NEARSHORE FISH POPULATIONS WITHIN ST. PAUL'S INLET, AN ESTUARINE SYSTEM IN WESTERN NEWFOUNDLAND©

by

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ABSTRACT

St. Paul's Inlets, a brackish water fjord-type estuary on Newfoundland' west coast, was sampled for fish populations during the month of August 2010. A total of 1451 fish were caught comprising 15 species and representing 9 families. Sampling was carried out using a 10-meter beach seine, minnow traps and multi-paneled gill nets. The objectives of this study had three components: document the nearshore fish fauna within St. Paul's Inlet and compare with other data sets from Newfoundland and Labrador, assess variability in species composition associated with different habitats at different sites and determine if variation in species composition was related to patterns in salinity concentrations within the inlet. A total of 7 sites were sampled. Along the Inlet and the outer bay, sites were chosen to best represent a potential range in salinities, as well as for ease of accessibility. At each site salinity, dissolved oxygen and water temperature measurements were taken. Site locations were plotted with GPS coordinates. Cluster analysis performed on species presence/absence data indicated 76% similarity between sites based on the Jaccard similarity coefficient. St. Paul's was then compared with Bonne Bay sites, a more marine fjord. This produced a dendrogram showing a distinct marine cluster comprised of Bonne Bay marine sites and a distinct estuarine cluster comprising the St. Paul's sites and the Bonne Bay river sites (Deer Arm barachois and Lomond River delta. The contribution of the Inlet to the overall biological productivity of the larger west coast marine ecosystem is under evaluation, as part of Memorial University's CURRA (Community-University Research for Recovery Alliance).

TABLE OF CONTENTS

Acknowledgements…………………………………………………………….……….i

Abstract……………………………………………………………………………ii

Table of Contents……………………………………………………………….....iii

List of Tables……………………………………………………………………...v

List of Figures……………………………………………………………………....vi

INTRODUCTION and LITERATURE REVIEW……………………………………..1

Coastal Waters………………………………………………………………1

The Estuary – a specific coastal environment………………………..…………5

Nearshore Fish Fauna of Newfoundland……………………………………......9

St. Paul's Inlet……………………………………………………………11

METHODS and MATERIALS……………………………………………….………15

Study Site……………………………………………………………………...15

Sampling Strategy……………………………………………………………..16

Sampling Sites……………………………………………………………...18

Methods of Fish Collection………………………………………………26

Statistical Analysis…………………………………………………………….28

RESULTS…………………………………………………………………………..31

Nearshore Fish Fauna within St. Paul's Inlet…………………………………….31

St. Paul's 2010 compared with 1979……………………………………………….35

St. Paul's Inlet Compared with Bonne Bay…………………………………...38

Species Variability Associated with Different Habitats…………………………38

Species Variability Related to Salinity Concentrations…………………………40

DISCUSSION……………………………………………………………………………42

St. Paul's Inlet…………………………………………………………………42

St. Paul's Inlet 2010 vs 1979……………………………………………………43

St. Paul's Inlet Compared with Bonne Bay……………………………………...44

LITERATURE CITED…………………………………………………………………..49

LIST OF TABLES

Table 1: Thirty-one species of fish caught from various sites in Bonne Bay, Newfoundland using gill nets, beach seines and bottom trawls between 2002 and 2008 (Currie et al., 2009)…………………………………………………….....10

Table 2: Site-species matrix showing all species captured, all sites sampled for all gear types used during August 2010 sampling of St. Paul's Inlet…………………….32

Table 3: Species richness and Shannon-Wiener diversity index at each sampling site for all gear types during August 2010 in St. Paul's Inlet……………………………33

Table 4: Catch per unit effort for each species using the 10 metre beach seine (number of fish caught/100m of shoreline) during August 2010 sampling in St. Paul's Inlet.33

Table 5: Catch per unit effort for each species using the minnow traps (number of fish caught/trap/hour) during August 2010 sampling in St. Paul's Inlet……………..34

Table 6: Species and common name for fish identified in St. Paul's Inlet comparing data from 1979 (Carter & MacGregor) and 2010……………………………………..37

Table 7: Benthic substrates and species richness for each sampling site in St. Paul's Inlet during August 2010 sampling. The benthic substrate type is in accordance with substrate types identified by Carter and MacGregor (1979)……………………..40

Table 8. Species richness, salinity, dissolved oxygen, and temperature at each sampling site during August 2010 sampling in St. Paul's Inlet and also Bonne Bay 2002-2008 (Currie et al., 2009). The salinity, dissolved oxygen and temperature readings is from data recorded during the Biology 3714 field course at the Bonne Bay Marine Station in June 2010. All values represent a mean at 1 m in depth followed by a range in brackets (when available). SP=St. Paul's sites where BB=Bonne Bay sites…………………………………………………………..41

LIST OF FIGURES

Figure 1: Location of Study – (A) Study sites within St. Paul's Inlet. 1=St. Paul's Bay, 2=Inlet Opening, 3A=Eastern Arm Peninsula, 3B=Eastern Arm Brook 1, 3C=Eastern Arm Brook 2, 4=Cliffy Point Cove, 5=Barachois, 6A=Alex Cove, 6B=Western Island, 7A=East Brook Cove, 7B=Bottom Brook and 7C=Between the Falls. (B) Location of St. Paul's Inlet in Newfoundland compared to Bonne Bay, Gilbert Bay and Trinity Bay, highlighting the location of Gros Morne National Park……………………………………………………………………….17

Figure 2: Cluster dendrogram and Jaccard's Coefficent matrix for 10 m beach seine data during August 2010 sampling in St. Paul's Inlet. ……………………………….36

Figure 3: Cluster dendrogram and Jaccard's Coefficient matrix for 10 m beach seine data comparing August 2010 St. Paul's data with Bonne Bay 2002-2008 (Currie et al. 2009). SP = St. Paul's sites and BB = Bonne Bay sites. 10 m beach seine were used in both studies……………………………………………………………….39

INTRODUCTION and LITERATURE REVIEW

Over the last several decades, management of the coastal marine resources surrounding the island of Newfoundland has been seen as being increasingly required as a response to continued declines in abundances of commercially fished species. The emphasis of this perspective is the importance of fisheries to the ecological, social and economic well-being of the communities which exist in these coastal regions. The Community-University Research for Recovery Alliance (CURRA) is a research program that focuses on that importance of fisheries to communities in Western Newfoundland. The CURRA derives support from researchers at MUN's St. John's and Grenfell campuses, as well as from numerous community groups and partners in western Newfoundland (http://www.curra.ca).

Coastal Waters

The term "coastal waters" describes the relatively shallow water areas adjacent to the coastlines of land masses and generally stretches 370 kilometres out from the shoreline (Thurman & Trujillo, 2010; Mann, 1982). These waters usually extend to the 200 metre depth contour which marks the beginning of the continental shelf (Mann, 1982). Coastal waters include the near-shore pelagic ocean as well as estuaries, lagoons and marginal seas (Thurman & Trujillo, 2010). Approximately 95% of the world's fisheries are found in these waters and 95% of the total biomass of the ocean is supported (Thurman & Trujillo, 2010). The coastal ocean represents approximately 7% of the world's marine waters (Wood's Hole Oceanographic Institution, 2010). Of this small percentage only a fraction is temperate coastal waters which are found between latitudes 45° and 50° north and south (Denny, 2008).

Globally, temperate coastal waters represent systems of high productivity and fish diversity (Suchanek, 1994). Temperate coastal waters are high in productivity because nutrient upwelling occurs each year. During the summer these waters have a shallow, mixed layer depleted of nutrients floating on cold, nutrient rich water divided by a thermocline (Denny, 2008). Autumn temperatures are cool enough to dissipate the thermocline and allow the deep, nutrient rich waters to be mixed up to the surface by winds and strong winter storms (Denny, 2008). There are specific zones along the continental edges where upwelling is pronounced usually in shallow regions with a shallow thermocline (Denny, 2008).

As described by Rao et al. (2009), there are potentially many locations along the coastal regions of Newfoundland where there is presence of areas important for the spawning of commercially important fish species. In addition these regions may contain rare or endangered species, unique ecosystems or marine features, areas of high biodiversity, areas of high species abundance, migration corridors, areas determined by the scientific community to be ecologically and biologically significant, and areas identified by local communities as requiring protection.

Coastal locations are of multi-faceted importance for fish populations of both migratory and non-migratory life histories. Migratory fish species use these locations as nursery grounds for breeding and rearing of early reproductive stages, and for feeding areas and stopover points along migrational routes (Blaber & Milton, 1990; Knox, 1986).

As well, populations of resident non-migratory fish species are supported (Currie et al., 2009). Coastal locations are particularly important to the commercial fisheries and have been recognized for demersal fish reproduction (Knox, 1986; Schneider et al., 1997). It has been documented that cod spawn in coastal areas as juveniles of age groups 0 and 1 tend to concentrate in these areas (Schneider et al., 1997). It is for these reasons that coastal regions such as estuaries are typically marked by increased fish abundance and diversity.

A critical attribute of such locations as nursery grounds is to act as refuges from extensive predation pressure (mainly from larger fish) which could lead to reduced juvenile mortality rates. Increased feeding opportunity has also been suggested (Mateo & Tobias, 2004). These feeding opportunities exist in these coastal waters because they often include high primary production systems such as estuaries with easily available food (Knox, 1986). According to Knox (1986) an estuarine system high in primary productivity is a function of six factors: 1. fresh water inflow, 2. nutrient trap effect, 3. tidal mixing, 4. tidal marsh nutrient modulation, 5. sediment trapping and 6. vascular plant “nutrient pump”.

Fresh water flowing into the system represents considerable input of nutrients and organic matter, both particulate and dissolved. Fresh water also plays a considerable role in the nutrient trap effect. Sediment characteristics, circulation and salinity patterns result in nutrient trapping in estuaries, causing nutrients to be recycled over and over. The high percentage of clay minerals, typical of estuarine systems, contains great adsorptive capacity and produces sediments with great quantities of associated nutrients, trace elements and other materials. The process of biodeposition adds to the nutrient where filter feeders remove suspended matter and exude feces which is incorporated in the sediments. The combination of mixing of water masses and different salinity regimes increases the tendency for nutrients to become trapped. The third factor leading to high productivity is tidal mixing, which is the effect of rising and falling tides, promoting the vertical mixing of nutrients from the bottom.

Tidal marsh nutrient modulation is the fourth factor which is the uptake of nutrients into the tidal marshes, mudflats and bottom sediments at times of high nutrient concentrations at the surface waters. At times of low nutrient concentrations there is a net release of nutrients from these sinks into the shallow waters. Sediment trapping is the fifth factor in which rivers deposit large quantities of mineral particulates and fine clay fractions derived from land erosion into the estuary producing nutrient rich tidal mud flats, low and high tidal marshes as well as terrestrial land. The last factor is the vascular plants as nutrient pumps in which plants such as eelgrasses and marsh plants intake nutrients from the sediments and lose them to the waters by death and decomposition, leaching from leaves, herbivory or direct excretion.

Secondary productivity in coastal locations is often high because of the high primary productivity, increased habitat complexity and hydrodynamics (Mateo and Tobias, 2004; Knox 1986). Secondary productivity represents the productivity of heterotrophic consumers such as fishes and crustaceans often measured in abundance or biomass (Knox, 1986). Habitat complexity is the presence of many different physical substratum of the seafloor and biogenic structures extending from it which serve as cover for many demersal fish species (Lindholm et al., 1999). This can lead to enhanced survivorship of juvenile fishes because these different habitat types provide more locations of refugia (Lindholm et al., 1999). Studies have shown that juvenile Atlantic cod prefer a cobble-gravel substratum because interstices between the cobble and gravel can provide protection from predators (Lindholm et al., 1999). Similar results have also been found for juvenile Atlantic cod and the use of sea grass beds for cover (Gotceitas et al., 1997). Hydrodynamics, or the fluid dynamics of liquid environments, can be important in determining juvenile fish survivorship. For benthic fish feeding on benthos, the flow of water may modify their behaviour as the disturbance due to this flow may alter behaviour and distribution of faunal prey within the sediments (Palmer, 1988). For example, benthic invertebrates suspended in the water column due to scouring currents and disturbance flows may be exposed to greater predation from fish (Palmer, 1988).

The estuary – a specific coastal environment

An estuary exists in some form where coastal marine waters meet the draining of inland fresh waters to form a brackish saline mixture. The most widely accepted definition of an estuary is that proposed by Pritchard (1967): “An estuary is a semi-enclosed coastal body of water which has a free connection with the open sea and within which sea water is measurably diluted with fresh water derived from land drainage”. The oceanographic properties of an estuary are the result of factors which influence the water column such as solar insolation, wind stress, freshwater runoff and tidal currents (Etherington et al., 2004).

The most important characteristic of an estuarine system is the salinity and the associated temporal and spatial fluctuation patterns (Knox, 1986). The fluctuations are the result of tidal influence, runoff, direct precipitation and evaporation (Pritchard, 1967).

Pritchard (1967) described three types of water dilution patterns within estuaries. Firstly, a positive estuary, or a semi-enclosed coastal water body which has free connection with the open sea within which runoff plus precipitation exceeds evaporation, causing the fresh water dilution of sea water. The second type is an inverse estuary where evaporation exceeds runoff and precipitation leading to a hypersaline system (more common in warm arid or semi-arid regions). The third type is a neutral estuary where there is a near balance between fresh water supply and evaporation. The majority of estuaries are a positive type estuary, which is the type most commonly found in Newfoundland as the region has excessively high precipitation coupled with low evaporation rates (Pollett & Wells, 1983).

The salinity concentration is primarily dependent upon the mixing of ocean water and inflowing fresh water which can lead to various types of vertical water column stratification. The density of water increases as the salt content increases. The density difference between the fresh water and sea water leads to fresh water entering the estuary and remaining primarily at the surface as it floats above the denser sea water resulting in a halocline. In addition there can be a flow leading to mixing where the basic flow pattern is the movement of surface fresh water towards the ocean and the opposite movement of subsurface salty seawater into the estuary (Carter & MacGregor, 1979).

Such a flow pattern can lead to four different types of mixing regimes as described by Thurman and Trujillo (2010): 1. vertically mixed, 2. slightly stratified, 3. highly stratified and 4. salt wedge. The vertically mixed estuary is shallow and low in water volume; here flow always proceeds from the head (most fresh) towards the mouth of the estuary (more saline). Salinity at any point is uniform from surface to bottom. The slightly stratified estuary is deeper; salinity increases from head to mouth at any depth, however distinct freshwater and salt water layers can be identified. These two layers are separated by a zone of mixing. The highly stratified estuary is deep and upper-layer salinity increases from head to the mouth reaching approximate ocean values (around 35% salinity). The deeper water has uniform open ocean salinity at any depth throughout the estuary developing relatively strong salinity gradients or haloclines at contact between upper and lower layers. The salt-wedge estuary has a saline water wedge which intrudes beneath the fresh water which is typical of the mouths of deep, high volume rivers. There is no horizontal salinity gradient, but there is a pronounced vertical salinity gradient, having a halocline that is shallow and highly developed at the mouth.

The water of an estuary is usually described as *brackish* water, defined as water with a salinity range of 1-33 parts per thousand (ppt).The salinity of freshwater ranges from 0-1 ppt while that of the open ocean is typically 33-38 ppt (Pritchard, 1967). A possible factor in the spatial distribution of fish species within an estuarine system may be the result of tolerances to certain salinities (Keup & Bayless, 1964). A fish which tolerates wide fluctuations of salinities is described as being euryhaline, while a fish which is not tolerant to fluctuations of salinity is called stenohaline. The physiological ability of fish to tolerate variation in salinity concentrations is the ability to regulate plasma ions via osmoregulatory adaptations of the neuroendocrine system (McCormick, 2001). A study done by Cyrus and Blaber (1992) showed that fluctuating conditions within an estuary may lead to extended distribution of freshwater, stenohaline species within the estuary. This study showed that extended periods of rainfall may decrease the salinity levels enough within the estuary to allow stenohaline freshwater fish to enter portions of the estuary from which they were previously unable to enter due to the high salt content.

In addition to the previous classifications estuaries can also be divided into four major classes based on the geological origin of the system as described by Thurman and Trujillo (2010): 1. coastal plain, 2. tectonic, 3. bar-built and 4. fjord. The coastal plain estuary is formed as the sea level rises and floods existing river valleys; an example is Chesapeake Bay in Maryland. Tectonic estuaries are formed when faulting or folding rocks create a restricted down-dropped area into which rivers flow, such as San Franscisco Bay. The bar-built estuary is shallow and separated from the ocean by sand bars that are deposited parallel to the coast by wave action, for example, Pamlico Soung in North Carolina. Finally, a fjord type estuary results as the sea rises to flood a deep glaciated valley, perhaps having shallowly submerged glacial till called moraine located near the ocean entrance. Fjords are highly influenced by freshwater inputs which alter the physical and chemical attributes of the first few metres of the water column by altering water density stratification, nutrient input and current systems (Nielsen & Anderson, 2002).

The geology and resulting physical environments of the western Newfoundland coast are the result of the most recent glaciations which occurred approximately 12 000 years ago (Rogerson, 1983). Therefore it is common to find fjord-like valleys in the landscape. St. Pauls Inlet in western Newfoundland is an example of a fjord-type estuary. Other fjord-type water bodies in western Newfoundland include Western Brook Pond (entirely fresh water with no inflow from the ocean) as well as Bonne Bay and Parson’s

Pond (both marine influenced). Examples of fjord estuaries in Labrador are Gilbert Bay and Tessiarsuk Inlet.

Nearshore fish fauna in Newfoundland

The term ‘nearshore fish’ denotes a fish which occurs within the 373 km (200 mile) Canadian fisheries jurisdiction (Scott & Scott, 1988). Nearshore is also synonymous with coastal waters, indicating shallow waters generally less than 200 m deep. A number of studies have looked at nearshore fish fauna in Newfoundland and Labrador estuaries, including Currie et al. (2009), Methven et al. (2001), Wroblewski et al. (2007); see Figure 1 B. The nearshore fish fauna of western Newfoundland was described by fish caught in Bonne Bay and reported by Currie et al. (2009). They reported 31 species caught over a span of 6 years from 2002-2008 (see Table 1). Species diversity in Trinity Bay as studied by Methven et al. (2001) was found to be 22 over two 16 month periods. A study done in Gilbert Bay, Labrador by Wroblewski et al. (2007) captured 25 fish species.

Table 1. Thirty-one species of fish caught from various sites in Bonne Bay, Newfoundland using gill nets, beach seines and bottom trawls between 2002 and 2008 (Currie et al., 2009).

Species	Common Name
Family Rajidae	
Raja erinacea	little skate
Raja ocellata	winter skate
Raja radiata	thorny skate
Family Clupeidae	
Clupea harengus	Atlantic herring
Family Salmonidae	
Salmo salar	Atlantic salmon
Salvelinus fontinalis	brook trout
Family Osmeridae	
Mallotus villosus	capelin
Osmerus mordax	rainbow smelt
Family Gadidae	
Gadus morhua	Atlantic cod
Gadus ogac	Greenland cod
Merluccius bilinearis	silver hake
Microgadus tomcod	Atlantic tomcod
Urophycis tenuis	white hake
Family Gasterosteidae	
Gasterosteus aculeatus	threespine stickleback
Gasterosteus wheatlandi	blackspotted stickleback
Apeltes quadracus	fourspine stickleback
Family Labridae	
Tautogolabrus adspersus	cunner
Family Zoarcidae	
Zoarces americanus	ocean pout
Family Stichaeidae	
Ulvaria subbifurcata	radiated shanny
Family Pholidae	
Pholis gunnellus	rock gunnel
Family Anarhichadidae	
Anarhichas lupus	wolffish
Family Ammodytidae	
Ammodytes americanus	American sandlance
Family Scorpaenidae	
Sebastes spp.	redfish
Family Cottidae	
Hemitripterus americanus	sea raven
Myoxocephalus aeneus	grubby
Myoxocephalus octodecemspinous	longhorn sculpin
Myoxocephalus scorpius	shorthorn sculpin
Family Agonidae	
Aspidophoroides monopterygius	alligator fish
Family Bothidae	
Scophthalmus squosus	windowpane flounder
Family Pleuronectes	
Limanda ferruginea	yellowtail flounder
Pseudopleuronectes americanus	winter flounder

St. Paul's Inlet

St. Paul's Inlet is considered to be an estuary because it is a semi-enclosed body of water that has a degree of free connection with the open sea and is measurably diluted with fresh water that is derived from land drainage. It is also considered a fjord because the Inlet's bathometry reveals a U-shaped bottom with steep walls having glacial moraine located near the mouth of the Inlet.

St. Paul's Inlet has been designated a marine area of interest by the Canadian Parks and Wildlife Society (CPAWS). It represents a transition zone between temperate and arctic environments as well as containing organisms requiring specific habitat requirements or life histories (Rao et al., 2009). An inlet (defined as a narrow body of water leading inland from a larger body of water) can be estuarine in nature, as is St. Paul's Inlet.

Economically the Inlet has in the past (1874-1970's) supported a lobster and herring fishery (Kudac et al., 2009). Since the 1970's, the herring were overfished to collapse and the lobster population supports only a small fishery of 12 men and women who now fish mainly outside of the Inlet (Kudac et al., 2009). Vital spawning habitat for herring still exist within the Inlet (in Eastern Brook Bay and Black Brook, specifically) which could be essential in reviving a sustainable fishery in the future (Rao et al., 2009). Salmon, halibut and capelin were also fished to a lesser extent (Kudac et al., 2009). Within the confines of the National Parks of Canada, St. Paul's Inlet is perhaps considered unique because it is a restricted fjord-type estuary which is representative of other such systems found on the west coast of Newfoundland (Carter & MacGregor, 1979). As well the Inlet contains many types of habitats in a small area potentially leading to a high density of diverse communities (Carter and MacGregor, 1979).

An initial study of the inlet in 1976/1977 suggested moderate near-shore fish diversity (23 species; Carter & MacGregor 1979). No studies on the inlet have been conducted since that time. St. Paul's Inlet can also be compared with more recent fish diversity studies undertaken for Bonne Bay (Currie et al. 2009), Gilbert Bay (Wroblewski et al. 2007), and Trinity Bay (Methven et al. 2001), see Figure 1 B. Note a bay is defined as a body of water which is mostly surrounded by land, having a wider opening than an inlet. The bay connects openly to the ocean, but has calmer waters. Bonne Bay is a larger fjord system composed of three arms located approximately 40 kilometres south of St. Paul's Inlet and is also bounded by Gros Morne National Park. This body of water has an estuarine system near two large fresh water inputs: Deer Brook and Lomond River. As well given the fjord nature of Bonne Bay it shares many potentially similar habitat types with St. Paul's Inlet. Gilbert Bay is a sub-arctic shallow fjord with the characteristics of an estuary. The Gilbert River and Shinneys River flow into the bay. This site as well contains substrates similar to St. Paul's Inlet with exposed bedrock and rocky beaches. It is located in the south east portion of Labrador and may contain arctic fish in their southernmost range. Trinity Bay is an estuarine environment located on the eastern coast of Newfoundland. It is flat, protected from waves and has a substrate of silt accumulating on rock.

Given the ecological, economic and social importance of St. Paul's Inlet to the local region, as well as a lack of scientific study done within the last 30 years this study's objective is to assess the fish assemblage currently present within the Inlet. Assessment of the fish assemblages in an area is crucial to understand future spatial and temporal variation in response to a changing environmental condition such as global warming (Gomes et al., 1995). Assemblages in estuaries are even more important to understand as estuaries are highly dynamic and characterized by abrupt environmental changes such as temperature, salinity or oxygen content (Methven et al., 2001). As well the spatial distribution of fish populations will be examined to see if there is a relationship with possible salinity gradients within the Inlet. The resulting data will provide important information of species presence for future conservation efforts.

Habitat type and sampling equipment are among the most important factors that influence observed patterns of species abundance, composition and size and structure of estuarine fish (Methven et al., 2001). In addition a factor in the spatial distribution of fish species within an estuarine system may be the result of species' tolerances to certain salinities and associated gradients (Keup & Bayless, 1964). It can be hypothesized that the fish species assemblages are a function of habitat type.

The objectives of this study were to (1) document the nearshore fish fauna within St. Paul's Inlet and compare with other data sets from Newfoundland and Labrador; in addition the fish sampled in this study will be compared with the 1979 marine inventory done by Carter and MacGregor on St. Paul's Inlet to examine any temporal changes in the fish species composition; (2) assess variability in species composition associated with different habitats at different sites; and (3) determine if variation in species composition was related to patterns in salinity concentrations within the inlet. These three objectives can be used to assess the importance of St. Paul's Inlet in the context of the larger coastal ecosystem of western Newfoundland. This relates closely to the CURRA project because the results of these objectives could potentially aid community stakeholders in providing information on fish species presence and abundance. This information could potentially be used to aid in the recovery of fish stocks within St. Paul’s Inlet.

METHODS and MATERIALS

Study Site

St. Paul's Inlet is located in western Newfoundland, near the northern limits of Gros Morne National Park (Figure 1 A). The park envelops a large portion of the land surrounding the Inlet as well as a significant portion of the waters, but does not encompass the entire inlet. St Paul's Inlet is the only brackish body of water found within the confines of the park. St. Paul's Inlet is 11 km in length and ranges from a 6 km width at its widest point in the western portion, tapering to approximately one km width at the eastern tail (Carter & MacGregor 1979). The surface area of the Inlet is approximately 30 km^2.

St. Paul's Inlet is a brackish fjord fed by 24 tributaries and connected to St. Paul's Bay by a restricted opening that is approximately 80 m in width (Carter & MacGregor 1979). The largest input of fresh water is Bottom Brook found at the eastern end of the inlet. The Inlet is characterized by shallow depths of 1-3 m towards the western portion extending into the bay. The eastern portion of the Inlet, from Middle Island to Bottom Brook is steeply sloped, descending to a maximum depth of 36 metres at the center. The coastline within St. Paul's Inlet is composed of substrate formed from glacial scouring resulting in a variety of steeply sloping rocky beaches as well as coarse, shallow, sandy beaches. The town of St. Paul's has a population of 309 and lies between the two water bodies of the inlet and the bay. St. Paul's Bay opens out to the Gulf of St. Lawrence (Statistics Canada, 2006). The bay is characterized by shallow water, never deeper than 3 meters and sandy bars with occasional rocky shores. There is a deeper trench which runs under the bridge from the mouth of St Paul's Bay to the Inlet that is up to 6 m in depth (Carter & MacGregor, 1979).

Sampling Strategy

Sampling took place during the month of August of 2010. A total of 7 sites were sampled: 6 within St. Paul's Inlet as well as one location along St. Paul's Bay (Figure 1 A). Sites were chosen to best represent a potential range in salinities, as well as for ease of accessibility. Site 1 was chosen to represent the more saline Bay habitat, being closest to the marine environment of the Gulf of St. Lawrence. The region of the Gulf of St. Lawrence closest to St. Paul's Inlet is called Esquiman Channel which has a salinity concentration ranging from 32 – 36 ppt (Galbraith, 2006). Site 2 was selected to examine the transition from the Bay into the Inlet defined by the restricted opening as well as having a strong tidal influence. Sites 3-7 were distributed in attempt to capture a salinity gradient within the Inlet ranging from most marine to a possible increased freshwater influence. The most marine environments were expected to be found nearest the opening into the Bay and the most fresh nearest the eastern portion of the Inlet, at Bottom Brook. Not all sites were sampled with the same gear types as the substrates at some locations did not permit their use. In addition the sites furthest from the town of St. Paul's were not sampled with as great intensity compared to the sites in closer proximity due to logistical restrictions and weather constraints. The wind on the Inlet was strong and often prohibited travel. Certain sites were given supplementary sub-sites to more comprehensively sample the fish fauna present at those sites.

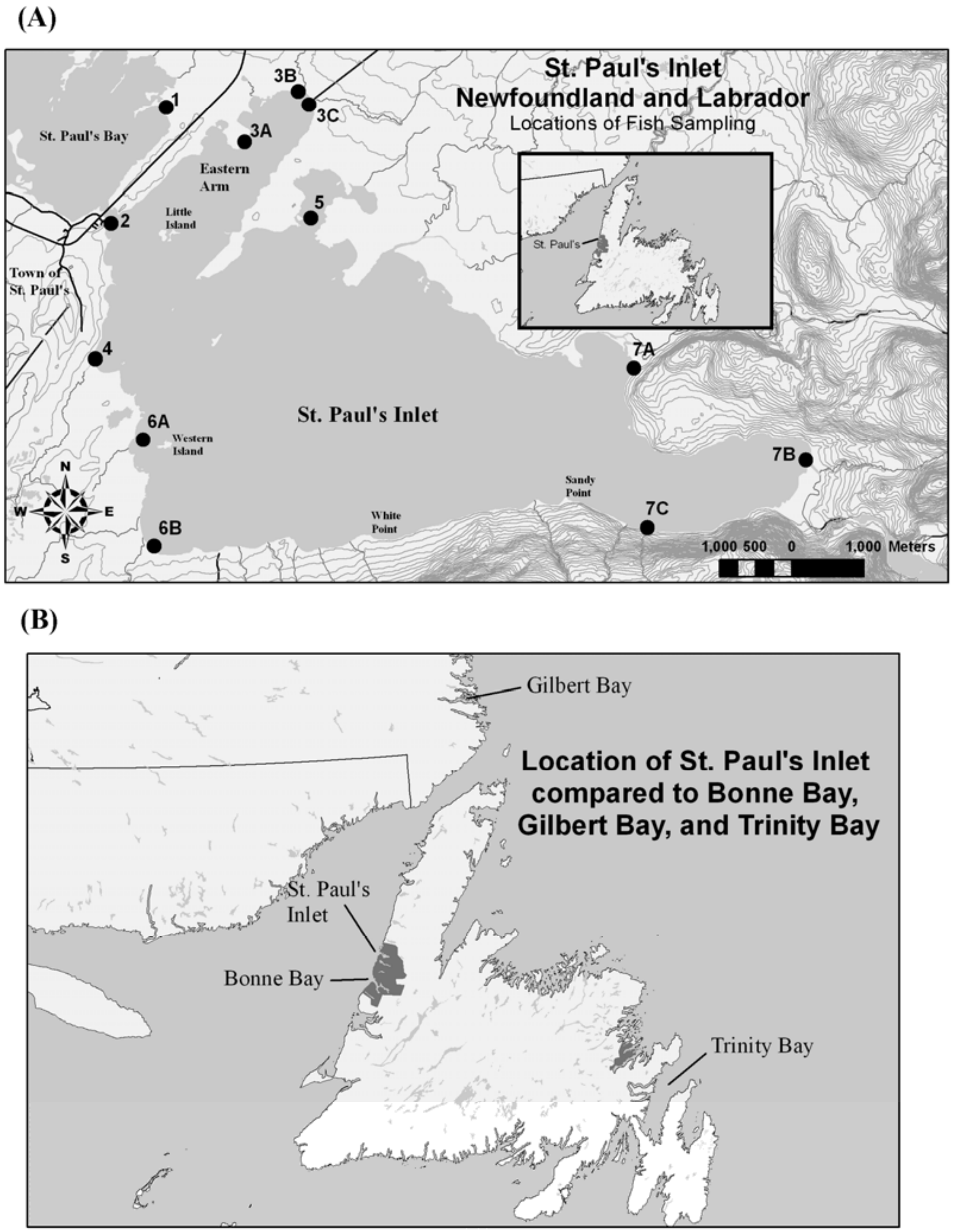


Figure 1: Location of Study – (A) Study sites within St. Paul's Inlet. 1=St. Paul's Bay, 2=Inlet Opening, 3A=Eastern Arm Peninsula, 3B=Eastern Arm Brook 1, 3C=Eastern Arm Brook 2, 4=Cliffy Point Cove, 5=Barachois, 6A=Alex Cove, 6B=Western Island, 7A=East Brook Cove, 7B=Bottom Brook and 7C=Between the Falls. (B) Location of St. Paul's Inlet in Newfoundland compared to Bonne Bay, Gilbert Bay and Trinity Bay, highlighting the location of Gros Morne National Park.

Sampling Sites

Site 1 – St. Paul's Bay

This site was characterized by a sandy substrate near shore leading to large clustered boulders and cobble as St. Paul's Bay was approached. The surrounding landscape was that of grassy knolls and grass wetland. One brook fed into the site 1 system. At 150 metres upstream it had a width of 2 metres, with less than 0.3 km/h flow rate. At the river mouth it was 10 metres wide with a negligible flow rate at both low and high tides. At low tide the stream flow shrunk considerably exposing more sandy bars.

Site 2 – Inlet Opening

This site was on the Inlet side of the opening and was considered to be the transition zone between the marine Bay and the brackish Inlet. The substrate consisted of exposed elevated bedrock nearest the opening leading to cobblestone beaches with sporadic large boulders approximately 250 metres along the shoreline into the Inlet. This area has the greatest marine influence being adjacent to the 80 metre Inlet opening. Tidal flow during high tide is quite strong bringing sea water from the bay into the Inlet (Carter

& MacGregor, 1979). The surrounding landscape consisted of coniferous forest with visible stunting. At approximately 1 metre the beach sloping quickly downward making full extension of the beach seine difficult.

Site 3A – Eastern Arm Peninsula

The beach substrate was composed mainly of sand with occasion larger stones. The water was shallow never exceeding 1 metre in depth within 100 metres of the shoreline. The surrounding landscape was a tall-grassed wetland. This site was very shallow which made use of the minnow traps difficult.

Site 3B – Eastern Arm Brook 1

The substrate at this site was sandy with significant amounts of cobblestones and boulders overlaid. The landscape was that of a grassy wetland transitioning into old growth coniferous forest. The system was fed by a large brook having a stream width of 3 metres at approximately 100 metres upstream. At this point the stream flow rate was less than 0.3 km/h. Twenty five metres from the stream mouth the width was 5 metres with a less than 0.3 km/h flow rate. This site had negligible tidal variation. The stream had significant organic debris in the bed which spilled out into the nearby brackish waters. No beach seining was done at this site due to distance from town and impeding boulders.

Site 3C – Eastern Arm Brook 2

The substrate at this site was primarily sandy with few cobblestones. The surrounding landscape was grassy shores again transitioning to old growth coniferous forest. This site was fed by a large brook having a stream width of 3 metres approximately 185 metres upstream. This point had less than 0.3 km/h flow rate. At 50 metres from the stream mouth the flow rate was less than 0.3 km/h and 25 metres wide. There was no tidal variation at this site.

Brook trout were observed schooling 200 metres upstream as well as schooling unidentified species near the stream mouth. No beach seining was done due to accessibility.

Site 4 – Cliffy Point Cove

The substrate at this site was primarily cobblestones with occasional boulders. The surrounding landscape was a grassy embankment leading to coniferous forest. This site was fed by a small stream. At 225 metres upstream the width was 4 metres with a 0.3 km/h flow rate. At 15 metres from the stream mouth it widened to 14 metres in width with less than 0.3 km/h flow rate. The water depth at this site was quite shallow making it difficult to use minor traps at certain locations. There was significant seaweed drift on the shoreline.

Site 5 – Barachois

The substrate at this site was primarily sandy with intermittent large boulders. The entire system never exceeds a depth of 1 metre. The surrounding landscape was grassy banks leading to coniferous forest with significant deadfall. The system is comprised of two segments. One larger portion which is exposed to the Inlet's main water and is acted upon by waves significantly. The second portion is smaller and sheltered from the Inlet and wave action. This smaller portion is also fed by a small brook. Approximately 50 metres upstream the width was 1 metre with a flow rate of 0.6 km/h. At the stream mouth it was 3 metres wide with a flow rate of 0.6 km/h.

The mouth of the barachois had many large boulders with much seaweed associated. Within the barachois no seaweed was observed. The shallow nature of the barachois made minnow trapping difficult. The presence of large boulders made beach seining impractical.

Site 6A/B – Alex Cove/Western Island

This site consisted of minnow trap sampling done offshore near western island in the shallow waters as well as beach seining done onshore nearby. The minnow traps were deployed from 100 metres offshore to 500 metres offshore in water that did not exceed 5 metres in depth. In these waters eelgrass dominated making the substrate not visible.

The beach substrate where the seining took place was gravel on a shallow beach. The surrounding landscape was coniferous forest.

Site 7A – East Brook Cove

This site was a very shallow cove never exceeding 3 metres in depth for its entirety. The substrate consisted of sand with some gravel. The surrounding landscape was that of coniferous forest. The system was heavily influenced by Eastern Brook which deposits significant amounts of freshwater into the Cove. There was some grass growing in the shallow water.

Site 7B – Bottom Brook

The substrate at this site was a sand/gravel mix on a shallow beach extending as such for approximately 100 metres before deepening quickly. The surrounding landscape was a grassy bank leading to coniferous forest. This site was influenced by the nearby fresh water Bottom Brook making the water quite low in salinity and giving the organic brownish hue.

Site 7C – Between the Falls

This site consisted of a gravel/cobblestone substrate on a steeply sloping beach. The slope was steep enough to prevent the full horizontal deployment of the beach seine into the water. The location where the beach seine was performed was just large enough to accommodate a 10 metre tow as the remainder of the shoreline at this site was large boulders. The surrounding landscape was grass barrens with stunted spruce trees leading to a cliff face and bouldered terrace. There were two waterfalls that fell over the cliff face on either side of the sampling location.

Methods of Fish Collection

During sampling 3 different gear types were utilized: a 10 m beach seine, minnow traps and multi-paneled gill nets (Table 2). In order to accurately represent the fish fauna present at any location multiple gear types must be used as size selectivity differs substantially between gear types (Methven & Schneider, 1998). These methods are similar to methods used in Methven et al. (2001), Wroblewski et al. (2007) and Currie et al. (2009).

Salinity (ppt), dissolved oxygen (mg/L) and water temperature (°C) measurements were taken at every sampling location using a YSI model 85.The YSI model 85 is manufactured to be accurate to within ± 1% for every measurement. Sampling locations were plotted with GPS coordinates.

For all samples, fish captured were removed from the trapping gear and placed into a large pail of inlet water to be removed individually for identification to species. Experience gained during the Biology 3714 estuarine fish ecology field course done at the Bonne Bay Marine Station coupled with the *Atlantic Coast Fishes* (Robins et al., 1986) field guide provided most taxonomic identification. If this could not be done in the field, photographs and detailed morphometric observations were made to identify the fish *ex situ*. All fish caught were measured for standard length to the nearest 1 millimetre on a wooden measuring board. Once the fishes were processed they were returned back to the waters unharmed.

Small beach seine – The seine was comprised of a 10 metre by 1.5 metre panel, with 10 millimetre stretch mesh netting. A tow length ranging from 10-50 m was selected based on an initial survey of the site. The seine was deployed perpendicular to the shoreline and towed parallel to the shore by two people at either end of the seine for the designated tow length. One person walked along the shore with one person at an approximate depth of 1 metre into the water with the seine extended. At least 2 tows were done at each site seined up to a maximum of 5 tows. Some sites did not permit the use of the small beach seine due to large obstructing boulders.

Minnow traps – The minnow traps were used on a regular basis to sample areas where beach seines could not be deployed and to increase the chances of catching fishes in the area over time. The traps were deployed approximately 5 to 10 metres from shore, fully submerged beneath the water. Each trap was baited with a cup of dry dog food and anchored to the shore by a tether and weight. Traps were typically set early morning and retrieved in the afternoon, active for 6-8 hours. On some occasions due to weather traps were left overnight to be retrieved early the next morning. There were a total of 30 minnow traps available for use. Depending on the sampling location traps were set at 50-150 m intervals along the shoreline.

Multi-panel Gill nets – Two nets were used, one consisting of 9 panels with increasing mesh sizes per panel (¾, 1, 1.5, 2, 2.5, 3, 3.5, 4, and 4.5 inches mesh stretch sizes) and the other consisting of 8 panels with the 3 inch mesh stretch panel excluded. Each panel was 15 m in length and 2.5 m in height. Total length of the 9 panel net was135 m, the 8 panel net was 120 m in length. The gill nets were only used for sampling for one day on August 15th, resulting in a singular deployment and retrieval for each net due to logistical and permit constraints. Sampling took place at Site 7B and 7C as they had appropriate depths for deployment.

Statistical Analysis

In order to evaluate patterns in fish species composition in St. Paul's Inlet, I utilized cluster analysis (UPGMA) based on Jaccard's coefficient of similarity. The Jaccard coefficient was used to determine similarities between fish assemblages at each sampling site. This measure of similarity is used for presence-absence data and is represented by equation:

$$S_J = \frac{a}{(a + b + c)}$$

Where a = number of species present at site X and site Y, b = number of species present only at site X and c = number of species only present at site Y (MacKenzie, 2005). Jaccard values range from 0, sample sites having no species in common, to 1, sample sites having all species in common. There are many measures of similarity. Jackson et al. (1989) found redundancy among the similarity coefficients using the Jaccard and Sorensen-Dice or using the Simple Matching and Rogers-Tanimoto coefficients. In addition, the simpler the coefficient, the easier the interpretation, indicating the use of Jaccard's would be preferred (Sokal & Sneath, 1963).

A limitation of presence-absence data is that a species may be noted as 'absent' from a certain site but in reality the sampling efforts failed to detect that species (MacKenzie, 2005). This produces a bias that reflects the ability of the sampler to detect the species on the landscape, rather than the actual distribution of the species on the landscape (MacKenzie, 2005). This becomes particularly important when attempting to detect rare species because the resulting data may only reflect the common, high abundance species.

Biologists commonly used cluster-analysis techniques in order to identify species assemblages and biogeographic patterns (Jackson et al. 1989). Cluster analysis is a method of classification of similarities for samples that can be defined statistically by grouping samples in respect to species abundances (Krebs, 1989). The hierarchical clustering technique assigns each site to a group, and then clusters the groups. The unweighted pair-group method using arithmetic averages (UPGMA) was utilized (Sokal & Sneath, 1963). The UPGMA cluster analysis is the most commonly used in the biological sciences and clusters the data based on a distance matrix (Pevsner, 2009). This was used to analyze the 10 m beach seine data from St. Paul's as well as the comparable Bonne Bay data from Currie et al. (2009). The Numerical Taxonomy and Multivariate Analysis System (NTSYSpc) version 2.2 was used to produce dendrograms created through cluster analysis (Rohlf, 2009).

Catch per unit effort (CPUE) data were calculated as well to indicate abundance of a species at a certain sampling site.

To evaluate the abundance of fish in terms of diversity the Shannon-Wiener diversity index was calculated for each site. The Shannon-Wiener diversity index is represented by the equation:

$$H' = -\sum_{i=1}^{k} Pi \log Pi$$

This index calculates the distribution of observations among categories, or in this study's case, the number of individuals of a certain species (Zar, 1996). The variable Pi is the number of fish of a particular species (n_i) divided by the total number of fish collected (N), with is then summed across all species (k) (Zar, 1996). Abundance distributed evenly among species displays a high diversity, in the case of fishes, a H′ value approaching two. Abundance dominated by one species displays low diversity with a H′ value approaching zero (Zar, 1996). The Shannon-Wiener diversity index is known to underestimate diversity in the sampled population; however this bias decreases with increasing sample size (Zar, 1996).

RESULTS

Nearshore Fish Fauna within St. Paul's Inlet

During the month of August 2010, a total of 1451 fish were caught comprising 15 species and representing 9 families (Table 2). Six species of fish accounted for 98% of the total fish sampled: *Gasterosteus aculeatus* (18%), *Gasterosteus wheatlandi* (7%), *Apeltes quadracus* (7%), *Pungitius pungitius* (60%), *Tautogolabrus adspersus* (4%), and *Myoxocephalus octodecemspinosus* (2%). Two species were only caught once during sampling: *Anguilla rostrata* and *Urophycis tenuis*.

The species richness was not equal at every sampling site. Species richness between the sampling sites ranged from 1 to 10 (Table 3). Richness was the highest at Site 2 and Site 4 with ten species and seven species respectively. The lowest species richness was at Site 6A and Site 6B with only one species being found at either. Species diversity between sampling sites also varied, as measured by the Shannon-Wiener Index (H') (Table 3). The lowest value recorded was at Site 3C with H′ = 0.5791 and the highest value at Site 2 with H′ = 1.6627. The abundance of fishes as represented by the catch per unit effort calculations showed high abundance in 10 m beach seine (Table 4), but low abundance in minnow traps (Table 5). The high abundance shown in the beach seine data is largely represented by the Gasterosteidae family representing 99% of the fish captured.

One species was cosmopolitan, being found at all fifteen sampling sites. This species was the threespine stickleback (*Gasterosteus aculeatus)* (Table 2). The threespine stickleback belongs to the Gasterosteidae family which also contains the subsequent three

Table 2. Site-species matrix showing all species captured, all sites sampled for all gear types used during August 2010 sampling of St. Paul's Inlet.

	10m Beach Seine							Minnow Trap								Gill Net		Total Fish Sampled
Species	Site 1	Site 2	Site 4	Site 6A	Site 7A	Site 7B	Site 7C	Site 1	Site 2	Site 3A	Site 3B	Site 3C	Site 4	Site 5	Site 6B	Site 7B	Site 7C	
Anguilla rostrata	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1
Apeltes quadracus	4	1	5	0	7	1	0	1	0	21	12	34	8	4	0	0	0	98
Gasterosteus aculeatus	2	11	56	7	36	5	8	13	0	9	92	1	13	6	0	0	0	259
Gasterosteus wheatlandi	67	0	6	0	21	3	2	1	0	0	1	0	0	0	0	0	0	101
Microgadus tomcod	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	1	4
Myoxocephalus aeneus	0	0	2	0	0	0	0	0	4	0	0	0	0	0	0	0	0	6
Myoxocephalus octodecemspinous	0	0	4	0	0	0	0	0	27	1	0	0	0	0	0	0	0	32
Myoxocephalus scorpius	0	0	0	0	0	0	0	0	5	2	0	0	0	0	0	0	0	7
Osmerus mordax	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	3
Pholis gunnellus	0	0	1	0	0	0	0	0	3	0	0	0	0	0	0	0	0	4
Pseudopleuronectes americanus	0	0	0	0	0	0	0	0	5	0	0	0	0	0	0	0	0	5
Pungitius pungitius	154	0	458	0	0	0	0	52	0	82	33	15	57	16	0	0	0	867
Salvelinus fontinalis	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	2
Tautogolabrus adspersus	0	0	0	0	0	0	0	0	44	0	0	0	0	0	7	2	8	61
Urophycis tenuis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1
Site Species Richness	4	2	7	1	3	3	2	4	8	5	4	3	3	3	1	3	3	
Total Fish Sampled	227	12	532	7	64	9	10	67	92	115	139	50	78	26	7	6	10	**1451**

Table 3. Species richness and Shannon-Wiener diversity index at each sampling site for all gear types during August 2010 in St. Paul's Inlet.

Site	Species Richness (S)	Shannon-Wiener Index (H')
1	4	0.7362
2	10	1.6627
3A	5	0.8628
3B	4	0.897
3C	3	0.5791
4	7	0.9251
5	3	0.9251
6A	1	-
6B	1	-
7A	3	0.9313
7B	6	1.6397
7C	5	1.2629

Table 4. Catch per unit effort for each species using the 10 metre beach seine (number of fish caught/100m of shoreline) during August 2010 sampling in St. Paul's Inlet.

	N	Site 1	Site 2	Site 4	Site 6A	Site 7A	Site 7B	Site 7C
Species								
Family Gasterosteidae								
Gasterosteus aculeatus	80	3.077	11	6.111	23.333	60	5.556	26.667
Gasterosteus wheatlandi	99	103.08		3.333		35	3.333	6.667
Apeltes quadracus	30	6.154	1	3.889		11.667	1.111	
Pungitius pungitius	612	236.92		254.444				
Family Pholidae								
Pholis gunnellus	1			0.556				
Family Cottidae								
Myoxocephalus octodecemspinosus	4			2.222				
Myoxocephalus aenaeus	2			1.111				
Total Fishes Captured	828	227	12	489	7	64	9	10
Species richness		4	2	7	1	3	3	2
Total number of meters towed	555	65	100	180	30	60	90	30
Total CPUE		349.23	12	271.666	23.333	106.667	10	33.334

Table 5. Catch per unit effort for each species using the minnow traps (number of fish caught/trap/hour) during August 2010 sampling in St. Paul's Inlet.

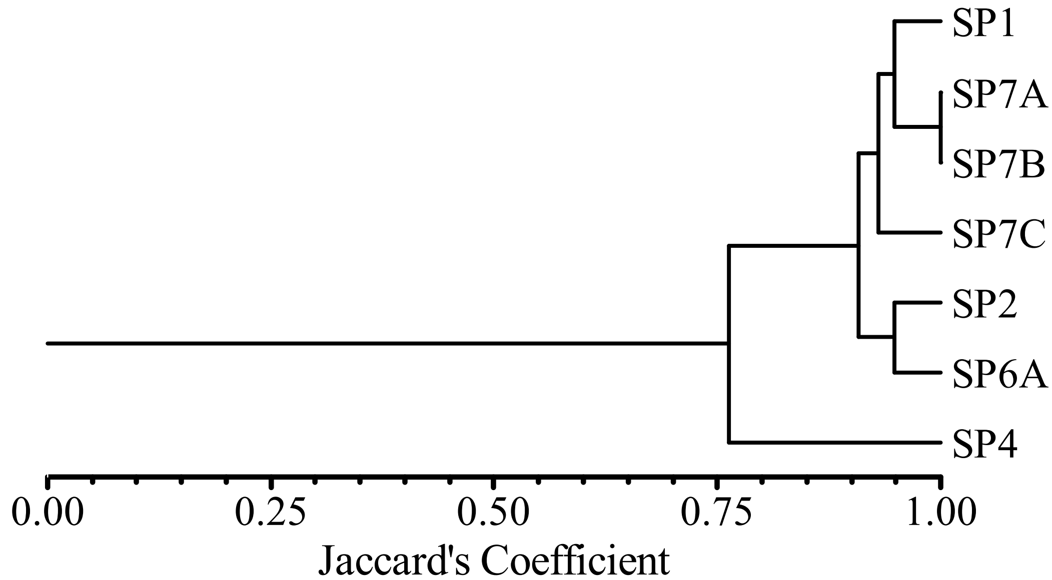
	N	Site 1	Site 2	Site 3A	Site 3B	Site 3C	Site 4	Site 5	Site 6B
Species									
Family Anguillidae									
Anguilla rostrata	1	0	0.0000663	0	0	0	0	0	0
Family Salmonidae									
Salvelinus fontinalis	1	0	0	0	0.00082	0	0	0	0
Family Gadidae									
Microgadus tomcod	3	0	0.000199	0	0	0	0	0	0
Family Gasterosteidae									
Gasterosteus aculeatus	134	0.0099	0.000597	0	0.0751	0.00048	0.0111	0.0026	0
Gasterosteus wheatlandi	2	0.0008	0	0	0.00082	0	0	0	0
Apletes quadracus	76	0.0008	0	0.00875	0.00979	0.0164	0.0043	0.013	0
Pungitius pungitius	255	0.0396	0.00544	0	0.0269	0.00725	0.0485	0.0069	0
Family Labridae									
Tautogolabrus adspersus	51	0	0.00292	0	0	0	0	0	0.0288
Family Pholidae									
Pholis gunnellus	4	0	0.000199	0.00062	0	0	0	0	0
Family Cottidae									
Myoxocephalus octodecemspinosus	28	0	0.00179	0.00062	0	0	0	0	0
Myoxocephalus scorpius	7	0	0.000332	0.00083	0	0	0	0	0
Myoxocephalus aenaeus	4	0	0.000265	0	0	0	0	0	0
Family Pleuronectidae									
Pseudopleuronectes americanus	5	0	0.000332	0	0	0	0	0	0
Total Fishes Captured	571	67	183	26	139	50	75	25	7
Species richness		4	10	4	5	3	3	3	1
Number of Traps		13	40	10	7	9	14	16	9
Total hours traps set	1379	102	377	240	175	230	84	144	27
Total CPUE		0.051	0.0121403	0.01082	0.11342	0.02413	0.0639	0.0225	0.0288

most commonly found species: fourspine stickleback (*Apeltes quadracus)*, ninespine stickleback (*Pungitius pungitius*), and blackspotted stickleback (*Gasterosteus wheatlandi*) (Table 4). These three species were found at nine, six and five out of fifteen sites respectively. Seven of the remaining species were found at two to four of fifteen sites: Tomcod (*Microgadus tomcod)*, grubby (*Myoxocephalus aeneus*), longhorn sculpin (*Myoxocephalus octodecemspinous)*, shorthorn sculpin (*Myoxocephalus scorpius)*, rock gunnel (*Pholis gunnellus),* brook trout (*Salvelinus fontinalis)*, and cunner (*Tautogolabrus adspersus)*. Four species were found exclusively at one sampling site: American eel (*Anguilla rostrata),* American smelt (*Osmerus mordax)*, winter flounder (*Pseudopleuronectes americanus)*, and white hake (*Urophycis tenuis)*.

Cluster analysis performed on the 10 m beach seine data using the Jaccard's coefficient of similarity showed no distinct clusters (Figure 2). All sites seemed quite similar with initial separation at 76% similarity where site 4 separated out from the rest of the Sites 1, 2, 4, 6A, 7A, 7B and 7C.

St. Paul's 2010 compared with 1979

Initial comparisons between this 2010 study and the 1979 Carter and MacGregor study revealed some differences in fish fauna sampled in St. Paul's Inlet (Table 6). A total of 23 species had been previously captured by Carter and MacGregor (1979). There were eleven species were not seen in the 2010 sampling that were captured in 1979: *Ammodytes americanus, Clupea harengus, Cyclopterus lumpus, Gadus morhua,*



	SP1	SP2	SP4	SP6A	SP7A	SP7B	SP7C
SP1	1.0000						
SP2	0.5000	1.0000					
SP4	0.5710	0.2860	1.0000				
SP6A	0.2500	0.5000	0.1430	1.0000			
SP7A	0.7500	0.6667	0.4290	0.3333	1.0000		
SP7B	0.7500	0.6667	0.4290	0.3333	1.0000	1.0000	
SP7C	0.5000	0.3333	0.2860	0.5000	0.6667	0.6667	1.0000

Figure 2. Cluster dendrogram and Jaccard's Coefficent matrix for 10 m beach seine data during August 2010 sampling in St. Paul's Inlet.

Table 6. Species and common name for fish identified in St. Paul's Inlet comparing data from 1979 (Carter & MacGregor) and August 2010.

Species	Common Name	1979	2010
Ammodytes americanus	American sandlance	X	
Anguilla rostrata	American eel	X	X
Apeltes quadracus	Fourspine stickleback		X
Clupea harengus	Herring	X	
Cyclopterus lumpus	Lumpfish	X	
Gadus morhua	Atlantic cod	X	
Gasterosteus aculeatus	Threespine stickleback	X	X
Gasterosteus wheatlandi	Black spotted stickleback		X
Limanda ferruginea	Yellowtail flounder	X	
Lumpenus maculatus	Daubed shanny	X	
Macrozoarces americanus	Ocean pout	X	
Microgadus tomcod	Tomcod	X	X
Myoxocephalus aeneus	Grubby	X	X
Myoxocephalus octodecemspinous	Longhorn sculpin	X	X
Myoxocephalus scorpius	Shorthorn sculpin	X	X
Osmerus mordax	American smelt	X	X
Pholis gunnellus	Rock gunnel	X	X
Pseudopleuronectes americanus	Winter flounder	X	X
Pungitius pungitius	Nine spine stickleback	X	X
Salvelinus fontinalis	Brook trout	X	X
Scomber scombrus	Mackerel	X	
Stichaeus punctatus	Arctic shanny	X	
Tautogolabrus adspersus	Cunner	X	X
Triglops murrayi	Mailed sculpin	X	
Ulvaria subbifurcata	Radiated shanny	X	
Urophycis tenuis	White hake		X

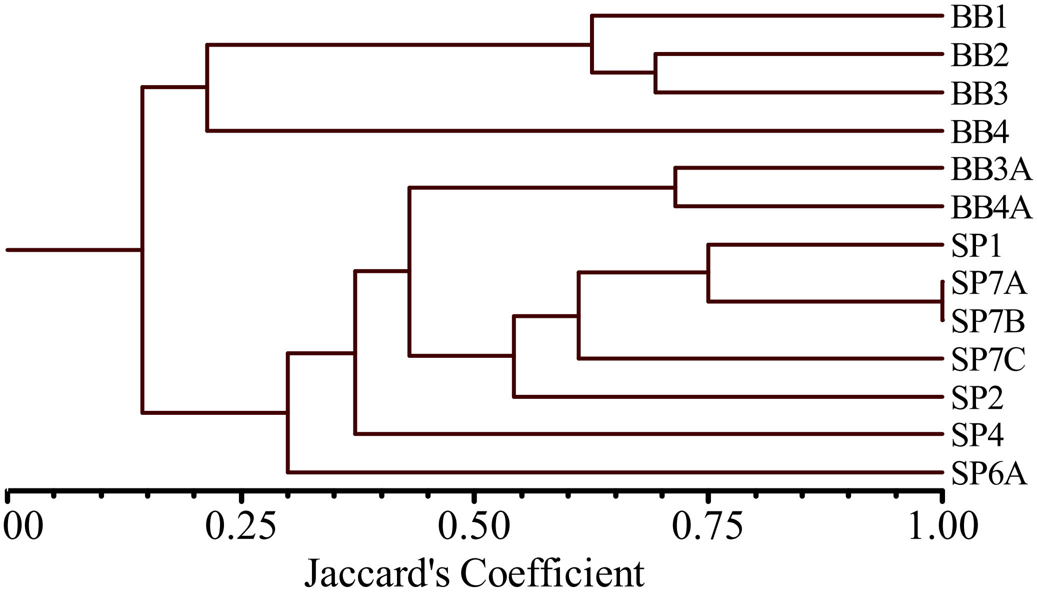
Limanda ferruginea, Lumpenus maculates, Macrozoarces americanus, Scomber scombrus, Ulvaria subbifurcata, Triglops murrayi, and *Ulvaria subbifurcata* (Table 5). There were three species recorded in 2010 not recorded in 1979: *Apeltes quadracus*, *Gasterosteus wheatlandi*, and *Urophycis tenuis.*

St. Paul's Compared with Bonne Bay

Cluster analysis was also performed comparing 10 m beach seine data taken from St. Paul's during the August 2010 with similar data for Bonne Bay taken during 2002-2008 (Figure 3). The results show an early formation of clusters, separating at 14% similarity. One cluster contains the Bonne Bay Sites 1 to 4 and the other cluster contains all the St. Paul sites as well as Bonne Bay sites 3A (Deer Arm barachois) and 4A (Lomond River delta). This is clustering the marine Bonne Bay sites together (Sites 1-4) while clustering the estuarine sites from Bonne Bay (3A and 3B) with the whole of the St. Paul's sites.

Species Variability Associated with Different Habitats

Assessment of species variability associated with different habitats at different sites showed no huge differences. Six substrate types were designated to different locations in St. Paul's Inlet by Carter and MacGregor (1979): exposed bedrock, boulders, cobble, gravel with mud, sand and mud or silt. Sampling sites from this study showed five of the six substrate types, the mud or silt not being represented (Table 7). The greatest species richness (10) was associated with the exposed bedrock substrate while the lowest richness (1) was associated with boulders and gravel with mud substrates.



	SP1	SP2	SP4	SP6A	SP7A	SP7B	SP7C	BB1	BB2	BB3	BB3A	BB4	BB4A
SP1	1.0000												
SP2	0.5000	1.0000											
SP4	0.5710	0.2860	1.0000										
SP6A	0.2500	0.5000	0.1430	1.0000									
SP7A	0.7500	0.6670	0.4290	0.3330	1.0000								
SP7B	0.7500	0.6670	0.4290	0.3330	1.0000	1.0000							
SP7C	0.5000	0.3330	0.2860	0.5000	0.6670	0.6670	1.0000						
BB1	0.1176	0.0625	0.2222	0.0667	0.1250	0.1250	0.1333	1.0000					
BB2	0.1538	0.0833	0.2857	0.0909	0.1667	0.1667	0.1818	0.6250	1.0000				
BB3	0.1538	0.0833	0.2857	0.0909	0.4286	0.1667	0.1818	0.6250	0.6933	1.0000			
BB3A	0.3750	0.2857	0.2727	0.1429	0.0000	0.4286	0.2857	0.2941	0.2000	0.3846	1.0000		
BB4	0.0000	0.0000	0.0000	0.0000	0.6000	0.0000	0.0000	0.2000	0.1667	0.2727	0.2500	1.0000	
BB4A	0.5000	0.4000	0.3333	0.2000	0.7500	0.6000	0.5000	0.2500	0.2308	0.3333	0.7143	0.1429	1.0000

Figure 3. Cluster dendrogram and Jaccard's Coefficient matrix for 10 m beach seine data comparing August 2010 St. Paul's data with Bonne Bay 2002-2008 (Currie et al. 2009). SP = St. Paul's sites and BB = Bonne Bay sites. 10 m beach seine were used in both studies.

Table 7. Benthic substrates and species richness for each sampling site in St. Paul's Inlet during August 2010 sampling. The benthic substrate type is in accordance with substrate types identified by Carter and MacGregor (1979).

Site	Benthic Substrate Type	Species Richness (S)
1	sand	4
2	exposed bedrock	10
3A	sand	5
3B	sand	4
3C	sand	3
4	boulders	7
5	boulders	3
6A	boulders	1
6B	gravel with mud	1
7A	sand	3
7B	sand	6
7C	boulders	5

Species Variability Related to Salinity Concentrations

Assessment of variability of species richness in relation to salinity concentrations within St. Paul's Inlet showed that there was no strong difference among sites based on salinity (Table 8). The average salinity concentrations at the different sites along the Inlet are very similar ranging from 13 ppt – 24.3 ppt, but the majority of sites were around the concentration of 21 ppt. The sites representing the greatest number of species as well as the lowest number of species had similar brackish water salinity concentrations. Bonne Bay data (Currie et al., 2009) was examined as well to make comparisons with St. Paul's Inlet (Table 8). In Bonne Bay the sites with higher salinity concentrations have higher species richness (BB Sites 1,2,3 and 4). An exception is Bonne Bay site 4A which has a high salinity with low species richness.

Table 8. Species richness, salinity, dissolved oxygen, and temperature at each sampling site during August 2010 sampling in St. Paul's Inlet and also Bonne Bay 2002-2008 (Currie et al., 2009). The salinity, dissolved oxygen and temperature readings are from data recorded during the Biology 3714 field course at the Bonne Bay Marine Station in June 2010. All values represent a mean at 1 m in depth followed by a range in brackets (when available). SP=St. Paul's sites and BB=Bonne Bay sites.

Site	Species Richness (S)	Salinity (ppt)	Dissolved Oxygen (mg/L)	Temperature (°C)
St. Paul's				
SP1	4	20.6 (21.4 - 22.8)	7.06 (6.28 - 7.88)	18.2 (18.1 - 18.3)
SP2	10	24 (20.8 - 27)	8.46 (8.13 - 9.1)	21.8 (21.3 - 22.2)
SP3A	5	21.2 (18.7 - 23.4)	6.8 (5.67 - 9.08)	21.5 (19.1 - 20.3)
SP3B	4	21.4 (20.7 - 22.4)	3.62 (0.35 - 7.84)	21.8 (21.1 - 22.9)
SP3C	3	19.9 (18.9 - 21.8)	4.53 (0.72 - 6.68	22.2 (20.4 - 22.8)
SP4	7	24.3 (23.5 - 25)	6.29 (2.99 - 8.44)	21.6 (19.9 - 21.7)
SP5	3	13 (11.6 - 14.8)	6.50 (4.76 - 7.65)	18.9 (17.4 - 20)
SP6A	1	20.6 (20.2 - 21.2)	7.98 (7.26 - 8.43)	21.9 (18.8 - 20.3)
SP6B	1	21.5 (21.3 - 21.7)	7.27	18.8
SP7A	3	18.1	8.39	21.2
SP7B	6	19.1 (18.2 - 20.8)	7.72 (7.35 - 8.24)	19.6 (18.3 - 22)
SP7C	5	16.6 (12.2 - 22.3)	7.65 (7.04 - 8.56)	19.6 (18.1 - 21.7)
Bonne Bay				
BB1	23	26.3 (26.2 - 26.5)		14.9
BB2	20	26		12.2
BB3	25	8		13
BB3A	7	1.8		20.3
BB4	14	24.1		12.6
BB4A	8	26		12.9

DISCUSSION and CONCLUSION

St. Paul's Inlet

The various sites in St. Paul's Inlet were not equal in species richness (Table 3). Site 2 was found to have the highest richness (10) and the highest Shannon-Wiener value ($H' = 1.6627$). This could be because this site is at the opening of the Inlet and is heavily influenced by the incoming marine water from the Gulf of St. Lawrence, being a corridor of travel for fishes (Figure 1A). Both salinity and habitat were hypothesized to cause variability in species richness between sites. Differing habitat does not seem to have a profound effect on the species richness in this study (Table 7). An exception was site 2 with the highest species richness (10) that was the only site that had exposed bedrock for a benthic substrate. Carter and MacGregor (1979) described the hard substrate habitat as containing the most diverse biota with St. Paul's Inlet. The salinity concentrations measured at each site does not seem to significantly influence the species composition (Table 8). The salinities recorded were all brackish water never becoming exceedingly fresh or marine indicating homogeneity in salinity concentrations around the Inlet at one metre in depth during August.

The dendrograms produced through cluster analysis on 10 m beach seine data within St. Paul's Inlet continues the indication of homogeneity of sites (Figure 2). The initial separation occurs at 76% similarity indicating high similarity in species assemblages at all sites. Site 4 does separate from the others because for the 10 m beach seine three species were caught only at this site: *Pholis gunnellus, Myoxocephalus aeneus,* and *Myoxocephalus octodecemspinous*. If examined further Sites 1, 7A and 7B cluster at about 89% similarity. This could be because all these sites are shallow and sandy, a habitat type frequented by the stickleback family Gasterosteidae (Scott & Scott, 1988). This does explain the relationship as three stickleback species are found at all three sites: *Gasterosteus aculeatus, Gasterosteus wheatlandi,* and *Apeltes quadracus* (Table 2).

Fish abundances within St. Paul's Inlet showed higher abundances with the 10 m beach seine but lower abundances with the minnow traps (Tables 4 & 5). The high abundances found in the 10 m beach seine data reflects high numbers of individuals captured from the Gasterosteidae family. These four species comprised 99% of the fish captured: *Gasterosteus aculeatus, Gasterosteus wheatlandi, Apeltes quadracus*, and *Pungitius pungitius*. Most sites were close to rivers or streams where these fish come to spawn (Scott & Scott, 1988). The minnow traps may more accurately reflect the low abundances of fish within St. Paul's Inlet. Low abundance is the result of low primary production and low nutrient loading commonly seen on the west coast of Newfoundland (Dunbar, 1972). Low nutrients in St. Paul's Inlet is the result of poor nutrient input from the surrounding landscape in the freshwater tributaries and as a result nutrients are supplied through the restricted opening from the Gulf of St. Lawrence (Carter & MacGregor, 1979).

St. Paul's Inlet – 2010 vs 1979

Results from this study indicated some differences in fish fauna between 2010 and the Carter and MacGregor 1979 study. The 1979 study used small beach seines and gill netting as primary sampling gears leading to the recording of 23 fish species. Sampling in August 2010 used primarily a small beach seine as well as minnow traps and identified

15 species of fish. There exists a discrepancy of 8 fish species not found in more recent years (Table 6). Site selection was similar in both studies and expanded in the 2010 sampling eliminating the chance of excluding a habitat previously sampled. The sampling took place during similar times in the season.

A striking difference between the sampling methods from the two studies is the intensity of gill net use with Carter and MacGregor having approximately 200 hours of gill netting. In this study only a total of 4 hours gill netting occurred. Gill netting is important for sampling those pelagic and benthic fish species which accurately represent the species discrepancy between the studies: *Clupea harengus, Cyclopterus lumpus, Gadus morhua, Limanda ferruginea, Lumpenus maculates, Macrozoarces americanus, Scomber scombrus, Ulvaria subbifurcata, Triglops murrayi,* and *Ulvaria subbifurcata*. A benefit to increased shallow water sampling done in 2010 is the identification and confirmation of three species: *Apeltes quadracus, Gasterosteus wheatlandi,* and *Pungitius pungitius* (suspected present but never confirmed). One species that was interestingly caught in the 2010 gill netting but not the 1978 gill netting was a white hake (*Urophycis tenuis*). Based on both data sets, a total of 26 species have been identified to within St. Paul's Inlet.

St. Paul's Inlet compared to Bonne Bay

St. Paul's Inlet can be compared to other estuarine fjords located in the province of Newfoundland which can be useful in determining locations of particularly high species diversity as well as abundance. This in turn can be used in conservation methods to preserve endemic species or locations of particularly high productivity. Various studies done in Bonne Bay have documented a total of 47 fish species (Hooper, 1975; Currie et al. 2009). This almost doubles the species richness of St. Paul's which has 26 species described. Both locations have similar fjord habits having mostly rocky beaches at the base of cliffs (Carter & MacGregor, 1979; Currie et al. 2009).

The feature that makes the two fjords different is the restricted nature of St. Paul's Inlet. This causes many hydrographic differences such as a greater marine influence in Bonne Bay and negligible tidal action within St. Paul's Inlet. On average the salinities found in Bonne Bay are much more variable compared to St. Paul's Inlet (Table 8). Bonne Bay has recorded salinities at 1 metre depth that range from 1.8 ppt to 26.3 ppt where St. Paul's only ranged from 13 ppt to 24.3 ppt. This could be result of two very large freshwater tributaries that feed into Bonne Bay, Lomond River and Deer Brook, in combination with Bonne Bay's open connectivity with the ocean creating a diversity of salinity concentrations (Currie et al., 2009). St. Paul's Inlet has the 80 m restricted opening and smaller freshwater tributaries, the largest being Bottom Brook.

Cluster analysis performed on comparable 10 m beach seine data sets from this study in St. Paul's Inlet and the 2002-2008 Currie et al. study in Bonne Bay produced a dendrogram displaying significant clustering (Figure 3). Initial separation occurred at 14% similarity creating two distinct clusters: one with Bonne Bay sites 1-4 and the other with all St. Paul's sites grouped with Bonne Bay sites 3A Deer Arm barachois and 4A Lomond River delta. The Bonne Bay sites 1-4 are highly influenced by ocean and typically have higher salinity concentrations (Table 8). The Bonne Bay sites 3A and 4A are associated with large freshwater tributaries, Deer Arm and Lomond River respectively, which create a greater freshwater influenced estuarine environment. These estuarine sites cluster with all of the St. Paul's Inlet sites which suggests the Inlet in terms of species composition is comparable with a more estuarine location rather than a more marine location. The marine sites contained 10 more species not found in the estuarine sites: *Urophycis tenuis, Gadus morhua, Gadus ogac, Tautogolabrus adspersus, Pholis gunnellus, Ammodytes americanus, Hemitripterus americanus, Myoxocephalus aeneus, Myoxocephalus octodecemspinous,*and *Myoxocephalus scorpius*. The only species found exclusively at the more estuarine locations were *Apeltes quadracus* and *Pungitius pungitius*.

In estuaries Methven et al. (2001) determined that one of the most important factors for determining species abundance and composition was the seasonal variation in fish assemblages. In terms of temporal scaling it can be examined at tidal, diel, lunar, seasonal or annual scales (Laevastu & Hayes, 1981). This study took place during one month and only during the day; therefore it would be reasonable to believe several species may not have been captured in St. Paul's Inlet because they were not there due to temporal variation in species. On a monthly scale Methven et al. (2001) found that fish abundance and species present was correlated with water temperature but not with salinity or hours of daylight in Trinity Bay, Newfoundland. They found that the summer months, particularly June, July and August had highest abundance and species richness were coldest months such as December, January and February lacked many species and had lower abundances. This is an indication that the month of August may provide the best opportunity to describe all the species of fish which enter St. Paul's Inlet.

There were several problems with the employed sampling strategy which may have caused biases in the data. The first problem was the lack of replicate sampling for some locations. The sites which required long boat travel or long hikes received less sampling. For example Sites 3B and 3C located in the Eastern Arm received seven and nine minnow traps respectively where Site 2 located near the mouth of the Inlet received 34 traps. This over represents the abundance of fish at Site 4 while under representing the Eastern Arm sites. The second sampling problem was the uneven sampling intensity in terms of gear used. The deployment was mostly minnow traps, totaling 1379 hours set, and the 10 m beach seine, totaling 555 m of shoreline towed. This strongly represents the nearshore, shallow water species such as the sticklebacks (family Gasterosteidae) and juveniles residing in shallow water. Under represented were the fish residing in the pelagic and benthic region of the Inlet which could have been sampled using the gill nets and bottom trawling.

In total 15 fish species were documented during August 2010 sampling representing 9 families. Comparing this with data collected by Carter and MacGregor in 1979 which found 23 species, many species were not recaptured perhaps due to lack of gill netting done during the study. Combining the species identified between the studies yields a total of 26 species collected from St. Paul's Inlet. Analysis of the data showed a high degree of similarity in species composition between sites with the Inlet. Comparisons between data sets from this study and one in Bonne Bay (Currie et al., 2009) showed higher species diversity and higher fish abundances in Bonne Bay. Sites compared between Bonne Bay and St. Paul's Inlet showed St. Paul's sites to be most similar in species composition to sites in Bonne Bay associated with rivers and estuarine in nature. Assessments in terms of variability in species composition at sites based on salinity concentrations and habitat type yielded no significant correlation. St. Paul's fits into the western Newfoundland ecosystem as being a system with moderate fish diversity, low fish abundance and generally a less productive system.

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