicity were: 1943-45, 1957-61, 1970-86, followed by a “mixed period” from 1993-2010 with the highest toxicities in 2008. The sites with the least risk of high PSP toxin levels and the shortest periods of closures for harvesting shellfish were Harbour De Lute, Bar Road, and Ingalls Head.

RÉSUMÉ

Hamer, A., Martin, J.L., Robinson, S., Page, F., Hill, B., Powell, F. and Justason, A. 2012. Spatial and temporal trends in paralytic shellfish poisoning levels in the soft shell clam, *Mya arenaria*, along the southwestern coast of New Brunswick in the Bay of Fundy. Can. Tech. Rep. Fish. Aquat. Sci. 2982: viii +97p.

Les mollusques filtreurs de la Baie de Fundy accumulent les toxines responsables de l'intoxication paralysante par les mollusques (IPM) lorsqu'ils consomment une espèce de phytoplancton, l'*Alexandrium fundyense*. Un programme de surveillance de la salubrité des mollusques de la baie de Fundy existe depuis 1943 et continue à ce jour. L'objectif de cette étude est de résumer les effets des toxines de l'IPM sur les ressources de myes, *Mya arenaria*, de la région côtière du sud-ouest du Nouveau Brunswick en analysant les tendances temporelles et spatiales de la banque de données des années 1943-2010.

Ces résultats ont mis en évidence une corrélation positive entre tous les emplacements à des degrés divers et démontrent que les concentrations maximales de toxines se retrouvent dans la saison estivale. Les plus longues périodes de fermetures étaient à Crow Harbour, Lepreau Basin et Ross Island Thoroughfare. Les cycles de toxicité élevée, 1943-45, 1957-61, 1970-86 allongent la durée des fermetures et celles-ci sont suivies d'une "période mixte" de 1993-2010 avec les toxicités plus élevées ayant lieu en 2008. Les emplacements ayant un risque minimal d'un niveau élevé de contamination par les toxines de l'IMP et avec les périodes de fermeture les plus courtes étaient Harbour De Lute, Bar Road, et Ingalls Head.

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INTRODUCTION

Harmful Algal Blooms (HABs) are sometimes called “red tides” and often refer to the phenomenon or syndrome associated with toxins produced by certain species of algae or phytoplankton. In the Bay of Fundy region, this is associated with the species, *Alexandrium fundyense* and resulting paralytic shellfish poisoning (PSP) toxins (Needler 1949; Martin and Richard 1996). HABs have been responsible for losses and restrictions in Canada as well as other regions of the world to the aquaculture industry, the herring fishery, as well as commercial or recreational shellfisheries, including Clam Fishing Areas (CFAs) worldwide (White 1981, 1982; Martin 1990; Zhou et al. 1999; Martin et al. 2006). Organisms in other regions also known to produce the PSP group of toxins include *Gymnodinium* spp., *Pyrodinium* spp., and *Alexandrium* spp. are also harmful to vertebrate consumers. *A. fundyense* produces a suite of toxins including saxitoxin (STX) that result in PSP which can accumulate in the tissues of shellfish (or bivalves) (Martin et al. 1995).

During an *Alexandrium* HAB event, zooplankton can consume *A. fundyense* and accumulate toxins in their tissues. Contaminated zooplankton or toxic phytoplankton can be consumed by shellfish that accumulate toxins over time annually without obvious visible effect (White 1981). However, fish exposed to harmful algae can exhibit mortality as a result of depleted oxygen levels, ingesting toxins from algae or contaminated zooplankton, or through suffocation (Martin 1990). PSP has also been proven to have harmful effects in humans, ranging from severe illness to death (Van Dolah 2000). When a contaminated shellfish is ingested by a human consumer, the individual can have mild symptoms such as tingling sensations or numbness around the lips to severe symptoms such as incoherent speech and respiratory difficulty to extreme symptoms of paralysis and loss of nerve function or death (Prakash et al. 1971; Martin 1990).

The presence of *A. fundyense* and PSP toxins in the Bay of Fundy can affect both salmon and bivalve aquaculture, as well as recreational and commercial bivalve fisheries (Needler 1949; Martin et al. 2006) through fish kills or harvest area closures.

The PSP monitoring program was developed in the Bay of Fundy in 1943 by J.C. Medcof at the Atlantic Biological Station, Fisheries Research Board of Canada following a request by commercial harvesters to process mussels for canning to meet war time needs (Medcof et al. 1947; Prakash et al. 1971). It has and continues to serve as a model for PSP monitoring programs nationally and internationally. A wide survey of shellfish (mostly blue mussels, but some soft-shell clams) from the Bay of Fundy, the Atlantic coast of Nova Scotia and the southern Gulf of St. Lawrence was undertaken. Due to the rapid accumulation of toxins in blue mussels and the fact that they accumulate toxins at higher levels than clams, it was suggested that the commercial fishing of mussels be prohibited in the Bay of Fundy while researchers studied the problem. The mussel toxicities in the winters of 1943-44 and 1944-45 showed that mussel toxicities, even in the worst areas were low, which Medcof felt was justifiable evidence for treating them in a similar manner to the soft-shell clams (Medcof et al. 1947). Results showed that the toxins were occasionally present in both blue mussels and soft-shell clams from the Bay of Fundy and the other areas where shellfish were tested were toxin-free. At that time, strict harvesting and processing regulations were implemented in the Bay of Fundy for soft-shell clams and the harvesting of blue mussels was prohibited (Prakash et al. 1971).

Today, the soft-shelled clam, *Mya arenaria*, is the primary study species. Samples were historically processed using a mouse bioassay (AOAC 1990), and are now analyzed through the use of High Performance Liquid Chromatography (HPLC) (DeGrasse et al. 2011; van de Riet et al. 2011). The World Health Organization (WHO) has set the level at which shellfish may not be harvested at 80 µg STX/100 g tissue. Today the Canadian Food Inspection Agency (CFIA) and Department of Fisheries and Oceans (DFO) close any harvesting area for a minimum of three weeks if a sample shows a level of 80 µg STX equiv/100 g tissue or greater. The harvesting area will reopen after three weeks as long as three consecutive samples return with a PSP level below the threshold. The blue mussel industry was closed to harvesting in 1944 and the ‘wild’ fishery remains closed today. In the early 2000s, a restricted mussel aquaculture industry was initiated through the Integrated Multi-Trophic Aquaculture (IMTA) programme (Troell et al. 2003; Lander et al. 2004; Ridler et al. 2006).

The Bay of Fundy has been divided into zones of interest called “Clam Fishing Areas” (CFAs) (Fig. 1). A typical CFA is composed of various harbours, coves or beaches where commercial or recreational clam harvesting occurs. Because of the size of the monitoring areas, CFIA is unable to collect and process samples from all the locations on the same day, or even the same week. Given these restrictions, and due to existing closures, CFIA examines key locations representative of each entire CFA. In addition to these key locations, historical recreational clam harvesting areas are tested, as are sites important to industry. Since 1943, over 33 000 *M. arenaria* samples have been collected and analysed for toxins from the Bay of Fundy. The data from 1943-2010 has been shared with researchers at the DFO St. Andrews Biological Station (SABS) Red Tide Research Programme to be mined for possible temporal and spatial trends in PSP levels along the southwestern coast of New Brunswick. Following are results from the analyses to date.

METHODS

DATASET DESCRIPTION

The dataset provided by CFIA includes samples taken from areas in the Northumberland Strait as well as the Bay of Fundy with the majority of the sampling from the southwest coast of New Brunswick in the Bay of Fundy and as such, this area is the focus of this report. The sampling area of concern, from Musquash Harbour west to Bar Road in St. Andrews, and south to Grand Manan, was broken into Clam Fishing Areas (CFAs). An individual CFA can contain multiple sampling sites or, in some cases, only one sampling site. Each CFA has been labelled (NB-10A, NB-16B, NB-9C, etc., Fig. 1). Sampling occurred from 37 different CFAs, each with a different number of sampling sites, yielding a total of 168 sites over the course of the monitoring program. *M. arenaria* samples have been collected by the same method since the inception of the monitoring program (Prakash et al. 1971). Each sample contained 100 g of soft-shelled clam meat and was analyzed by mouse bioassay throughout the years (Prakash et al. 1971; AOAC 1990). Analyses of samples for toxins were changed from a modified mouse bioassay to HPLC in 2010 (Todd 1997; van de Riet 2011).

The shellfish toxicity dataset provided by the CFIA was originally designed for protecting human health. As such, the intent of the data collection was not for research purposes and therefore has inherent limitations. One major factor causing limitations is the variability in sampling effort. When testing *M. arenaria* samples for PSP, CFIA would also occasionally sample sites which were important to the shellfish industry in addition to historically tested sites. As such, sampling priority

changed from year to year to accommodate both current closures, and possible industry interests. This is reflected in the variability, both between and within CFAs, in the number of samples taken in total as well as yearly (Fig. 2, 3). The sampling protocol in the Pocologan area was a source of some confusion. CFIA sampled at different locations within this area and has often closed some sites but not others. This compartmentalization of the Pocologan area has resulted in multiple ‘sub-Pocologan’ sampling sites. Pocologan, Pocologan West, and Mclean Cove Pocologan West are three of these ‘sub-sites’ which have been sampled enough to be included in the analysis.

SAMPLING EFFORT

Sampling effort was examined at different levels. The first was a simple count of the total number of samples taken from each CFA, then a count of the number of samples taken at each site within a zone. Sampling effort was further examined by assigning each sample a numerical day of the year, and plotting this by year for each site. In order to narrow the focus of the dataset, differences in sampling effort were examined. CFAs with a total sample size of less than 500 samples ($n < 500$) were removed, leaving a total of 14 CFAs to be examined. Some CFAs had a key site that was sampled more consistently than other sites in the same CFA, and CFIA used these key sites as representative of the whole CFA. With this in mind, the number of samples taken at each site within a CFA was examined. Sites with a sample size of 500 or more ($n \geq 500$) were kept in the analysis, leaving 16 sampling sites within 14 CFAs (Fig. 1). If more than one site within a CFA met the minimum sample size requirements, they were all included in the study.

TIME BUNDLING

Once the dataset was narrowed down to sites with the required sample sizes, time bundles were assigned to the dataset. Each sample was originally represented by a specific date. However, due to the sheer area of sampling (from Saint John to Grand Manan), not all sites were sampled on the same day. In order to create a correlation matrix for these sites, samples needed to be pooled. Each sample was assigned a value for the following time indices: year, season, month, 14-day period, and 7-day period. These were determined by the calculations presented in Appendix A (Tables 30-37).

In the original dataset a minimum PSP toxin concentration was obtained via the bioassay sensitivity. When a sample had a PSP toxin concentration of less than 40 $\mu\text{g STX}/100\text{ g}$, it was recorded as $<40\text{ }\mu\text{g STX}/100\text{ g}$ in the dataset. For examination purposes, these levels were adjusted to 29 $\mu\text{g STX}/100\text{ g}$. Mean PSP levels per year for all sites were calculated and plotted. Each year that the mean PSP value was determined to be above threshold (80 $\mu\text{g STX}/100\text{ g}$) was termed a ‘hot’ year, and when it was below threshold, it was determined to be a ‘cold’ year. Within the dataset, a ‘cold’ period, ‘hot’ period, and a ‘mixed’ period were examined as well. ‘Hot’ and ‘cold’ periods were determined by finding the longest time period in which mean PSP levels were either above or below threshold (80 $\mu\text{g STX}/100\text{ g}$) levels respectively. The ‘mixed’ period was determined to be the longest period where there were an even number of ‘hot’ and ‘cold’ years without encroaching on either ‘hot’ or ‘cold’ period previously mentioned.

SITE CLOSURES

Closure of a site to harvesting occurs when PSP toxin levels in any sample are 80 µg STX/100 g tissue or greater. All closures last a minimum of three weeks, and continue until three consecutive samples show PSP toxin levels below 80 µg STX/100 g tissue. Multiple samples taken on the same day from a particular site can be used to determine whether to reopen that site. However if even one of those samples returns a value at or above 80 µg STX/100 g tissue, the site remains closed.

In order to determine the length of each closure (days), the replicate date samples were removed. In each case, all replicate date samples were removed from the analysis with the exception of the sample that returned the highest PSP toxin level for that site. In this way, if the remaining sample was higher than the threshold concentration, the site would be listed as closed, but if the site values were below the threshold, it would count toward the three samples required for reopening.

The lengths of individual closures were determined by separating the dataset by site and finding the difference (in days) between the reopening date and the closing date of a particular site. The total length of closures was calculated by taking the sum of the length (in days) of individual closures at a site. The percent duration of closures at a site was calculated over the sample life of each site. Percent length of closure of a site was examined by year, season, and month in periods identified as 'hot', 'cold', and 'mixed' periods.

MEAN PSP LEVELS

Mean PSP levels per year, season, and month were calculated and analyzed for each site. Weekly mean PSP values were calculated for each site and used to build a correlation matrix in Statistical Package for the Social Sciences (SPSS) statistical software (IBM). Weekly values were also used to create 3 dimensional Non-Metric Multi Dimensional Scaling (MDS) plots in Primer 6.1.1.0 (Primer-E). The data was separated into blocks of time (years) in which the greatest number of week data was available. Time blocks used included early and late periods, as well as 'hot', 'cold', and 'mixed' periods. The data was organized, within each block of time, using week number as variables, and site and year as factors. Due to missing values, the data was further refined into a sub-grouping of weeks particular to that time period based on completeness of data. The data was then interpolated, using the average of the previous and following cell to replace a missing value. In cases where two or more consecutive cells were blank, those cells were not included in the MDS plot. Data was imported into Primer 6.1.1.0 and standardized by total. The standardized values were then used to create a Draftsman plot as well as a Resemblance Matrix using Euclidian distances. Parameters for the MDS plot included a Kruskal stress formula of 1, and a minimum stress of 0.1 using first the site then year factor. For each time period an Analysis of Similarity (ANOSIM) was used to determine the similarity of weeks between years.

RESULTS

Since the shellfish toxicity sampling protocol used by CFIA was not designed for research purposes, there was high temporal and spatial variability in sampling effort. The dataset provided by CFIA included PSP samples taken from a variety of species from 52 CFAs with 233 sampling sites. Because the majority of the dataset (84.24%) was comprised of *M. arenaria* samples, the dataset was narrowed to 37 CFAs which encompassed 168 sampling sites along the southwest coast of New Brunswick in the Bay of Fundy. Variability in the sampling effort between each of these CFAs was high, with some CFAs being sampled consistently, while others showed very low numbers of samplings (Fig. 2A). For example, CFA NB-9A was sampled 2521 times whereas zone NB-9B was sampled 114 times (Fig. 2A). In addition to the spatial variation in sampling effort, there was high temporal variation in sampling effort. CFA NB-13B was sampled a total of 2501 times (Fig. 2A) however, the majority of the sampling was done from 1969 to 1986 and from 1993-2010 (Fig. 2B). The two sampling sites Crow Harbour and Red Head Harbour are within NB-13B. Examination of how the sampling effort within NB-13B was distributed between sites showed that Red Head Harbour was sampled in 1944, stopped until 1947, then continued for three years at which point sampling ended, only resuming in recent years from 1992-2010 (Fig. 3A). Crow Harbour was originally sampled from 1946 until 1949, and resumed for the year 1951. Crow Harbour was not sampled again until 1957 and continued until 2003 when it stopped for 3 years, and resumed again from 2006-2010 (Fig. 3A).

In addition to the temporal variation between sites within a CFA when examined on a decadal scale, there was also temporal variation even within each year. Fig. 3B shows the within year sampling effort in NB-13B as well as the difference between Red Head Harbour and Crow Harbour in number of samples. This figure also shows the within year variation in sampling for each site, where the majority of the samples that were taken occur between day 120 and 360 at both sites (Fig. 3B). NB-13B is an example of variation between sites within a CFA and is indicative of all CFAs in that sampling effort between sites varied greatly both spatially and temporally. Because of this variability, the dataset was narrowed from all CFAs to 14 and from 168 to 16 sites, which represents 72.35% of the *M. arenaria* samples taken from 1943-2010 (Fig. 1).

PERCENT DURATION OF CLOSURES

Yearly

Examination of the percent duration of closures showed Crow Harbour and Red Head Harbour closed the majority of the time at 85.06% and 81.60% respectively (Fig. 4, Table 1). Lepreau Basin was found to have been closed 52.07% of the time (Fig. 4). The remaining 13 sites were closed less than 50% of the time since sampling began, with Ingalls Head and Harbour De Lute being closed less than 1 percent of the time (0.87% and 0.24% respectively) (Fig. 4, Table 1). The Eastern locations (i.e. Crow Harbour, Red Head Harbour, Pocologan, McLean Cove, and Lepreau Basin) showed the highest percent duration of closure, along with Ross Island Thoroughfare on the south east coast of Grand Manan (Fig. 5). An exception to this was Lepreau Harbour, which showed a relatively low percent duration of closure (16.65%) as compared to other eastern locations (Table 1). Both Simmons Cove and Letete Passage show relatively long closure lengths, as opposed to the locations west of Letete Passage, such as Bar Road (4.06%), Northern Harbour (5.50%), Stuart Town (13.76%), Harbour De

Lute (0.25%), Deep Cove (7.41%), Duck Cove (18.1%), as well as Ingalls Head (0.88%) (Fig. 5, Table 1).

Division of the sampling time into 'hot' years and 'cold' years showed similar trends (Fig. 6, Table 1). In 'hot' years Crow Harbour and Red Head Harbour were closed the majority of the time (83.30% and 79.18% respectively) followed by: Lepreau Basin (61.69%); Ross Island Thoroughfare (50.10%); Letete Passage (45.65%); Simmons Cove (38.38%); Pocologan West (30.27%); McLean Cove, Pocologan West (26.63%); Lepreau Harbour (24.97%) and Duck Cove (20.95%). The remaining sites all had a percent duration of closures during 'hot' years below 20%: Stuart Town (19.14%), Northern Harbour (10.89%), Deep Cove (5.97%), Bar Road (5.09%), Ingalls Head (1.62%), and Harbour De Lute (0.50%).

In 'cold' years, percent duration of closures was similar but lower for most locations (Fig. 6, Table 1). During 'cold' years, Red Head Harbour was closed more frequently than Crow Harbour (72.66% and 64.99% respectively) followed by Lepreau Basin (41.13%), and Pocologan West (31.02%). The remaining sites were closed less than 20% of the time during the 'cold' years: Ross Island Thoroughfare (19.47%), Simmons Cove (15.76%), McLean Cove (11.03%), Letete Passage (10.12%), Lepreau Harbour (9.23%), Duck Cove (8.51%), Stuart Town (3.08%), Northern Harbour (1.48%), Bar Road (1.33%), Deep Cove (0.62%), Ingalls Head (0.16%) and Harbour De Lute (0%). 'Hot' years showed higher percent duration of closures for all locations than 'cold' years, except Pocologan West, which showed a higher percent duration of closures in 'hot' years than in 'cold' (Fig. 6, Table 1).

The 'cold' period from 1948-1956 was examined for percent duration of closures (Fig. 7A, Table 2). It was found that of sites sampled during that time period, only Crow Harbour, Red Head Harbour and Lepreau Basin showed a percent duration of closure of 96.74%, 97.60%, and 45.02%, respectively (Table 2). Although not visible on Fig. 7A, Ross Island Thoroughfare was closed 4.2% of the time from 1948-1956. Among other sites sampled during that time period, Pocologan, Lepreau Harbour, and Northern Harbour were closed 2.71%, 0.6%, and 0.4 % of the time (Table 2).

During the 'hot' period of 1970-1986, all 16 sites were sampled, and all but five showed a percent duration closure of over 20% (Fig. 7B, Table 2). Red Head Harbour was closed 100% during this time period, followed by Crow Harbour (92.14%), Lepreau Basin (74.99%), Letete Passage (63.59%), Ross Island Thoroughfare (55.60%), Simmons Cove (55.21%), McLean Cove (Pocologan West) (51.12%), Pocologan West (30.35%), Duck Cove (30.22%), Stuart Town (28.69%), and Lepreau Harbour (26.37%) (Fig. 7B, Table 2). The remaining sites showed a percent duration of closure under 10%: Northern Harbour (8.78%), Deep Cove (8.20%), Bar Road (3.03%), Ingalls Head (1.00%) and Harbour De Lute (0.00%) (Fig. 7B, Table 2).

During the 'mixed' time period (1993-2010), Crow Harbour was closed 97.64% of the time, followed by Pocologan (44.02%), Simmons Cove (39.35%), Red Head Harbour (36.70%), Ross Island Thoroughfare (32.62%), and Lepreau Basin (27.09%) (Table 2). The remaining sites were closed less than 20% of the time; Lepreau Harbour (17.79%), Letete Passage (17.72%), Duck Cove (8.39%), Stuart Town (7.53%), Northern Harbour (6.76%), Bar Road (5.98%), Deep Cove (3.20%), Ingalls Head (2.02%) and Harbour De Lute (0.91%) (Table 2).

During the ‘hot’ years in this 1993-2010 period, Crow Harbour, Red Head Harbour and Ross Island Thoroughfare had a percent duration of closures of 98.08%, 52.51%, and 48.04% respectively, followed by Pocologan West (44.57%), Simmons Cove (41.37%), Lepreau Basin (39.91%), Letete Passage (29.10%) and Lepreau Harbour (26.45%) (Fig. 8, Table 2). The remaining sites were closed less than 20% of the time during the ‘hot’ years from 1993-2010; Duck Cove (13.82%), Stuart Town (13.12%), Northern Harbour (12.88%), Bar Road (10.50%), Deep Cove (6.39%), Ingalls Head (3.41%) and Harbour De Lute (1.83%) (Fig. 8, Table 2).

During the ‘cold’ years in the ‘mixed’ period from 1993-2010, Crow Harbour, Pocologan West, Simmons Cove and Red Head Harbour had a percent duration of closures of 97.20%, 43.47%, 37.32%, and 20.88% respectively, with the remaining sites closed <20% (Fig. 8, Table 2). The remaining sites were below 20% closure duration: Ross Island Thoroughfare (17.20%), Lepreau Basin (14.28%), Lepreau Harbour (9.13%), Letete Passage (6.33%), Duck Cove (2.95%), Stuart Town (1.95%), Bar Road (1.46%), Ingalls Head and Northern Harbour (0.64%), and Harbour De Lute and Deep Cove were not closed at all during the ‘cold’ years (Fig. 8, Table 2).

Seasonal Closures

Examination of seasonal closures of sites from 1943-2010 showed that the summer season has the highest percent duration of closures (Fig. 9, Table 3). The sites with the highest percent duration of summer closures were Crow Harbour, Lepreau Basin, and Ross Island Thoroughfare being closed 83.14%, 71.12%, and 55.45% of the time, respectively. All other sites showed closure lengths of less than 50% (Table 3): Letete Passage (47.73%), Lepreau Harbour (41.37%), Simmons Cove (36.17%), Duck Cove (30.43%), McLean Cove (24.54%), Stuart Town (24.38%), Red Head Harbour (24.33%), Northern Harbour (17.04%), Pocologan West (11.96%), Bar Road (9.48%), Deep Cove (8.39%), Ingalls Head (2.67%), and Harbour De Lute (0.94%). Each site showed an increase in the percent duration of closures from winter to spring, with the exception of Deep Cove which exhibited a slight decrease in closure length from 2.03% in winter to 1.81% in spring (Table 3). All sites showed an increase in the percent length of closure from spring to summer, and a decrease from summer to fall (Table 3). When moving from fall to winter for percent closure lengths, most sites showed a decrease except McLean Cove, Pocologan West (15.84% to 17.52%), Red Head Harbour (11.41% to 12.12%), Bar Road (0.22% to 0.57%), and Deep Cove (1.47% to 2.03%) (Table 3).

Examination of percent duration of seasonal closures showed that closures in ‘hot’ years were typically longer than those in ‘cold’ years (Fig. 10, 11). Regardless of whether a year was ‘hot’ or ‘cold’, the summer showed the higher percent duration of closure than other seasons, with the exception of Crow Harbour, where spring showed percent duration of closures as 75.38%, higher than summer at the same site (75.06%) in ‘cold’ years (Table 4, Fig. 12). There were certain sampling sites which exhibited a more drastic change in closure length between seasons than others when comparing ‘hot’ to ‘cold’ years (Fig. 12). For example, Lepreau Basin showed a 24.77% increase in closure duration when going from spring to summer in ‘cold’ years, and a 24.49% increase between the same seasons in ‘hot’ years (Table 4), whereas Northern Harbour showed a 4.17% increase from spring to summer in ‘cold’ years and a 25.28% increase during ‘hot’ years (Table 4).

Examination of the percent duration of seasonal closures during the ‘cold’ period (1948-1956) showed that though there were slight differences between seasons, the percent duration of closures was fairly

consistent between seasons (Fig. 13A). Lepreau Basin was the only site which had the majority of closures in the summer (61.59%). In Crow Harbour, closures were found to have occurred marginally more in the spring (44.44%) than the summer (42.63%), and Red Head Harbour showed fall and summer to be the same (88.89%), while closure duration in the spring was greater (100%) (Fig. 13A). This was not the case during the 'hot' period (1970-1986) where Red Head Harbour was closed 100% of the time during all seasons. All sites showed the highest percent duration of closures in the summer season except Pocologan [fall (34.40%); summer (29.41%)], Red Head Harbour (closed 100% of the time), and Simmons Cove [fall (58.38%); summer (54.48%)] (Fig. 13B).

When examining the 'mixed' period from 1993-2010, it was found that all sites showed the highest percent duration of closures in the summer (Fig. 14). All sites except Pocologan and Crow Harbour had 10-15% difference between the percent duration of summer closures and the percent duration of closures in other seasons (Fig. 14). The 'cold' years during the 'mixed' period showed a greater percent duration of closure for most sites in the summer season (Fig. 15A). However, Pocologan experienced the same percent closure in winter, spring, and summer (44.44%) while the percent duration for fall closures was lower (40.58%). Crow Harbour was closed 100% of the time in all seasons during this period (Fig. 15A). Simmons Cove showed both winter (44.44%) and spring (41.03%) had longer closures than did summer (32.85%) (Fig. 15A). Examination of the 'hot' years during the 'mixed' period revealed that the highest percent duration of closures occurred in the summer season at all sites, except Pocologan (Fig. 15B). Duration of closures at Pocologan was highest in the winter (45.19%), and lowest in the fall (44.08%) (Fig. 15B).

Monthly Closures

When examining the percent monthly duration of closures for the entire sample period (1943-2010), it was found that both Red Head Harbour and Crow Harbour maintained an approximately 80% closure duration for all months (Fig. 16A; Table 5). Crow Harbour was found to have the lowest percent duration of closure in December (77.94%) and the highest in August (85.63%), with Red Head Harbour displaying the lowest percent duration of closure in December (70.97%) and the highest in July (91.13%) (Fig. 16A; Table 5). Both McLean Cove and Pocologan displayed the same trend where they showed similar percent duration of closures month to month (Fig. 16A; Table 5). The lowest percent duration of closure in Pocologan occurred in April (29.26%) and the highest in September (36.23%). In McLean Cove, Pocologan West, the lowest percent duration of closure occurred in December (14.80%) and the highest in August (26.38%) (Fig. 16A; Table 5). Lepreau Basin was closed more in August (77.18%) and July (74.62%) than other months, and closed the least in March (40.23%) and April (38.77%). Lepreau Harbour was closed the most in July (51.85%) and least in February (2.36%) (Fig. 16A). Simmons Cove and Letete Passage were also closed most in July (38.99% and 47.96% respectively) and August (36.76% and 56.21%, respectively) and the least in February (23.63% and 21.17%, respectively) (Fig. 16B). Stuart Town, Northern Harbour and Bar Road showed their highest percent duration in July (31.26%, 24.38%, and 16.84%, respectively). Stuart Town was closed the least in April (4.85%), Northern Harbour was not closed at all from December to March inclusive, and Bar Road was not closed from November to January inclusive (Fig. 16B; Table 5). Ross Island Thoroughfare showed the same trend as Lepreau Basin, with the longest closures in July (55.69%) and August (63.66%) and the shortest in March (21.91%) and April (21.42%) (Fig. 16C; Table 5). Duck Cove was closed the most in August (35.96%) and the least in February (4.52%). Deep Cove was closed the longest in July (12.14%) and the least in February

(0.74%) Harbour De Lute showed a 2.13% duration closure in July, and 0% closure from September to May inclusive (Fig. 16C; Table 5). Ingalls Head, unlike the other site located in Grand Manan (Ross Island Thoroughfare) was closed the longest in August (3.32%), the least in June, and from November to March (0%) (Fig. 16C; Table 5).

Examination of percent duration of closures by month during the ‘hot’ period from 1970-1986 showed a similar pattern as the examination of the monthly closure data for all years from 1943-2010, although the closure lengths were more pronounced during ‘hot’ years (Fig. 18A, B, C). Red Head Harbour was closed 100% of the time for this time period, followed by Crow Harbour as the highest percent duration for monthly closures. Crow Harbour was closed the most with 100% during July, 98.10% during August, 97.65% during September, and the least in February (82.35%) and March (84.44%) (Fig. 18A). Lepreau Basin showed high closure lengths for all months, with the highest percent duration of closure occurring in August (96.77%), and the lowest in October (68.69%). Pocologan showed consistent percent duration of closure for all months from 1970-1986, with a slight spike in closure length in November and December (34.71% and 35.71%, respectively) and the lowest closure duration in October (26.19%). McLean Cove was closed longer than Pocologan, with the highest percent duration of closure in July (64.14%), August (70.02%) and September (64.51%), and the lowest in March (39.85%) and April (40.98%) (Fig. 18A). Lepreau Harbour showed a visibly different pattern from the other eastern sites (Fig. 18A), although the longest closures were in July (63.95%), August (76.66%), and September (58.24%) and the lowest percent duration of closures was from October to May (1.89% to 17.65%), with the lowest in February (1.89%). Letete Passage showed a similar trend as Lepreau Basin, albeit to a lesser degree, with the highest percent duration of closures occurring in August (93.55%) and September (91.76%), and the lowest occurring in February (51.47%) (Fig. 18B). Simmons Cove had consistent percent duration of closures during the ‘hot’ period from 1970-1986, ranging from 52.94% to 58.82% with the highest occurring in June, November, and December while the lowest occurred in September, and Jan-April, inclusive (Fig. 18B). Stuart Town was closed the most in July (46.68%) and August (46.30%), and the least in April (19.41%). Northern Harbour experienced the most closures during August (33.21%) whereas the least amount of closures occurred from December to March (0%). Bar Road was rarely closed during this ‘hot’ period with the highest percent duration of closures occurring during the month of July (12.52%) It was not closed at all from October to April (Fig. 18C).

Examination of the percent duration of closure during the ‘cold’ period from 1948-1956 showed that Red Head Harbour had the highest levels of closure duration (Fig. 19). Red Head Harbour percent duration of closure was consistently high for each month ranging from 86.38% to 100% in January and April-June respectively (Fig. 19). Crow Harbour showed a similar pattern to Red Head Harbour during this time period, but to a much lesser degree (Fig. 19). The highest percent duration of closure for Crow Harbour was 44.44% in January-August while the lowest was 33.33% in October-December (Fig. 19). Lepreau Basin was less consistent in closure duration than Red Head Harbour and Crow Harbour, with the highest percent duration of closure occurring in July (57.71%), August (57.71%), September (70.37%), and October (59.86%), and the lowest in February (19.84%). The remaining sites that were sampled during this period all had percent duration of closures lower than 15% (Fig. 19). Ross Island Thoroughfare showed 11.11% length of closure in September, October and November with 0% length of closure for the remaining months, with the exception of August (5.73%) (Fig. 19). Pocologan had two spikes in percent duration of closure, one in June (8.52%) and one in August (11.11%), with a 0% length of closure from October-April (Fig. 19). Lepreau Harbour had a

percent duration of closure of 5.02% in July, and 2.59% in June, and was not closed at all from August-May (Fig. 19). Northern Harbour was not closed at all from October to July and had a percent duration of closure of 3.23% in August and 1.85% in September (Fig. 19).

The ‘mixed’ period from 1993-2010 was examined, and it was found that Crow Harbour was the site that was closed for the longest duration in all months (Fig. 20A). Crow Harbour had the highest percent duration of closure in January, February, March, and July (100%), and the lowest in October (88.89%). Pocologan showed a similar pattern of consistency as Crow Harbour, but the percent duration of closures at Pocologan was much lower (Fig. 20A). The highest percent length of closures in Pocologan was in January (45.16%), while the lowest was 38.53% in December (Fig. 20A). Red Head Harbour showed the highest percent duration of closures in June (60.37%), July (83.15%), and August (77.78%), while the lowest percent length of closure was in March and April, 17.74% and 17.78%, respectively (Fig. 20A). Lepreau Basin had its highest percent length of closures in June (44.44%), July (76.16%), and August (66.67%) and the lowest (0.36%) in March (Fig. 20A). Lepreau Harbour showed the same pattern of closure durations as Lepreau Basin: highest in June (31.48%), July (68.28%), and August (51.97%) and lowest in March (1.43%). Simmons Cove had a similar pattern with the highest percent length of closures occurring during June (43.33%), July (60.57%), and August (53.94%), however the lowest (21.48%) occurred in April (Fig. 20A). Letete Passage was slightly different from the previous four sites, with the highest percent duration of closure occurring in August (61.83%), second highest in July (46.59%), and lowest occurring in November (4.81%). Examination of the eastern sites (excluding Grand Manan) revealed that all sites had a similar trend, with the highest percent duration occurring in July for all sites (Fig. 20B). Northern Harbour had the highest percent duration of closures (44.27%), followed by Duck Cove (43.37%) and Stuart Town (43.37%), then Bar Road (34.05%), Deep Cove (21.68%), and Harbour De Lute (8.06%). Both Duck Cove and Stuart Town had high percent duration of closures in August as well, 37.46% and 34.23% respectively. All eastern sites had 0% duration of closures from November to May during this period with the exception of Bar Road, which was closed 0% from September to January (Fig. 20B). The Grand Manan sites were markedly different in their percent duration of closures, with Ross Island Thoroughfare showing a consistently higher percent closure than Ingalls Head. Ross Island Thoroughfare had the highest percent duration of closures in July and August (69.35% and 68.64%, respectively), with the lowest in February and April (15.28% and 14.44% respectively). Ingalls Head was open the majority of the time from 1993-2010, but showed 7.35% duration of closure in July, 5.91% in August and 8.33% in September while showing 0% from November to March, as well as June (Fig. 20C).

Comparison of the percent duration of closures by month in the ‘hot’ and ‘cold’ years within the ‘mixed’ period showed that for most sites, ‘hot’ years had a higher percent duration of closures than ‘cold’ years (Fig. 21). This comparison also showed that for the most part, trends in percent closure duration by month were similar between ‘hot’ and ‘cold’ years (Fig. 21). Some notable exceptions to this were Crow Harbour and Letete Passage (Fig. 21). Examination of the differences in the percent duration of monthly closures at Crow Harbour showed that ‘cold’ years could exceed ‘hot’ years (Fig. 21). In Crow Harbour, ‘cold’ years were equal to, or greater than ‘hot’ years in monthly percent duration of closures in all months except June (Fig. 21). Letete Passage was different from all sites during this period in that ‘cold’ years did not follow the same trend as ‘hot’ years (Fig. 21). During the winter months (January, February and March), the ‘hot’ years showed the lowest (3.58%, 0%, 0%), whereas the ‘cold’ years showed the highest (44.44%) percent duration of closures (Fig. 21).

Following the summer peak (in 'hot' years) there was a decline in monthly percent duration of closures until April, when closures began to increase (Fig. 21). The opposite occurred during the 'cold' years in Simmons Cove, in that the percent duration of monthly closures increased from the summer months to April, when the percent duration of monthly closures decreased (Fig. 21).

MEAN PSP CONCENTRATION

Mean PSP toxin levels were examined for the same time periods as percent duration of closures. Initial examination began with taking the mean PSP toxin level across all key sites (Fig. 22). It was found that there was a cyclical trend in mean PSP levels in the Bay of Fundy. There have been spikes in mean PSP toxin levels since 1943. The first spike occurred in 1945 (253.19 $\mu\text{g STX}/100\text{ g tissue}$). Following 1945, from 1948 to 1956 was a 'cold' period, where the mean PSP toxin level was below 80 $\mu\text{g STX}/100\text{ g tissue}$ each year (Fig. 22). Following this 'cold' period, there was a gradual increase in mean PSP toxin levels from 1957 to a spike (227.33 $\mu\text{g STX}/100\text{ g tissue}$) in 1961, followed by a drop and a gradual decrease to below 80 $\mu\text{g STX}/100\text{ g tissue}$ (Fig. 22). From 1970 to 1986 there was a continuous 'hot' period in which the mean PSP toxin levels were consistently above 80 $\mu\text{g STX}/100\text{ g tissue}$, with a maximum of 395.15 $\mu\text{g STX}/100\text{ g tissue}$ in 1980. From 1993 to 2010, there was a 'mixed' period of an equal number of 'hot' and 'cold' years, with the highest level of mean PSP toxins occurring in 2008 (148.59 $\mu\text{g STX}/100\text{ g tissue}$), and the lowest in 2000 (33.68 $\mu\text{g STX}/100\text{ g tissue}$). Examination of the mean PSP toxin levels for each site across time yielded results which showed which sites had higher levels of toxins (Table 7). Crow Harbour had the highest mean PSP toxin levels (382.30 $\mu\text{g STX}/100\text{ g tissue}$), followed by Lepreau Basin (136.38 $\mu\text{g STX}/100\text{ g tissue}$), and Simmons Cove (125.35 $\mu\text{g STX}/100\text{ g tissue}$) (Table 7; Fig. 23, Fig. 24). The sites with the lowest mean PSP toxin levels were Harbour De Lute, Ingalls Head, Deep Cove (31.40, 34.12, and 37.60 $\mu\text{g STX}/100\text{ g tissue}$, respectively) (Table 7; Fig. 23, Fig. 24).

Seasonal Mean PSP Concentration

Further examination of mean PSP toxin levels was performed at a seasonal level (Fig. 25, Table 8). When the seasonal values were examined over the entire dataset (1943-2010), it was found that the summer season showed the highest levels of PSP toxin at each site (Fig. 25; Table 8). In general, spring mean PSP toxin levels were greater than winter, with the exception of Duck Cove, which dropped from 49.65 $\mu\text{g STX}/100\text{ g tissue}$ in the winter to 49.22 $\mu\text{g STX}/100\text{ g tissue}$ in the spring, and Pocologan (from 45.49 to 44.48 $\mu\text{g STX}/100\text{ g tissue}$) (Table 8). In all cases, fall levels were lower than the summer season (Fig. 25; Table 8). Examination of the seasonal mean PSP toxin levels during 'hot' and 'cold' years from 1943-2010 also show that the summer season had the highest levels (Fig. 26 A, B; Table 9). All PSP toxin levels in 'hot' years from 1943-2010 were higher than those in 'cold' years during the same time frame (Fig. 27A, B; Table 9).

During the 'cold' period from 1948 to 1956, only 10 of 16 sites were sampled at all, and of those, only 3 had samples taken during each season (Fig. 28B; Table 10). The majority of sites showed the summer season as having the highest mean seasonal PSP toxin concentrations (Fig. 28B; Table 10). Lepreau Harbour was the only site which showed spring as having the higher concentrations (32.15 $\mu\text{g STX}/100\text{ g tissue}$ in spring to 30.56 $\mu\text{g STX}/100\text{ g tissue}$ in summer).

The 'hot' period (1970-1986) showed a similar pattern in mean seasonal PSP toxin levels, in that the summer season showed the highest levels (Fig. 28A; Table 11). One exception to this was Deep Cove

which showed its highest mean seasonal PSP values in the winter rather than the summer (Fig. 28A; Table 11). PSP toxin levels at Deep Cove went from a winter concentration of 54.25 µg STX/100 g tissue to a summer concentration of 47.04 µg STX/100 g tissue (Fig. 28A; Table 11). Most sites showed an increase in PSP toxin concentrations from winter to spring during this 'hot' period, with the exception of Lepreau Basin, Simmons Cove, Harbour De Lute, and Deep Cove (Fig. 28A; Table 11). Each of these sites showed a decrease in PSP toxin concentrations: Lepreau Basin (101.38 to 90.98 µg STX/100 g tissue), Simmons Cove (198.03 to 185.55 µg STX/100 g tissue), Harbour De Lute (30.40 to 29.75 µg STX/100 g tissue), and Deep Cove (54.25 to 45.07 µg STX/100 g tissue) (Fig. 28A; Table 11). There were no samples taken from Pocologan in the spring or summer, and no samples taken from Red Head Harbour in any season during this 1970-1986 time period (Fig. 28A; Table 11).

Further examination of mean PSP toxin concentrations showed that during the 'mixed' period from 1993-2010, Crow Harbour had the highest levels (482.50 µg STX/100 g tissue) followed by: Red Head Harbour (116.32 µg STX/100 g tissue), Simmons Cove (98.05 µg STX/100 g tissue), and Ross Island Thoroughfare (96.58 µg STX/100 g tissue) (Fig. 29, Table 12). The sites with the lowest mean PSP toxin concentrations during this time period were Harbour De Lute, Ingalls Head and Deep Cove (34.65, 35.22, 38.59 µg STX/100 g tissue, respectively) (Fig. 29, Table 12). When the 'mixed' period at a seasonal level was examined, it was found that summer was the season with the highest mean PSP toxin concentrations at all sites except Harbour De Lute which showed a spring value of 35.49 µg STX/100 g tissue and a summer value of 35.33 µg STX/100 g tissue (Fig. 30B, Table 12). All sites showed an increase in mean PSP toxin concentrations from winter to spring, with the exception of Ingalls Head (decreased from 32.79 to 31.87 µg STX/100 g tissue), and Pocologan (decreased from 50.52 to 29 µg STX/100 g tissue) (Fig. 30B; Table 12).

In the 'hot' years during the 'mixed' period from 1993-2010, all sites except Harbour De Lute showed the highest mean PSP toxin concentrations in summer (Fig. 31B; Table 13). Spring had the highest mean PSP toxin concentrations during this time period at Harbour De Lute, with mean PSP toxin levels of 38.67 µg STX/ 100 g tissue over 38.30 µg STX/100 g tissue in the summer (Table 13). Also, during the 'hot' years from 1993-2010, Crow Harbour showed the highest mean PSP toxin concentrations in all seasons, with a peak concentration of 1423.50 µg STX/ 100 g during the summer (Fig. 31A; Table 13). Crow Harbour, Red Head Harbour, Ross Island Thoroughfare, and Lepreau Basin showed the highest mean seasonal PSP concentrations, whereas Deep Cove, Ingalls Head, and Harbour De Lute showed the lowest (Table 13). Examination of the 'cold' years during the 'mixed' period showed that the summer season had the highest mean PSP toxin level with the exception of Simmons Cove, Bar Road, and Northern Harbour (Table 13; Fig. 32). All three exceptions moved from higher mean PSP concentrations in the spring to the summer: Simmons Cove (101.85 µg STX/ 100 g to 93.82 µg STX/100 g), Bar Road (35.7 µg STX/100 g to 29.78 µg STX/100 g), and Northern Harbour (35.1 µg STX/100 g to 34.09 µg STX/100 g) (Table 13). All sites except for Ingalls Head and Pocologan showed an increase in mean PSP toxin concentrations when moving from winter to spring (Table 13, Fig. 32). Mean PSP toxin levels at Ingalls Head moved from 31.8 to 29.55 µg STX/100 g, while Pocologan decreased from 36.29 to 29 µg STX/100 g (Table 13; Fig. 32).

Monthly Mean PSP Concentration

Due to the distribution of the data, mean monthly PSP toxin concentrations were not graphically represented, but instead are presented in tabular form. Examination of the mean monthly PSP toxin concentrations from sites was performed using the same time blocks as previous sections. Simple ranking was used to compare between sites and between months. When comparing between sites from 1943 to 2010, the three sites which had the highest mean PSP toxin concentrations were (from highest to lowest) Crow Harbour, Simmons Cove, and Lepreau Basin (Table 14). The four sites with the lowest levels of mean PSP toxin concentrations were (from highest to lowest) Deep Cove, Ingalls Head, Bar Road, and Harbour De Lute (Table 14). Both the three worst (highest mean PSP toxin concentrations) and the three best (lowest mean PSP toxin concentration) sites were consistent when examined for both the ‘cold’ years and the ‘hot’ years from 1943-2010 (Table 17), as well as the ‘hot’ period from 1970-1986 (Table 15, 16). Examination of monthly PSP data for the ‘cold’ period from 1948 to 1956 showed a different trend, with Ingalls Head being the ‘best’ site followed by Crow Harbour (Table 18). There were large gaps in sampling within this ‘cold’ period, with some sites (like Crow Harbour) only sampled once, which resulted in a skewed perspective of which sites were “better” or “worse”. During the ‘mixed’ period between 1993 and 2010, the three sites with the highest mean levels of PSP toxins were Crow Harbour, Red Head Harbour, and Ross Island Thoroughfare (Table 19). However, when examining ‘cold’ years during the same time period, the three sites which had the highest mean monthly PSP toxin concentrations were (highest to lowest) Crow Harbour, Simmons Cove, and Red Head Harbour (Table 20). The three sites with the highest mean PSP toxin concentrations during the ‘hot’ years were (high to low concentration) Red Head Harbour, Ross Island Thoroughfare, and Crow Harbour (Table 21). The four sites with the lowest mean monthly PSP toxin concentrations when examining all years from 1993-2010 were (highest to lowest) Ingalls Head, Bar Road, Deep Cove, Harbour De Lute (Table 19). This trend was seen in the ‘hot’ years during the same period, with a slight variation: (from highest to lowest) Bar Road, Deep Cove, Ingalls Head, Harbour De Lute (Table 21).

Monthly Perspective

When examining the mean monthly PSP toxin levels for the entire range of the dataset (1943-2010) it was found that, on average, June, July, August, and September were the months showing the highest levels. There was some variability between sites in respect to the months with the highest levels in each (Table 22). The sites where July, August and September were the months with the highest mean PSP toxin concentrations were: Ross Island Thoroughfare, Ingalls Head, Duck Cove, Letete Passage, Simmons Cove, Crow Harbour, McLean Cove, Lepreau Harbour, and Lepreau Basin (Table 22). The sites which showed June, July, and August as the months with the highest mean PSP toxin concentration were Deep Cove, Harbour De Lute, Northern Harbour, and Red Head Harbour (Table 22). Bar Road mean PSP toxin concentrations were highest in May, June, and July whereas Pocologan showed high levels in July and August as well as February (Table 22).

The ‘cold’ years from 1943 to 2010 showed a similar pattern, in that July, August, and September were the months with the highest mean PSP toxin concentrations for the majority of the sites (Table

23). The few exceptions to the rule were Northern Harbour, Simmons Cove, Crow Harbour, and Red Head Harbour which showed the 'hottest' months as June, July and August (Table 23). Bar Road was different again during these 'cold' years, with the 'hottest' months being May, June, and July (Table 23). During the 'hot' years from 1943 to 2010, a similar trend was apparent, although with some variation. June, July, August, and September were the 'hottest' months for most sites, with the exception of Bar Road where May, June, July, and August were the months with the highest mean PSP toxin concentrations (Table 24). Pocologan, Deep Cove, and Harbour De Lute showed some winter months being among the months with the highest mean monthly PSP toxin concentrations: Pocologan (February), Deep Cove (January and February), and Harbour De Lute (January) (Table 24).

An examination of the 'hot' period from 1970 to 1986 showed similar trends as previous examinations though with more variability in the 'hot' months (Table 25). The majority of sites showed that June, July, August and September were the 'hottest' months, with some exceptions (Table 25). Harbour De Lute showed January as the 'hottest' month while the other 'hot' months were June, July, and August (Table 25). Bar Road again showed its 'hot' months in May, June, July, and August (Table 25). It was found that sampling was limited during the 'cold' period from 1948 to 1956 and as such, the trends visible for each site during other time periods were not similar (Table 26). There was a similar overall trend when examining this 'cold' period in that the 'hot' months were still shown to be from May to September (Table 26). Examination of the 'mixed' period from 1993-2010 showed that the 'hottest' months were from June to September and at some sites started in May (Table 27). Harbour De Lute was an exception to this rule, with January showing as the third 'hottest' month (Table 27). The 'cold' years during the 'mixed' period from 1993 to 2010 showed a similar trend, with the 'hot' months from May to September (Table 28). Ingalls Head was an exception, with two 'hot' months near the beginning of the year (March and April), and two in the fall (September and October) (Table 28). The 'hot' years during the 'mixed' period showed the same trend as other time periods, with June to September being the 'hot' months, with the exception of Deep Cove, with January being the third 'hottest' month (Table 29).

CORRELATION AND RESEMBLANCE

The Pearson Correlation Matrix showed that all sites were positively correlated with one another to varying degrees (Table 38). The highest correlation was between Letete Passage and Simmons Cove ($R=0.903$, $p<0.000$). Letete Passage was also correlated with Stuart Town ($R=0.821$, $p<0.000$). Bar Road showed the lowest correlation with all other sites, with 14 of 15 sites having a correlation factor of less than 0.350 except Northern Harbour ($R=0.596$, $p<0.000$) (Table 38). Bar Road was the second lowest correlated with Lepreau Basin ($R=0.316$, $p<0.000$), just above Ingalls Head ($R=0.274$, $p<0.000$). Ingalls Head also showed low correlation with all other sites (13 of 15 sites had an $R<0.450$), with the highest being with McLean Cove Pocologan West ($R=0.541$, $p<0.000$) and Harbour De Lute ($R=0.505$, $p<0.000$) while the lowest correlation was with Bar Road ($R=0.103$, $p<0.019$). Pocologan West showed some significant correlations with other sites; Crow Harbour ($R=0.884$, $p<0.000$), Lepreau Basin ($R=0.802$, $p<0.000$), Lepreau Harbour ($R=0.781$, $p<0.000$), and Ross Island Thoroughfare ($R=0.777$, $p<0.000$). Pocologan also showed 5 non-significant correlations, two of which were negative; Harbour De Lute ($R=-0.183$, $p=0.590$, $n=11$) and Ingalls Head ($R=-0.160$, $p=0.554$, $n=16$) (Table 38). These non significant correlations may be the result of small sample size. Pocologan West was sampled primarily from 1943 to 1962, with sampling occurring in

1981 and 1982, then recommencing in 1999. Many of the other sites were sampled fairly continuously throughout the period following 1962. McLean Cove, Pocologan West was sampled in alternate years from Pocologan; therefore a correlation was not possible between the two sites. Crow Harbour was positively correlated with all sites, the highest correlation with Pocologan ($R=0.884$, $p<0.000$). This site was also correlated with McLean Cove, Pocologan West ($R=0.808$, $p<0.000$), Lepreau Harbour ($R=0.708$, $p<0.000$) and Northern Harbour ($R=0.676$, $p<0.000$) (Table 38).

Examination of weekly PSP values between sites in different years by MDS showed little to no difference between sites, but some differences between years. The early period examined (1958-1962) showed no difference between sites, but did exhibit some grouping of years (Fig. 33A, B). Within this time period, 1961 was found to be significantly different from all years, except for 1959 ($p=0.056$) (Fig. 33A). Examination of the later period 2008-2010 showed no significant grouping of years or sites, indicating no difference between them (Fig. 34A, B).

During the ‘hot’ years from 1980 to 1985, 1980 was significantly different from all other years and 1981 was different from all years except 1984 (Fig. 35A). All sites in 1980 except Bar Road grouped out from all other sites, and 1984 was different from all years but 1984 (Fig. 35A, B). Examination of site differences from 1980-1985 showed that Bar Road was different from Crow Harbour ($p=0.029$) (Fig. 35B). During the ‘cold’ period (1963-1969), there were no differences between sites, and few differences between years (Fig. 36A, B). During the ‘mixed’ period (2001-2006), all years were significantly different from each other except 2002 and 2006 ($p=0.472$) (Fig. 37A). Site examination during this period revealed differences as well (Fig. 37B). Bar Road was shown to be different from Duck Cove ($p=0.032$), Letete Passage ($p=0.037$), Red Head Harbour ($p=0.002$) and Ross Island Thoroughfare ($p=0.038$). Deep Cove was different from Red Head Harbour ($p=0.008$), Letete Passage from Northern Harbour (0.045), and Northern Harbour from Red Head Harbour ($p=0.002$) (Fig. 37B).

DISCUSSION

There was a large amount of variability in the dataset provided by CFIA. The variability in sampling effort within CFAs led to the need to choose ‘key’ locations to represent a particular CFA for comparison purposes. Due to the lack of consistent spatial sampling within a CFA, the chosen ‘key’ location may not have been appropriate to act as a representative site. Consistent spatial sampling within a CFA over time would have allowed for a comparison between PSP toxin levels from all sites within a CFA. This comparison could have been used to investigate whether a site belongs within a particular CFA, or if new CFA borders should be created. There was also high variability in the sampling effort between CFAs. This led to large gaps in the area an analysis could include. Without consistent sampling effort between CFAs, it was difficult to determine whether some CFAs acted differently from others in terms of PSP toxin levels.

In addition to the spatial variability in sampling effort, the high temporal variability present in the dataset led to another set of problems. It is important to note that the data was not collected for research purposes, but for human health and to protect the consumer. Sites were sampled at different and inconsistent times. Any given site had inconsistencies in its sampling protocol as well. These inconsistencies resulted in an inability to monitor the onset of PSP toxins and their uptake within bivalve species. Sampling effort at a given location was determined by a variety of factors. Some of

these factors included logistics such as: time available to sample, the number of samplers available, the tides, as well as the ability to process a certain number of samples. Another factor used to determine sampling effort at a site was PSP toxin levels. For instance, if a sample from a site showed PSP toxin levels higher than the threshold, sampling was discontinued for three weeks. Since an area was closed to harvesting, it was not important to determine the highest levels of toxins detected. This practice resulted in a limited dataset as the potential maximum concentrations of PSP toxins at a given site was not quantified. A rigorous sampling protocol within a particular site would have allowed for long term statistical analyses to be performed. For example, sites should have been sampled in a consistent manner in terms of the number of samples taken, and the time the samples were taken (i.e. Tuesdays, every second week, daily, etc.).

In terms of PSP toxin concentrations, the sites tested in the Bay of Fundy acted in concert, with each increasing with the others. The sites were all positively correlated with each other to varying degrees. On the whole, sites to the east (Crow Harbour, Red Head Harbour, Pocologan, McLean Cove, Lepreau Basin, Simmons Cove, Letete Passage) tended to have the highest PSP toxin concentrations. Among those sites with the highest PSP toxin levels was Ross Island Thoroughfare. Lepreau Harbour was geographically located with these sites, but tended to have lower PSP toxin levels than the rest. This high correlation between these sites (except Lepreau Basin) suggests that oceanographic or geographic properties may be involved. Lepreau Basin is relatively sheltered geographically speaking and may have less water exchange than other nearby sites.

Harbour De Lute was the site which showed the lowest levels of PSP toxins and percent duration of closures. Bar Road and Ingalls Head also showed low levels of PSP toxins when the eastern sites showed high levels. These sites are also geographically sheltered from the eastern sites, which may result in less water exchange, leading to lower levels of PSP toxins and thus lower percent duration of closures.

There were differences between 'hot' and 'cold' years in terms of PSP toxin levels, which were expected, as the delineation between these types of years were PSP concentrations of 80 µg STX/100 g tissue. It is important to note however, that 'cold' years could still exhibit long closures and high PSP toxin levels in different sites. Seasonal differences between sites in terms of both PSP toxin levels and percent duration of closures were consistent in trend. Summer was the season with both the highest PSP toxin concentrations and highest percent duration of closures while winter was the opposite (low PSP toxin levels, low percent duration of closures). That being said, winter still showed closures and high levels for certain sites (i.e. Crow Harbour, Red Head Harbour, Lepreau Basin, etc.). Examination of monthly closures showed that the majority of sites had higher PSP levels in June, July, August, and September, and as a result, higher percent duration of closures. Though variability exists in PSP toxin levels within each month, the percent duration of closures stayed relatively constant, due to the PSP levels staying high, as well as to CFIA restrictions on closure times.

In terms of potential sites for commercial fishing or aquaculture development, there were a variety of sites which may have lower risk to crops from high PSP toxin levels. Harbour De Lute, Bar Road, and Ingalls Head had the lowest risk of PSP toxin exposure, as did Northern Harbour. By examining the correlation matrix in Table 38, it will be possible to compare sites and evaluate the relative risk of an increase in PSP toxin levels. Ideally, harvest should occur between October and May in order to ensure lower PSP concentrations. However, it is important to note that though this time frame shows

on average lower levels of PSP toxins, there can still be CFA closures or sites which will show high relative PSP toxin levels.

The samples collected by CFIA have been those of *M. arenaria* from the intertidal zone. Some samples of the blue mussel (*Mytilus edulis*) have been collected and analysed, if on a much smaller scale than *M. arenaria*. As such, a comparison of the two would have very low statistical significance. A new sampling protocol would need to be established to allow testing of individuals of *M. edulis*. Currently, when a CFA is closed due to high PSP toxin levels from soft-shell clam results collected in the intertidal area by CFIA, the area is closed for all shellfish harvesting including blue mussels being raised on aquaculture sites within the CFA. With the increased interest in the aquaculture industry in the Bay of Fundy, and the beginning of Integrated Multi-trophic Aquaculture, a comparison of PSP toxin concentrations between intertidal and raft mussels would be beneficial in determining if these aquaculture site closures are necessary or if the timing of increased and decreased toxin levels coincides with the inshore soft-shell clam levels.

In addition, with the current CFIA dataset, further analysis will be hampered due to gaps in the data. Moving forward, it would be beneficial for analyses purposes if a rigorous sampling protocol was instituted to standardize sample size and sampling dates within and between sites. By instituting a sampling protocol based on larger sample size and sampling on a regular basis even at sites which are closed, a more comprehensive and continuous dataset would be obtained which would allow for a more detailed examination of spatial and temporal trends in PSP toxin concentrations in the intertidal zones of the Bay of Fundy.

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LITERATURE CITED

- AOAC 1990. Paralytic shellfish poison. Biological method. Final action. In Hellrich, K. (Ed.), Official Methods of Analysis, 15th ed., Sec. 959.08. Association of Official Analytical Chemists, Arlington, Virginia, USA. pp. 881-882.
- DeGrasse, S.L., van de Riet J., Hatfield R., Turner A. 2011. Pre-versus post-column oxidation liquid chromatography fluorescence detection of paralytic shellfish toxins. *Toxicon*. 57(4): 619-624.
- Lander, T., Barrington, K., Robinson, S., MacDonald, B. and Martin, J. 2004. Dynamics of the blue mussel as an extractive organism in an integrated multi-trophic aquaculture system. *Bulletin of the Aquaculture Association of Canada*. 104(3): 19-28.
- Martin, J. 1990. Red Tides. In *Underwater world* (1). Canadian Department of Fisheries and Oceans, Communications Directorate, Ottawa, Ontario:12 p.
- Martin, J.L., and Richard, D. 1996. Shellfish toxicity from the Bay of Fundy, eastern Canada, 50 years in retrospect. In *Harmful and toxic algal blooms: Proceedings of the seventh international conference on toxic phytoplankton*. Sendai, Japan 12-16 July 1995. Edited by T. Yasumoto, Y. Oshima, and Y. Fukuyo. IOC/UNESCO. pp. 3-6.
- Martin, J.L., Wildish, D.J., LeGresley, M.M., and Ringuette, M.M. 1995. Phytoplankton monitoring in the southwest Bay of Fundy during 1990-1992. *Can. Manuscr. Rep. Fish. Aquat. Sci.* 2277: 157 p.
- Martin, J.L., LeGresley, M.M., Haya, K., Sephton, D.H., Burrige, L.E., and Chang, B.D. 2006. Salmon mortalities associated with a bloom of *Alexandrium fundyense* in 2003 in the Bay of Fundy, and subsequent early warning approaches for industry. *Afr. J. Mar. Sci.* 28(2): 431-434.
- Medcof, J.C., Leim, A.H., Needler, A.B., Needler, A.H., Gibbard, J. and Naubert, J. 1947. Paralytic shellfish poisoning on the Canadian Atlantic Coast. *Bull. Fish. Res. Board. Can.* LXXV. 32 p.
- Needler, A.B. 1949. Paralytic shellfish poisoning and *Goniaulax tamarensis*. *J. Fish Res. Board Can.* 7(8): 490-504.
- Prakash, A., Medcof, J.C. and Tennant, A.D. 1971. Paralytic shellfish poisoning in eastern Canada. *Bull. Fish. Res. Board Can.* 177: 87 p.
- Ridler, N., Robinson, B., Chopin, T., Robinson, S., and Page, F. 2006. Development of integrated multi-trophic aquaculture in the Bay of Fundy, Canada: a socio-economic case study. *World Aquac.* 37(3): 43-48.
- Todd, E.C.D. 1997. Seafood-associated diseases and control in Canada. *Rev. Sci. Tech. Off. Int. Epizoot.* 16(2): 661-672.

- Troell M, Halling, C., Neori, A., Chopin, T., Buschmann, A.H., Kautsky, N. and Yarish, C. 2003. Integrated mariculture: asking the right questions. *Aquaculture* 226: 69-90.
- van de Riet, J., Gibbs, R.S., Muggah, P.M., Rourke, W.A., MacNeil, J.D. and Quilliam, M.A. 2011. Liquid chromatography post-column oxidation (PCOX) method for the determination of paralytic shellfish toxins in mussels, clams, oysters, and scallops: collaborative study. *J. AOAC International*. 94(4): 1154-1176.
- Van Dolah, F.M. 2000. Marine algal toxins: origins, health effects, and their increased occurrence. *Environ. Health Perspect.* 108 (1): 133-141.
- White, A.W. 1981. Marine zooplankton can accumulate and retain dinoflagellate toxins and cause fish kills. *Limnol. and Oceanogr.* 26(1): 103-109 pp.
- White, A.W. 1982. Intensification of *Gonyaulax* blooms and shellfish toxicity in the Bay of Fundy. *Can. Tech. Rep. Fish. Aquat. Sci.* 1064, 15 p.
- Zhou, M., Li, J., Luckas, B., Yu, R., Yan, T., Hummert, C., and Kastrup, S. 1999. A recent shellfish toxin investigation in China. *Mar. Pollut. Bul.* 39(1): 331-334.

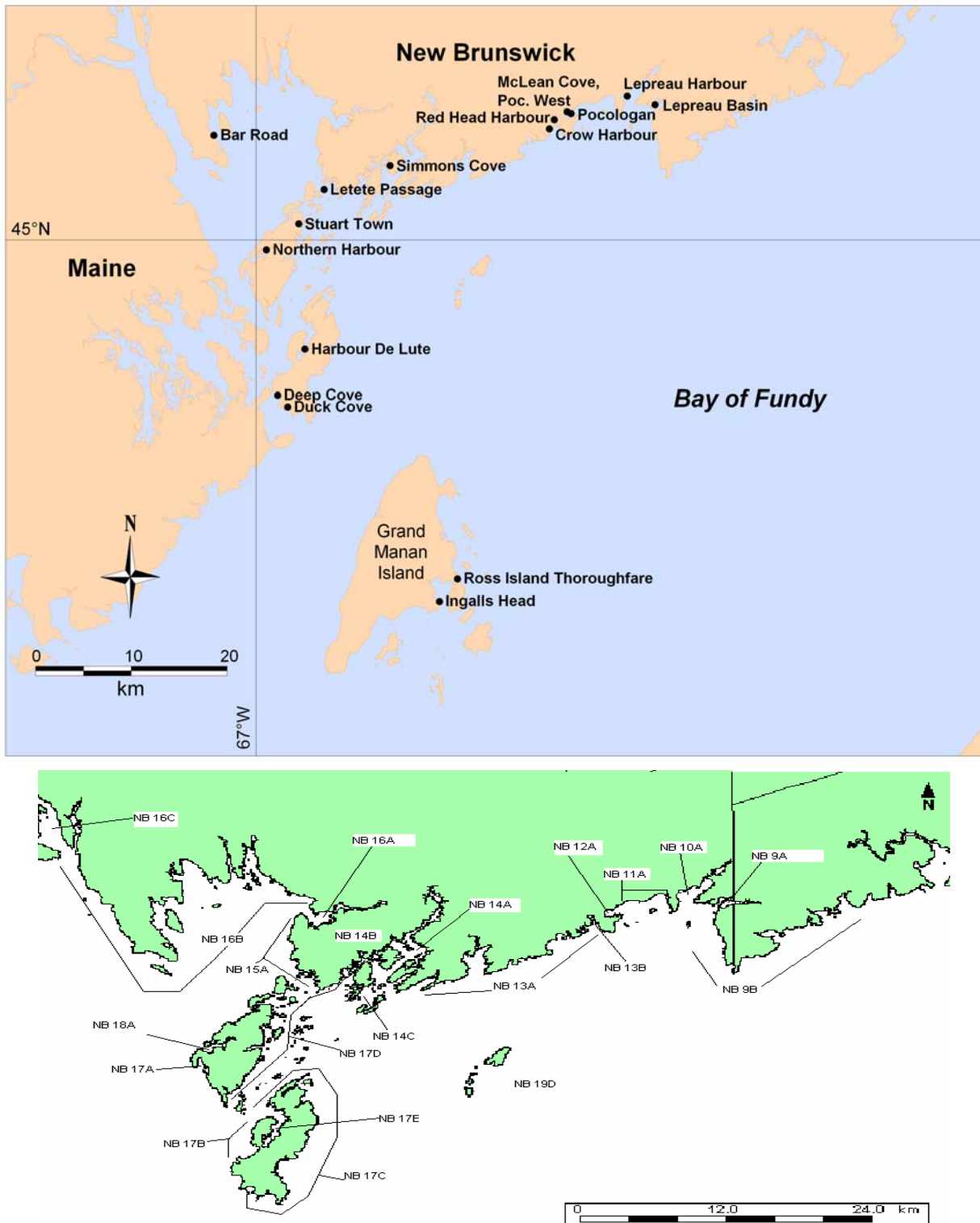


Fig. 1: Map of PSP sampling locations for the Canadian Food Inspection Agency along the southern coast of New Brunswick in the Bay of Fundy.

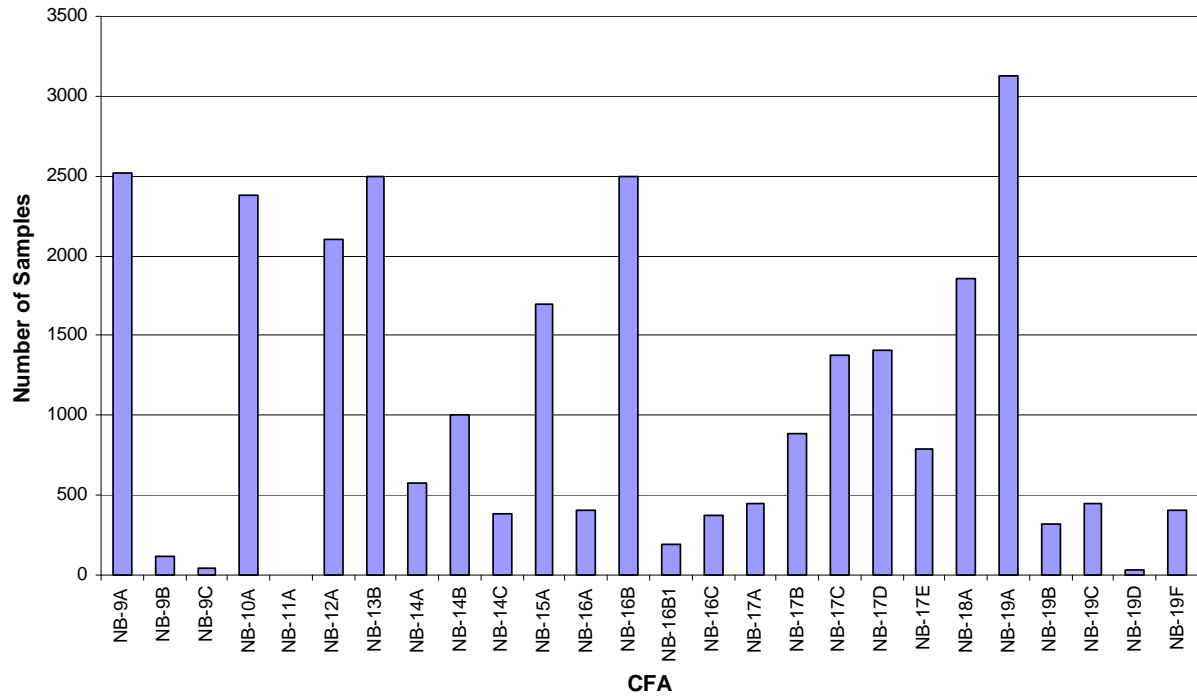
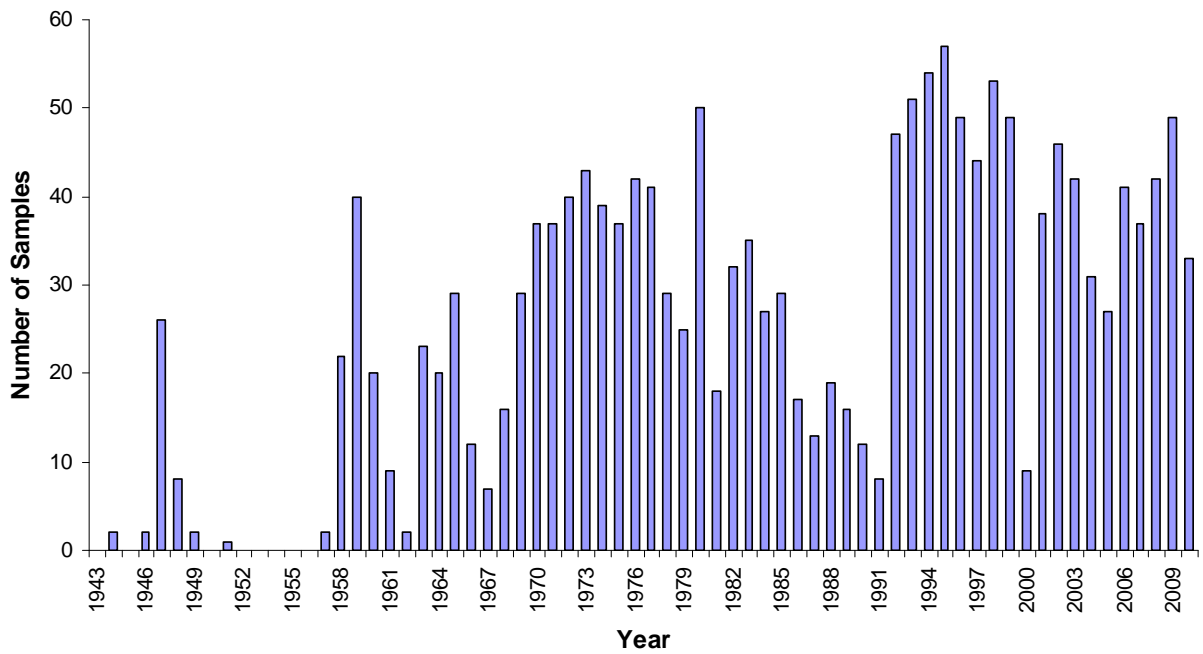
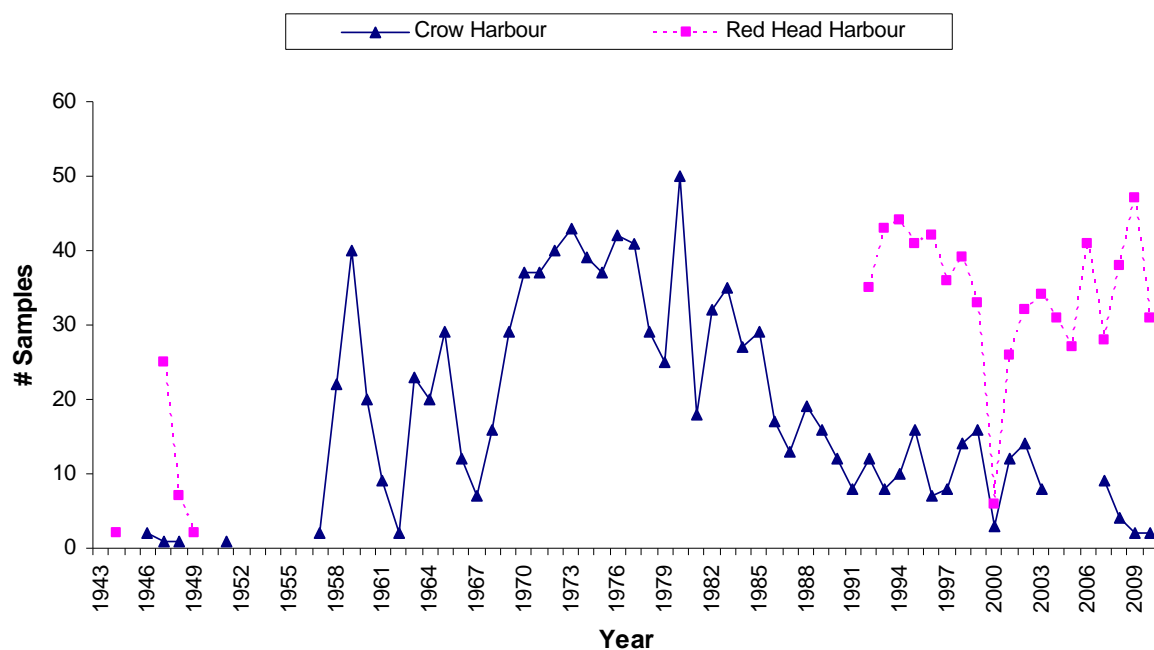
**A****B**

Fig. 2: Variability in the original CFIA dataset in regards to sampling effort. (A) number of *Mya arenaria* samples taken in each Clam Fishing Area from 1943-2010 and (B) number and temporal distribution of *M. arenaria* samples taken within Clam Fishing Area NB-13B

A



B

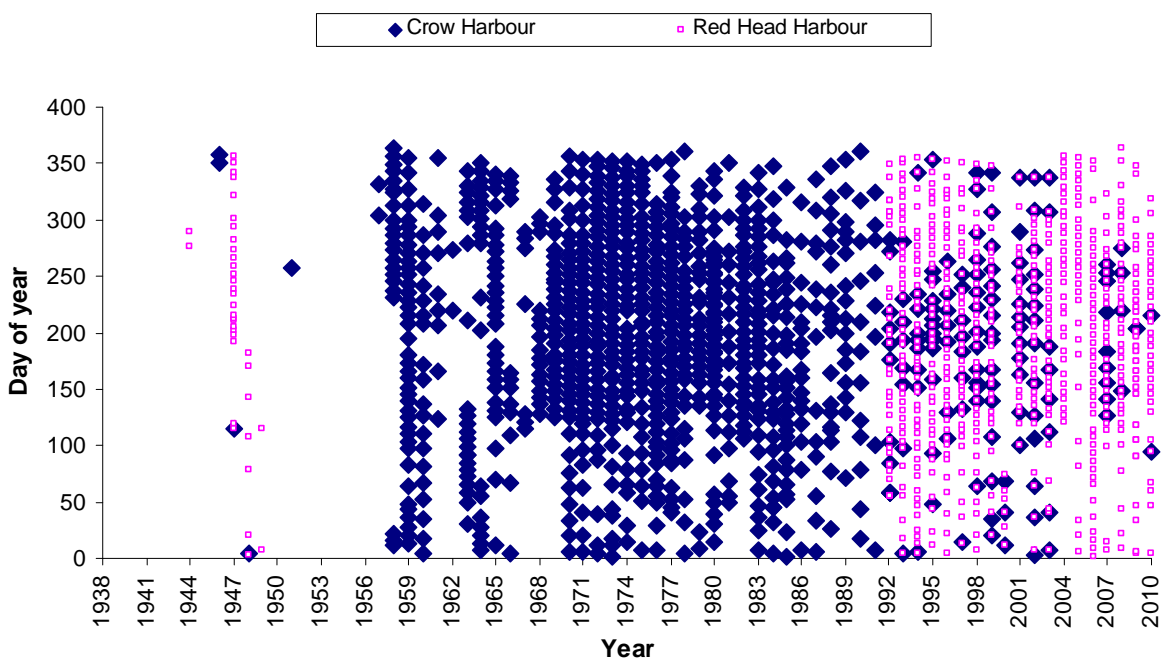


Fig. 3: (A) Number of *M. arenaria* samples taken each year within Clam Fishing Area NB-13B from 1943-2010 and (B) the temporal distribution of *M. arenaria* samples taken within each year for sites (Crow Harbour and Red Head Harbour) within Clam Fishing Area NB-13B.

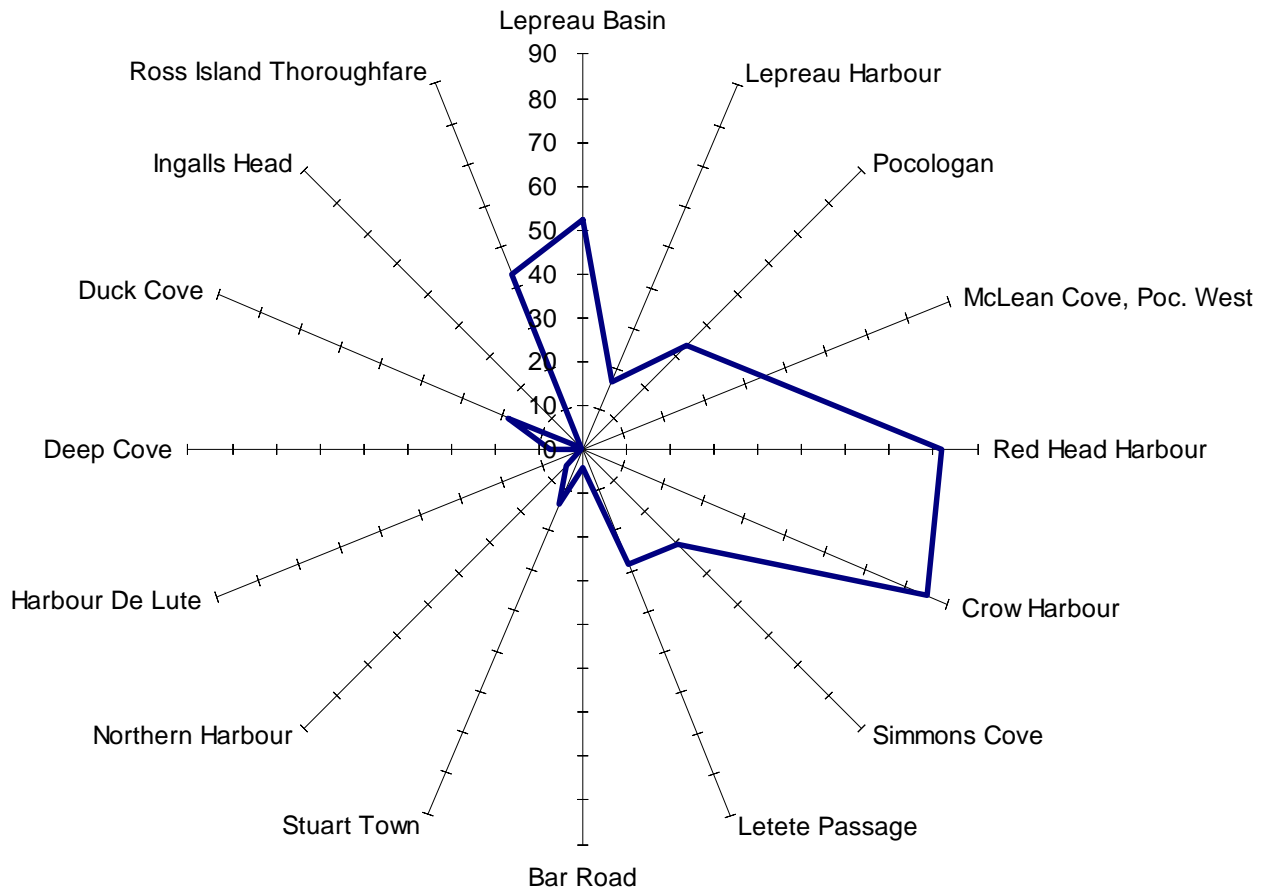


Fig. 4: Percent of time a site is closed. Both Crow Harbour and Red Head Harbour show the greatest amount of time spent closed 85.06% and 81.60% respectively.

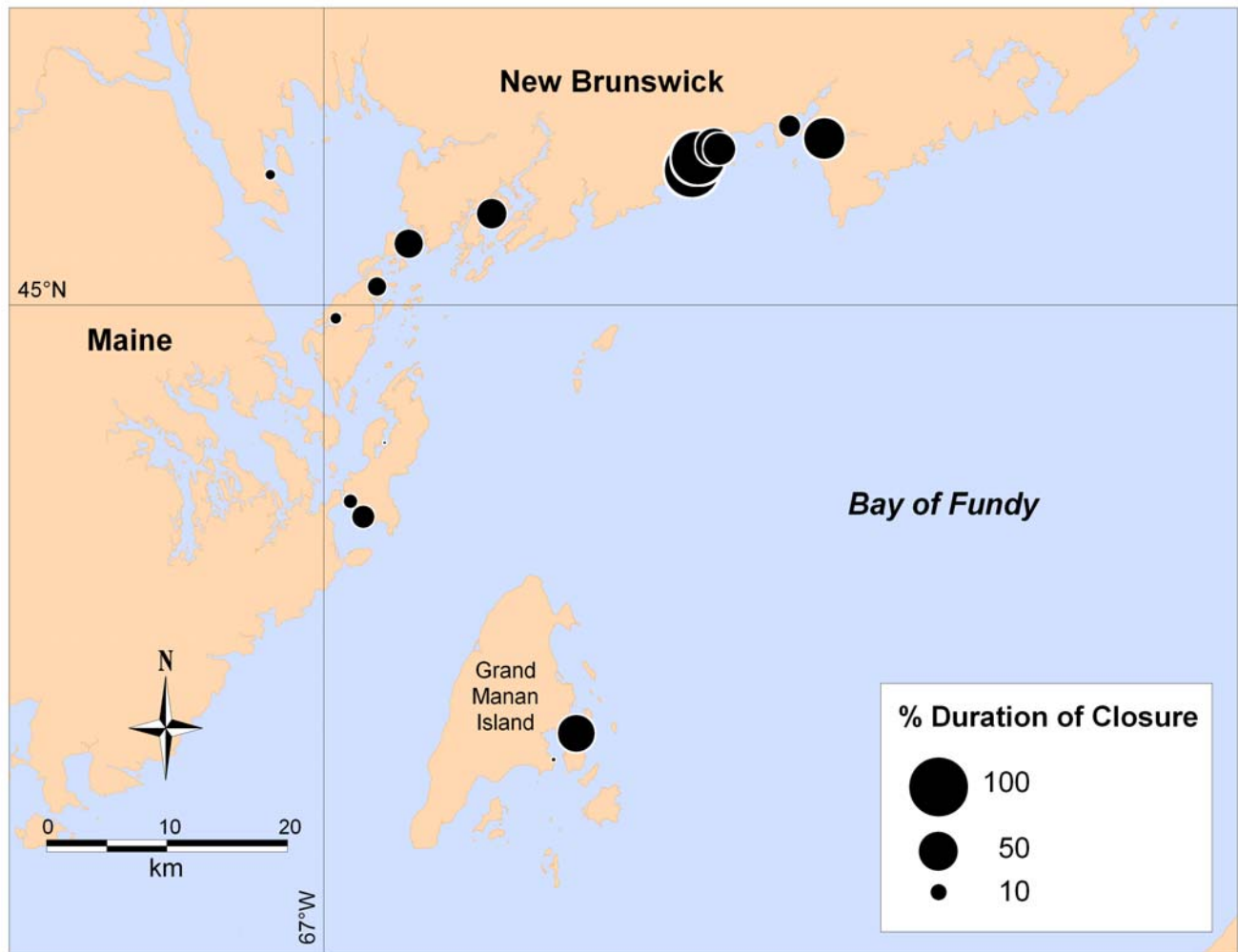


Fig. 5: Map of sample locations detailing the percent duration of closure at different sites.

Table 1: Percent duration of closures in total, for ‘hot’ years and for ‘cold’ years over the sample life of each site.

Location	All years	Hot Years	Cold Years
Crow Harbour	85.06	83.30	64.99
Red Head Harbour	81.60	79.18	72.66
Lepreau Basin	52.07	61.69	41.13
McLean Cove, Poc. West	44.18	26.63	11.03
Ross Island Thoroughfare	43.06	50.10	19.47
Pocologan	33.42	30.27	31.02
Simmons Cove	30.25	38.38	15.76
Letete Passage	28.14	45.65	10.12
Duck Cove	18.08	20.95	8.51
Lepreau Harbour	16.65	24.97	9.23
Stuart Town	13.76	19.14	3.08
Deep Cove	7.41	5.97	0.62
Northern Harbour	5.50	10.89	1.48
Bar Road	4.06	5.09	1.33
Ingalls Head	0.87	1.62	0.16
Harbour De Lute	0.24	0.50	0.00

Table 2: Percent duration of closures for the ‘cold’ period (1948-1956), the ‘hot’ period (1970-1986), and the ‘mixed’ period (1993-2010). Note that blank cells show that a particular location was not sampled.

Location	% Duration of Closures for ‘Mixed’ Period from 1993-2010			% Duration of Closure from 1948-1956	% Duration of Closure from 1970-1986
	Mixed Period Total	Hot Years	Cold Years		
Crow Harbour	97.64	98.08	97.20	96.74	92.14
Pocologan	44.02	44.57	43.47	2.71	30.35
Simmons Cove	39.35	41.37	37.32		55.21
Red Head Harbour	36.70	52.51	20.88	97.60	100.00
Ross Island					
Thoroughfare	32.62	48.04	17.20	4.17	55.60
Lepreau Basin	27.09	39.91	14.28	45.02	74.99
Lepreau Harbour	17.79	26.45	9.13	0.61	26.37
Letete Passage	17.72	29.10	6.33		63.59
Duck Cove	8.39	13.82	2.95	0	30.22
Stuart Town	7.53	13.12	1.95	0	28.69
Northern Harbour	6.76	12.88	0.64	0.43	8.78
Bar Road	5.98	10.50	1.46		3.03
Deep Cove	3.20	6.39	0.00		8.20
Ingalls Head	2.02	3.41	0.64	0.00	1.00
Harbour De Lute	0.91	1.83	0.00		0.00
McLean Cove, Pocologan West					51.12

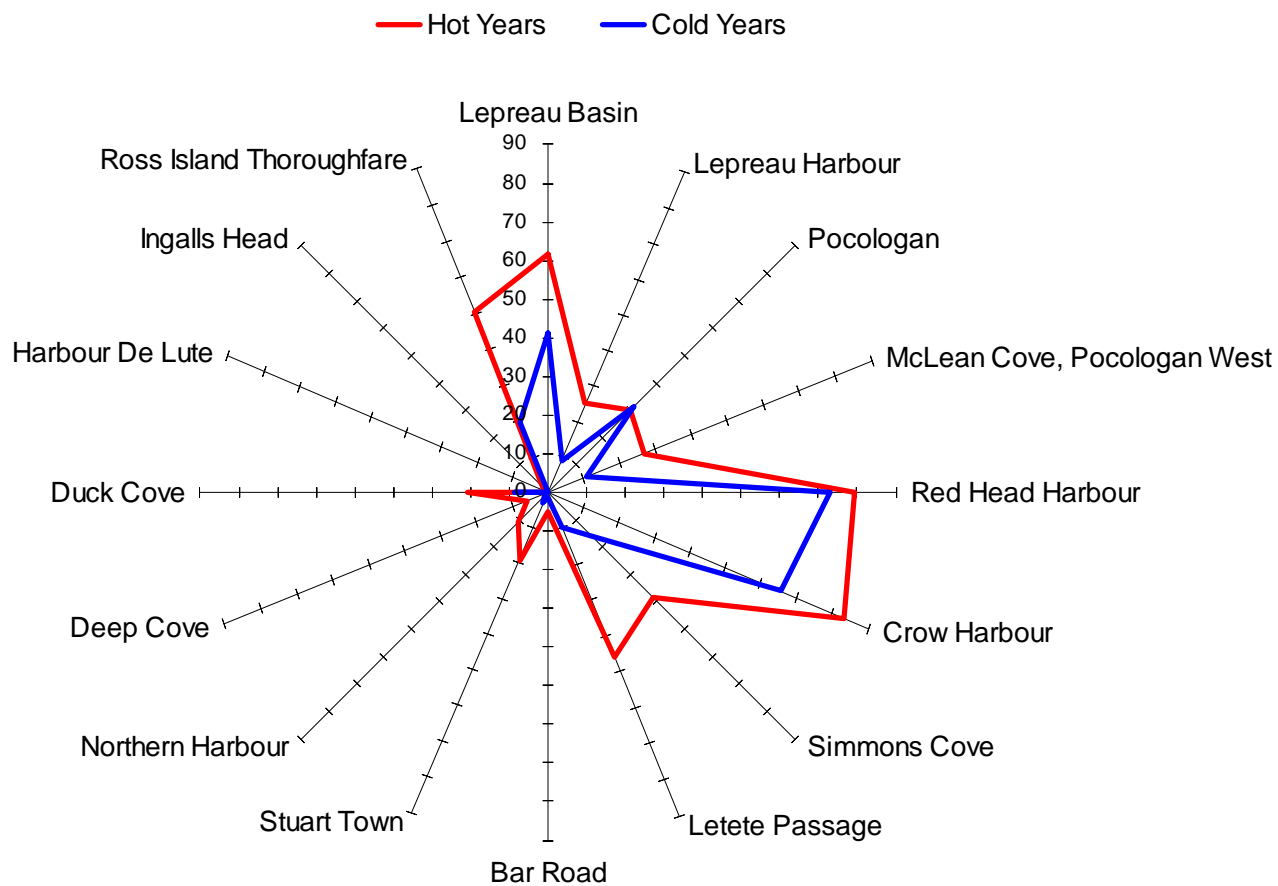


Fig. 6: Percent duration of closure in 'hot' and 'cold' years from 1943-2010. 'Hot' years are defined as any year having an average PSP level above $80 \mu\text{g STX}/100 \text{ g tissue}$ whereas 'cold' years represent mean PSP levels below $80 \mu\text{g STX}/100 \text{ g tissue}$.

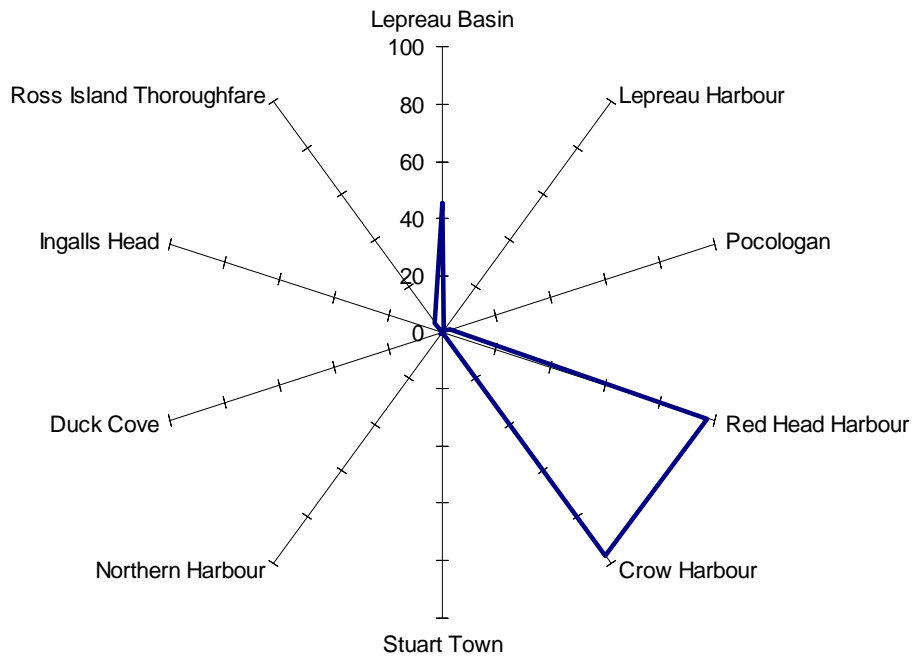
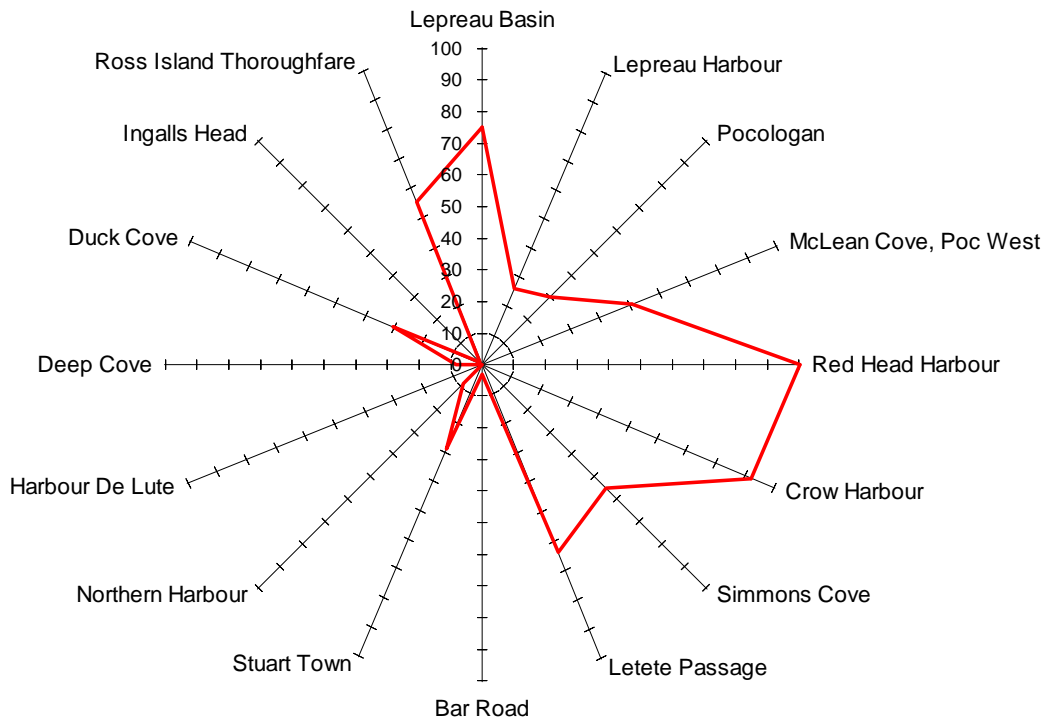
**A****B**

Fig. 7: Percent duration of closures in (A) the 'cold' period of 1948-1956, where yearly mean PSP levels were consistently below 80 μg STX/100 g tissue and (B) the 'hot' period of 1970-1986 where yearly mean PSP levels were consistently above 80 μg STX/100 g tissue.

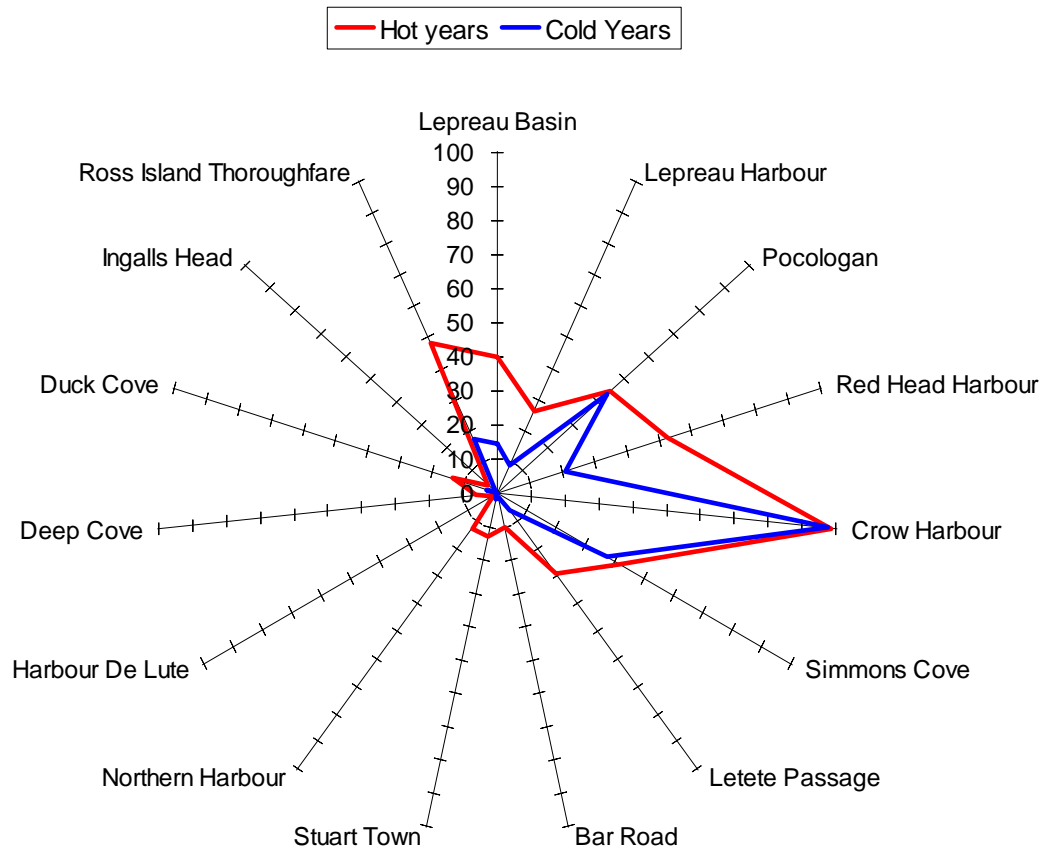


Fig. 8: Percent duration of closures for the 'mixed' period between 1993 and 2010. This mixed period is defined as the longest period to have equal numbers of 'hot' and 'cold' years. This period also contains the highest number of samples in the dataset.

Table 3: Percent duration of seasonal closures from 1943-2010. Seasons are defined by 3 month intervals (i.e. winter - January to March, spring - April to June, summer - July to September, fall - October to December, inclusive).

Location	Season			
	Winter	Spring	Summer	Fall
Crow Harbour	76.19	80.17	83.14	77.03
Lepreau Basin	41.49	46.48	71.12	47.14
Ross Island Thoroughfare	23.12	27.23	55.45	32.37
Letete Passage	18.15	22.62	47.73	21.76
Lepreau Harbour	4.08	11.78	41.37	8.12
Simmons Cove	27.06	28.38	36.17	28.32
Duck Cove	6.01	9.53	30.43	10.17
McLean Cove, Pocologan West	17.52	17.55	24.54	15.84
Stuart Town	5.42	6.71	24.38	6.28
Red Head Harbour	12.12	16.24	24.33	11.41
Northern Harbour	0.00	3.25	17.04	0.82
Pocologan	4.51	6.98	11.96	9.38
Bar Road	0.57	2.76	9.48	0.22
Deep Cove	2.03	1.81	8.39	1.47
Ingalls Head	0.00	0.32	2.67	0.13
Harbour De Lute	0.00	0.02	0.94	0.00

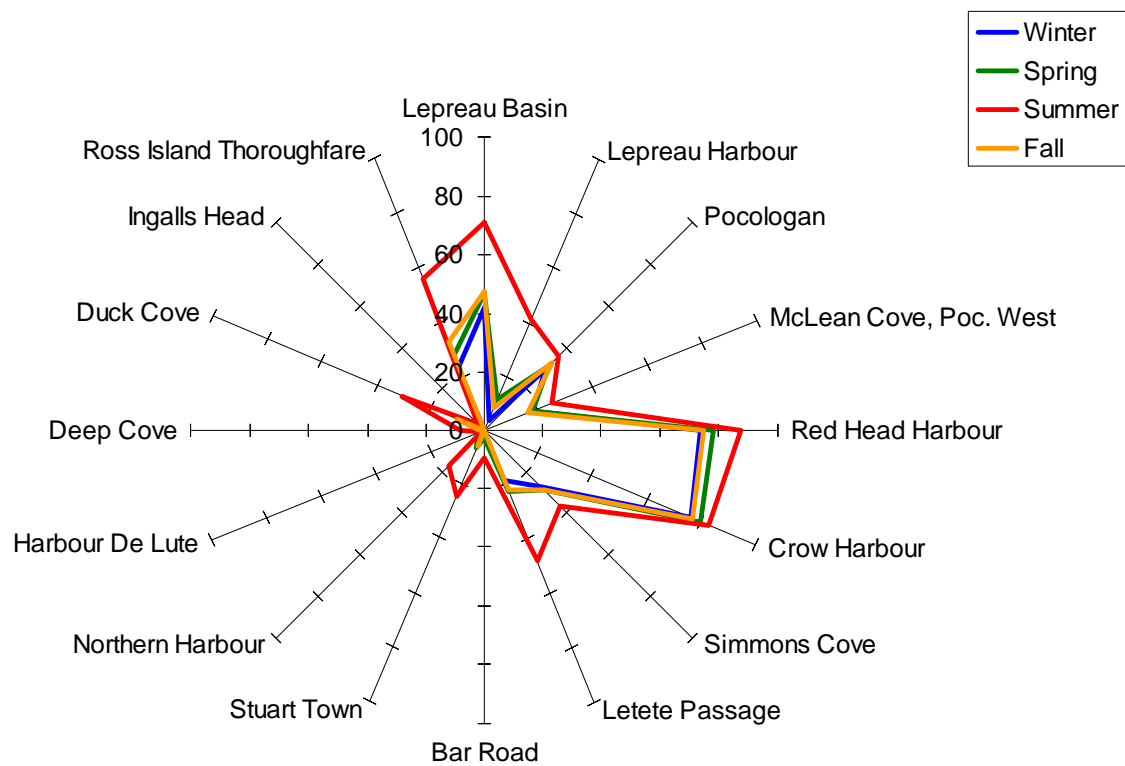


Fig. 9: Percent duration of seasonal closure for each site from 1943-2010.

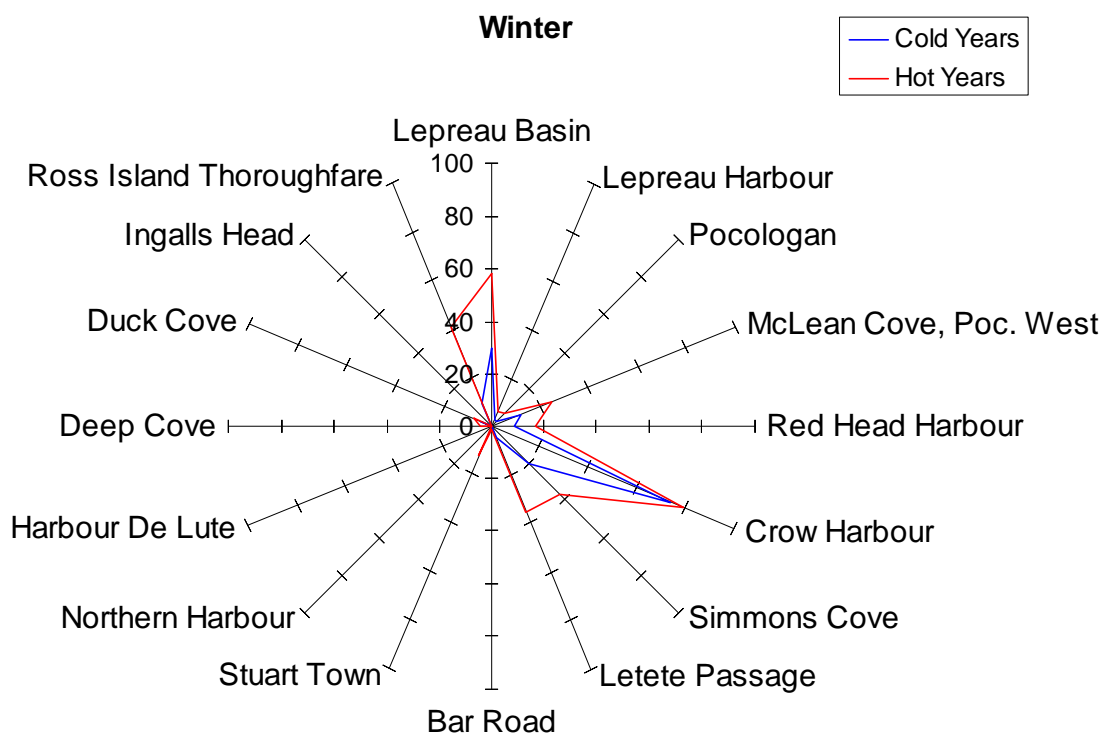
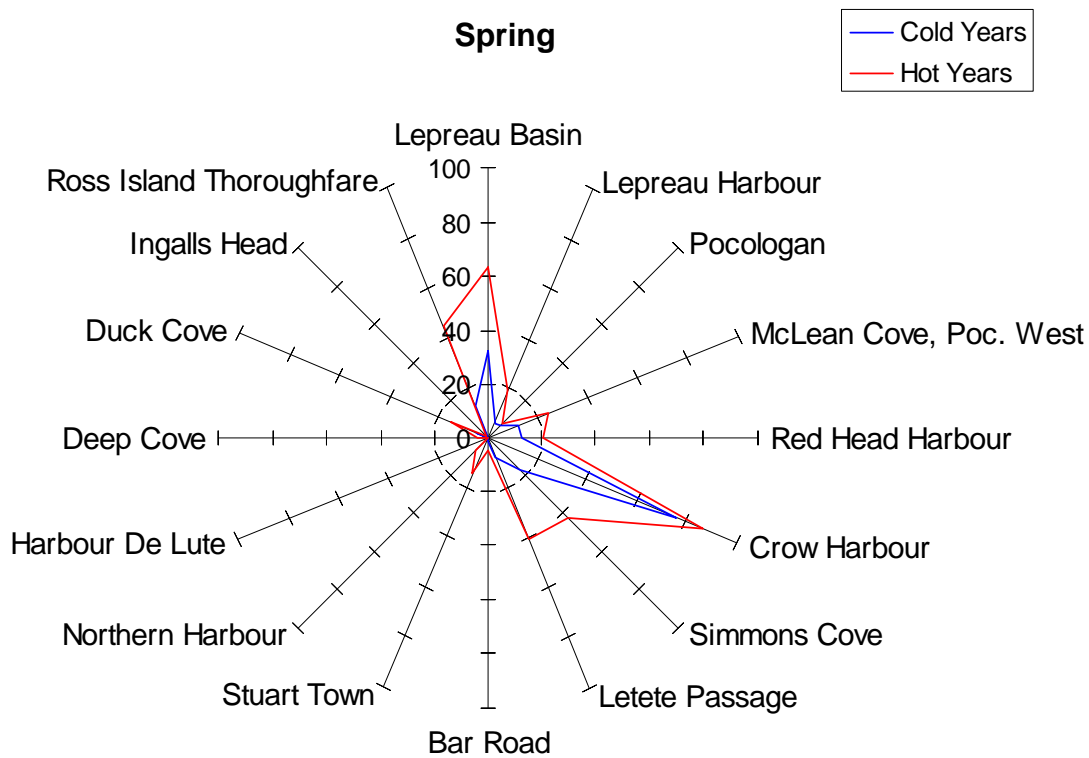
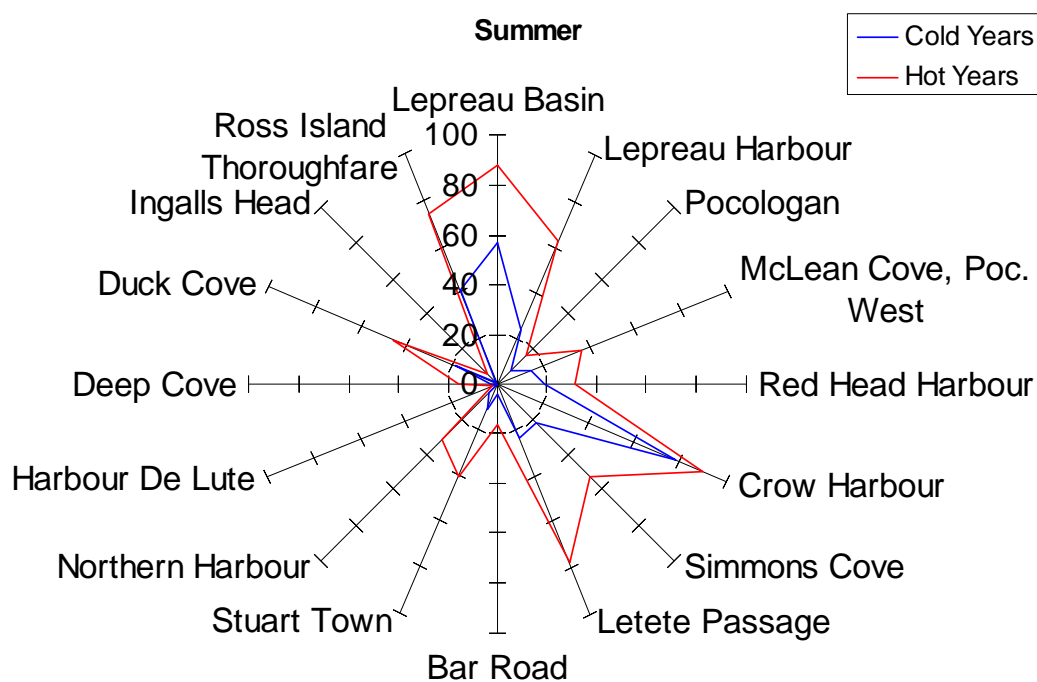
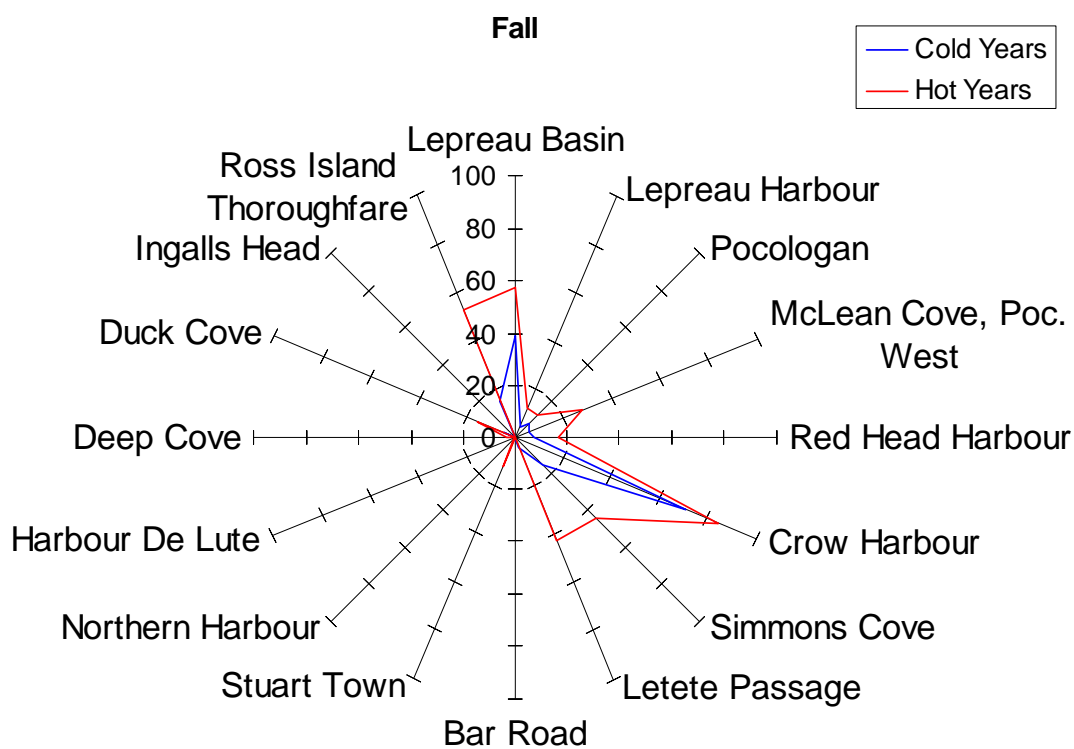
A**B**

Fig. 10: Percent duration of seasonal closures for (A)winter and (B) spring in 'hot' and 'cold' years from 1943-2010.

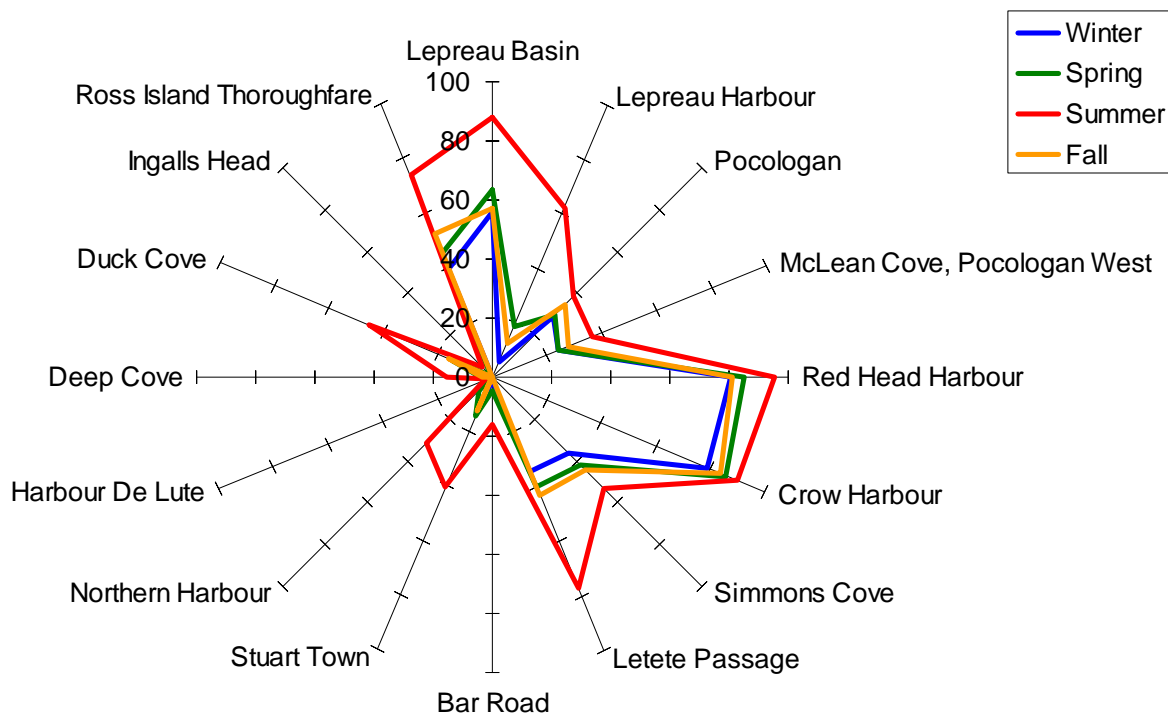


A

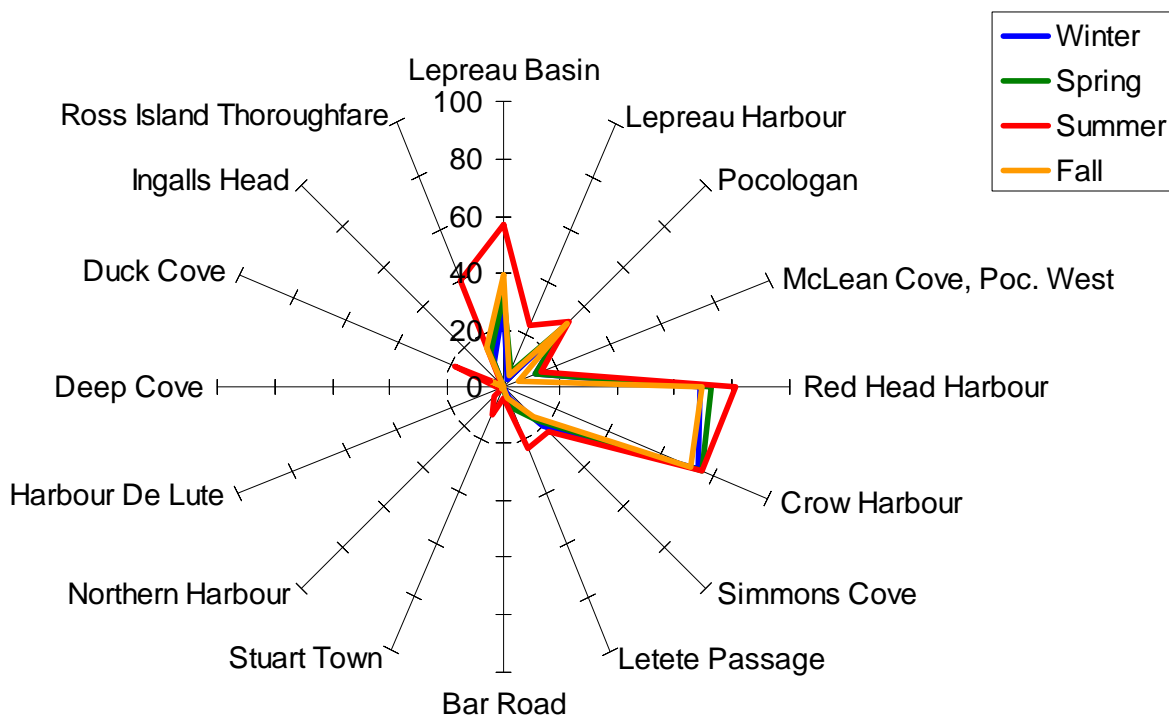


B

Fig. 11: Percent duration of seasonal closures for (A) summer and (B) fall in 'hot' and 'cold' years from 1943-2010.



A



B

Fig. 12: Percent duration of seasonal closures for (A) all 'hot' years from 1943-2010 and (B) all 'cold' years from 1943-2010.

Table 4: Percent duration of seasonal closures for all ‘cold’ and ‘hot’ years from 1943 - 2010.

Location	'Cold' Years				'Hot' Years			
	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall
Lepreau Basin	29.40	32.25	57.02	38.92	55.91	63.45	87.94	56.94
Lepreau Harbour	2.70	5.79	23.74	4.55	5.73	18.93	62.41	12.38
Pocologan	29.73	30.62	32.43	31.26	29.25	30.38	39.13	34.89
McLean Cove, Poc. West	11.98	11.94	14.69	6.05	24.12	24.25	36.29	27.52
Red Head Harbour	68.38	72.26	80.82	69.21	80.47	84.86	95.55	81.07
Crow Harbour	73.96	75.38	75.06	71.03	78.85	85.89	89.55	84.19
Simmons Cove	19.70	16.81	22.06	14.92	35.84	42.18	53.02	44.32
Letete Passage	4.71	7.99	23.24	4.11	34.19	40.09	76.96	42.81
Bar Road	0.00	1.10	3.79	0.41	1.25	4.75	16.27	0.00
Stuart Town	0.00	0.36	10.72	0.85	11.90	14.29	40.67	12.76
Northern Harbour	0.00	0.65	4.82	0.41	0.00	6.35	31.63	1.30
Harbour De Lute	0.00	0.00	0.00	0.00	0.00	0.04	2.07	0.00
Deep Cove	0.00	0.00	2.47	0.00	4.44	3.97	15.46	3.23
Duck Cove	4.68	4.99	18.16	5.20	7.60	14.96	45.09	16.09
Ingalls Head	0.00	0.00	0.44	0.18	0.00	0.71	5.33	0.07
Ross Island Thoroughfare	9.43	12.36	40.33	15.31	39.46	44.98	73.49	52.73

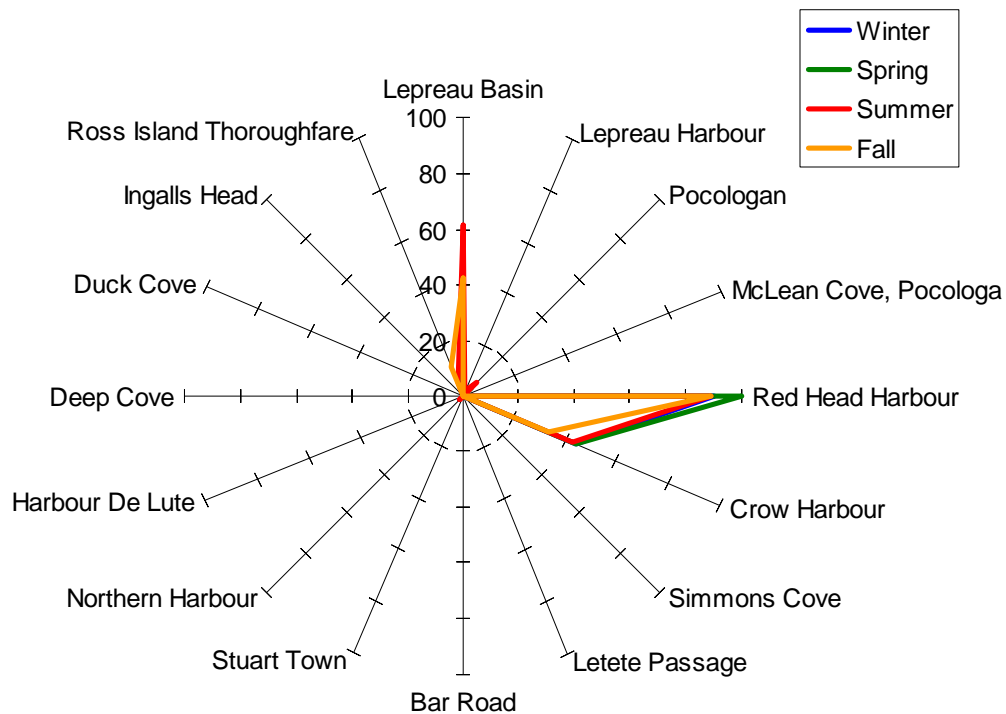
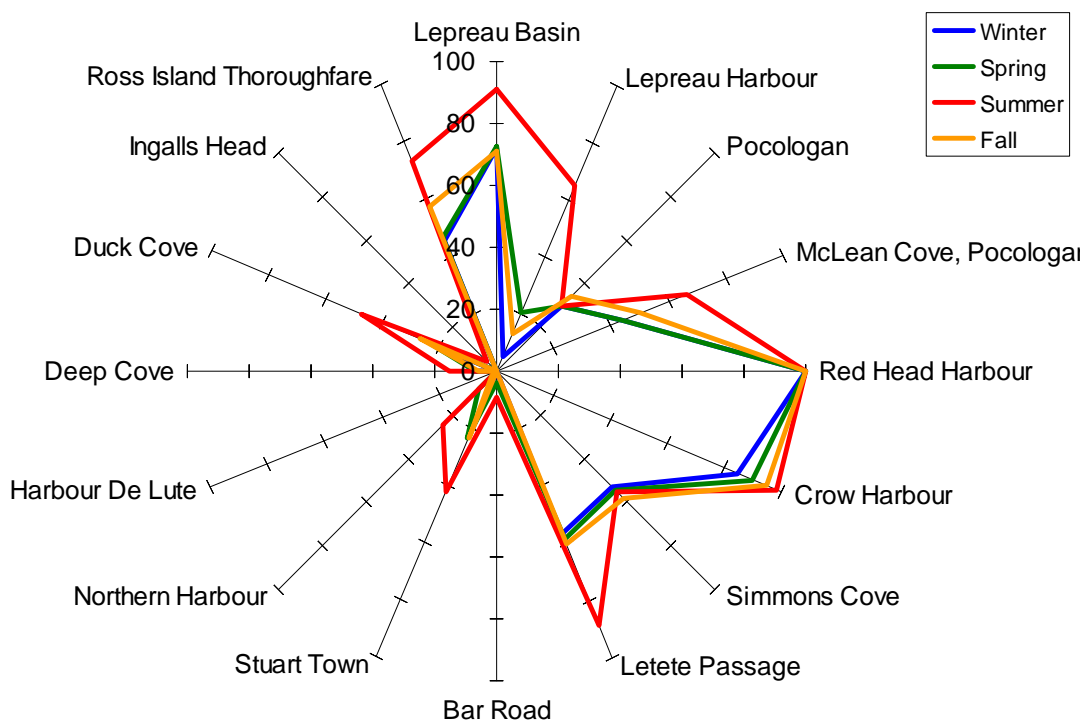
**A****B**

Fig. 13: Percent duration of seasonal closures for (A) the 'cold' period from 1948 to 1956 and (B) the 'hot' period between 1970 and 1986.

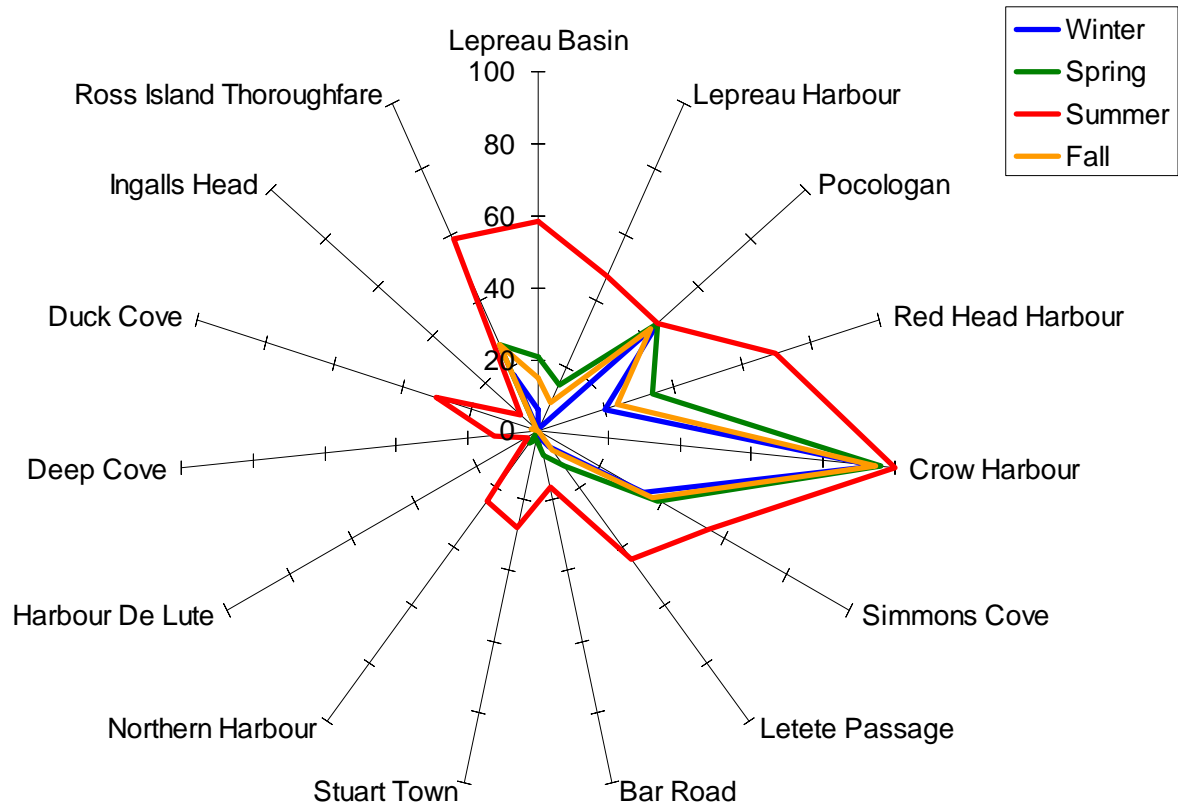
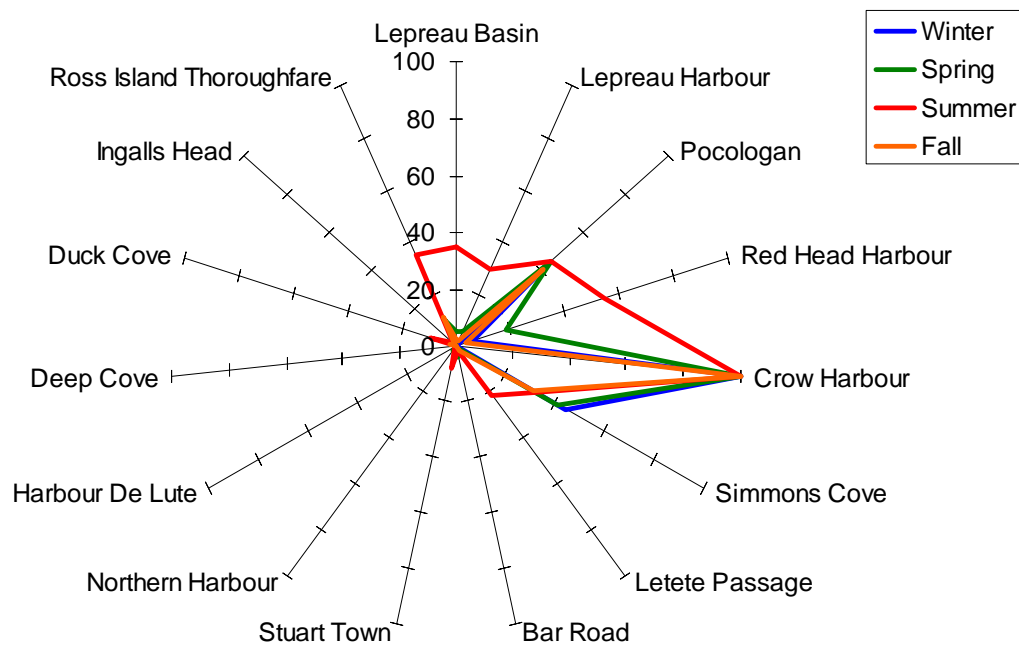
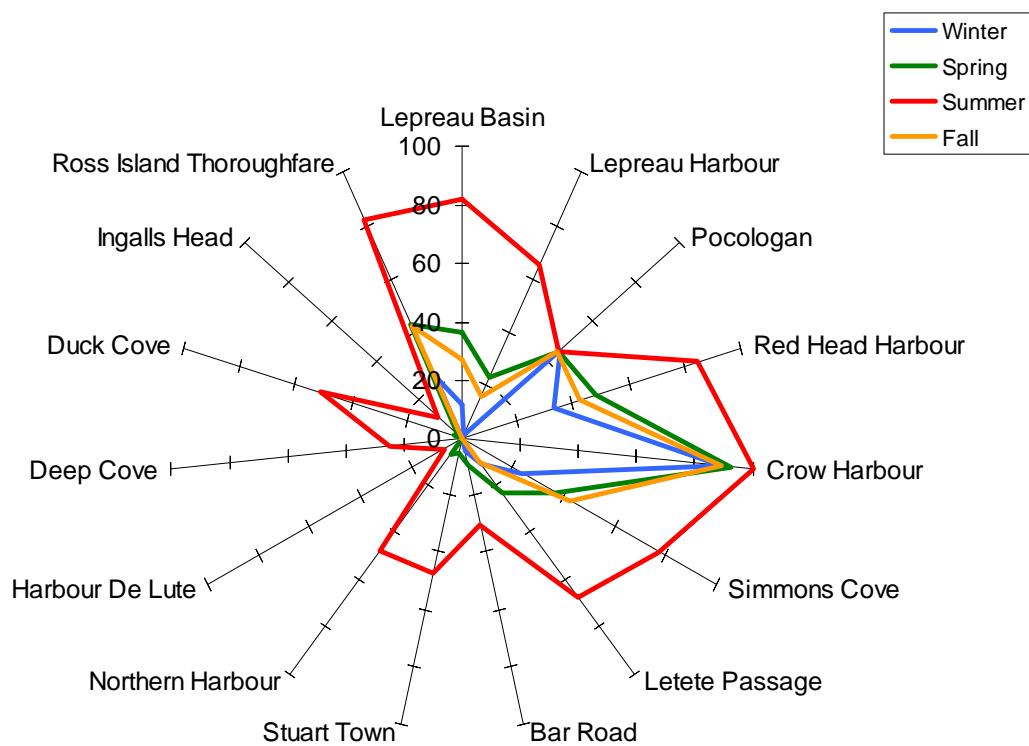


Fig. 14: Percent duration of seasonal closures for the 'mixed' period from 1993-2010.



A



B

Fig. 15: Percent duration of seasonal closures during the 'mixed' period (1993-2010) for (A) the 'cold' years and (B) the 'hot' years.

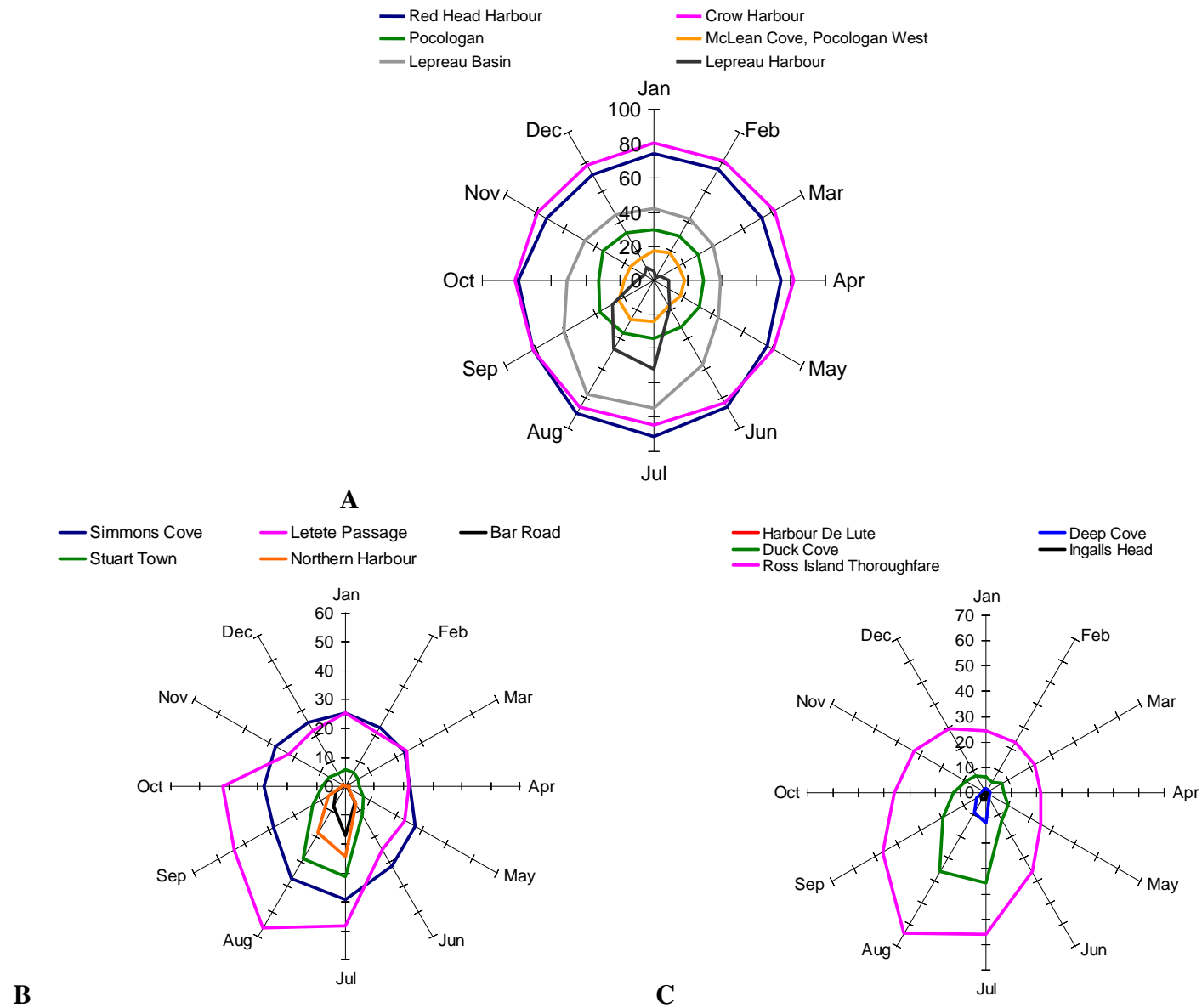


Fig. 16: Percent duration of monthly closures for all years. (A) eastern sites, (B) sites to the northwest and (C) southern sites.

Table 5: Percent duration of closures by month from 1943 - 2010

Location	Month											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Bar Road	0.00	0.21	1.47	1.32	0.85	6.23	16.84	8.06	3.68	0.66	0.00	0.00
Crow Harbour	80.36	80.67	81.40	81.37	80.17	82.55	84.35	85.63	81.42	80.93	78.53	77.94
Deep Cove	1.47	0.74	1.47	1.47	1.47	2.55	12.14	9.01	3.97	1.47	1.47	1.47
Duck Cove	6.31	4.52	7.16	7.21	9.91	12.21	35.53	35.96	19.41	12.81	9.12	8.02
Harbour De Lute	0.00	0.00	0.00	0.00	0.00	0.05	2.13	0.81	0.00	0.00	0.00	0.00
Ingalls Head	0.00	0.00	0.00	0.05	1.00	0.00	2.89	3.32	2.50	0.33	0.00	0.00
Lepreau Basin	42.22	41.12	40.23	38.77	43.03	56.91	74.62	77.18	60.44	50.47	46.13	44.4
Lepreau Harbour	5.83	2.36	4.17	8.38	9.58	18.53	51.85	46.16	27.50	9.63	5.88	8.63
Letete Passage	25.28	21.17	24.15	21.86	23.67	25.00	47.96	56.21	43.63	41.79	22.21	21.96
McLean Cove, Poc. West	16.98	18.75	16.84	17.60	17.74	17.25	23.81	26.38	23.43	17.03	15.69	14.80
Northern Harbour	0.00	0.00	0.00	1.37	1.14	7.35	24.38	18.45	6.52	1.09	1.32	0.00
Pocologan	29.60	29.52	29.41	29.26	30.93	31.32	34.16	35.82	36.23	32.35	34.12	31.83
Red Head Harbour	73.77	74.79	72.91	73.82	75.85	85.39	91.13	89.71	81.67	78.80	72.50	70.97
Ross Island Thoroughfare	24.29	23.21	21.92	21.42	24.86	35.64	55.69	63.66	46.57	35.67	32.35	28.80
Simmons Cove	25.14	23.63	23.53	22.01	27.56	31.96	38.99	36.76	28.24	27.94	27.50	25.33
Stuart Town	5.69	5.36	5.22	4.85	7.21	11.18	31.26	28.98	13.04	7.78	5.98	5.08

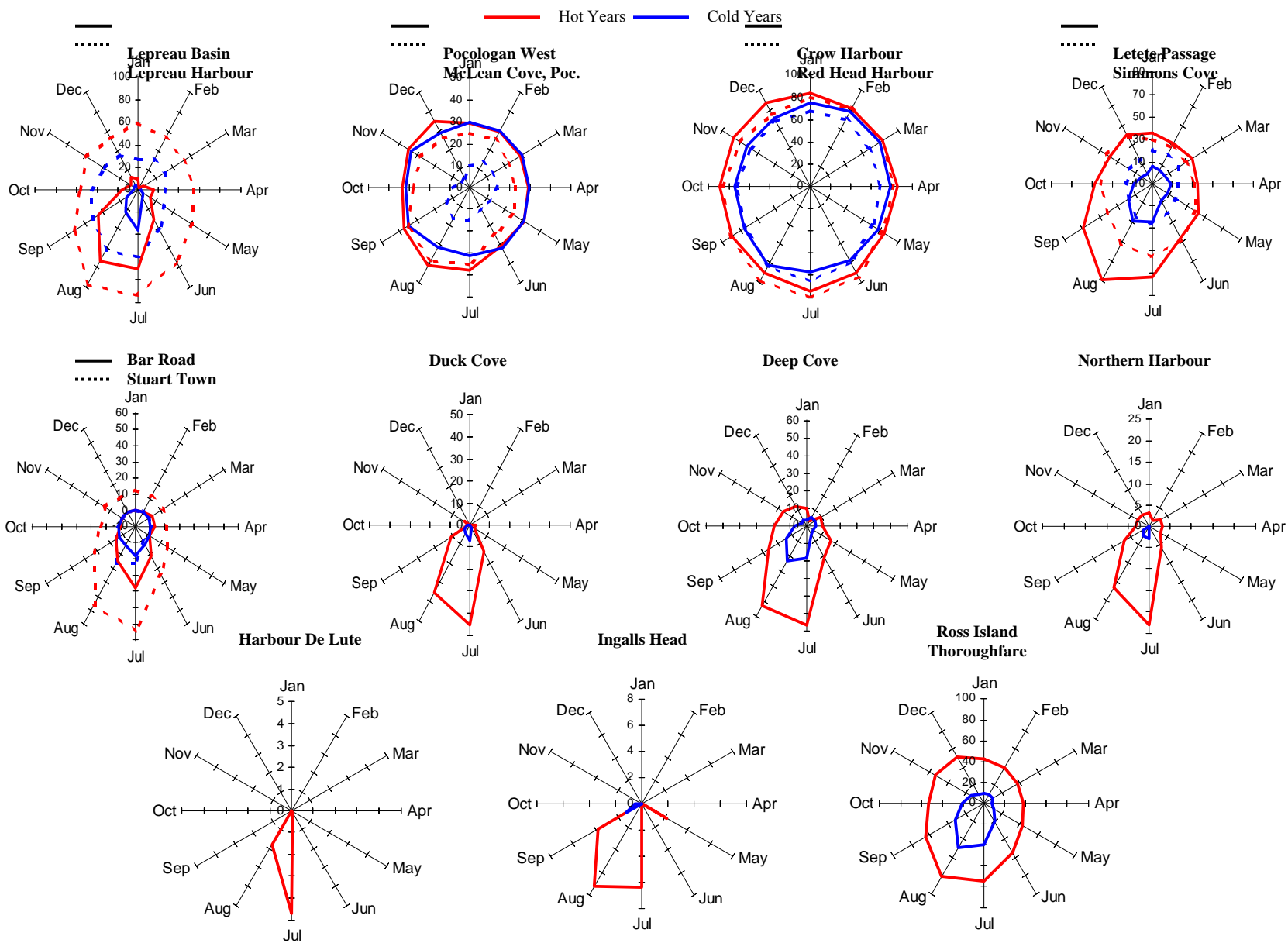


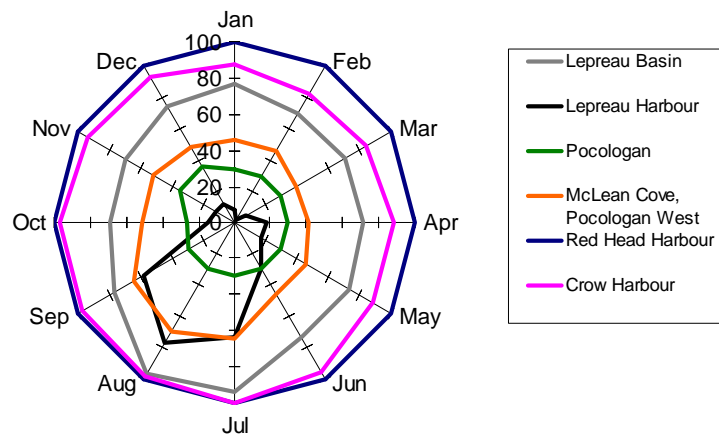
Fig. 17: Percent duration of monthly closures of a site in 'hot' and 'cold' years from 1943-2010.

Table 6: Percent duration of closures by month for ‘hot’ and ‘cold’ years from 1943 to 2010

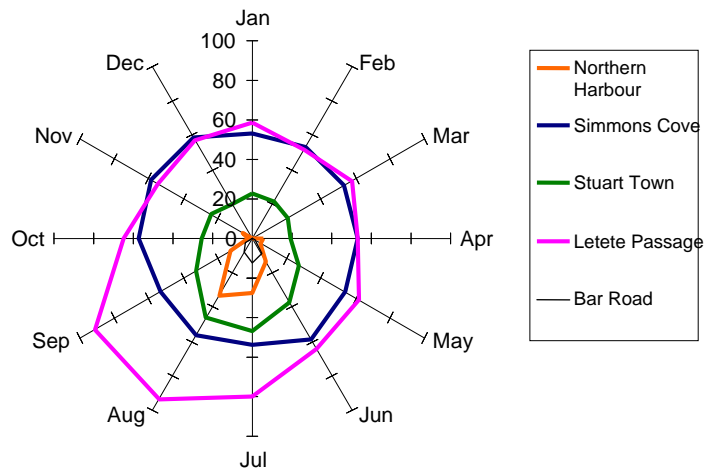
	Location															
	Lepreau Basin		Lepreau Harbour		Pocologan		McLean Cove		Red Head Harbour		Crow Harbour		Simmons Cove		Letete Passage	
Month	Hot	Cold	Hot	Cold	Hot	Cold	Hot	Cold	Hot	Cold	Hot	Cold	Hot	Cold	Hot	Cold
Jan	59.83	27.46	9.57	2.7	29.45	29.73	25.18	10.11	80.12	68.44	83.66	74.89	30.07	21.01	35.48	5.93
Feb	53.11	31.08	1.96	2.7	29.26	29.73	25.23	13.32	80.65	69.88	80.65	77.99	29.03	19.11	31.45	4.44
Mar	51.61	30.69	5.93	2.7	29.03	29.73	21.85	12.64	80.65	66.43	81.79	78.38	29.03	18.92	35.48	3.84
Apr	53.76	26.22	15.05	2.79	29.03	29.46	22.47	13.51	80.65	68.11	84.95	78.38	30.86	14.59	34.3	8.74
May	60.77	28.16	13.42	6.36	31.32	30.6	25.18	11.51	82.21	70.53	83.87	77.07	40.06	17.09	42.56	7.85
Jun	74.62	42.07	30.75	8.29	30.75	31.8	24.95	10.81	93.76	78.38	89.68	76.58	47.74	18.74	46.02	7.39
Jul	93.24	59.02	70.45	36.27	37.77	31.12	35.17	14.3	98.75	84.74	93.55	76.63	54.84	25.72	72.94	24.32
Aug	96.36	61.12	73.36	23.37	41.1	31.39	38.4	16.3	97.5	83.17	89.59	82.3	52.65	23.45	89.49	28.33
Sep	71.72	50.99	44.52	13.24	37.74	34.95	35.38	13.42	90.32	74.41	89.03	75.05	41.61	17.03	68.71	17.21
Oct	56.71	45.25	15.71	4.53	33.3	31.56	27.99	7.85	86.47	72.36	88.76	74.37	41.94	16.22	46.93	8.63
Nov	57.42	36.67	7.96	4.14	35.16	33.24	28.28	5.14	78.39	67.57	87.1	71.35	41.94	15.41	39.03	2.7
Dec	52.55	34.87	13.01	4.97	35.28	28.95	26.33	5.14	75.03	67.57	86.37	70.88	39.44	13.51	40.79	0.78

Table 6: Continued - Percent duration of closures by month for 'hot' and 'cold' years from 1943 to 2010

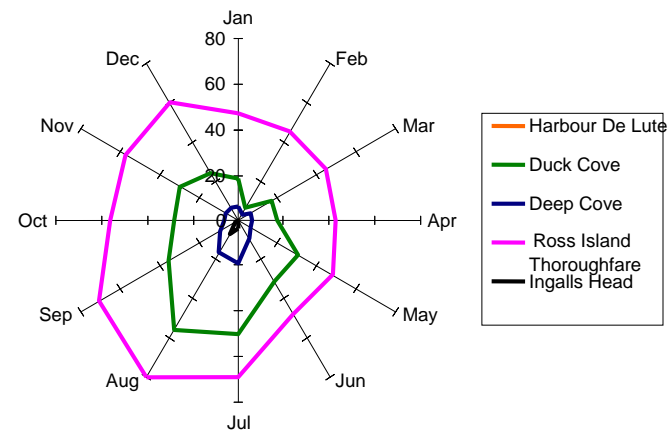
Month	Location															
	Bar Road		Stuart Town		Northern Harbour		Harbour De Lute		Deep Cove		Duck Cove		Ingalls Head		Ross Island Thoroughfare	
	Hot	Cold	Hot	Cold	Hot	Cold	Hot	Cold	Hot	Cold	Hot	Cold	Hot	Cold	Hot	Cold
Jan	0	0	12.49	0	0	0	0	0	3.23	0	9.89	3.31	0	0	42.56	8.98
Feb	0.46	0	11.75	0	0	0	0	0	1.61	0	3.46	5.41	0	0	39.17	9.85
Mar	3.23	0	11.45	0	0	0	0	0	3.23	0	9.26	5.41	0	0	36.73	9.5
Apr	2.9	0	10.65	0	3.01	0	0	0	3.23	0	9.35	5.41	0.11	0	38.06	7.48
May	0.94	0.78	14.57	1.05	2.5	0	0	0	3.23	0	16.65	4.27	2.19	0	42.56	10.03
Jun	10.65	2.52	24.52	0	13.8	1.98	0.11	0	5.59	0	20.43	5.32	0	0	54.52	19.82
Jul	27.68	7.76	54.11	12.12	45	7.15	4.68	0	23.1	2.96	56.4	18.05	6.35	0	74.82	39.67
Aug	13.74	3.31	45.06	15.52	35.5	4.18	1.77	0	16.4	2.79	52.13	22.41	7.28	0	80.96	49.17
Sep	4.84	2.7	22.37	5.23	10.5	3.15	0	0	6.77	1.62	25.91	13.96	3.87	1.35	64.41	31.62
Oct	0	1.22	14.05	2.53	1.04	1.13	0	0	3.23	0	19.25	7.41	0.1	0.52	53.28	20.92
Nov	0	0	13.12	0	2.9	0	0	0	3.23	0	16.13	3.24	0	0	53.98	14.23
Dec	0	0	11.13	0	0	0	0	0	3.23	0	12.9	3.92	0	0	51.4	9.85



A



B



C

Fig. 18: Percent duration of closures by month for the 'hot' period of 1970-1986. (A) north-eastern sites (B) north-western sites and (C) south-western sites (including Grand Manan).

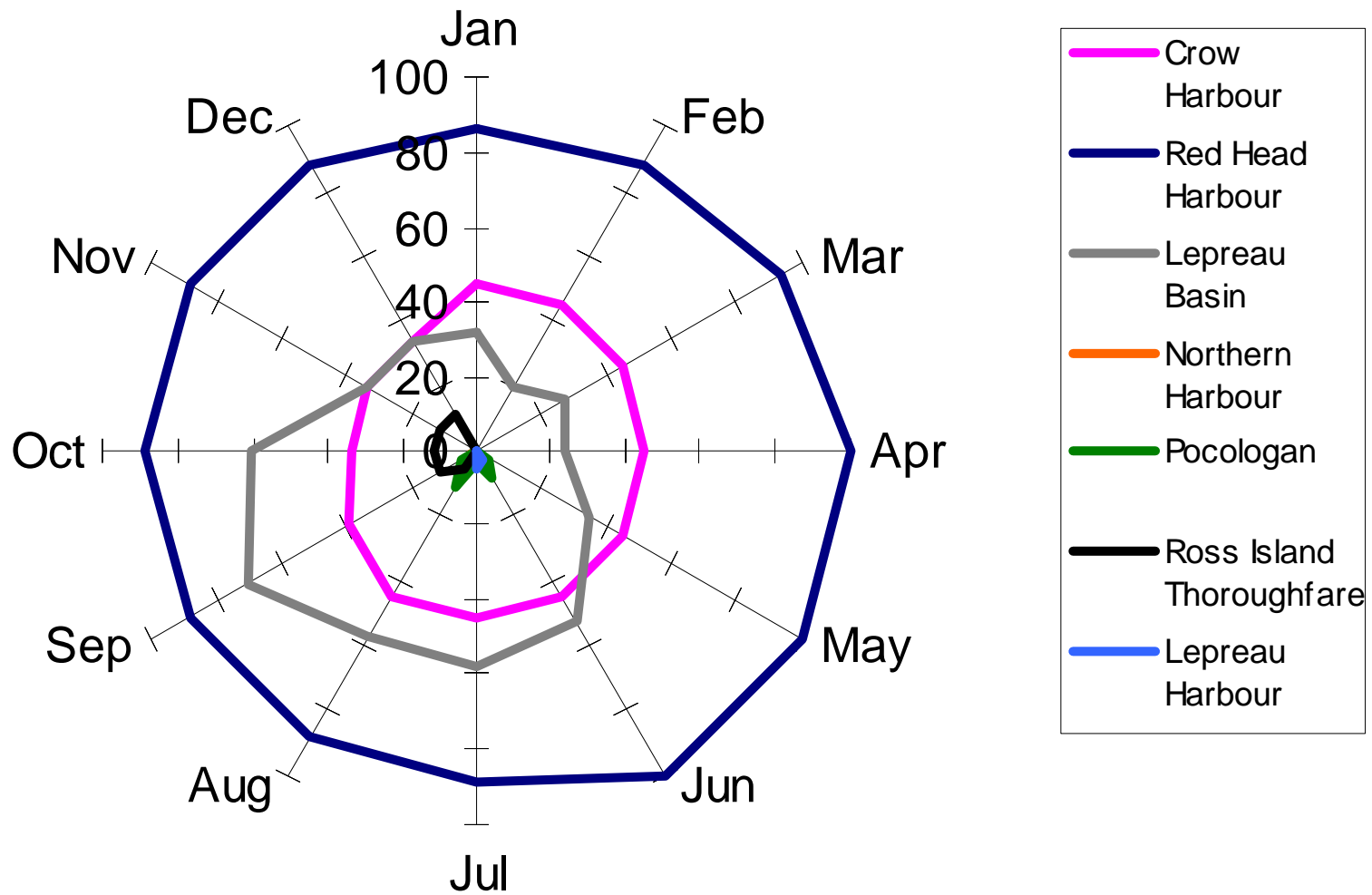


Fig. 19: Percent duration of closures monthly during the 'cold' period from 1948 to 1956.

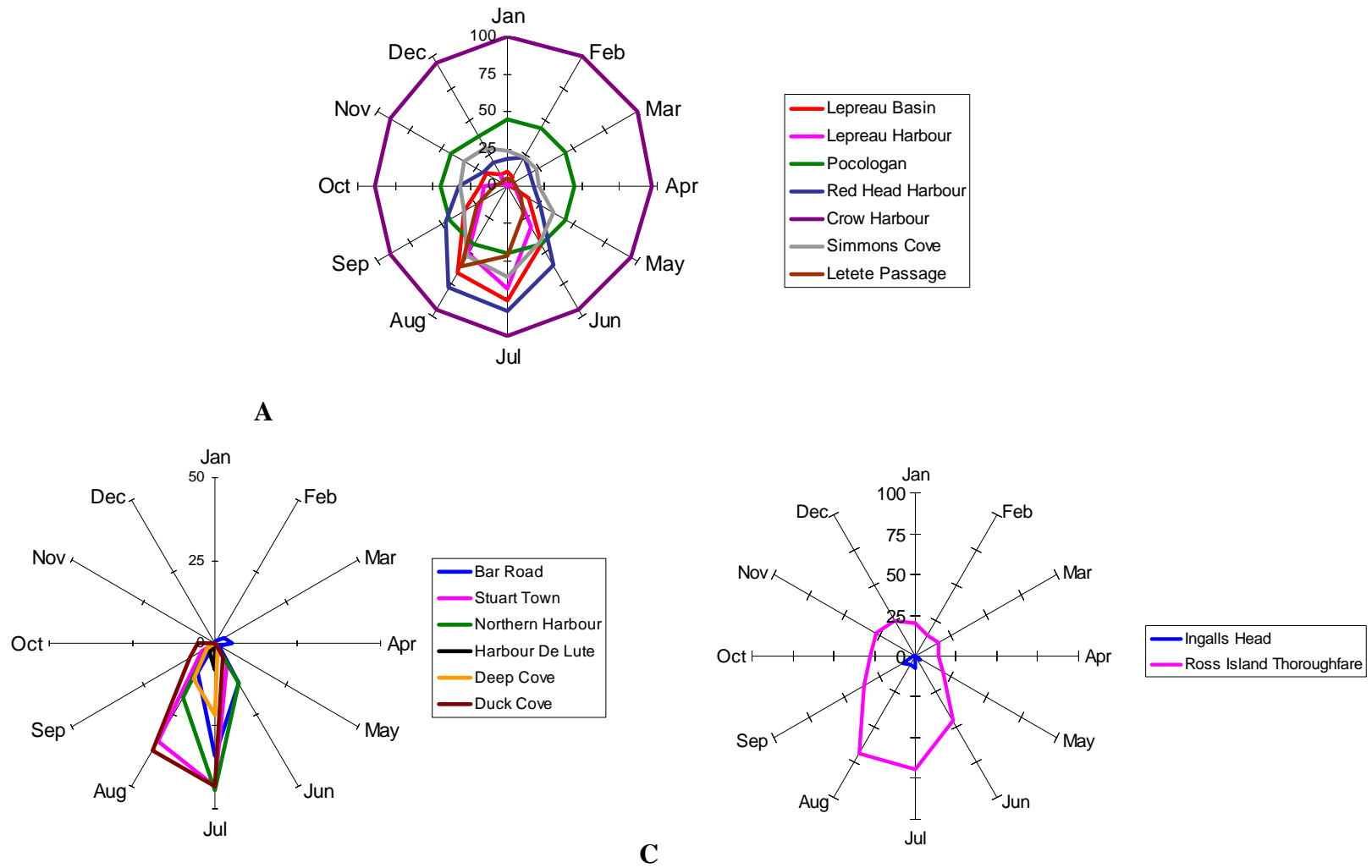


Fig. 20: Percent duration of monthly closures for 'mixed' period 1993-2010; (A) northeast sites (B) northwest sites (C) Grand Manan.

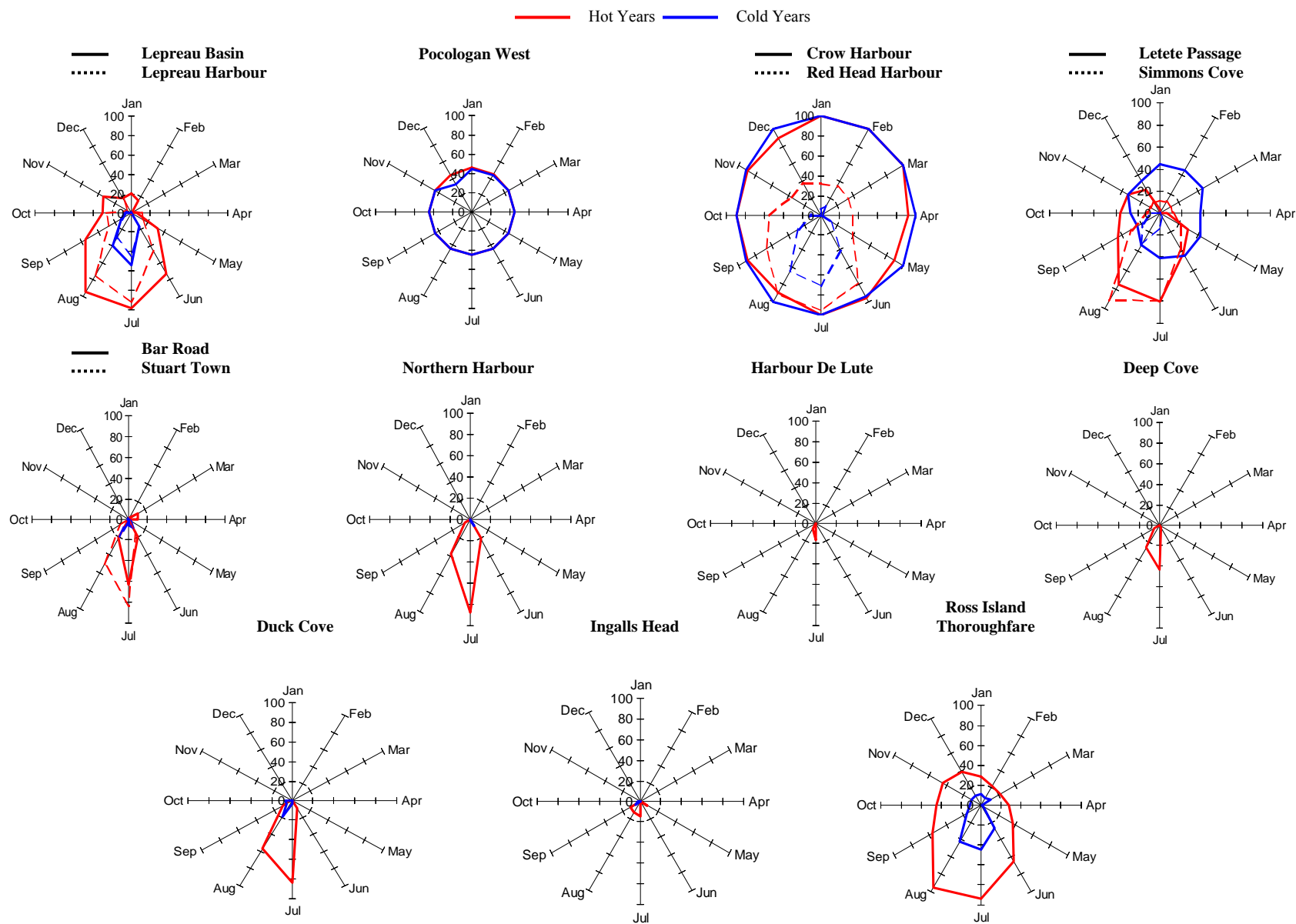


Fig. 21: Percent duration of monthly closures for 'hot' and 'cold' years in the 'mixed' period 1993-2010.

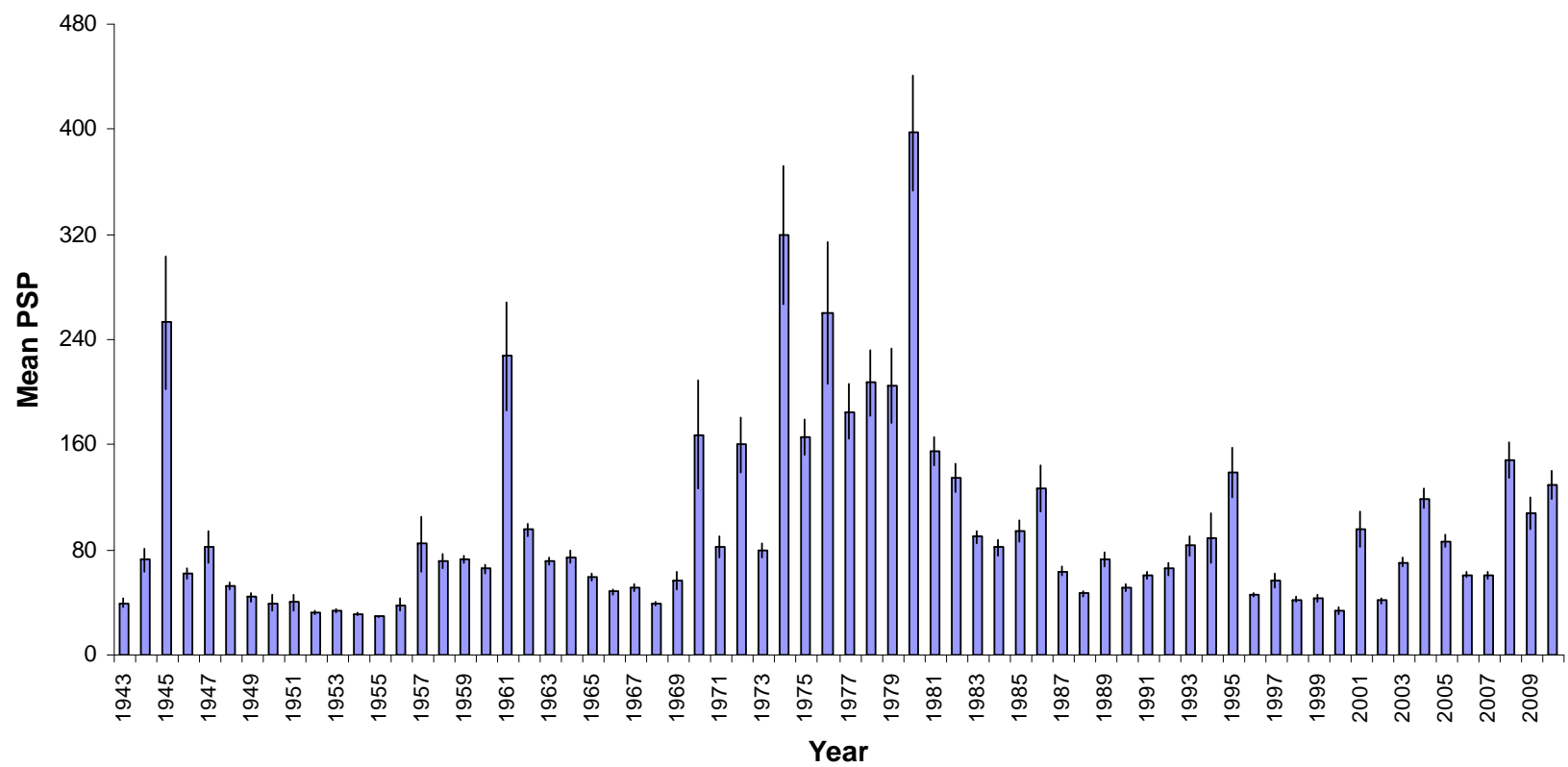


Fig. 22: Mean PSP toxin levels (µg STX/100 g tissue) between sites each year. Error bars are S.E.M.

Table 7: Mean PSP toxin levels ($\mu\text{g STX}/100 \text{ g tissue}$) for all years, with sample size (n), standard deviation, S.E.M., maximum and minimum PSP toxin level.

Location	n	Mean PSP	Standard Deviation	S.E.M.	Max	Min
Crow Harbour	1027	382.30	677.485	21.1405	8200.00	29.00
Lepreau Basin	2520	136.38	354.751	7.0668	9100.00	29.00
Simmons Cove	832	125.35	214.693	7.4432	4200.00	29.00
McLean Cove, Poc. West	933	124.34	323.652	10.5959	5400.00	29.00
Red Head Harbour	690	117.32	257.370	9.7979	4000.00	29.00
Ross Island Thoroughfare	1748	106.46	204.287	4.8862	3100.00	29.00
Letete Passage	1685	88.53	211.442	5.1510	6400.00	29.00
Stuart Town	1396	68.87	157.071	4.2039	3500.00	29.00
Duck Cove	1372	65.59	88.244	2.3824	1500.00	29.00
Lepreau Harbour	2375	63.38	127.883	2.6241	2516.00	29.00
Pocologan	589	59.27	107.085	4.4123	1553.00	29.00
Bar Road	1429	45.85	162.490	4.2984	4120.00	29.00
Northern Harbour	1856	44.37	56.031	1.3006	1100.00	29.00
Deep Cove	875	37.60	22.553	0.7624	260.00	29.00
Ingalls Head	806	34.12	18.557	0.6536	300.00	29.00
Harbour De Lute	782	31.40	8.928	0.3190	123.00	29.00

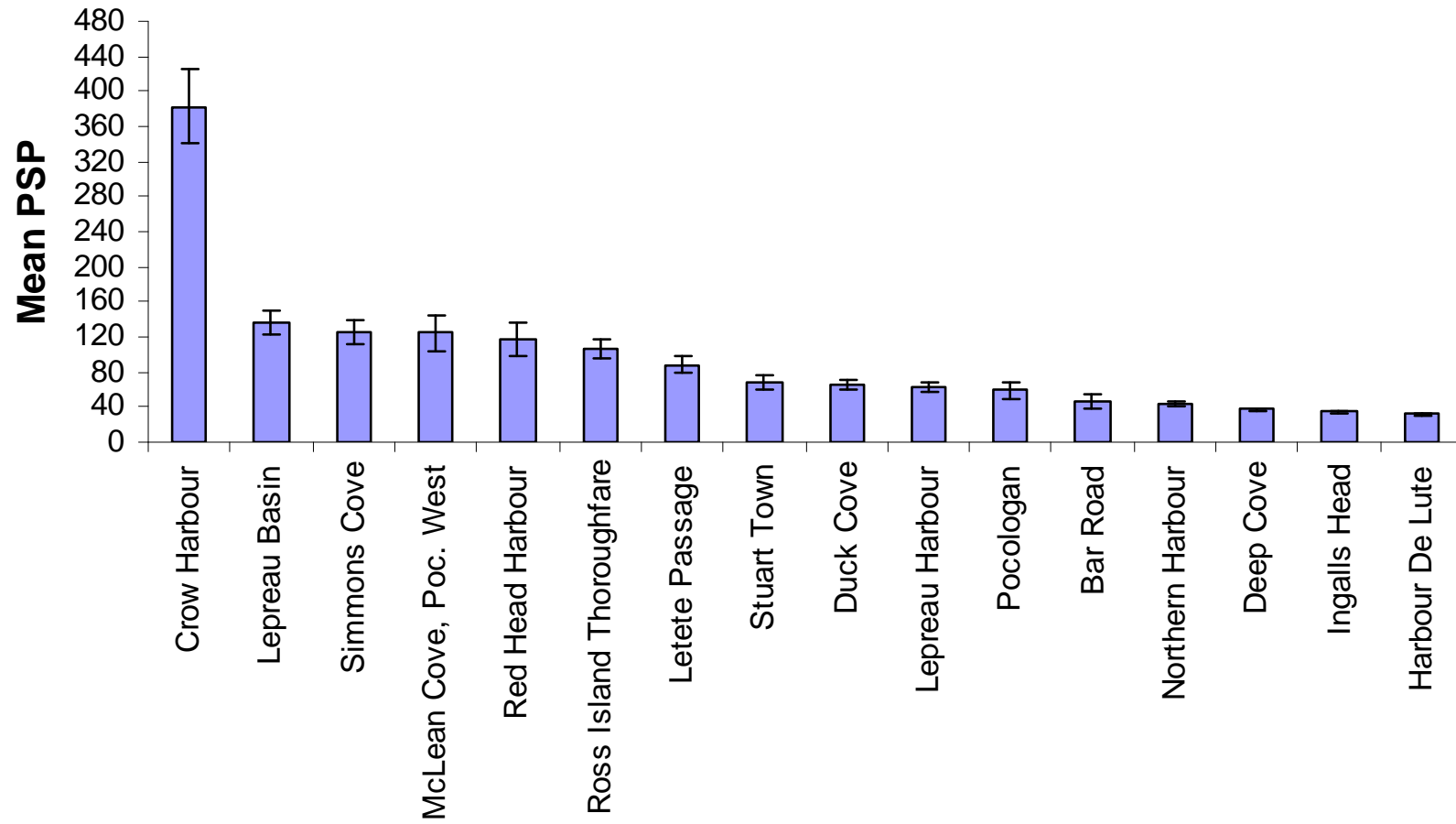


Fig. 23: Mean PSP toxin levels ($\mu\text{g STX/ 100 g tissue}$) for each site for all years. Error bars represent 2 S.E.M.

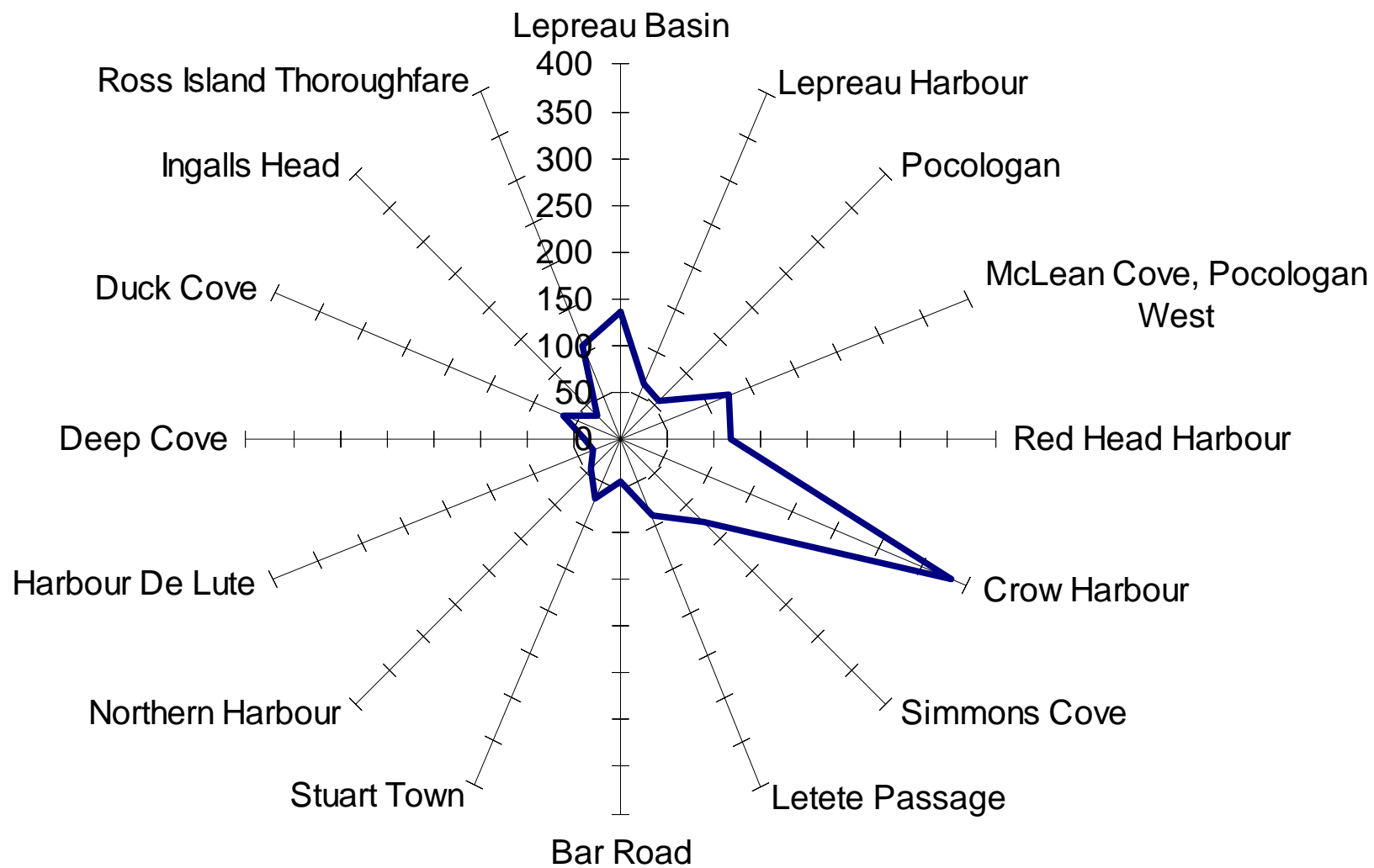


Fig. 24: Mean PSP levels ($\mu\text{g STX}/100 \text{ g tissue}$) for each sampled site from 1943-2010.

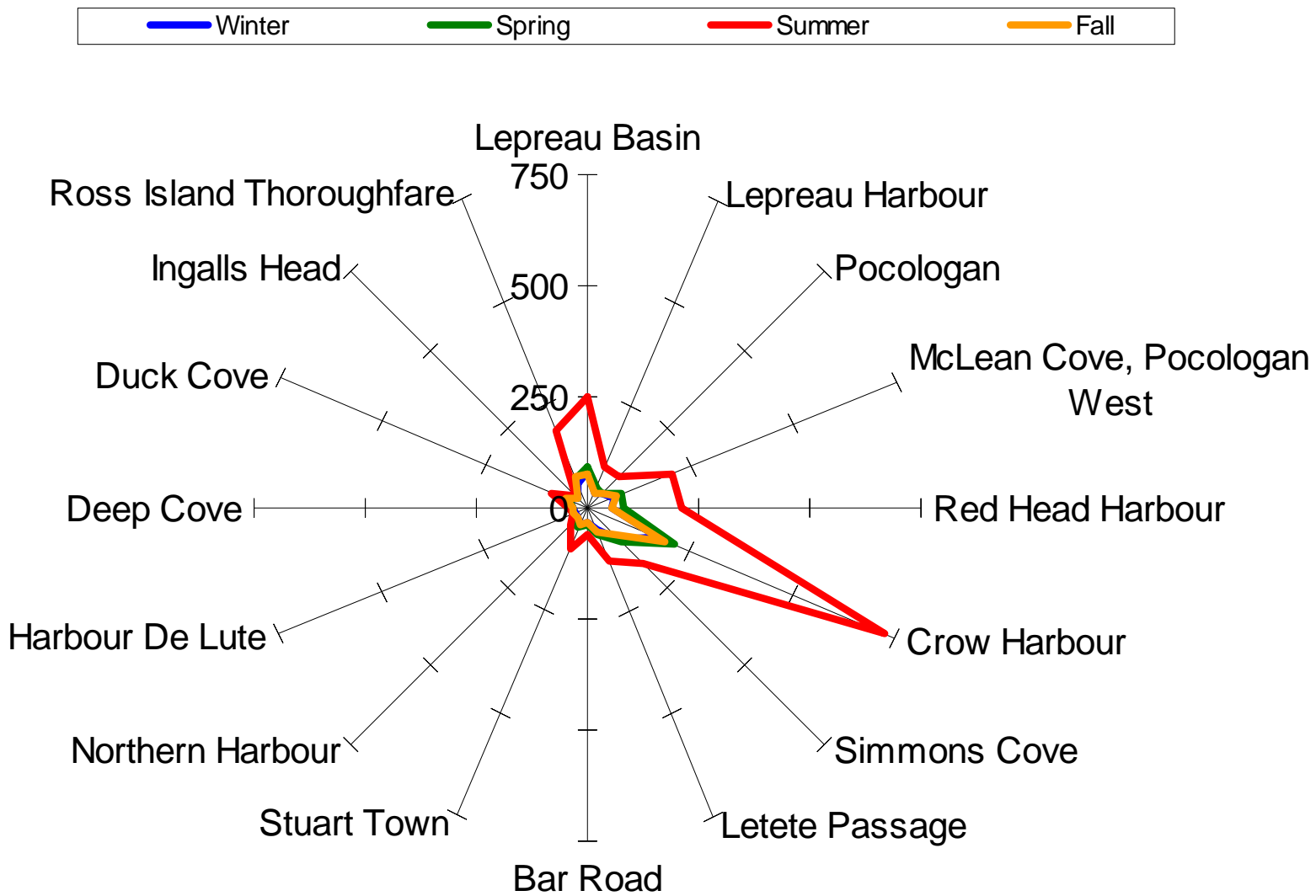


Fig. 25: Mean seasonal PSP toxin levels ($\mu\text{g STX}/100 \text{ g tissue}$) for all sites from 1943-2010.

Table 8: Mean seasonal PSP toxin levels ($\mu\text{g STX}/100 \text{ g tissue}$) from 1943-2010.

Location	Winter	Spring	Summer	Fall
Lepreau Basin	83.09	91.79	248.55	77.77
Lepreau Harbour	40.25	49.16	98.43	38.53
Pocologan	45.49	44.48	95.62	44.81
McLean Cove, Poc West	65.43	80.66	208.51	68.57
Red Head Harbour	52.7	83.06	210.67	56.87
Crow Harbour	170.01	210.14	725.73	188.41
Simmons Cove	100.95	107.47	174.89	86.26
Letete Passage	56.95	66.69	131.55	62.06
Bar Road	29.89	38.59	62.33	30.07
Stuart Town	42.47	50.91	104.13	40.78
Northern Harbour	31.17	40.87	55.84	31.96
Harbour De Lute	29.31	31.35	32.35	30.18
Deep Cove	32.34	34.99	42.97	31.86
Duck Cove	49.65	49.22	88.26	54.07
Ingalls Head	30.84	30.91	38.65	30.26
Ross Island Thoroughfare	59.27	71.45	187.95	74.77

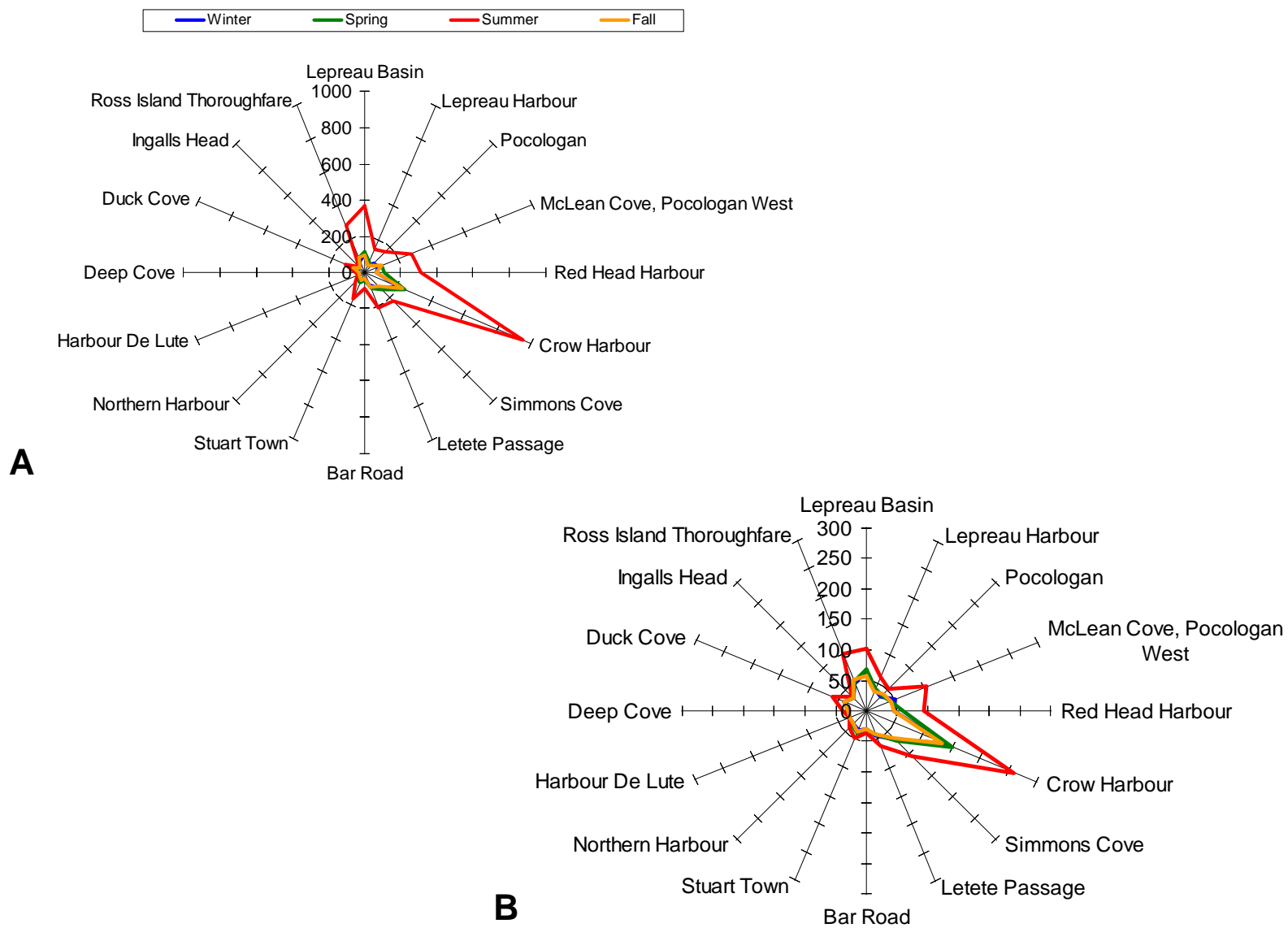


Fig. 26: Mean seasonal PSP toxin levels ($\mu\text{g STX}/100 \text{ g tissue}$) for all sites in (A) all 'hot' years, and (B) all 'cold' years, from 1943-2010.

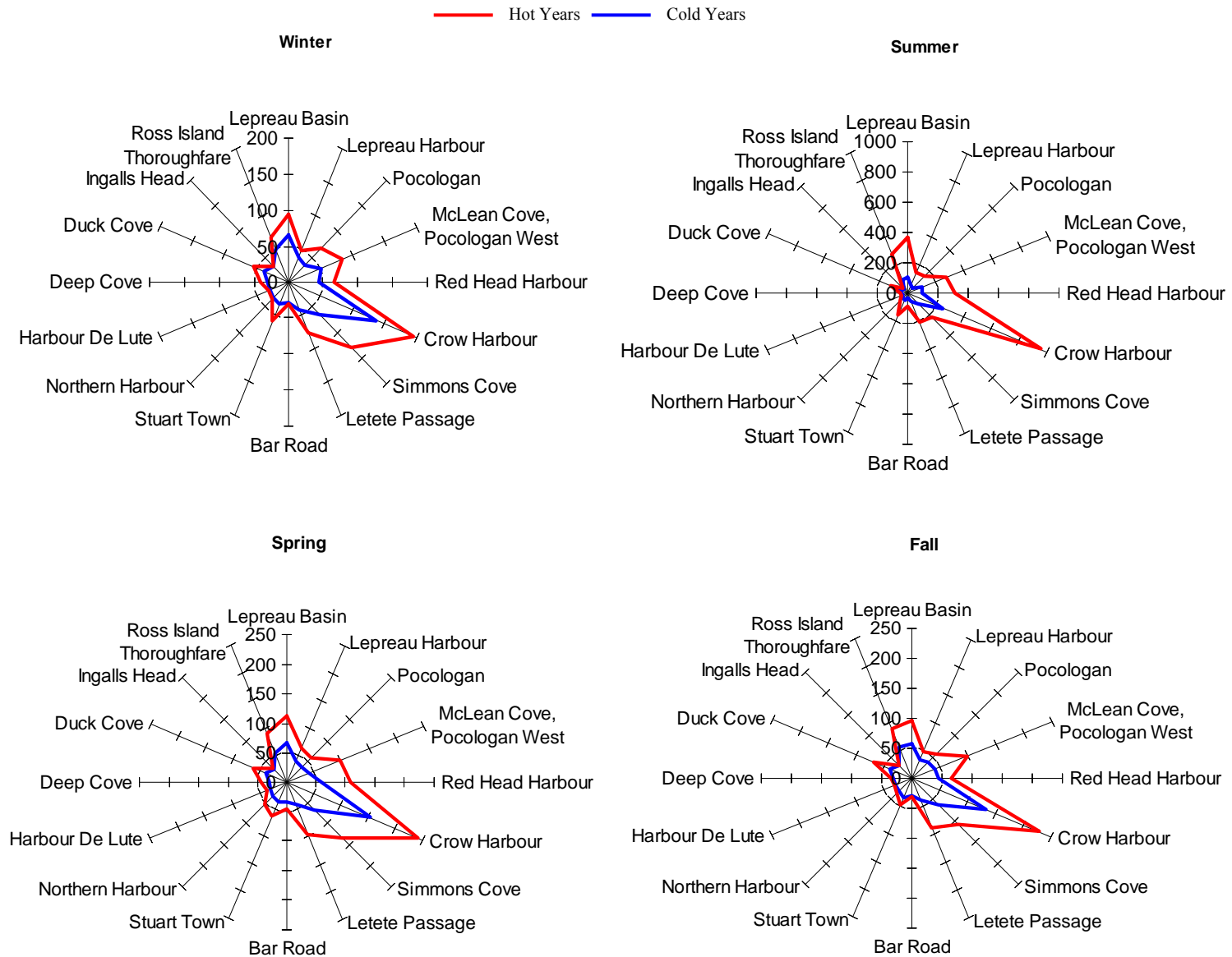


Fig. 27: Mean seasonal PSP toxin levels (μg STX/100 g tissue) for the 'hot' and 'cold' years from 1943-2010.

Table 9: Mean seasonal PSP toxin levels ($\mu\text{g STX}/100 \text{ g tissue}$) for 'hot' years and 'cold' years from 1943-2010.

Location	'Hot' Years				'Cold' Years			
	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall
Lepreau Basin	93.89	111.86	366.14	95.72	65.61	66.64	102.06	56.92
Lepreau Harbour	46.51	62.31	141.15	47.22	36.50	38.53	58.81	32.76
Pocologan	66.90	59.77	163.53	57.80	33.13	36.65	51.24	38.31
McLean Cove, Poc. West	84.18	98.51	280.81	100.18	49.75	41.49	106.20	41.36
Red Head Harbour	65.93	108.42	308.50	66.17	43.51	59.83	92.00	44.62
Crow Harbour	195.18	241.90	949.65	228.38	137.49	152.80	258.90	133.71
Simmons Cove	128.53	133.29	223.06	106.95	64.59	67.32	104.63	62.29
Letete Passage	75.67	95.06	209.45	88.01	42.14	40.82	60.60	41.12
Bar Road	31.07	45.34	86.87	31.00	29.20	33.02	35.70	29.42
Stuart Town	58.59	63.58	160.15	48.57	34.31	37.81	48.52	35.18
Northern Harbour	33.57	52.66	75.71	35.73	29.69	32.52	40.91	29.66
Harbour De Lute	30.32	35.23	36.27	31.59	29.00	29.09	29.40	29.51
Deep Cove	40.08	42.49	50.00	33.87	29.96	30.30	38.58	30.56
Duck Cove	54.76	60.87	120.34	69.13	38.16	39.26	58.14	40.61
Ingalls Head	31.64	32.85	45.28	31.12	29.98	29.39	33.23	29.52
Ross Island Thoroughfare	67.14	88.19	276.03	88.38	49.57	52.88	98.90	55.05

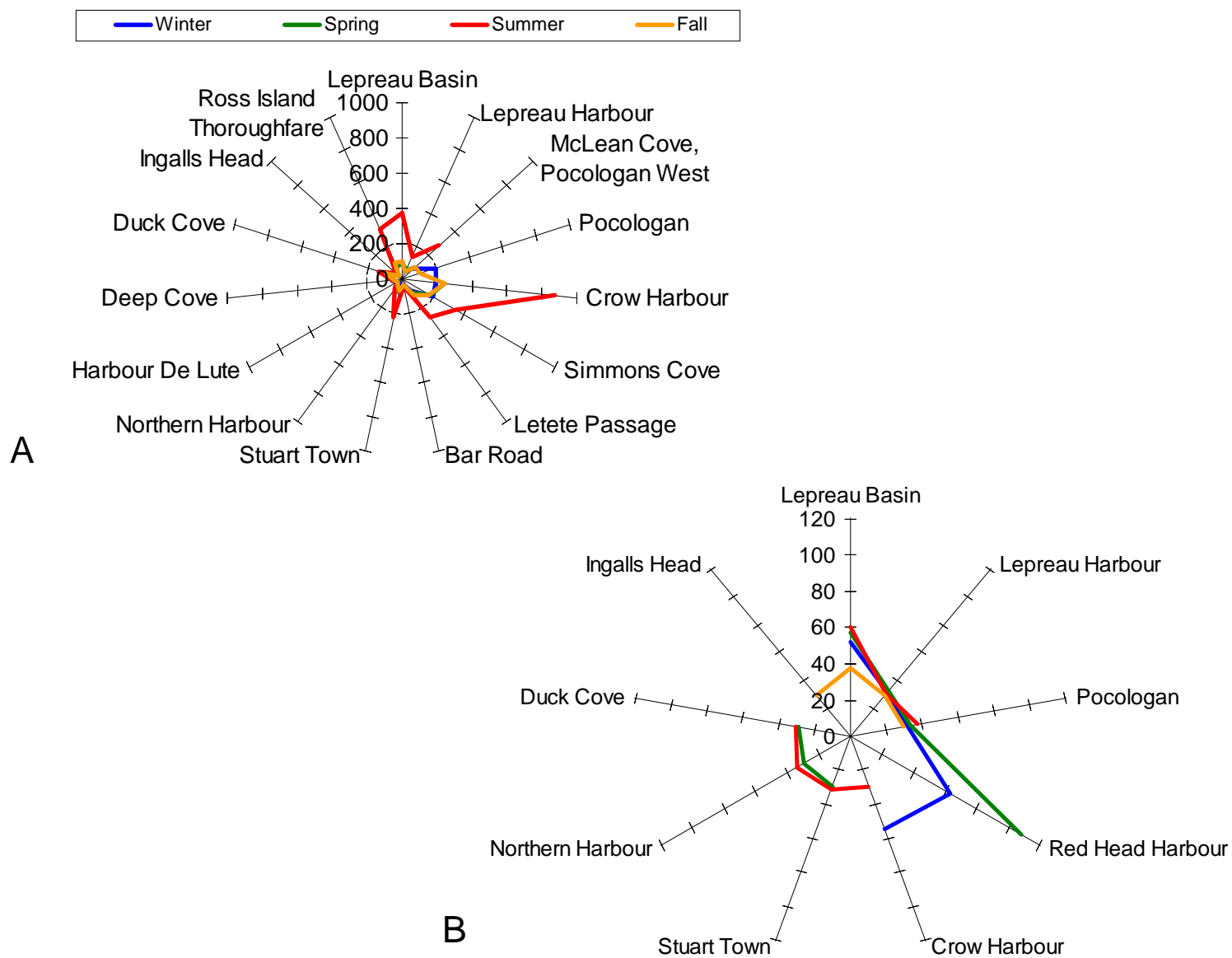


Fig. 28: Mean seasonal PSP toxin levels ($\mu\text{g STX}/100 \text{ g tissue}$) for (A) the 'hot' period 1970-1986, and (B) the 'cold' years 1948-1956.

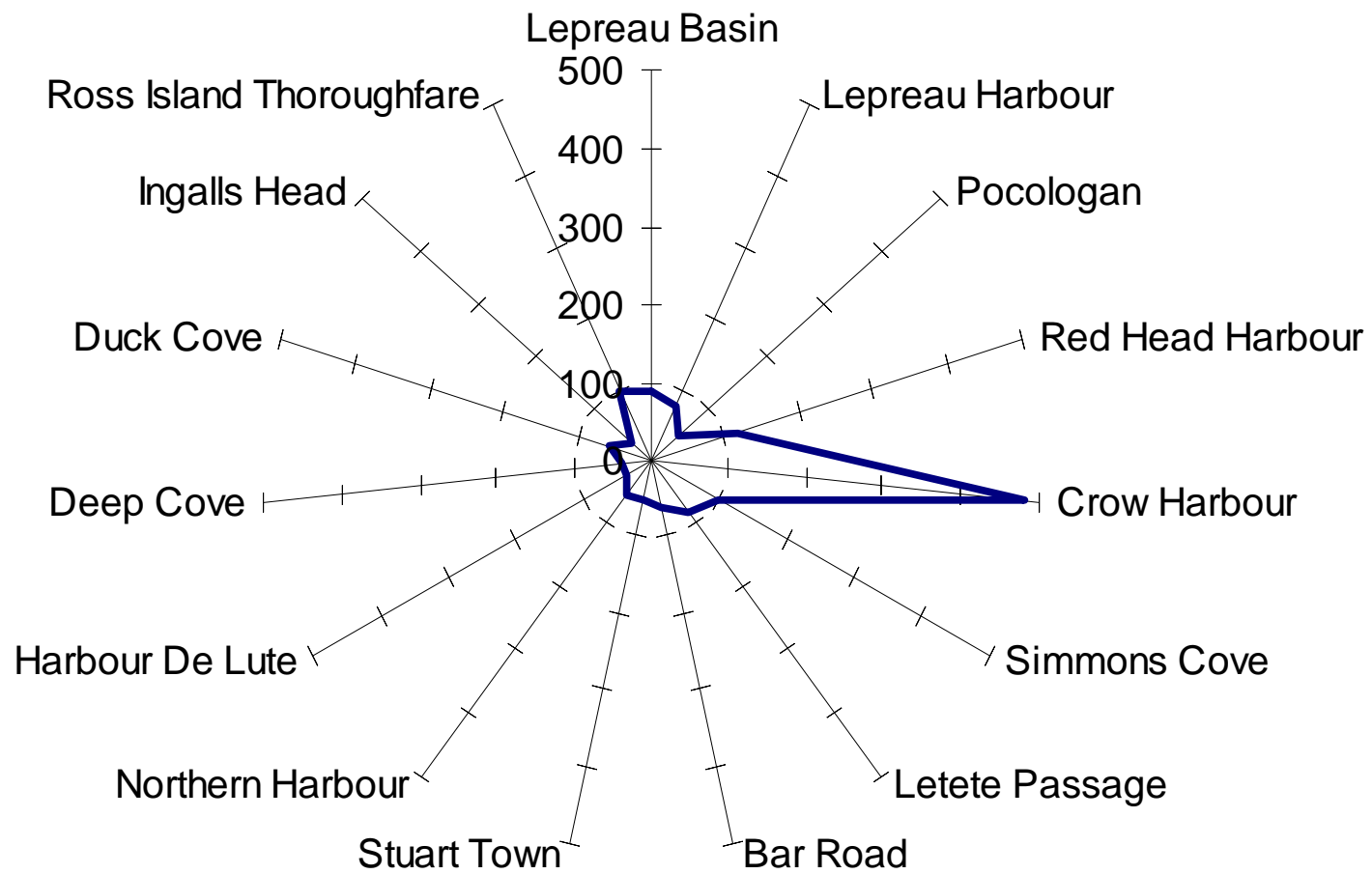


Fig. 29: Mean PSP toxin levels (µg STX/100 g tissue) for 1993 - 2010.

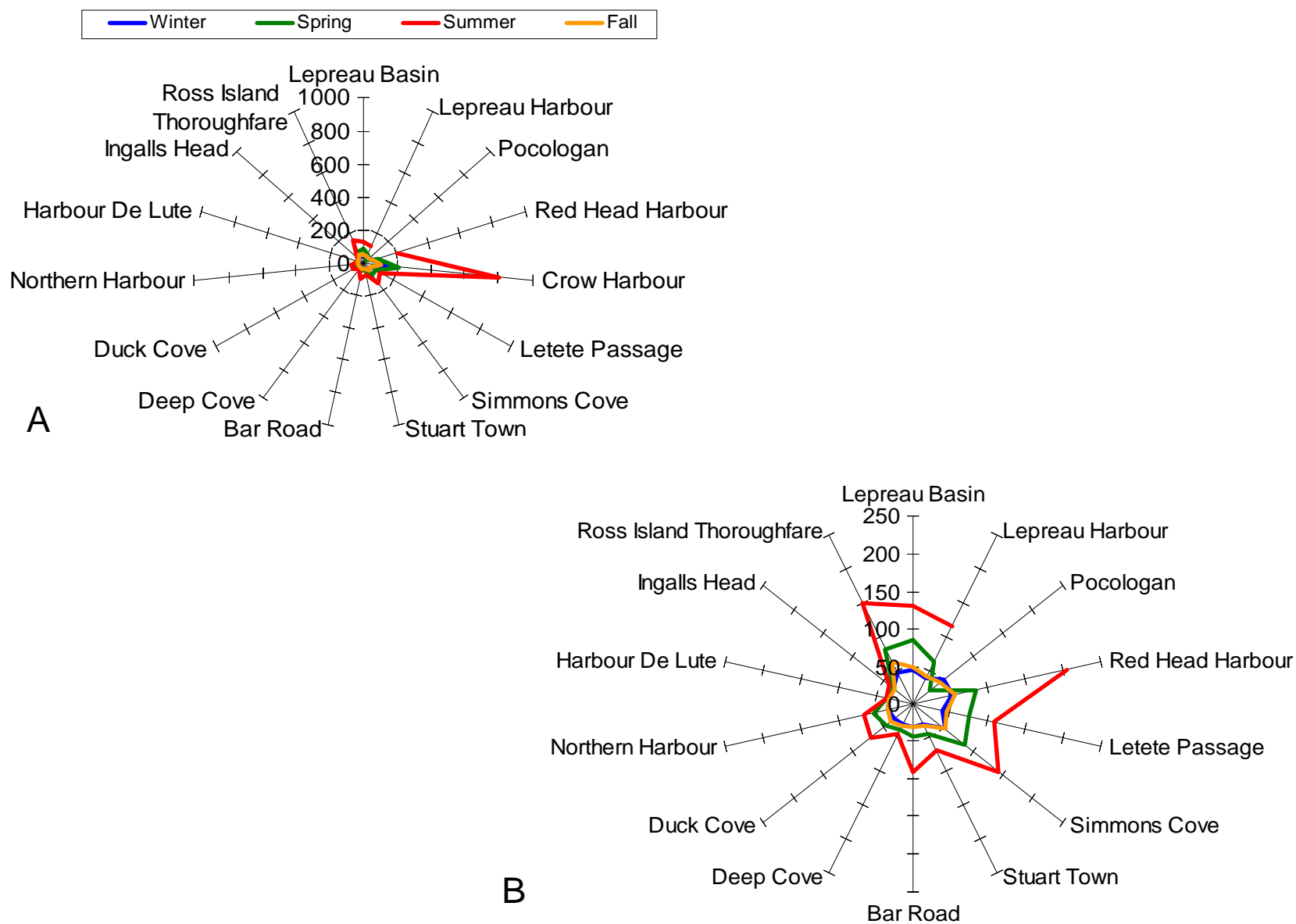


Fig. 30: Mean seasonal PSP toxin levels ($\mu\text{g STX}/100 \text{ g tissue}$) for the 'mixed' period from 1993-2010 for (A) all sites and (B) all sites except Crow Harbour.

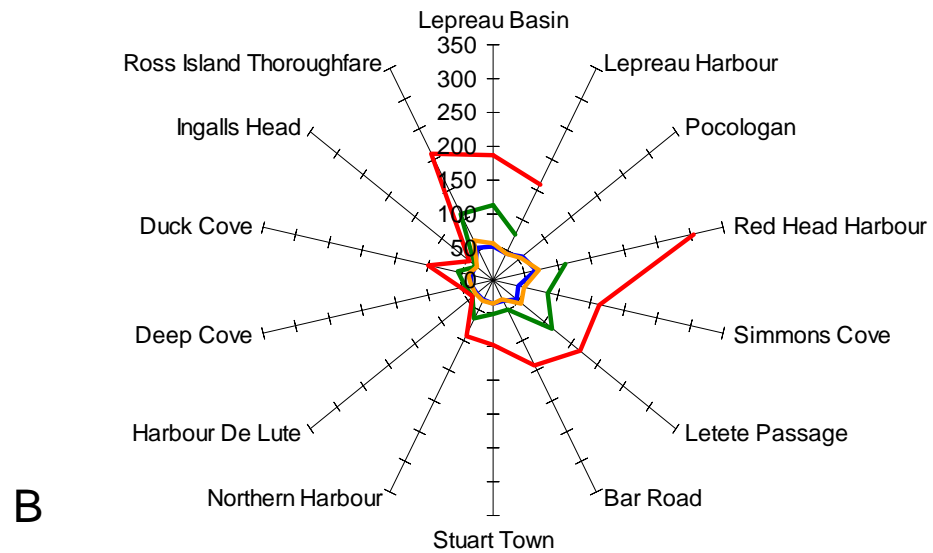
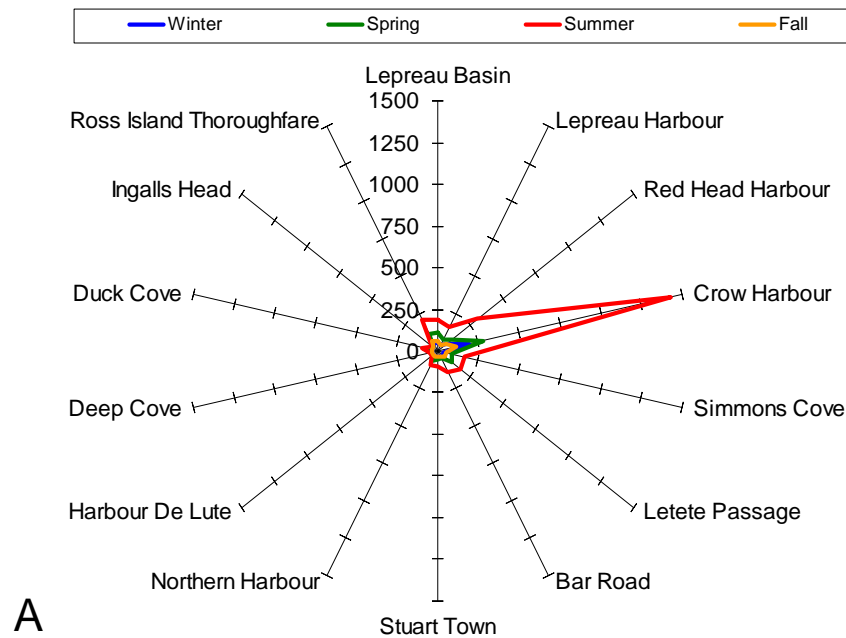


Fig. 31: Mean seasonal PSP toxin levels ($\mu\text{g STX}/100 \text{ g tissue}$) for the 'hot' years during the period 1993-2010 for (A) all sites in all years, and (B) all sites except Crow Harbour.

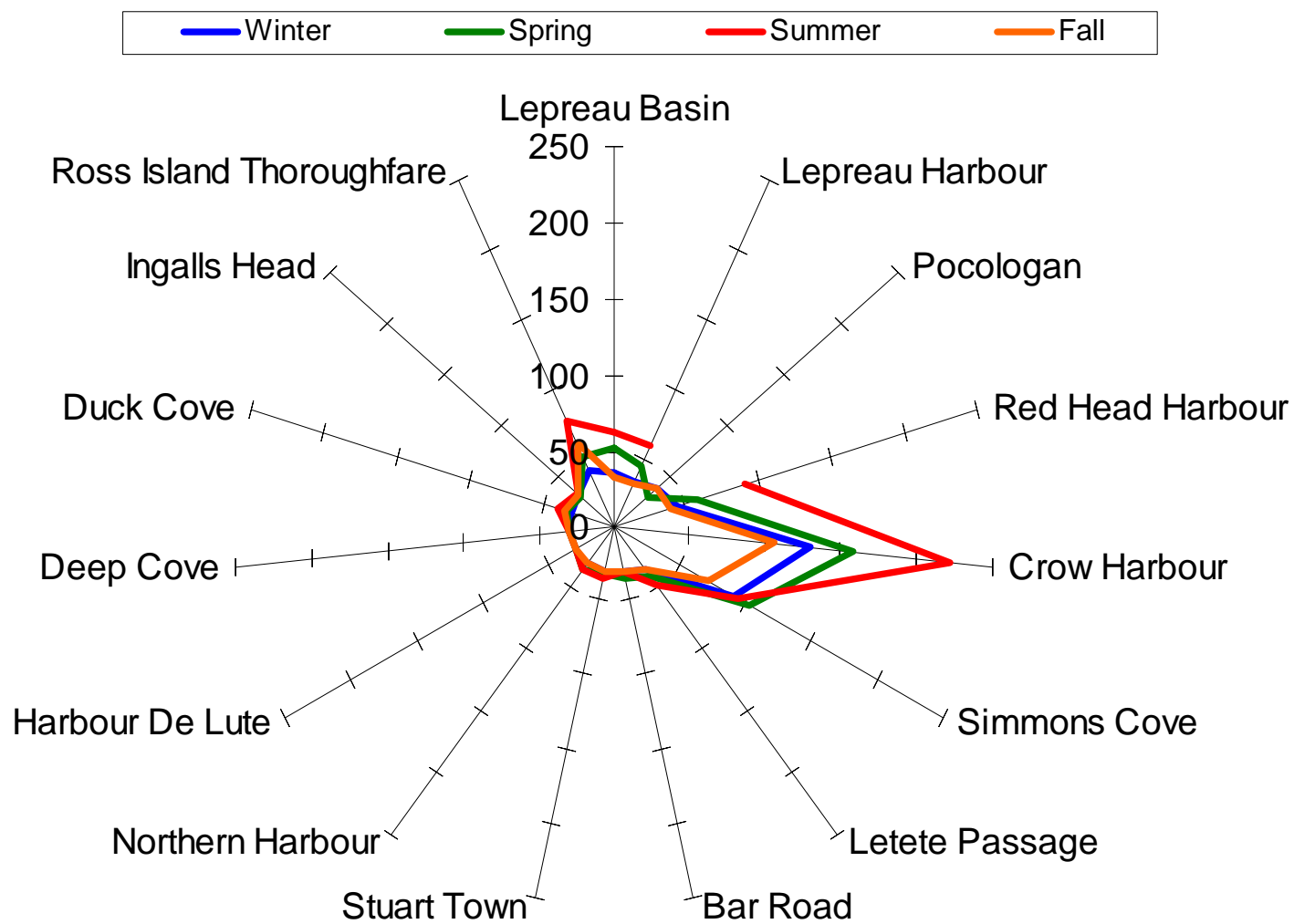


Fig. 32: Mean seasonal PSP toxin levels ($\mu\text{g STX}/100 \text{ g tissue}$) for the 'cold' years during the 'mixed' period from 1993 - 2010.

Table 10: Mean seasonal PSP concentration ($\mu\text{g STX}/100 \text{ g tissue}$) during the 'cold' period from 1948-1956.

Location	Season			
	Winter	Spring	Summer	Fall
Lepreau Basin	51.79	56.90	60.35	37.79
Lepreau Harbour	31.43	32.15	30.56	29.54
Pocologan	32.03	33.81	37.81	29.95
Red Head Harbour	62.75	107.80		
Crow Harbour	54.00		29.00	
Stuart Town		29.00	30.82	
Northern Harbour	29.00	29.41	33.54	29.21
Duck Cove		29.00	31.00	
Ingalls Head				29.00
Ross Island Thoroughfare		46.75	168.00	

Table 11: Mean seasonal PSP concentration ($\mu\text{g STX}/100 \text{ g tissue}$) during the 'hot' period of 1970-1986.

Location	Season			
	Winter	Spring	Summer	Fall
Lepreau Basin	101.38	90.99	375.68	101.06
Lepreau Harbour	51.15	58.58	131.80	53.22
McLean Cove, Pocologan West	84.18	98.51	280.81	100.18
Pocologan	199.80			109.42
Crow Harbour	195.12	242.16	871.90	240.07
Simmons Cove	198.03	185.55	337.69	171.47
Letete Passage	87.16	92.89	265.22	110.92
Bar Road	29.20	42.00	44.86	29.88
Stuart Town	73.96	77.68	228.56	65.07
Northern Harbour	33.63	46.55	70.09	39.47
Harbour De Lute	30.40	29.75	32.67	29.00
Deep Cove	54.25	45.07	47.04	38.80
Duck Cove	58.03	65.86	141.34	103.03
Ingalls Head	29.78	31.29	52.67	29.00
Ross Island Thoroughfare	75.92	76.47	309.70	100.17

Table 12: Mean PSP concentration ($\mu\text{g STX}/100 \text{ g tissue}$), including seasonal means, during the ‘mixed’ period from 1993-2010.

Location	Winter	Spring	Summer	Fall	Mean of all years
Lepreau Basin	44.73	85.32	131.08	48.24	88.07
Lepreau Harbour	38.56	61.17	113.45	40.70	76.87
Pocologan	50.52	29.00		45.16	47.51
Red Head Harbour	53.38	83.90	205.54	56.41	116.32
Crow Harbour	140.94	203.77	804.17	106.94	482.50
Letete Passage	39.24	74.23	108.65	46.18	82.10
Simmons Cove	53.11	86.67	143.22	52.54	98.05
Stuart Town	31.20	42.70	68.89	33.30	51.60
Bar Road	31.38	42.90	91.28	30.60	60.70
Deep Cove	30.94	37.17	42.98	32.16	38.59
Duck Cove	31.00	45.24	71.08	36.29	55.52
Northern Harbour	31.80	52.40	65.46	32.39	53.22
Harbour De Lute	30.22	35.49	35.33	31.65	34.65
Ingalls Head	32.79	31.87	39.00	31.50	35.22
Ross Island Thoroughfare	47.61	81.64	148.63	63.37	96.58

Table 13: Mean seasonal PSP concentration ($\mu\text{g STX}/100 \text{ g tissue}$) for 'hot' and 'cold' years in the 'mixed' period from 1993-2010.

Location	'Hot' years				'Cold' Years			
	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall
Lepreau Basin	50.00	112.16	186.04	55.22	34.84	51.42	62.39	32.90
Lepreau Harbour	44.27	75.15	157.80	44.59	32.85	44.28	57.13	31.25
Pocologan					36.29	29.00	0.00	37.11
Red Head Harbour	65.93	108.46	305.49	68.95	42.43	57.99	89.60	38.66
Crow Harbour	196.67	281.77	1423.50	110.67	128.08	157.68	221.26	104.70
Simmons Cove	36.80	82.33	161.13	48.32	90.18	101.85	93.82	71.17
Letete Passage	44.22	113.76	166.66	54.39	35.35	39.31	47.26	34.91
Bar Road	34.35	48.43	140.66	31.62	29.00	35.73	29.78	29.00
Stuart Town	34.18	51.25	95.34	35.33	29.00	30.65	35.77	29.52
Northern Harbour	33.68	64.50	90.97	34.25	30.18	35.10	34.09	29.00
Harbour De Lute	30.22	38.67	38.30	32.53	0.00	29.00	29.38	29.00
Deep Cove	33.00	41.53	50.67	33.29	29.00	29.61	29.78	29.00
Duck Cove	32.25	54.16	97.34	37.55	29.00	32.73	38.19	33.50
Ingalls Head	33.42	33.46	43.06	31.64	31.80	29.55	33.12	31.11
Ross Island Thoroughfare	52.61	108.77	209.11	66.07	39.83	50.79	76.05	58.67

Table 14: Ranking of sampling sites by mean monthly PSP toxin levels ($\mu\text{g STX}/100 \text{ g tissue}$) for all years from 1943-2010. Ranking is from lowest concentration (1) to highest concentration (16). Data used for ranking is shown in Appendix A (Table 30).

Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Harbour De Lute	2	1	1	1	1	2	1	1	1	1	3	1	16
Bar Road	1	3	2	2	4	4	6	2	2	2	1	2	31
Ingalls Head	3	2	4	4	2	1	2	3	4	3	2	3	33
Deep Cove	4	5	5	3	3	3	3	4	3	4	5	5	47
Northern Harbour	5	4	3	5	5	5	4	5	5	5	4	4	54
Lepreau Harbour	6	6	7	7	7	9	9	7	7	6	7	7	85
Pocologan	8	12	6	6	6	6	5	9	6	7	8	9	88
Stuart Town	7	8	8	9	9	8	7	8	10	8	6	6	94
Duck Cove	9	7	11	8	8	7	8	6	8	9	9	8	98
Red Head Harbour	10	9	9	10	10	15	15	11	9	10	10	10	128
Letete Passage	11	11	10	11	11	10	10	10	11	11	11	12	129
Ross Island Thoroughfare	13	10	13	12	12	11	12	12	15	13	12	14	149
McLean Cove, Poc. W.	12	13	12	14	14	12	13	14	13	12	14	11	154
Lepreau Basin	14	14	14	13	13	14	14	15	14	14	13	13	165
Simmons Cove	15	15	15	15	15	13	11	13	12	15	15	15	169
Crow Harbour	16	16	16	16	16	16	16	16	16	16	16	16	192

Table 15: Ranking of sampling sites by mean monthly PSP toxin levels ($\mu\text{g STX}/100 \text{ g tissue}$) for all 'cold' years from 1943-2010. Ranking is from lowest concentration (1) to highest concentration (16). Data used for ranking is shown in Appendix A (Table 31).

Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Harbour De Lute	1	1	1	1	1	1	1	1	2	1	5	1	17
Bar Road	2	5	1	1	5	6	3	2	1	2	3	3	34
Ingalls Head	4	1	4	5	2	2	2	3	5	4	2	1	35
Deep Cove	3	1	5	3	3	3	4	4	4	5	4	5	44
Northern Harbour	5	4	1	4	4	4	6	5	3	3	1	4	44
Stuart Town	7	6	8	8	9	7	7	6	6	7	7	8	86
Lepreau Harbour	8	9	9	6	7	9	10	7	8	6	6	6	91
Pocologan	6	7	7	7	10	5	5	9	12	9	11	7	95
Duck Cove	9	8	6	10	6	10	8	8	9	8	12	10	104
Letete Passage	10	10	10	9	8	11	9	10	7	10	8	12	114
Red Head Harbour	11	11	12	13	12	15	12	12	10	12	10	9	139
McLean Cove, Poc. West	12	13	13	11	11	8	15	15	11	11	9	11	140
Ross Island Thoroughfare	13	12	11	12	13	12	11	13	14	13	13	15	152
Lepreau Basin	14	15	15	15	14	13	13	11	15	14	14	14	167
Simmons Cove	15	14	14	14	15	14	14	14	13	15	15	13	170
Crow Harbour	16	16	16	16	16	16	16	16	16	16	16	16	192

Table 16: Ranking of sampling sites by mean monthly PSP toxin levels ($\mu\text{g STX}/100 \text{ g tissue}$) for all 'hot' years from 1943-2010. Ranking is from lowest concentration (1) to highest concentration (16). Data used for ranking is shown in Appendix A (Table 32).

Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Harbour De Lute	3	1	1	1	1	2	1	1	1	3	1	3	19
Ingalls Head	2	2	4	4	2	1	2	4	4	1	3	2	31
Bar Road	1	3	2	2	4	4	5	2	3	2	2	1	31
Deep Cove	5	5	5	3	3	3	3	3	2	4	5	5	46
Northern Harbour	4	4	3	5	5	5	4	5	5	5	4	4	53
Lepreau Harbour	6	6	7	7	7	8	9	7	7	6	7	7	84
Duck Cove	7	7	9	8	9	6	7	6	8	10	9	8	94
Stuart Town	8	9	8	10	8	7	6	9	10	8	6	6	95
Pocologan	9	13	6	6	6	9	8	12	6	7	8	10	100
Red Head Harbour	10	10	11	9	10	15	15	8	9	9	10	9	125
Ross Island Thoroughfare	11	8	12	11	11	11	12	13	15	13	11	12	140
Letete Passage	13	11	13	12	12	12	10	11	11	11	12	14	142
McLean Cove, Poc. West	12	14	10	15	14	10	13	14	14	12	15	15	158
Lepreau Basin	14	12	14	13	13	14	14	15	12	14	13	11	159
Simmons Cove	15	15	15	14	15	13	11	10	13	15	14	13	163
Crow Harbour	16	16	16	16	16	16	16	16	16	16	16	16	192

Table 17: Ranking of sampling sites by mean monthly PSP toxin levels ($\mu\text{g STX}/100 \text{ g tissue}$) for all 'cold' years from 1943-2010. Ranking is from lowest concentration (1) to highest concentration (16). Data used for ranking is shown in Appendix A (Table 33).

Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Harbour De Lute	4	1	1	1	1	1	1	2	1	1	1	1	16
Ingalls Head	1	3	3	3	2	2	2	4	3	1	1	1	26
Bar Road	2	1	1	4	4	3	4	1	2	3	1	1	27
Deep Cove		8	5	1	3	6	5	3	4	4			39
Pocologan		15								13	9	12	49
Northern Harbour	3	4	4	5	5	4	3	5	5	5	4	4	51
Lepreau Harbour	6	5	7	8	7	5	8	6	7	6	6	8	79
Red Head Harbour	7	7	6	6	6	13	13	8	6	7	7	6	92
Duck Cove	5	6	8	7	8	8	7	7	8	14	11	7	96
Stuart Town	8	11	9	9	9	9	6	13	9	8	5	5	101
Ross Island Thoroughfare	9	9	12	10	11	7	11	9	13	12	8	11	122
Letete Passage	12	10	11	12	12	10	9	12	11	10	12	13	134
McLean Cove, Poc. West	10	13	10	13	13	11	12	10	10	9	13	10	134
Lepreau Basin	11	12	13	11	10	12	14	11	12	11	10	9	136
Simmons Cove	14	14	15	14	14	14	10	14	14	15	14	14	166
Crow Harbour	13	16	14	15	15	15	15	15	15	16	15	15	179

Table 18: Ranking of sampling sites by mean monthly PSP toxin levels ($\mu\text{g STX}/100 \text{ g tissue}$) for the ‘cold’ period from 1948-1956. Ranking is from lowest concentration (1) to highest concentration (10). Data used for ranking is shown in Appendix A (Table 34).

Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Ingalls Head												1	1
Crow Harbour	5								1				6
Duck Cove					1	1	2	3					7
Stuart Town					1	1	1	2	5				10
Northern Harbour	1	1	1	1	3	3	3	5	4	2	1	3	28
Lepreau Harbour	3	2	2	2	4	5	4	1	2	1	2	2	30
Ross Island Thoroughfare					6	6	6	7	7				32
Red Head Harbour	6		5	5	8	8							32
Pocologan	2	3	3	3	5	4	5	4	3	3	3	4	42
Lepreau Basin	4	4	4	4	7	7	7	6	6	4	4	5	62

Table 19: Ranking of sampling sites by mean monthly PSP toxin levels ($\mu\text{g STX}/100 \text{ g tissue}$) for the ‘mixed’ period from 1993-2010. Ranking is from lowest concentration (1) to highest concentration (15). Data used for ranking is shown in Appendix A (Table 35).

Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Harbour De Lute	6	1	1	1	3	2	1	1	1	3	2	4	26
Deep Cove	4	3	5	4	1	3	3	3	2	1	6	7	42
Bar Road	1	7	3	3	6	5	7	4	3	2	1	1	43
Ingalls Head	7	2	7	8	2	1	2	2	6	4	3	1	45
Northern Harbour	5	5	3	7	7	7	4	5	4	5	5	3	60
Stuart Town	3	4	6	6	5	4	6	6	5	6	4	5	60
Duck Cove	2	6	1	5	4	6	5	7	7	7	7	6	63
Pocologan	13	13	10	1						8	12	10	67
Lepreau Harbour	8	8	9	9	8	8	9	8	9	9	8	8	101
Letete Passage	9	9	8	11	9	9	8	9	8	10	11	9	110
Lepreau Basin	11	10	11	10	12	11	10	10	11	11	10	11	128
Simmons Cove	14	11	12	14	13	10	12	11	10	13	9	12	141
Ross Island Thoroughfare	10	12	13	12	10	12	11	12	13	14	14	14	147
Red Head Harbour	12	14	14	13	11	13	13	13	12	12	13	13	153
Crow Harbour	15	15	15	15	14	14	14	14	14	15	15	15	175

Table 20: Ranking of sampling sites by mean monthly PSP toxin levels ($\mu\text{g STX}/100 \text{ g tissue}$) for the ‘cold’ years during the ‘mixed’ period from 1993-2010. Ranking is from lowest concentration (1) to highest concentration (15). Data used for ranking is shown in Appendix A (Table 36).

Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Harbour De Lute					1	1	1	1	1	1	1	1	8
Deep Cove	1	1	1	1	1	3	2	1	3	1	1	1	17
Bar Road	1	1	1	1	6	7	4	1	1	1	1	1	26
Northern Harbour	6	1	1	1	7	6	5	5	4	1	1	1	39
Stuart Town	1	1	1	6	5	4	7	6	5	5	1	1	43
Duck Cove	1	1	1	1	4	5	6	7	7	10	1	1	45
Pocologan	9	8		1						11	12	12	53
Ingalls Head	5	1	9	8	1	1	3	4	8	7	8	1	56
Lepreau Harbour	8	7	7	7	8	9	10	8	10	6	7	1	88
Letete Passage	10	10	6	10	9	8	8	10	6	9	11	1	98
Lepreau Basin	7	9	10	9	10	11	11	9	9	8	9	11	113
Ross Island Thoroughfare	11	12	8	11	11	10	9	11	13	13	13	14	136
Red Head Harbour	12	11	11	12	12	12	13	12	11	12	10	13	141
Simmons Cove	13	13	12	13	13	13	12	13	12	15	14	1	144
Crow Harbour	14	14	13	14	14	14	14	14	14	14	15	15	169

Table 21: Ranking of sampling sites by mean monthly PSP toxin levels ($\mu\text{g STX}/100 \text{ g tissue}$) for the ‘hot’ years during the ‘mixed’ period from 1993-2010. Ranking is from lowest concentration (1) to highest concentration (15). Data used for ranking is shown in Appendix A (Table 37).

Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Harbour De Lute	3	1	1	1	3	2	1	1	1	4	2	3	23
Ingalls Head	5	2	8	7	2	1	2	2	4	2	3	1	39
Deep Cove	7	3	3	3	1	3	3	3	2	1	6	6	41
Bar Road	1	8	5	2	6	4	7	4	3	3	1	2	46
Duck Cove	2	5	1	4	4	6	4	7	7	7	7	7	61
Northern Harbour	3	7	3	6	7	7	5	5	5	5	5	4	62
Stuart Town	6	4	6	5	5	5	6	6	6	6	4	5	64
Pocologan	14	13	9							8	10	12	66
Simmons Cove	8	6	7	9	10	9	9	9	8	10	8	9	102
Lepreau Harbour	9	10	11	8	8	8	8	8	10	9	9	8	106
Letete Passage	10	9	10	11	9	10	10	10	9	11	12	10	121
Lepreau Basin	12	12	12	10	13	11	11	11	11	12	11	11	137
Crow Harbour	15	15		14	14	14	14	14	14	15		15	144
Ross Island Thoroughfare	11	11	13	12	11	12	12	12	13	13	13	14	147
Red Head Harbour	13	14	14	13	12	13	13	13	12	14	14	13	158

Table 22: Ranking (by month) of mean monthly PSP toxin levels ($\mu\text{g STX}/100 \text{ g tissue}$) for the years from 1943-2010. Ranking is from lowest concentration (1) to highest concentration (12). Data used for ranking is shown in Appendix A (Table 30).

Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Ross Island Thoroughfare	2	1	4	3	5	9	12	11	10	8	6	7
Ingalls Head	7	2	8	9	3	6	12	11	10	5	4	1
Duck Cove	2	3	8	5	1	7	12	11	10	9	6	4
Deep Cove	3	9	5	2	1	11	12	10	8	4	6	7
Harbour De Lute	9	1	1	1	4	11	12	10	6	7	8	5
Northern Harbour	5	4	1	7	8	11	12	10	9	6	2	3
Stuart Town	3	6	4	8	5	9	11	12	10	7	1	2
Bar Road	3	7	1	5	10	11	12	9	8	6	4	2
Letete Passage	1	5	3	4	2	9	12	11	10	6	7	8
Simmons Cove	5	8	6	1	7	9	12	11	10	4	2	3
Crow Harbour	1	5	2	8	6	9	12	11	10	7	4	3
Red Head Harbour	2	3	6	5	4	10	12	11	9	8	7	1
McLean Cove, Poc. W.	1	8	2	7	6	9	12	11	10	4	5	3
Pocologan	2	10	1	3	4	8	11	12	9	5	6	7
Lepreau Harbour	2	4	8	7	6	9	12	11	10	1	3	5
Lepreau Basin	5	7	8	3	2	9	12	11	10	6	1	4
Total	53	83	68	78	74	147	190	173	149	93	72	65

Table 23: Ranking (by month) of mean monthly PSP toxin levels ($\mu\text{g STX}/100 \text{ g tissue}$) for the ‘cold’ years from 1943-2010. Ranking is from lowest concentration (1) to highest concentration (12). Data used for ranking is shown in Appendix A (Table 31).

Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Ross Island Thoroughfare	7	4	1	2	6	8	12	10	11	9	3	5
Ingalls Head	7	1	9	8	3	4	11	10	12	5	6	1
Duck Cove	6	3	1	7	2	8	12	10	11	5	9	4
Deep Cove	4	1	7	2	3	8	12	11	10	5	6	9
Harbour De Lute	1	1	1	1	1	8	9	10	11	1	12	1
Northern Harbour	9	2	1	5	8	11	12	10	7	3	4	6
Stuart Town	4	1	5	9	7	8	12	11	10	6	2	3
Bar Road	4	7	1	1	10	11	12	9	3	5	8	6
Letete Passage	9	2	7	4	1	8	12	11	10	5	3	6
Simmons Cove	9	2	5	3	6	10	12	11	8	7	4	1
Crow Harbour	2	6	7	9	1	10	12	11	8	4	5	3
Red Head Harbour	6	2	4	9	5	10	12	11	7	8	3	1
McLean Cove, Poc. West	7	9	8	6	1	4	12	11	10	5	2	3
Pocologan	1	3	4	6	7	5	11	10	12	8	9	2
Lepreau Harbour	4	8	7	5	6	9	12	10	11	1	3	2
Lepreau Basin	5	8	6	7	4	9	12	10	11	3	2	1

Table 24: Ranking (by month) of mean monthly PSP toxin levels ($\mu\text{g STX}/100 \text{ g tissue}$) for the 'hot' years from 1943-2010. Ranking is from lowest concentration (1) to highest concentration (12). Data used for ranking is shown in Appendix A (Table 32).

Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Ross Island Thoroughfare	2	1	6	3	4	9	12	11	10	7	5	8
Ingalls Head	7	3	6	9	4	8	12	11	10	5	2	1
Duck Cove	1	2	6	4	3	8	12	11	10	9	7	5
Deep Cove	9	10	7	4	1	11	12	8	3	2	6	5
Harbour De Lute	10	1	1	1	5	11	12	9	7	8	4	6
Northern Harbour	5	4	1	6	8	11	12	10	9	7	3	2
Stuart Town	3	8	5	7	4	9	11	12	10	6	1	2
Bar Road	4	7	1	6	10	11	12	9	8	5	2	3
Letete Passage	5	1	2	3	4	9	12	11	10	7	6	8
Simmons Cove	4	7	6	2	8	9	12	11	10	5	1	3
Crow Harbour	1	4	2	6	7	9	12	11	10	8	5	3
Red Head Harbour	1	8	6	4	2	10	12	11	9	5	7	3
McLean Cove, Poc. West	2	8	1	5	3	7	12	11	10	4	6	9
Pocologan	4	10	1	3	2	9	11	12	7	5	6	8
Lepreau Harbour	2	3	6	7	5	10	12	11	9	4	1	8
Lepreau Basin	4	5	7	1	2	9	12	11	10	8	3	6

Table 25: Ranking (by month) of mean monthly PSP toxin levels ($\mu\text{g STX}/100 \text{ g tissue}$) for the 'hot' period from 1970-1986. Ranking is from lowest concentration (1) to highest concentration (12). Data used for ranking is shown in Appendix A (Table 33).

Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Ross Island Thoroughfare	2	4	7	5	6	1	11	10	12	9	3	8
Ingalls Head	6	7	4	5	8	9	11	12	10	1	1	1
Duck Cove	1	2	4	3	5	7	12	11	9	10	8	6
Deep Cove		7	6	1	2	8	9	4	5	3		
Harbour De Lute	12	1	1	1	1	9	10	11	1	1	1	1
Northern Harbour	5	3	2	6	7	9	10	12	11	8	1	4
Stuart Town	3	9	4	6	5	7	10	12	11	8	1	2
Bar Road	5	1	1	7	10	11	12	8	9	6	1	1
Letete Passage	7	1	2	4	3	5	11	12	10	8	6	9
Simmons Cove	7	6	9	1	8	5	10	11	12	4	2	3
Crow Harbour	1	4	2	7	6	8	11	12	10	9	5	3
Red Head Harbour	2	3	6	5	4	10	12	11	9	8	7	1
McLean Cove, Poc. West	2	8	1	5	3	7	12	11	10	4	6	9
Pocologan		4								2	1	3
Lepreau Harbour	4	1	6	7	5	8	12	11	10	3	2	9
Lepreau Basin	4	7	6	2	1	9	12	11	10	8	3	5

Table 26: Ranking (by month) of mean monthly PSP toxin levels ($\mu\text{g STX}/100 \text{ g tissue}$) for the ‘cold’ period from 1948-1956. Ranking is from lowest concentration (1) to highest concentration (12). Data used for ranking is shown in Appendix A (Table 34).

Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Ross Island Thoroughfare					1	2	3	4	5			
Ingalls Head												1
Northern Harbour	1	1	1	1	6	9	11	12	10	7	1	8
Duck Cove					1	1	3	4				
Stuart Town					1	1	1	4	5			
Crow Harbour	2								1			
Red Head Harbour	1		2	5	3	4						
Pocologan	1	9	10	8	11	6	12	7	4	2	5	3
Lepreau Harbour	3	10	12	11	7	8	9	4	5	1	6	1
Lepreau Basin	4	9	6	10	8	7	11	5	12	2	3	1
Total	12	29	31	35	38	38	50	40	42	12	15	14

Table 27: Ranking (by month) of mean monthly PSP toxin levels ($\mu\text{g STX}/100 \text{ g tissue}$) for the ‘mixed’ period from 1993-2010. Ranking is from lowest concentration (1) to highest concentration (12). Data used for ranking is shown in Appendix A (Table 35).

Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Ross Island Thoroughfare	2	1	5	3	4	11	12	10	9	8	7	6
Ingalls Head	8	2	9	10	1	5	12	7	11	6	4	3
Duck Cove	2	5	1	6	3	11	12	10	9	8	7	4
Deep Cove	6	3	2	7	1	11	12	10	4	5	9	8
Harbour De Lute	10	1	1	1	4	11	12	8	6	9	4	7
Northern Harbour	3	6	1	8	9	11	12	10	7	4	5	2
Stuart Town	4	3	1	8	6	11	12	10	9	7	5	2
Bar Road	4	8	2	7	9	11	12	10	6	5	1	3
Letete Passage	5	2	1	6	4	11	12	10	8	7	9	3
Simmons Cove	8	1	3	5	9	11	12	10	6	7	2	4
Crow Harbour	9	4	3	7	6	10	12	11	8	1	2	5
Red Head Harbour	1	5	6	3	2	11	12	10	9	7	8	4
Pocologan	7	5	3	1						2	5	4
Lepreau Harbour	7	1	3	4	5	11	12	10	9	6	8	2
Lepreau Basin	5	2	3	1	8	11	12	10	9	6	7	4

Table 28: Ranking (by month) of mean monthly PSP toxin levels ($\mu\text{g STX}/100 \text{ g tissue}$) for the ‘cold’ years during the ‘mixed’ period from 1993-2010. Ranking is from lowest concentration (1) to highest concentration (12). Data used for ranking is shown in Appendix A (Table 36).

Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Ross Island Thoroughfare	4	3	1	2	5	9	11	8	12	10	7	6
Ingalls Head	8	1	11	10	1	1	6	5	12	9	7	1
Duck Cove	1	1	1	1	7	8	11	9	12	10	1	1
Deep Cove	1	1	1	1	1	11	12	1	10	1	1	1
Harbour De Lute					1	1	8	1	1	1	1	1
Northern Harbour	8	1	1	1	10	11	12	9	7	1	1	1
Stuart Town	1	1	1	9	8	7	12	11	10	6	1	1
Bar Road	1	1	1	1	11	12	10	1	1	1	1	1
Letete Passage	9	3	2	6	5	10	12	11	8	4	7	1
Simmons Cove	9	6	3	5	8	11	10	12	2	4	7	1
Crow Harbour	9	3	4	7	8	11	12	10	6	1	2	5
Red Head Harbour	7	3	4	6	8	11	12	10	9	5	2	1
Pocologan	5	2		1						4	6	2
Lepreau Harbour	8	2	6	4	7	11	12	9	10	5	3	1
Lepreau Basin	4	3	8	6	7	11	12	10	9	5	2	1

Table 29: Ranking (by month) of mean monthly PSP toxin levels ($\mu\text{g STX}/100 \text{ g tissue}$) for the ‘hot’ years during the ‘mixed’ period from 1993-2010. Ranking is from lowest concentration (1) to highest concentration (12). Data used for ranking is shown in Appendix A (Table 37).

Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Ross Island Thoroughfare	2	1	5	3	4	11	12	10	9	7	8	6
Ingalls Head	7	4	8	11	3	6	12	10	9	5	2	1
Duck Cove	2	5	1	4	3	11	12	10	9	8	7	6
Deep Cove	10	4	2	6	1	11	12	9	3	5	8	7
Harbour De Lute	8	1	1	1	5	11	12	9	7	10	4	6
Northern Harbour	3	8	1	9	7	11	12	10	6	5	4	2
Stuart Town	6	5	1	7	4	11	12	10	9	8	3	2
Bar Road	4	9	2	6	8	11	12	10	7	5	1	3
Letete Passage	3	2	1	5	4	11	12	10	9	7	8	6
Simmons Cove	5	2	1	5	4	11	12	10	7	8	3	6
Crow Harbour	6	5		4	2	8	10	9	7	1		3
Red Head Harbour	1	8	6	3	2	11	12	10	9	5	7	4
Pocologan	5	6	1							1	4	3
Lepreau Harbour	5	6	3	2	7	11	12	10	9	4	8	1
Lepreau Basin	5	2	3	1	8	11	12	10	9	7	6	4

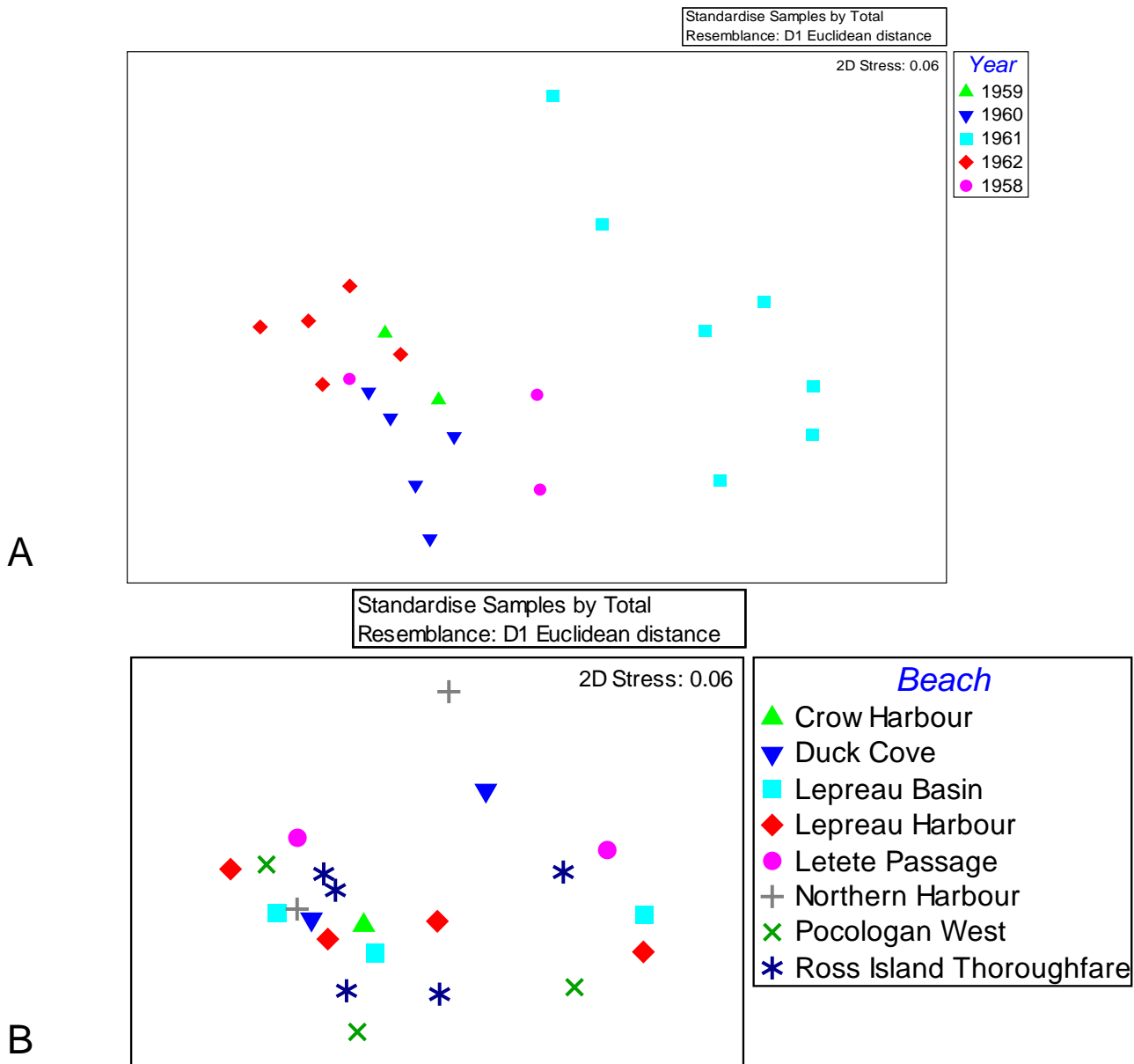


Fig. 33: MDS plot comparing weekly mean PSP values ($\mu\text{g STX}/100 \text{ g tissue}$) of different sites in different years. This represents an early period (1958-1962) and shows (A) the grouping of certain years and (B) the similarity of all sites to each other, regardless of week.

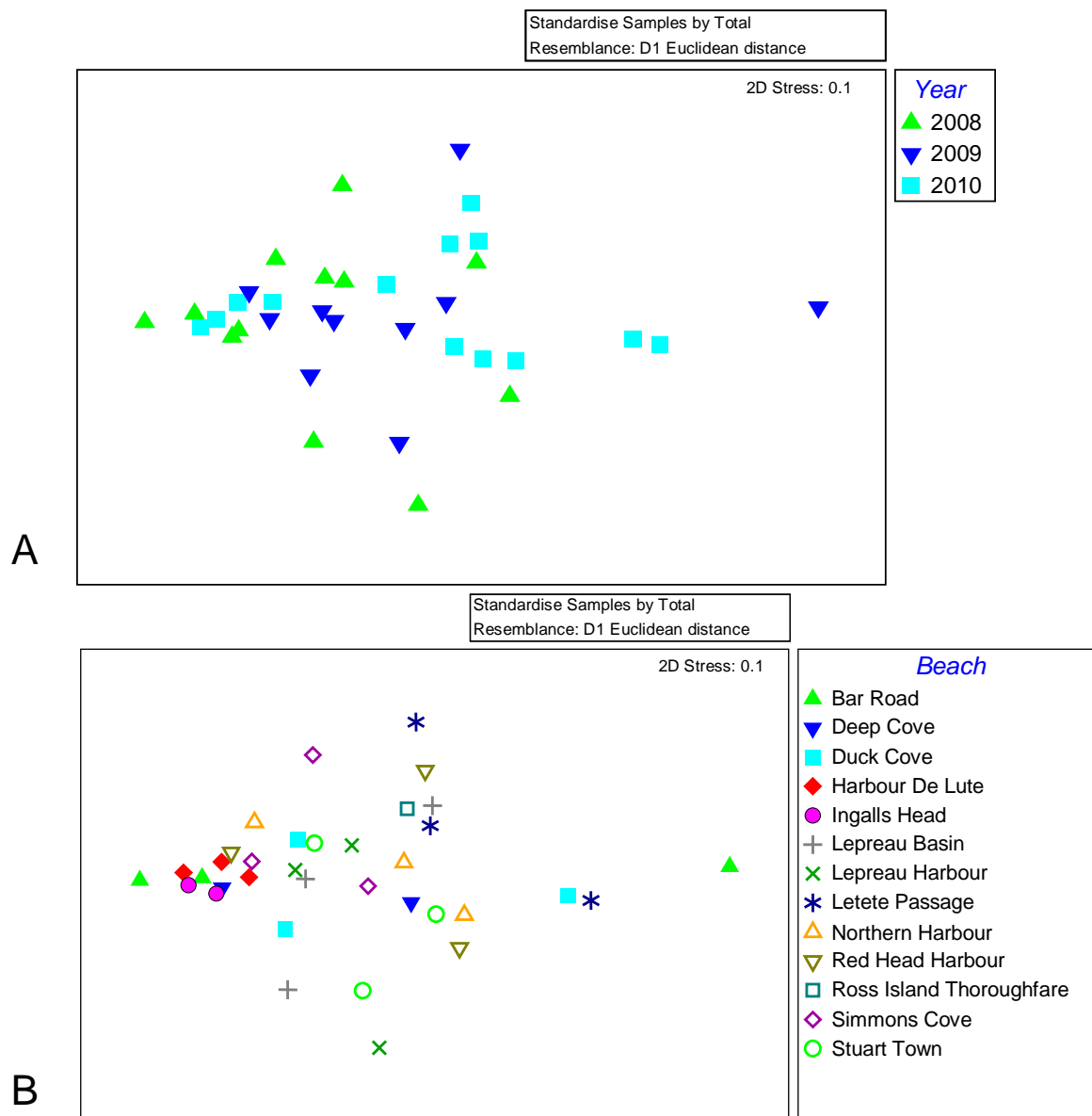


Fig. 34: MDS plot of mean PSP values ($\mu\text{g STX}/100 \text{ g tissue}$) during a late time period (2008-2010). **(A)** shows comparison by year factor and **(B)** compares by site.

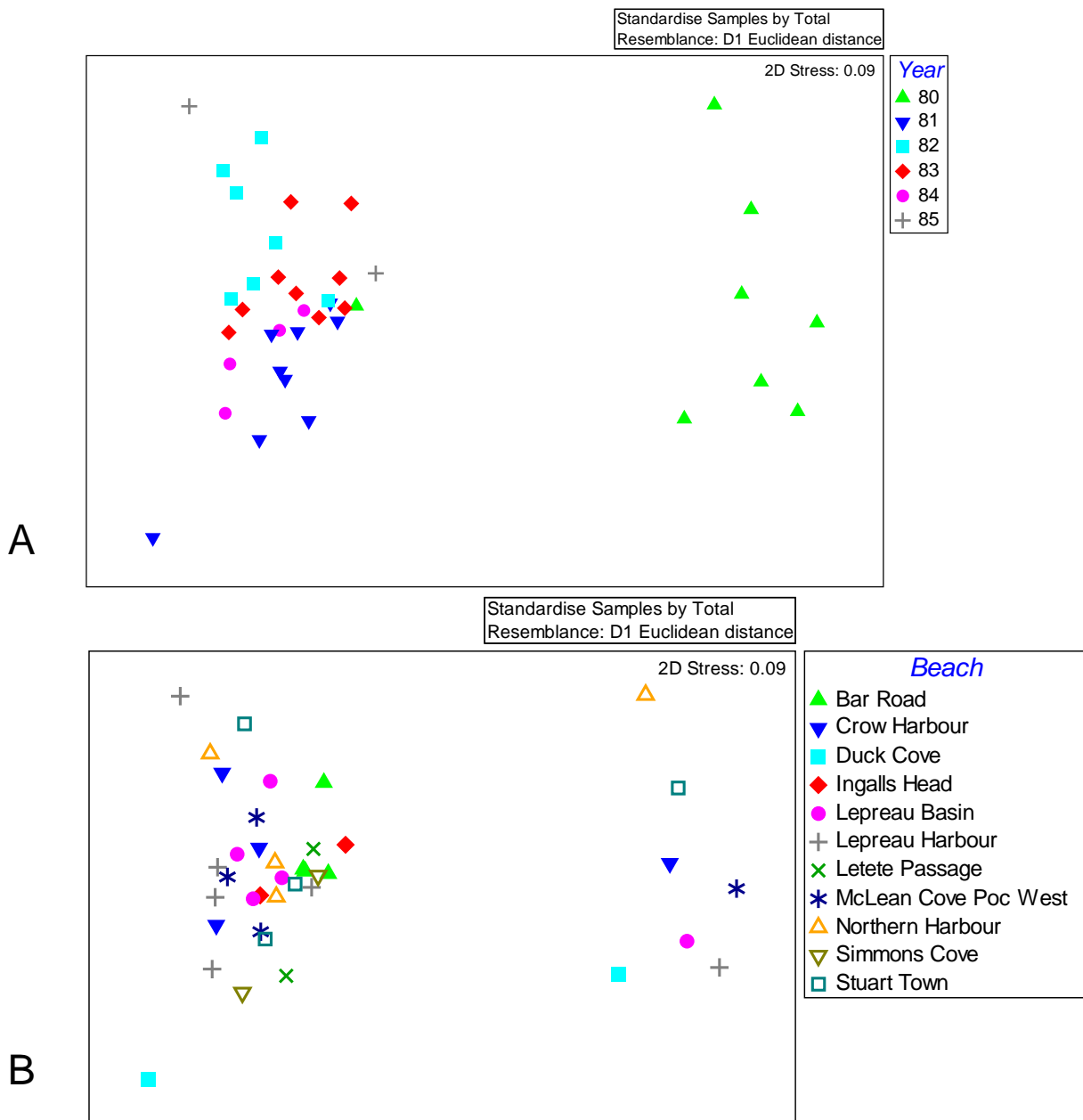


Fig. 35: MDS plot of mean PSP values ($\mu\text{g STX}/100 \text{ g tissue}$) during 'hot' years 1980-1985 comparing weeks by **(A)** year, and **(B)** site

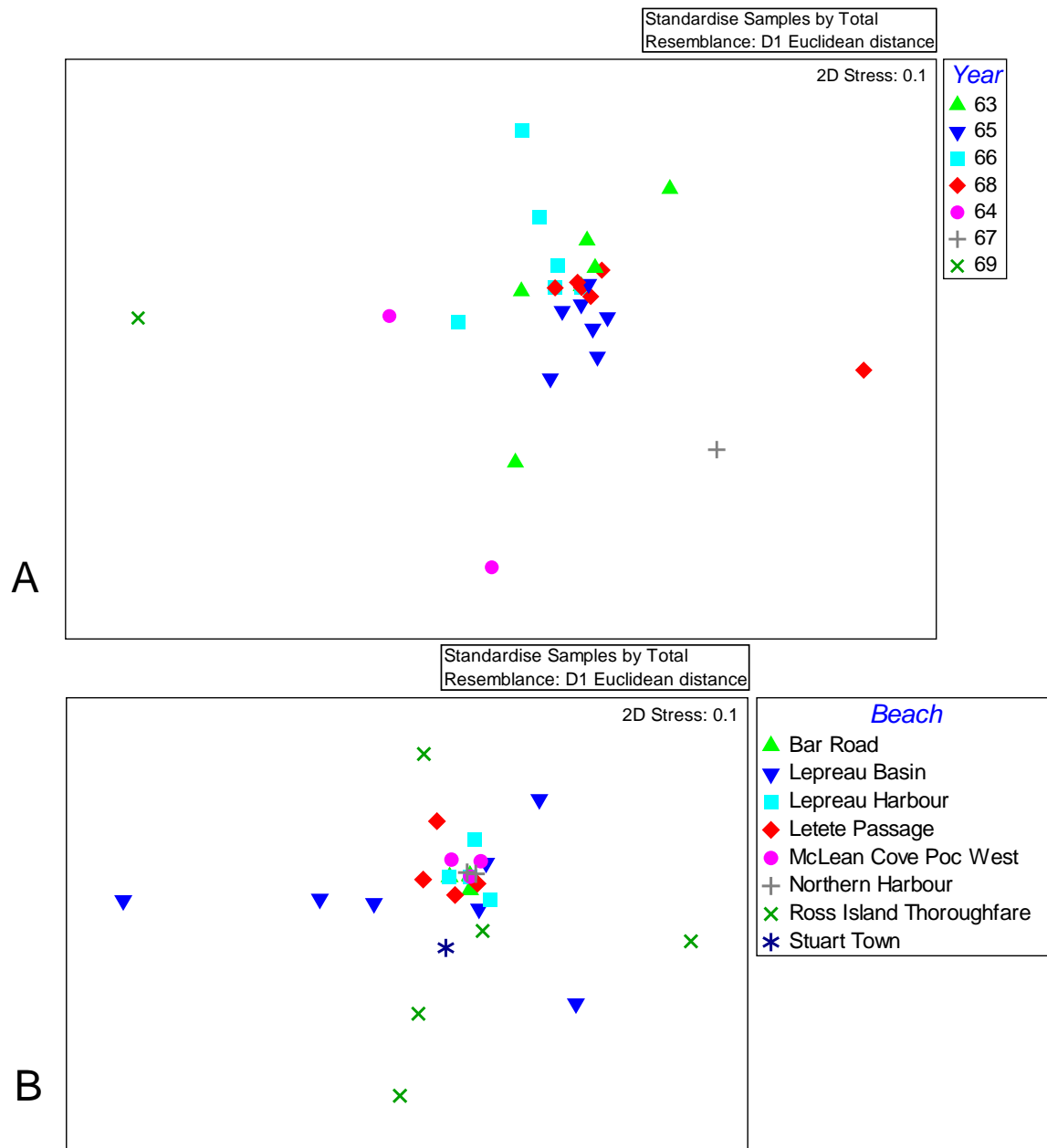


Fig. 36: MDS plot of 'cold' years 1963-1969 of **(A)** comparison of weeks between years, and **(B)** comparison of weeks between sites.

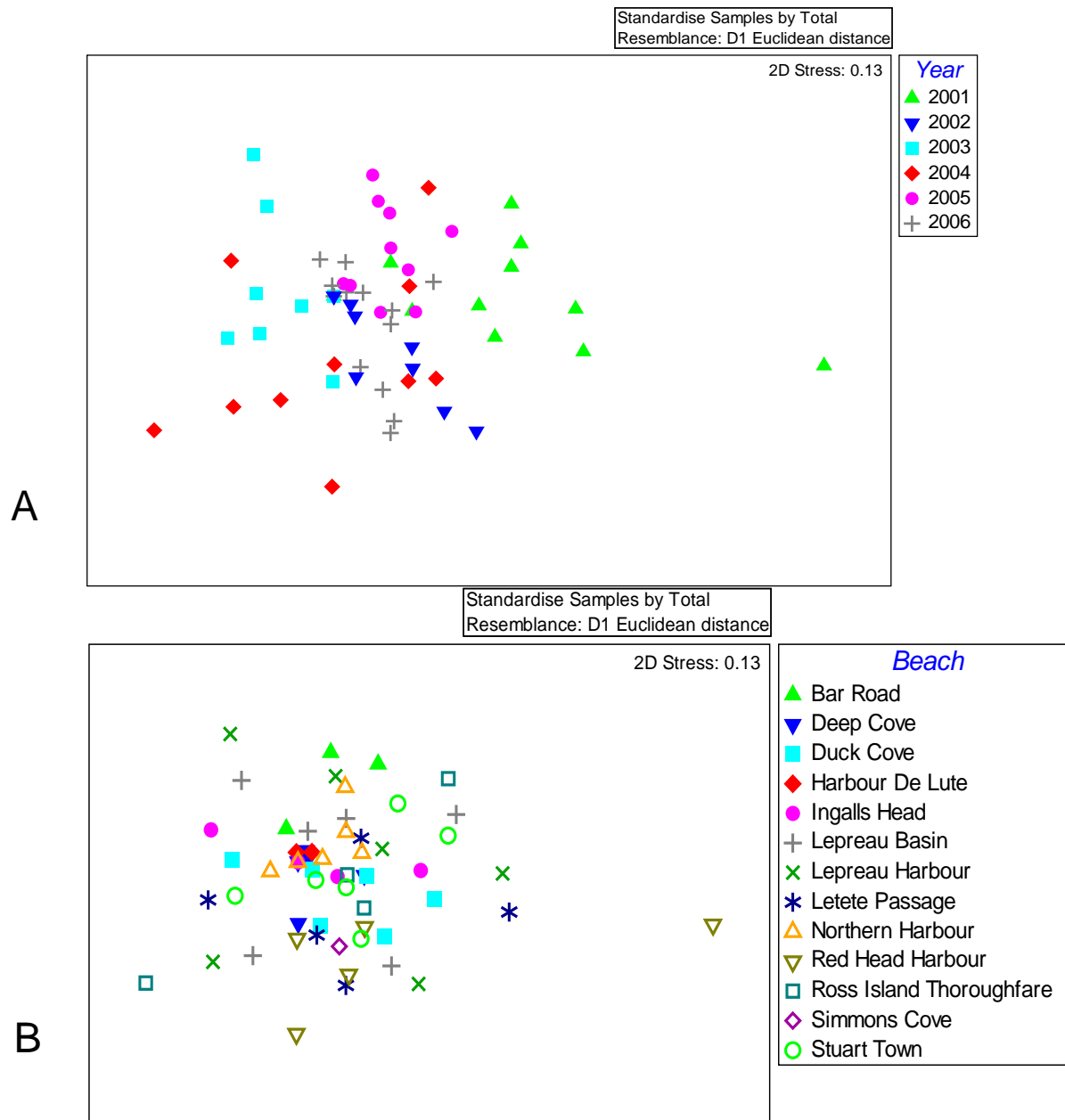


Fig. 37: MDS plot of mean PSP values ($\mu\text{g STX}/100 \text{ g tissue}$) during ‘mixed’ years from 2001-2006 comparing weeks by (A) year, and (B) site.

APPENDIX A

Table 30: Mean monthly PSP toxin concentration ($\mu\text{g STX}/100 \text{ g tissue}$) for the entire dataset from 1943-2010.

Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Ross Island Thoroughfare	59.47	56.24	61.81	60.31	62.09	87.98	255.55	154.80	153.89	80.44	64.21	79.94
Ingalls Head	31.17	29.84	31.29	32.18	29.91	31.14	44.81	35.51	34.88	30.70	30.10	29.60
Duck Cove	42.44	44.64	57.89	47.80	41.94	56.55	126.62	73.01	66.77	58.46	53.95	45.31
Deep Cove	31.53	33.40	31.63	31.02	30.62	39.81	57.55	35.96	32.58	31.59	32.00	32.50
Harbour De Lute	30.92	29.00	29.00	29.00	29.38	33.64	34.80	31.21	30.04	30.15	30.74	29.50
Northern Harbour	32.59	31.52	29.87	33.28	34.05	49.60	77.67	48.76	38.49	32.87	30.94	31.08
Stuart Town	38.71	45.35	43.11	51.42	44.19	56.93	116.21	119.47	75.96	45.56	34.56	35.77
Bar Road	29.75	30.62	29.23	30.36	34.04	45.48	106.67	33.79	31.32	30.38	29.92	29.56
Letete Passage	55.34	58.88	56.41	57.69	55.87	79.18	182.91	129.03	83.11	60.18	62.38	67.57
Simmons Cove	90.03	109.59	101.85	82.00	106.93	121.14	228.22	163.40	129.83	87.45	83.51	86.66
Crow Harbour	150.48	187.98	172.83	202.13	194.44	230.47	962.23	699.89	479.35	198.12	185.77	172.98
Red Head Harbour	50.79	51.48	55.88	55.40	51.57	131.53	395.05	144.06	69.89	59.69	58.18	50.35
McLean Cove, Poc. W.	59.38	81.06	60.94	79.20	75.09	88.23	315.97	226.79	137.73	69.67	71.65	62.28
Pocologan	39.05	60.81	35.61	39.82	40.47	52.36	105.48	120.74	56.61	42.86	45.43	46.64
Lepreau Harbour	38.12	40.10	42.58	42.49	41.43	59.88	161.22	76.22	60.27	37.84	38.20	40.40
Lepreau Basin	75.95	85.36	87.24	72.93	71.77	123.84	379.03	231.09	139.95	84.44	71.13	74.94

Table 31: Mean monthly PSP toxin concentration ($\mu\text{g STX}/100 \text{ g tissue}$) for the 'cold' years from 1943-2010.

Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Ross Island Thoroughfare	53.04	50.34	44.62	47.84	50.89	58.18	122.82	85.37	88.69	60.85	50.22	50.51
Ingalls Head	30.14	29.00	30.53	30.23	29.18	29.26	34.34	30.71	34.63	29.66	29.74	29.00
Duck Cove	40.41	37.11	33.33	40.67	34.71	43.27	78.08	47.18	48.17	39.08	44.93	38.21
Deep Cove	30.06	29.00	30.76	29.67	29.71	31.03	47.56	33.88	32.00	30.18	30.33	31.75
Harbour De Lute	29.00	29.00	29.00	29.00	29.00	29.21	29.24	29.41	29.59	29.00	31.15	29.00
Northern Harbour	31.03	29.11	29.00	29.70	30.86	35.16	54.39	34.90	30.62	29.35	29.57	30.43
Stuart Town	34.74	32.00	35.43	38.40	37.65	37.78	62.12	41.97	40.73	35.96	33.85	34.64
Bar Road	29.21	29.40	29.00	29.00	31.48	36.12	45.65	29.99	29.13	29.27	29.79	29.29
Letete Passage	44.53	38.79	42.11	40.41	37.01	44.26	84.67	53.90	44.98	41.32	39.92	42.08
Simmons Cove	70.47	58.17	63.07	60.19	63.76	76.13	147.31	100.43	66.37	65.48	60.67	50.00
Crow Harbour	131.12	139.80	143.15	158.96	128.54	173.47	413.18	208.24	153.78	133.98	135.32	131.17
Red Head Harbour	47.42	38.95	44.63	50.43	47.29	79.28	135.85	81.67	48.81	50.32	40.63	36.85
McLean Cove, Poc. West	49.09	51.00	49.82	45.59	37.94	42.53	204.94	104.80	52.51	42.96	40.00	40.49
Pocologan	31.44	34.39	35.14	36.54	37.93	35.57	52.23	47.95	53.94	39.18	40.88	33.91
Lepreau Harbour	34.99	37.59	37.18	35.75	35.78	42.84	86.92	43.88	45.14	32.40	33.43	32.78
Lepreau Basin	61.95	71.14	63.80	65.22	61.48	72.29	137.90	74.71	90.36	61.30	55.86	50.33

Table 32: Mean monthly PSP toxin concentration ($\mu\text{g STX}/100 \text{ g tissue}$) during the 'hot' years from 1943-2010.

Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Ross Island Thoroughfare	64.22	61.62	75.96	71.56	72.50	113.94	386.82	228.23	214.33	96.37	73.20	96.95
Ingalls Head	32.06	30.62	32.00	34.04	31.17	33.35	58.83	40.91	35.19	31.84	30.56	30.31
Duck Cove	44.47	48.88	61.67	52.50	52.17	73.18	185.59	98.01	85.99	79.81	63.43	54.26
Deep Cove	39.33	43.23	35.25	33.73	32.07	52.83	75.46	38.84	33.57	33.43	34.73	34.50
Harbour De Lute	35.25	29.00	29.00	29.00	30.27	39.76	41.22	33.34	30.96	32.82	30.00	30.38
Northern Harbour	35.71	34.35	31.40	37.88	39.31	68.15	112.71	65.61	48.49	38.30	32.88	32.64
Stuart Town	48.45	67.29	58.05	61.97	51.99	73.21	170.87	196.98	111.57	58.90	35.28	38.35
Bar Road	31.07	32.22	29.61	32.06	37.67	55.24	157.67	37.24	33.68	31.87	30.09	30.11
Letete Passage	79.39	73.68	76.00	76.93	77.46	115.95	283.07	204.90	132.01	85.72	81.98	111.59
Simmons Cove	112.20	134.28	134.17	98.96	137.65	144.75	284.85	198.95	181.32	112.28	97.62	108.32
Crow Harbour	168.40	221.21	194.04	227.64	231.70	260.14	1197.54	958.01	639.96	238.84	226.92	207.59
Red Head Harbour	55.07	73.42	71.14	60.93	56.66	183.77	625.44	193.98	86.34	68.24	71.52	57.67
McLean Cove, Poc. West	77.79	111.12	70.72	99.19	93.97	102.70	388.64	330.70	193.69	95.29	101.49	113.13
Pocologan	49.83	107.54	37.25	46.38	45.20	85.93	194.22	216.93	61.15	51.85	54.10	67.65
Lepreau Harbour	44.22	44.36	50.20	51.38	48.88	79.07	246.37	112.32	75.19	46.18	44.19	54.19
Lepreau Basin	86.41	95.01	98.44	78.35	80.13	167.92	595.70	349.43	177.70	104.67	84.35	95.40

Table 33: Mean monthly PSP toxin concentration ($\mu\text{g STX}/100 \text{ g tissue}$) during the ‘cold’ period from 1948-1956.

Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Ross Island Thoroughfare					46.00	47.50	49.00	95.60	887.00			
Ingalls Head												29.00
Northern Harbour	29.00	29.00	29.00	29.00	29.27	29.68	31.31	37.55	31.00	29.35	29.00	29.38
Duck Cove					29.00	29.00	30.00	32.00				
Stuart Town					29.00	29.00	29.00	30.60	35.00			
Crow Harbour	54.00								29.00			
Red Head Harbour	54.33		88.00	125.50	93.00	97.50						
Pocologan	29.15	33.92	36.71	33.65	37.53	31.15	46.57	32.82	30.71	29.38	31.00	29.43
Lepreau Harbour	29.38	32.93	33.67	33.30	31.06	31.84	32.13	29.41	29.89	29.29	29.96	29.29
Lepreau Basin	44.54	59.77	51.08	63.83	55.10	53.06	66.15	47.06	66.82	36.31	41.04	34.59

Table 34: Mean monthly PSP toxin concentration ($\mu\text{g STX}/100 \text{ g tissue}$) during the 'hot' period from 1970-1986.

Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Ross Island Thoroughfare	69.77	74.09	88.71	79.74	82.32	68.04	307.20	280.97	333.58	117.15	73.43	114.20
Ingalls Head	29.71	30.25	29.38	29.42	31.88	33.50	57.09	60.50	38.27	29.00	29.00	29.00
Duck Cove	49.83	50.79	63.43	57.36	67.76	72.92	183.53	143.52	114.65	129.33	91.40	71.20
Deep Cove		56.17	48.50	29.00	34.88	63.73	76.00	39.93	40.57	38.80		
Harbour De Lute	43.00	29.00	29.00	29.00	29.00	30.71	33.00	33.61	29.00	29.00	29.00	29.00
Northern Harbour	37.80	34.11	32.06	40.05	44.48	50.77	60.15	84.88	64.45	46.39	32.05	34.20
Stuart Town	63.80	91.75	67.43	79.23	70.38	83.13	158.64	359.71	178.30	85.60	37.06	44.13
Bar Road	30.00	29.00	29.00	30.81	41.56	46.11	62.36	30.88	31.18	30.76	29.00	29.00
Letete Passage	103.50	80.93	88.44	92.96	89.47	95.93	248.94	352.65	207.59	106.08	100.47	155.20
Simmons Cove	193.00	189.63	215.00	141.67	211.81	183.67	265.29	369.00	381.67	183.04	150.44	180.40
Crow Harbour	163.88	224.11	194.00	242.23	239.02	245.23	913.93	1025.10	677.09	253.84	231.92	221.30
Red Head Harbour	50.79	51.48	55.88	55.40	51.57	131.53	395.05	144.06	69.89	59.69	58.18	50.35
McLean Cove, Poc. West	77.79	111.12	70.72	99.19	93.97	102.70	388.64	330.70	193.69	95.29	101.49	113.10
Pocologan		199.80								120.00	89.80	124.00
Lepreau Harbour	50.56	45.55	56.43	61.08	53.78	61.76	204.79	122.32	87.07	50.08	46.70	74.35
Lepreau Basin	92.95	104.04	103.90	84.85	80.11	110.05	628.64	339.14	213.57	107.38	91.13	103.10

Table 35: Mean monthly PSP toxin concentration ($\mu\text{g STX}/100 \text{ g tissue}$) for the 'mixed' period from 1993-2010.

Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Ross Island Thoroughfare	45.55	44.93	52.00	45.72	50.97	131.10	241.20	117.20	86.13	66.39	61.46	60.34
Ingalls Head	33.00	30.22	34.13	36.26	30.08	31.65	46.64	32.51	36.75	32.45	31.05	30.24
Duck Cove	31.60	33.33	29.00	34.31	32.02	56.58	114.80	51.80	39.28	38.12	34.61	33.08
Deep Cove	31.82	30.83	30.10	32.94	29.63	42.93	58.93	35.24	30.94	31.40	33.50	33.13
Harbour De Lute	32.67	29.00	29.00	29.00	30.22	39.70	41.00	31.78	30.71	32.23	30.22	31.20
Northern Harbour	32.43	33.00	29.85	34.96	35.71	69.88	113.10	42.59	33.46	32.77	32.83	30.75
Stuart Town	31.67	31.43	30.27	34.70	32.52	52.88	115.60	47.23	35.45	34.47	32.50	31.38
Bar Road	30.38	33.63	29.85	31.75	34.19	53.64	187.20	35.33	31.63	31.43	29.42	30.24
Letete Passage	42.86	37.92	36.86	44.05	40.56	106.40	204.80	73.11	46.47	45.54	49.88	40.55
Simmons Cove	67.08	44.45	45.92	53.50	68.64	114.10	270.50	87.03	53.97	58.46	44.76	46.77
Crow Harbour	168.90	119.80	118.50	136.90	134.60	284.80	1427.00	318.80	164.80	87.40	96.00	127.10
Red Head Harbour	50.45	53.93	55.97	51.51	51.48	134.50	398.70	132.00	66.55	57.31	58.90	51.58
Pocologan	51.62	50.00	40.00	29.00						38.80	50.00	44.00
Lepreau Harbour	40.14	35.29	39.29	39.36	40.07	86.88	209.10	62.34	53.88	40.09	43.10	38.65
Lepreau Basin	46.25	42.90	44.93	41.04	54.61	131.10	235.50	85.91	57.22	48.70	49.16	46.00

Table 36: Mean monthly PSP toxin concentration ($\mu\text{g STX}/100 \text{ g tissue}$) during the ‘cold’ years from 1993-2010.

Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Ross Island Thoroughfare	43.07	42.50	33.83	39.41	43.79	65.67	74.86	64.87	88.63	67.89	51.23	50.80
Ingalls Head	31.67	29.00	34.20	32.38	29.00	29.00	31.03	29.71	41.05	32.29	31.43	29.00
Duck Cove	29.00	29.00	29.00	29.00	30.19	34.88	38.37	36.88	39.46	37.31	29.00	29.0
Deep Cove	29.00	29.00	29.00	29.00	29.00	30.17	30.60	29.00	29.63	29.00	29.00	29.00
Harbour De Lute					29.00	29.00	30.00	29.00	29.00	29.00	29.00	29.00
Northern Harbour	32.25	29.00	29.00	29.00	34.59	36.91	37.21	33.88	30.37	29.00	29.00	29.00
Stuart Town	29.00	29.00	29.00	31.00	30.72	30.50	38.47	35.44	32.59	30.00	29.00	29.00
Bar Road	29.00	29.00	29.00	29.00	34.06	38.94	31.11	29.00	29.00	29.00	29.00	29.00
Letete Passage	39.75	33.57	32.50	36.90	35.50	43.05	53.17	51.44	37.81	35.37	37.50	29.00
Simmons Cove	108.00	83.00	71.50	77.25	102.22	115.43	109.53	118.14	56.91	71.78	89.50	29.00
Crow Harbour	146.40	114.75	118.50	138.75	139.75	179.60	327.23	177.55	131.60	69.50	96.00	131.00
Red Head Harbour	46.13	39.31	41.80	45.50	46.45	78.00	137.53	76.36	48.03	42.04	35.87	34.18
Pocologan	39.00	32.67		29.00						38.00	40.67	32.67
Lepreau Harbour	35.50	30.00	32.71	32.10	34.97	56.38	80.76	43.15	43.37	32.13	30.86	29.00
Lepreau Basin	34.00	32.91	37.25	35.78	37.15	72.72	91.00	49.16	41.90	34.24	31.92	30.57

Table 37: Mean monthly PSP toxin concentration ($\mu\text{g STX}/100 \text{ g tissue}$) during the 'hot' years from 1993-2010.

Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Ross Island Thoroughfare	47.37	46.35	62.90	53.88	56.56	182.79	407.57	155.51	84.16	65.50	67.50	65.37
Ingalls Head	33.89	31.20	34.10	39.09	30.91	33.32	59.29	34.38	34.25	32.50	30.87	30.75
Duck Cove	32.25	35.50	29.00	35.27	33.55	72.98	178.55	61.96	39.10	38.48	36.59	36.00
Deep Cove	39.33	32.14	30.83	34.46	30.08	50.05	75.40	38.50	31.82	32.36	34.73	34.50
Harbour De Lute	32.67	29.00	29.00	29.00	31.36	43.84	45.83	33.17	31.79	33.67	30.38	31.75
Northern Harbour	32.67	37.00	30.83	37.94	36.61	92.51	180.19	49.07	35.97	34.79	34.50	32.11
Stuart Town	35.67	34.67	31.80	36.67	33.97	68.41	182.25	56.00	37.70	36.86	33.94	33.22
Bar Road	32.14	38.25	31.20	33.40	34.30	65.07	310.81	39.80	34.11	32.82	29.69	31.33
Letete Passage	47.00	43.00	42.67	50.00	48.15	171.47	352.11	90.02	56.22	54.32	56.06	50.17
Simmons Cove	41.50	35.89	33.13	45.58	56.04	113.85	351.00	80.42	52.82	53.85	38.80	48.25
Crow Harbour	225.00	140.00		135.00	121.00	460.00	2220.70	491.44	231.20	99.33		122.00
Red Head Harbour	55.07	73.42	71.14	57.28	56.66	183.77	633.78	177.90	82.50	70.61	73.29	61.15
Pocologan	57.22	63.00	40.00							40.00	55.60	55.33
Lepreau Harbour	44.36	44.80	43.90	43.39	45.03	111.96	312.26	77.07	62.18	44.19	47.00	41.87
Lepreau Basin	51.04	48.68	50.06	45.69	69.76	171.79	356.98	112.64	70.05	57.37	55.84	50.91

Table 38: Correlation matrix using mean weekly PSP levels ($\mu\text{g STX}/100 \text{ g tissue}$) as a metric.

		Bar Road	Crow Harbour	Deep Cove	Duck Cove	Harbour De Lute	Ingalls Head	Lepreau Basin	Lepreau Harbour
Bar Road	Pearson Correlation	1.000							
	Sig (2-tailed)								
	N	1172							
Crow Harbour	Pearson Correlation	0.301	1.000						
	Sig (2-tailed)	0.000							
	N	425	962						
Deep Cove	Pearson Correlation	0.259	0.675	1.000					
	Sig (2-tailed)	0.000	0.000						
	N	483	142	581					
Duck Cove	Pearson Correlation	0.170	0.625	0.844	1.000				
	Sig (2-tailed)	0.000	0.000	0.000					
	N	728	428	493	1035				
Harbour De Lute	Pearson Correlation	0.223	0.485	0.661	0.533	1.000			
	Sig (2-tailed)	0.000	0.000	0.000	0.000				
	N	422	157	404	443	499			
Ingalls Head	Pearson Correlation	0.103	0.364	0.396	0.416	0.505	1.000		
	Sig (2-tailed)	0.019	0.000	0.000	0.000	0.000			
	N	513	158	427	447	331	655		
Lepreau Basin	Pearson Correlation	0.316	0.635	0.576	0.494	0.451	0.274	1.000	
	Sig (2-tailed)	0.000	0.000	0.000	0.000	0.000	0.000		
	N	884	890	422	815	360	484	2055	
Lepreau Harbour	Pearson Correlation	0.145	0.708	0.492	0.491	0.361	0.309	0.670	1.000
	Sig (2-tailed)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	
	N	961	682	483	828	409	523	1569	1868

Table 38: Continued - Correlation matrix using mean weekly PSP levels ($\mu\text{g STX}/100\text{ g tissue}$) as a metric.

		Bar Road	Crow Harbour	Deep Cove	Duck Cove	Harbour De Lute	Ingalls Head	Lepreau Basin	Lepreau Harbour	Letete Passage
Letete Passage	Pearson Correlation	0.160	0.667	0.708	0.710	0.426	0.258	0.480	0.566	1.000
	Sig (2-tailed)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	
	N	869	566	426	685	352	463	1070	1081	1350
McLean Cove	Pearson Correlation	0.098	0.808	0.718	0.481	0.317	0.541	0.748	0.641	0.740
	Sig (2-tailed)	0.043	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000
	N	430	390	83	300	112	100	507	571	445
Northern Harbour	Pearson Correlation	0.596	0.676	0.653	0.483	0.510	0.330	0.328	0.424	0.468
	Sig (2-tailed)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	N	885	476	471	802	405	499	1078	1160	905
Pocologan	Pearson Correlation	0.325	0.884	0.493	0.731	-0.183	-0.160	0.802	0.781	0.654
	Sig (2-tailed)	0.075	0.000	0.148	0.000	0.590	0.554	0.000	0.000	0.000
	N	4	82	101	88	11	16	438	463	140
Red Head Harbour	Pearson Correlation	0.098	0.639	0.690	0.709	0.721	0.261	0.733	0.695	0.624
	Sig (2-tailed)	0.054	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	N	384	122	297	340	209	338	523	460	370
Ross Island Thoroughfare	Pearson Correlation	0.154	0.529	0.654	0.761	0.503	0.332	0.496	0.418	0.735
	Sig (2-tailed)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	N	819	631	408	756	329	516	1244	1099	959
Simmons Cove	Pearson Correlation	0.104	0.624	0.616	0.773	0.398	0.329	0.589	0.502	0.903
	Sig (2-tailed)	0.018	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	N	517	261	319	433	289	354	538	5584	560
Stuart Town	Pearson Correlation	0.137	0.675	0.702	0.616	0.614	0.372	0.425	0.454	0.821
	Sig (2-tailed)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	N	796	449	473	775	404	501	869	889	781

Table 38: Continued - Correlation matrix using mean weekly PSP levels ($\mu\text{g STX}/100 \text{ g tissue}$) as a metric.

		McLean Cove	Northern Harbour	Pocologan	Red Head Harbour	Ross Island Thorough-fare	Simmons Cove	Stuart Town
McLean Cove	Pearson Correlation	1.000						
	Sig (2-tailed)							
	N	632						
Northern Harbour	Pearson Correlation	0.67	1.000					
	Sig (2-tailed)	0.000						
	N	394	1470					
Pocologan	Pearson Correlation	0.242	0.514	1.000				
	Sig (2-tailed)	0.758	0.000					
	N	4	256	532				
Red Head Harbour	Pearson Correlation		0.407	0.501	1.000			
	Sig (2-tailed)		0.000	0.000				
	N	0	398	46	609			
Ross Island Thorough-fare	Pearson Correlation	0.452	0.513	0.777	0.659	1		
	Sig (2-tailed)	0.000	0.000	0.000	0.000			
	N	399	922	197	442	1613		
Simmons Cove	Pearson Correlation	0.654	0.44	0.81	0.584	0.707	1	
	Sig (2-tailed)	0.000	0.000	0.000	0.000	0.000		
	N	244	494	23	270	454	696	
Stuart Town	Pearson Correlation	0.745	0.588	0.813	0.669	0.709	0.802	1
	Sig (2-tailed)	0.000	0.000	0.000	0.000	0.000	0.000	
	N	327	1036	85	388	788	489	1099

