THE MESOPELAGIC FISH AND INVERTEBRATE MACROZOOPLANKTON FAUNAS OF TWO NEWFOUNDLAND FJORDS WITH DIFFERING PHYSICAL OCEANOGRAPHY

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BY

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ABSTRACT

Mesopelagic fish and macrozooplankton assemblages were compared between two Newfoundland fjords which contain predominantly different deep-water masses and which differ in the nature and frequency of deep water exchange. Samples were collected using a 3 m Isaacs-Kidd Midwater Trawl in May 1982 and June 1983. The species composition of mesopelagic fishes was found to be dissimilar while the macrozooplankton fauna was largely the same. *Melanostigma atlanticum* and *Benthosema glaciale* were the most abundant fishes in Bay d'Espoir while *Mallotus villosus* was the most abundant fish collected from Fortune Bay. The macrozooplankton fauna in both fjords consisted largely of *Thysanoëssa raschii, T. inermis, Meganyctiphanes norvegica* and *Sagitta elegans*. Differences in species composition and relative abundances were partly attributed to the difference in deep water properties.

The structure and persistence of the mesopelagic fish assemblage were related to environmental stability. In Bay d'Espoir six of thirteen (46 %) species were collected in both years compared to two of eleven (18 %) species in Fortune Bay. Percentage similarity between years was high in Bay d'Espoir (91.5) and low in Fortune Bay (43.6). Species composition and rank order abundances within and between years were less variable in Bay d'Espoir than in Fortune Bay, as were catch rates for the dominant species. These results suggest that the faunal assemblage in Bay d'Espoir was regulated primarily by *in situ* biological processes while advective processes were more important in Fortune Bay. Similar results were not obtained for the macrozooplankton assemblage which was thought to respond primarily to short-term or seasonal changes in environmental conditions.

Species diversity and evenness, and average species richness of mesopelagic fishes was greater in Bay d'Espoir than in Fortune Bay. Similar results were not obtained for the macrozooplankton faunas and species diversity and evenness were higher in Fortune Bay than in Bay d'Espoir while average species richness was comparable between the fjords. These indices were not found to be useful in identifying the underlying processes structuring the fjord faunal assemblages. A comparison of biomass size spectra between the fjords showed no major differences.

The fish fauna in Bay d'Espoir was probably derived in part from the Laurentian and Hermitage Channels while that of Fortune Bay was probably derived from the St. Pierre and Hermitage Channels. A small fraction of the fish and macrozooplankton faunas in both fjords was derived from the offshore continental slope region.

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INTRODUCTION

1.1 Pelagic Zoogeography

The distributions of pelagic organisms are often strongly correlated with the physical and chemical characteristics of oceanic water masses (e.g. Pickford 1946; David 1958; Bieri 1959; Brinton 1962; Ebeling 1962; McGowan 1971, 1974; Backus *et al.* 1977). Pickford (1946), in her study of the cephalopod *Vampyroteuthis infernalis* Chun, provided one of the first concrete examples of the relationship between a species distribution and the T-S (temperature and salinity) characteristics of a water mass (see also Sverdrup *et al.* 1942). In the forty years following her publication, such a relationship has been shown to hold repeatedly for numerous taxa over a wide range of oceanographic conditions, and is a major theme underlying the study of marine zoogeography.

Many early zoogeographic studies examined the potential use of marine organisms as "indicators" of specific water masses and current systems. Chaetognaths, euphausiids, pteropods, heteropods and myctophid fishes are only a few of the organisms that were found to be useful as biological indicators of oceanographic conditions (Russell 1935, 1939; Fraser 1937, 1939, 1952; Hida 1957; Aron 1962; Ebeling 1962; Johnson and Brinton 1963). Fundamental to the concept of indicator species was a thorough knowledge of the fauna characteristic of the water mass or current system under examination.

Later zoogeographic studies were more comprehensive (e.g. Brinton 1962, Backus *et al.* 1977). Extensive oceanic surveys conducted throughout the

Atlantic, Pacific and Indian Oceans provided data on the distributional ranges of both fish and zooplankton species over wide geographical areas.

In the Pacific, major works such as those on chaetognaths (David 1958; Bieri 1959), euphausiids (Brinton 1962), and melamphaid fishes (Ebeling 1962), were instrumental in the establishment of the faunal provinces outlined by McGowan (1971, 1974). McGowan (1974) postulated that the provinces represented ecosystems, having a central core region where the fauna was essentially homogeneous. Movement towards the periphery of a province resulted in a progressive dilution of the characteristic core fauna. The areas between provinces were termed ecotones (McGowan 1974).

In the Atlantic, much work focused on the distribution of midwater fishes (Backus *et al.* 1965, 1969, 1970; Jahn and Backus 1976), culminating in the establishment of seven faunal regions for the area between the southern borders of the arctic waters and the subtropical convergence near 40°S (Backus *et al.* 1977). The establishment of these regions was based on the distribution patterns of over a hundred species of myctophid fish.

These and numerous other studies led to the development of the water mass hypothesis which proposed that species distributions coincided with the boundaries of oceanic water masses, thus making water masses the primary zoogeographic units (Fager and McGowan 1963; Haedrich and Judkins 1979). However, it is now acknowledged that few species have distributions limited to a single water mass, although they may show a greater affinity to a particular water type (Fasham and Angel 1975; Robertson *et al.* 1978). Even an area of rapidly changing oceanography, such as the Subtropical Convergence, does not constitute an impermeable boundary to pelagic organisms (Robertson *et al.* 1978). Backus *et al.* (1977) found that faunal boundaries for mesopelagic fishes were linked closely to changes in physical parameters, although the latter were in no way definitive. Faunal boundaries are often not sharply demarcated, but arise through a gradual change in species composition and abundances over a relatively large area (e.g. McKelvie 1985).

A major factor contributing to the gradation between faunal regions is expatriation, which may occur in a horizontal or vertical direction (Van der Spoel and Heyman 1983). Expatriation results when species are transported by oceanic currents beyond their optimal habitat into less favorable conditions. Once outside their optimal range, these individuals may be unable to reproduce because of stressful conditions including heavy predation, inadequate food supplies, or simply the lack of appropriate environmental cues (Ekman 1967; Boyd *et al.* 1978). The continued existence of the species in the expatriated areas depends on a constant influx of new individuals through advective mechanisms, such as continuous flow (O'Day and Nafpaktitis 1967), or the formation of cyclonic (e.g. Boyd *et al.* 1978; Wiebe and Boyd 1978) and anticyclonic rings (e.g. Wroblewski and Cheney 1984). Expatriation is known to occur in both pelagic fishes and invertebrates (Grainger 1963 ; Harding 1966; Zurbrigg and Scott 1972; Boyd *et al.* 1978; Wiebe and Boyd 1978; Cheney 1985a).

Although temperature and salinity are easily measured parameters, and may be strongly correlated with the distributional patterns of many organisms, they are not the only factors which influence a species' distribution. Dissolved oxygen concentration (Haffner 1952; Ebeling 1962; Brinton 1979), food availability (Bieri

1959), ocean currents (Jahn and Backus 1976; McGowan 1977), and thermal fronts (Backus *et al.* 1969; Haury 1984; Olson and Backus 1985) are all factors known to influence the distributions of pelagic organisms. However, the nature of these relationships is not clear and they appear to vary among regions and species. For example, the subtropical front in the Northeast Pacific does not constitute a faunal boundary for mesopelagic fishes (Willis 1984), although it appears to be an important boundary for microplanktonic groups such as coccolithophores (Okada and Honjo 1973; Honjo and Okada 1974) and radiolarians (Kling 1976). Backus and Craddock (1982) found the northern edge of the Gulf Stream to be a differential boundary for mesopelagic fishes, facilitating the movement of warm-water animals to the north. It is apparent that the parameters which interact to determine species' distributional limits are complex.

1.2 Pelagic Communities

An inherent problem in the study of pelagic zoogeography is the underlying assumption that species exist together in established communities, a problem thoroughly discussed by McKelvie (1984). In pelagic ecosystems, the question of how species assemblages are maintained is complicated, as biological and/or physical processes may interact to produce the observed patterns (McGowan 1977). Numerous studies in the Pacific Ocean have led to the belief that in an area of relatively homogeneous oceanography, such as the North Pacific central gyre, there exists a highly structured faunal assemblage regulated by *in situ* biological processes (McGowan 1974, 1977; McGowan and Walker 1979; Loeb 1979; Barnett 1983). *In situ* regulation implies that species which make up the faunal assemblage are long-term associates, co-adapted to exist together in a physically stable environment (McGowan 1977). Such a semi-closed ecosystem is characterized by a low variability in species composition and species rank order of abundance over large spatial and temporal scales (McGowan and Walker 1979; Loeb 1979, 1980; Barnett 1983).

Not all oceanic ecosystems are regulated by *in situ* events. Advective, or open ecosystems, such as the California Current (McGowan 1974), are areas where the observed faunal patterns result primarily from the large-scale horizontal advection of allochthonous material from adjacent water masses (McGowan 1974, 1977; McGowan and Walker 1979). In an advective ecosystem, it is difficult to discern how individual species might interact to form communities because the faunal composition is continuously changing. An advective ecosystem is thus characterized by large fluctuations in biomass, species composition and relative abundances over small spatial and temporal scales (McGowan 1977).

The studies of McGowan and his co-workers suggest that local oceanographic conditions are important in determining the degree of interaction among species inhabiting a given area. Relatively static, or constant, oceanographic conditions would increase interactions among species, promoting the formation of a structured, biologically regulated community. This implies that the degree of interaction among species inhabiting advective systems is too brief to be of any long-term significance. Although McGowan and Walker (1985) maintain that the regulatory mechanisms in the North Pacific central gyre are biological processes, and not physical, the mechanisms have yet to be identified.

1.3 Fjord Ecosystems

Fjords are deep, glacially carved estuaries characteristic of coastlines in high latitudes (Brattegard 1980). They are typified by a deep main basin with a shallow sill toward the seaward entrance limiting the free exchange of deep water with the sea outside (Pickard and Emery 1982). Fjords are often highly stratified and the internal circulatory pattern is driven by a brackish outflowing surface layer counterbalanced by a deeper inflowing saline layer (Farmer and Freeland 1983).

A common feature of all fjords is that they are subject to periodic renewal of the water below sill depth. A number of studies have investigated factors which regulate deep water renewal in fjords (e.g. Pederson 1978; Gade and Edwards 1980; de Young 1983; Farmer and Freeland 1983) and the results indicate that the process is highly variable. In general, deep water renewal occurs when the external water at and above sill depth is at a greater density than resident water inside the fjord (Farmer and Freeland 1983). The forcing mechanism which drives the denser water across the sill may be long-term, such as seasonal changes in wind speed and direction (de Young 1983), or short-term, such as tidal cycles (Gade and Edwards 1980). Depending upon the density differential between the external and resident water masses, the renewal may be partial or complete.

Fjords offer an unusual combination of physical, topographical and biological characteristics. Geomorphologically, they are well defined entities and constitute relatively semi-enclosed ecosystems (Brattegard 1980). They are subject to less environmental variability than the adjacent coastal and oceanic areas but possess similar basic biological properties (Eilertsen *et. al.* 1981). Biological processes occurring in fjords can, in some instances, be regarded as representative of similar larger-scale processes in the open ocean (Eilertsen *et al.* 1981).

The fauna in deep (~ 400 m) fjords is often a mixture of local representatives and species found at similar depths elsewhere in the ocean (Brattegard 1980). Some of these species exist at a considerable distance from the open coast and to a large extent are isolated from oceanic stocks (Matthews and Heimdal 1980). However, this is not true in all cases, and recruitment to local stocks has been shown to occur through the advection of external water sources across the fjord sill (Matthews 1973; Sands 1980; De Ladurantaye *et al.* 1984).

The relative ease with which physical and biological data can be collected in fjords has led to several large interdisciplinary studies of fjord ecosystems. Two examples are the Balsfjord Project at the University of Tromso, Norway (see Eilertsen *et al.* 1981), and the Korsfjord Project at the University of Bergen, Norway (see Matthews and Sands 1973). The general developmental scheme for these projects involves an initial study of the topography and oceanography of the fjord followed by studies of the biological parameters, including primary productivity (Hopkins 1981; Eilertsen and Taasen 1984), zooplankton population dynamics (Matthews 1973; Matthews and Pinnoi 1973; Jörgensen and Matthews 1975; Bakke 1977; Sands 1980; Falk-Peterson and Hopkins 1981; Tande 1983), trophic organization, and the transfer of energy in pelagic fjord ecosystems (Matthews and Bakke 1977, Hopkins 1981).

These studies have provided valuable information on the complex interactions among species in the pelagic ecosystem, a feat difficult to accomplish in more open-oceanic areas because of the time and expense involved in the collection of samples and the increased variability in environmental conditions.

1.4 Objectives and Hypotheses

Most zoogeographic studies examine the variability in species distributions over vast areas of the ocean. The area sampled ranges from scales of hundreds (e.g. Barnett 1983), to thousands (e.g. Aron 1962; Backus *et al.* 1970; Jahn and Backus 1976; Willis 1984; McKelvie 1985), to tens of thousands (e.g. Backus *et al.* 1977) of kilometers. There is little real potential for faunas in the areas sampled to be similar in species composition because of the wide area sampled and the number of different water masses and/or current systems transgressed.

In the present study, I examine the mesopelagic fish and macrozooplankton faunas of Bay d'Espoir and Fortune Bay, two fjords located off the southern coast of Newfoundland, Canada. The fjords, separated by a distance of only 40 km, contain predominantly different deep water masses, yet have similar near-surface water properties above sill depth (de Young 1983; Richard and Hay 1984). The deep water mass in Bay d'Espoir is relatively warm and saline, while the deep water mass in Fortune Bay is predominantly cold and fresh, with a pronounced seasonal warm water component. The two fjords also differ in the nature and frequency of deep water exchange.

The close proximity of the fjords and their similar near-surface water properties implies that there is a real potential for the deep water, or mesopelagic, faunas to be the same. This is especially true considering that a large majority of mesopelagic species have larval stages which are almost entirely epipelagic (Haedrich and Judkins 1979). Larvae of mesopelagic species in both fjords would have similar dispersal routes. A comparison of the mesopelagic faunas between the fjords could provide an indication of the relative importance of local oceanographic conditions, such as temperature, salinity, and the frequency and dynamics of deep water renewal, in determining the composition and persistence of the resident fauna.

The first objective of my thesis is to examine how the species composition and relative abundance of mesopelagic fishes and macrozooplankton are influenced by the local oceanographic conditions in Bay d'Espoir and Fortune Bay. My hypothesis is that the fjords should contain predominantly different species assemblages with warm-water species more abundant in Bay d'Espoir and cold-water species more abundant in Fortune Bay.

Secondly, I will compare the structure and persistence of the faunal assemblage in Bay d'Espoir with that in Fortune Bay and comment on the relative importance of biological and physical processes in structuring the assemblages. My hypothesis is that advective processes will be more important in structuring the faunal assemblage in Fortune Bay due to the dynamic nature of deep water renewal in that fjord. In Bay d'Espoir, where deep water renewal is an annual event and the properties of the deep water mass remain relatively homogeneous, biological processes should play a greater role in structuring the faunal assemblage. The faunal assemblage in Fortune Bay should be characterized by higher spatial and temporal variability in species composition, relative abundance, and biomass than the assemblage in Bay d'Espoir.

I will also examine several community parameters such as the species diversity and evenness, average species richness, and biomass, of the faunal assemblages to see what information they may provide regarding processes structuring the fjord faunas. In general, physically static ecosystems are characterized by a high species diversity while physically dynamic ecosystems have a low species diversity (Rainer 1981). Timonin (1971) found that plankton communities in upwelling regions of the Indian Ocean were characterized by a low species diversity and high biomass, while areas where the water column was typically stratified had a high species diversity and low biomass. The faunal assemblage in Fortune Bay should therefore be characterized by a lower species diversity and higher biomass compared to that in Bay d'Espoir.

The difference in the nature of water mass renewal between the fjords should also be reflected in the size frequency distribution (biomass size spectra) of the faunal assemblages. My hypothesis is that in an area of frequent perturbations, such as Fortune Bay, there should be a smaller-sized faunal assemblage than in Bay d'Espoir. In general, smaller size coincides with a shorter life span, and individuals are better able to complete their life cycle in the time interval between disturbances. This has been proposed as the reason for the successful exploitation of Gulf Stream rings by the myctophids, *Hygophum benoiti* (Cocco), and *Lampanyctus pusillus* (Johnson), (Backus and Craddock 1982). In Bay d'Espoir, where the water column is typically stratified and static, a greater proportion of the faunal assemblage should consist of larger individuals.

Finally, I will compare the faunas in Bay d'Espoir and Fortune Bay to those of the confluent Hermitage, Laurentian and St. Pierre Channel systems, and I will comment on possible faunistic links between the fjords and external water masses.

DESCRIPTION OF STUDY AREA

2.1 Topography

The study area is located off the south coast of Newfoundland, Canada, and consists of two fjords, Bay d'Espoir and Fortune Bay, and the associated Laurentian, Hermitage and St. Pierre Channel systems (Fig. 1).

The Laurentian Channel is a deep trench extending from the edge of the continental shelf to the Gulf of St. Lawrence. The channel is approximately 1200 km long and separates the Grand Banks from the Scotian Shelf. Southeastward from Cabot Strait, the channel depth varies from 400 to 600 m.

An eastward branch of the Laurentian Channel, Hermitage Channel, is oriented along a SW-NE axis leading directly into Hermitage Bay and Bay d'Espoir. Hermitage Channel is approximately 137 km long and 40 km wide, and has a mean depth of 200 m. The channel has a maximum depth of about 375 m.

St. Pierre Channel is located to the southeast of Fortune Bay, parallel to the long axis of the Burin Peninsula. It is a relatively large, shallow trough, approximately 275 km long and 45 km wide, and has a mean depth of 120 m (de Young 1983). Southeast of the island of St. Pierre the channel divides into two branches which run east into Fortune Bay and west into Hermitage Channel. Both branches are relatively shallow and depths do not exceed 146 m.

2.1.1 Fortune Bay

Fortune Bay is a relatively large fjord located approximately 40 km to the southeast of, and roughly parallel to, Bay d'Espoir (see Fig. 1). The fjord is bounded by the Burin Peninsula to the east, the French islands of St. Pierre and Miquelon to the south, and Hermitage Channel to the west. Fortune Bay is approximately 137 km long and 40 km wide, and has a mean depth of 120 m (de Young 1983). The maximum depth of 526 m occurs at the head of the fjord, in Belle Bay.

Fortune Bay has three outer sills and one inner sill. Two of the outer sills are located adjacent to Hermitage Channel on the northwestern edge of the bay. They are referred to as the Miquelon and Sagona sills, at depths of 125 m and 115 m, respectively. The third sill, referred to as the St. Pierre sill, has a depth of 100 m and is located to the southwest in St. Pierre Channel. The inner sill is approximately 195 m deep and separates Belle Bay from the main basin of the fjord.

The main source of freshwater in Fortune Bay is the Bay du Nord River which empties into Belle Bay. The mean annual flow of the river is estimated at 39.7 m^3sec^{-1}, with periods of increased flow in the spring and fall (de Young 1983). The average total freshwater flow into Fortune Bay is approximately 100 m^3sec^{-1}, or $3 \times 10^9 m^3yr^{-1}$ (de Young 1983).

2.1.2 Bay d'Espoir

Bay d'Espoir is a deep, narrow, fjord consisting of an outer basin connected to two principal arms (Fig. 2). The first arm extends north from the outer basin, and shoals to form two subsidiary bays, North Bay and East Bay. The distance from the mouth of the fjord to the head of North Bay is approximately 26 km. The second arm branches eastward from the outer basin and is oriented along a SW-NE axis. Bois Island separates two passages: Lampidoes Passage and South Bois Island Passage. These passages coalesce north of the island and continue for approximately 21 km to the head of the bay at St. Alban's. The distance from the mouth of the fjord to the head of the eastern arm is approximately 50 km. Maximum water depth in the outer basin is 773 m, considerably deeper than in either of the two principal arms. Bottom depths in the northern arm are less than 350 m while in the eastern arm the maximum depth is 280 m, in Lampidoes Passage.

The main sources of freshwater are outflow from the Bay d'Espoir power plant, Conne River and Southeast Brook, which drain into the eastern arm of the fjord in the headwater region near St. Alban's. The combined flow from these three sources is estimated to vary between 16.2 and 23.2 m^3sec^{-1} during the summer months (Anon. 1980). Fresh-water input in the northern arm is derived from the d'Espoir Brook and Salmon River. The inflow from these two sources has not been measured.

Bay d'Espoir has one outer sill and nine inner sills. The outer sill, Hermitage Sill, is located at the head of Hermitage Channel at a depth of approximately 280 m. Eight of the nine inner sills are dispersed throughout the eastern arm of the fjord. The remaining sill is located midway between the channel connecting the eastern arm of Bay d'Espoir and Hermitage Bay.

2.2 Physical Oceanography

The physical oceanography in the region off the south coast of Newfoundland is influenced by two distinct water types: Modified Slope Water (MSW) and Labrador Current Water (LCW). MSW is formed in the continental shelf region by mixing of the Labrador Current and Slope Water masses (McLellan 1957). This water type is relatively warm and saline, characterized by a temperature of 4 to 6°C and a salinity of 34.5 °/oo (parts per thousand). MSW is transported to the Bay d'Espoir - Fortune Bay region through the Laurentian and Hermitage Channels, where it is present below 150 m (Lauzier and Trites 1958; Lively 1983; de Young 1983).

LCW in comparison, is cold and of low salinity, characterized by temperatures of -0.5 to -1.0°C and a salinity of 33 °/oo. It is transported to the south coast of Newfoundland primarily through the Avalon and St. Pierre Channels to the east (Petrie and Anderson 1983), but augmented by flow through the Strait of Belle Isle to the northwest (Garrett and Petrie 1981; Petrie and Anderson 1983). Estimations of the volume transport of the Labrador Current in Avalon Channel have varied from $4 \times 10^5 m^3 s^{-1}$ (Petrie and Anderson 1983) to $6 \times 10^5 m^3 s^{-1}$ (Smith *et al.* 1937). de Young (1983) estimated a transport of $6.4 \times 10^4 m^3 s^{-1}$ for the Labrador Current in St. Pierre Channel.

LCW is also present in Laurentian and Hermitage Channels. de Young (1983) detected a strong, but variable, inflow of LCW along the southeastern side of Hermitage Channel at intermediate depths above 150 m. This water arrives in part through the St. Pierre Channel (de Young 1983) and also through the Laurentian Channel (Petrie and Anderson 1983).

2.2.1 Fortune Bay

Fortune Bay has three outer sills and two independent sources of deep water (de Young 1983). The deep water sources are the warm and saline MSW of Hermitage Channel and the cold and relatively fresh LCW of the Avalon and St. Pierre Channels (Lively 1983; de Young 1983). The water mass resident inside the fjord at any given time is a mixture of these two sources, with water properties reflective of the mixing ratio. A typical temperature and salinity profile for the fjord at the time of sampling during the present study is shown in Fig. 3.

The physical oceanography of Fortune Bay, with particular emphasis on deep water renewal processes, was examined by de Young (1983). Deep water renewal in Fortune Bay occurs bi-annually, in the winter and in the summer (de Young 1983). In the winter, the deep-water mass inside the fjord is replaced by MSW. This process is correlated with a seasonal increase in wind speed and a shift in wind direction along the south coast of Newfoundland (de Young 1983). Strong northerly and northeasterly winds generate upwelling in Hermitage Channel resulting in the transport of MSW over the Miquelon and Sagona sills and into Fortune Bay. The inflowing MSW is warmer and more dense than the resident water mass and sinks to the bottom of the fjord. Following this inflow, maximum temperatures of between 2 and 2.5°C occur in the deep water of the fjord. The transport of MSW into Fortune Bay occurs only during the winter. Throughout the remainder of the year a continuous inflow of MSW into the fjord is prevented by the shallow depth of the Miquelon and Sagona sills (< 125 m).

During the summer, deep water replacement occurs via an inflow of LCW over the St. Pierre sill. This inflow is described by de Young (1983) as a tidally modulated, density current inflow with maximum inflow at flood tide and minimum inflow at ebb tide. Coincident with inflowing LCW, temperatures near 0°C often occur throughout the water column in the outer basin of the fjord.

The result of these two independent water sources, each having markedly different water properties, is that deep water renewal in Fortune Bay is accompanied by intense vertical mixing of the water column (de Young 1983). Stratification may occur in deeper water, below 150 m, but it is weak compared to that in Bay d'Espoir. The change in σ_t values with depth was compared between two stations for the deep water (> 150 m) in Fortune Bay and the deep water (> 300 m) in Bay d'Espoir. Sigma-*t* increased by 7.4×10^{-4} units m^{-1} in Fortune Bay compared to 4.8×10^{-5} units m^{-1} in Bay d'Espoir.

2.2.2 Bay d'Espoir

The circulation of Bay d'Espoir is such that the outer and inner (Lampidoes Passage) basins differ markedly both in water properties and in the nature and frequency of deep water exchange (Richard and Hay 1984). Following is a brief description of the oceanography of the outer basin, the focal area in the present study.

The water column of the outer basin is well-stratified and consists of three layers: a near-surface layer, an intermediate depth cold-water (IDCW) layer, and a deep layer. The near-surface layer is influenced by surface heating and cooling and fluctuations in the volume of freshwater runoff. It often encompasses the upper 20 m of the water column, although the thickness varies both temporally and spatially. It is generally impossible to distinguish between the near-surface and IDCW layers during the winter due to wind induced vertical mixing.

The IDCW layer occurs between depths of approximately 20 and 150 m and is derived from two independent sources: LCW and winter-cooled surface water. The volume of LCW in the intermediate depth layer varies with the volume transport of LCW to the south coast of Newfoundland. This transport is highly variable as illustrated by de Young (1983), who detected an outflow of LCW from St. Pierre Channel into Hermitage Channel of 5.2 x $10^4 m^3 sec^{-1}$ in May 1982. A similar outflow was not detected in May 1983.

Much of the IDCW layer is formed locally during the winter months by wind-induced vertical mixing in the upper water column. Mixing in the upper water column contributes to the formation of the IDCW layer in the Gulf of St. Lawrence (El-Sabh 1973, 1977; Dickie and Trites 1983), and can result in uniformly cold water ($< 0°C$) to depths of 125 m. Water temperatures in the IDCW layer are lowest during the spring when the layer reaches its maximum thickness (> 100 m).

The deep layer is comprised of warm and relatively saline MSW. T-S diagrams show this layer to be a consistent feature in the outer basin below 200 to 300 m, although warm water (4°C) is found as shallow as 175 m in the spring and early summer (Richard and Hay 1984). A temperature and salinity profile typical of Bay d'Espoir at the time of sampling during the present study is shown in Fig. 4.

Deep water renewal in the outer basin is thought to occur each spring, although it may be only partial. The forcing mechanism is believed to be the same as that in Fortune Bay during the winter - strong northerly and northeasterly winds (Richard and Hay 1984). However, unlike Fortune Bay, deep water renewal in Bay d'Espoir involves only the MSW mass and the deep (280 m) outer sill permits a continuous inflow of MSW into the fjord above sill depth. At the time of deep water renewal it is MSW of a greater density that replaces the resident water in the deep outer basin.

MATERIALS AND METHODS

3.1 Sampling Program

Forty-one samples were collected with a 3 m Isaacs-Kidd Midwater Trawl (IKMT) aboard the CSS Dawson in May 1982 and June 1983: 14 in Bay d'Espoir, 15 in Fortune Bay, 7 in Hermitage Channel, 4 in Laurentian Channel, and 1 in St. Pierre Channel (Table 1). Sampling stations in Bay d'Espoir and Fortune Bay are shown in Fig. 5. The net had an approximate mouth opening of 8 m^2, a 10 mm mesh stretch liner and a codend mesh of 471 μm. The IKMT was fished open at all times, generally at a ship speed of between 2.0 and 2.5 knots. Although the net was not equiped with an opening-closing device, fishing was minimal during launching. All tows were horizontal and ranged from 27 to 91 min. in duration. The total time fished was measured as the time interval between stopping paying wire out until the net was hauled on deck. The net was retrieved at a rate ranging from 7 to 50 m min^{-1}. Fishing depths for the May 1982 collections were estimated using the meters of wire payed out and assuming a wire angle of 45°. In June 1983, a Benthos time-depth recorder (model number 1170-1000) was used to record sampling depth.

The sampling program consisted of a series of horizontal tows made at discrete depths. Together these tows provided an integrated sample of the water column. Sampling depths ranged from 212 to 636 m in Bay d'Espoir, and from 50 to 424 m in Fortune Bay. In the selection of sampling depths consideration was given to the fact that most mesopelagic fishes (Badcock 1970; Badcock and

Merrett 1976) and invertebrates (Roe 1974) undergo diurnal vertical migrations. Backus *et al.* (1970) reported that few mesopelagic fishes were collected during the day at depths shallower than 200 m while most species migrated to depths shallower than 300 m at night. In the present study day tows were generally made at depths greater than 200 m. Night tows were generally shallower than 300 m, although in Bay d'Espoir several night tows were made between 300 and 500 m. The adjustment of sampling depth, according to the time of sampling, was an attempt to maximize the number of animals collected. Tows were designated as being "night" or "day" tows based on the time of collection. Night tows were those made in the time interval between one-half hour after sunset and one-half hour before sunrise while day tows were those made in the time interval between one-half hour following sunrise and one-half hour before sunset. Tows made in the time interval one-half hour before and after sunrise and sunset were designated "dawn" and "dusk" tows, respectively.

All fish and most macrozooplankton were saved. The samples were preserved in 4 % formaldehyde buffered with borax and later stored in 70 % ethanol. At stations where only representative samples of the macrozooplankton could be kept because of large catches, the proportion of the sample discarded was estimated volumetrically using a sieve or sorting tray. In 1982 only qualitative collections of macrozooplankton were made at stations 1208 to 1212 in Bay d'Espoir and data from these stations were used only when calculating species richness.

3.2 Laboratory Processing

3.2.1 Fish

Larval, juvenile and adult fishes were counted and identified to species whenever possible. Fishes not identified to species were generally those in poor condition. Larval fish were categorized as fish which did not possess the full complement of adult characteristics. Following Fahay (1983), larval fish of the genus *Ammodytes* were not identified to species, and the same was done for larval redfish, *Sebastes*. Larval fish are not discussed herein, although a list of the species collected is given in Appendix A. Adult and juvenile specimens are discussed collectively in this study. Juvenile specimens were distinguished from adults primarily on the basis of length.

All juvenile and adult specimens were individually weighed (wet weight, ± 0.01 g) on a Mettler digital balance (model PE3600) and measured (± 0.05 mm) with dial calipers. For individuals exceeding 100 mm in length, measurements were accurate to only ± 1.0 mm. Standard length (SL) was recorded for all individuals, with the exception of *Melanostigma atlanticum* Koefoed and species of the genus *Paraliparis* for which total length (TL) was measured.

Literature used in identification of juvenile and adult fishes included: Nafpaktitis *et al.* (1977) for Myctophidae; Mukhacheva (1964), Kobayashi (1973), and Badcock (1982) for Gonostomatidae; McAllister and Rees (1964), and Leim and Scott (1966) for Zoarcidae; Leim and Scott (1966) for Osmeridae, Pleuronectidae, Scorpaenidae, and Stichaeidae; Able and McAllister (1980) for Liparidae; and Marshall and Iwamoto (1973) for Macrouridae. Most larval fish were identified using Fahay (1983).

3.2.2 Macrozooplankton

In the present study, the macrozooplankton consisted of representatives from seven major groups of zooplankton. These were: amphipods, chaetognaths, euphausiids, mysids, pelagic polychaetes, pteropods and shrimp. Although many copepods and gelatinous zooplankters are members of the macrozooplankton (see Parsons *et al.* 1984) they were not included in this study. Macrozooplankton were identified only from samples collected in Bay d'Espoir and Fortune Bay. Species comprising more than 1 % of the total number of macrozooplankton collected from each fjord were categorized as common.

Subsampling was used to obtain estimates of the total number of animals collected per trawl for the more abundant species, while shrimp, the euphausiid *Meganyctiphanes norvegica* (M. Sars), and most rare species were enumerated in full. Occasionally, juvenile specimens of the shrimp *Pasiphaea multidentata* Esmark and *M. norvegica* were found in the subsamples, but this did not seriously influence the population estimates.

Prior to subsampling, all samples were sorted manually to remove large and rare specimens. Initial splits were made by dividing the sample into equal aliquots, using beakers, until a suitable volume (~ 300 ml) for use in a Folsom plankton splitter was obtained. This device was then used to split the remaining portion of the sample.

To ensure that all specimens were enumerated with equal precision, a predetermined level of sampling error was chosen based on Alden *et al.* (1982). In the present study an error of 15 % was chosen. This required counting a minimum of 144 individuals of each species per sample. If the required number of individuals did not occur in the first split, more concentrated splits were examined until the appropriate number was obtained. In some cases, the exceedingly low densities of the rarer species (relative to the more abundant species) made it impractical to count the number of individuals necessary to maintain the chosen sampling error. In these cases an error greater than 15 % occurred.

Estimates of the number of animals collected, variance, standard deviation and 95 % fiducial limits were calculated for each species in each sample, using formulae from Horwood and Driver (1976) (see Appendix B). Wet preserved biomass was measured for all macrozooplankton species examined as total weight per species per station. At most stations the wet weight biomass of the remaining portion of the zooplankton sample consisting primarily of copepods and gelatinous zooplankton, and hereafter referred to as the miscellaneous zooplankton, was also measured. The total wet weight of the macrozooplankton and the miscellaneous zooplankton together comprised the total zooplankton biomass. Miscellaneous zooplankton was measured at all stations in Fortune Bay with the exception of station 1413 and all stations in Bay d'Espoir with the exception of stations 1419, 1420, 1424 and 1426.

Literature used in identification of macrozooplankton species included Allen (1967), Rice (1967), and Smaldon (1979) for Pasiphaeidae, Pandalidae, and Sergestidae; Einarsson (1945), and Mauchline (1971) for Euphausiidae; Tattersall (1951); Tattersall and Tattersall (1951), and Brunel (1960) for Mysidae; Dunbar (1963) for Hyperiidae; Fraser (1952, 1957) for Chaetognatha; Muus (1953), and Stop-Bowitz (1948) for Tomopteridae; and Morton (1957) for Clionidae.

3.3 Data Analysis

The overall catch rate of individual fish species in each fjord was calculated by dividing the total number of individuals collected per species by the total time fished and converting this to number per hour. The overall catch rate for all fishes in each fjord was calculated by dividing the total number of all fishes collected by the total time fished and converting this to number per hour. Catch rates of fishes and also macrozooplankton were determined separately for collections in 1982 and 1983 by dividing the total number of individuals collected per species per year by the total time fished in each year and converting this to number per hour. Biomass per hour per year was also calculated in this manner.

Catch rates by depth strata were determined separately for the fish and macrozooplankton species in Bay d'Espoir and Fortune Bay. Tows within each fjord from both years were combined and then grouped into day and night collections within 100 m depth intervals. Tows which were started at dusk and completed at night were included with the night collections, while tows which began at dawn and were completed by day were grouped with the day collections. The catch rate for each species was then calculated by dividing the total number of specimens collected by the combined time for all tows within a given depth interval, and converting this to the number collected per hour. The catch rate was then log transformed using $\log_{10}(x + 1)$ where x is the catch rate per species per depth stratum.

Several community parameters were measured for both the fish and macrozooplankton faunas. Percent similarity (Jahn and Backus 1976) was used to measure the overall degree of similarity between collections in 1982 and 1983. Percent similarity (PS) was calculated as follows:

$$PS = 100 - 0.5 \sum_{n=1}^{n} |p_{ij} - p_{ik}|,$$

where p_{ij} and p_{ik} are percentages of the *i*th species in the *j*th and *k*th data sets. The range of values for PS is from 0 (total dissimilarity) to 100 % (total similarity).

Species diversity (H') was measured by the Shannon-Wiener index (Green 1979):

$$H' = -\Sigma\, p_i \ln p_i,$$

where p_i is the proportion of the sample comprised of individuals of the *i*th species.

Species evenness (E) was measured by the Heip Index (Heip 1974):

$$E = (e^{H} - 1)/(S - 1),$$

where H is the diversity (measured by the Shannon-Wiener index) and S is the number of species.

Species richness was calculated as the number of species collected per sample while average species richness was calculated as the mean number of species collected in all samples from a given depth interval or area. Catch per unit effort (CPUE) was calculated as the total preserved wet weight of all species (fishes and macrozooplankton separately) collected in a given area divided by the total time fished. CPUE is expressed as grams preserved wet weight collected per minute fished.

To determine whether species collected in both fjords differed in relative abundance, catch rates were compared using a Mann-Whitney U-test (Sokal and Rohlf 1981). The analysis was performed using individual station data standardized by converting to number per hour. Catch rates of macrozooplankton species collected from both fjords were compared only if greater than 30 individuals was encountered during the sorting and splitting of the samples in at least one fjord. This number was chosen arbitrarily and was used to remove "rare" species from the analysis. Catch rates of fish species were compared only when there was more than one record of occurrence from each fjord. The analysis was performed using the SPSSX statistical analysis package (Anon. 1983), on the Vax 11/780 at Memorial University of Newfoundland.

PS and Spearman rank correlation coefficients were used to measure the degree of similarity in species relative abundances and species rank order of abundances among stations within and between years in Bay d'Espoir and Fortune Bay. PS values were calculated as above. The frequency distribution of PS values for all station pairs in each fjord was examined. PS values for the macrozooplankton faunas appeared to be normally distributed, while those for the fish faunas were skewed. As a result, a t-test was used to compare PS values between fjords for the macrozooplankton faunas while a Mann-Whitney U-test was used to compare PS values between fjords for the fishes. A Mann-Whitney U-test was also used to compare PS values of day station pairs and night station pairs between fjords for the macrozooplankton. All analyses were conducted using the SPSSX statistical analysis package (Anon 1983) on the Vax 11/780 at Memorial University. *Nezumia bairdii* (Goode & Bean) was not included in the calculations of PS and Spearman rank correlation coefficients in Bay d'Espoir because it is a demersal species (Leim and Scott 1966).

Composition according to higher taxonomic group (i.e. fish, shrimp, euphausiids, mysids, amphipods, chaetognaths, pteropods, polychaetes; hereafter referred to as group-composition) was determined separately for the fauna in Bay d'Espoir and Fortune Bay. Group composition was measured by determining the percentage of the total fish plus macrozooplankton preserved wet weight biomass contributed by each of the major taxonomic groups and the number of species contained within each group.

Biomass size spectra were also determined for the faunal assemblages in Bay d'Espoir and Fortune Bay. To calculate the biomass size spectrum, the mean preserved wet weight for each species was calculated by dividing the total preserved wet weight of the species by the total number of specimens collected, and converting this value to $\log_2$. Using the converted mean weight, species were placed in $\log_2$ weight size classes. The total preserved wet weight of all species within a given weight size class was determined and expressed as a percentage of the total fish and macrozooplankton preserved wet weight collected.

Only 1983 data were used in determining the group composition and biomass size spectra. This was because the sampling program in the fjords was more extensive in 1983 and also because of large between year differences in the catch rates of several species.

RESULTS

4.1 Species Composition and Relative Abundances

4.1.1 Fish Fauna

In Bay d'Espoir a total of 913 fishes representing 8 families and at least 13 species was identified (Table 2). The most abundant species was a zoarcid, *Melanostigma atlanticum*, which occurred in all collections and accounted for 53.7 % and 36.0 %, by number and weight respectively, of the fish fauna. Several species typically associated with the open ocean were also collected. These were *Benthosema glaciale* (Reinhardt), *Chauliodus sloani* Bloch and Schneider, and five species belonging to the genus *Cyclothone*. *B. glaciale* was the second most abundant species, occurring in all collections and accounting for 39.3 % of the total number and 42.4 % of the total weight.

In Fortune Bay, 592 individuals were collected representing eight families and at least eleven species (Table 3). The fauna consisted almost entirely (96.3 % by number, 93.8 % by weight) of juvenile capelin, *Mallotus villosus* (Müller), although they occurred in only five of the 15 collections made. Excluding the large numbers of capelin (n = 570), the fauna was numerically depauperate, with nine fish collected in 1982, and 13 in 1983.

Most of the juvenile capelin collected in Fortune Bay were from a series of four consecutive samples made between 0 and 300 m at night (Fig. 6). Adult capelin were not collected in the fjord. Six of the remaining species were also represented only by juvenile specimens (Table 3). Four of these species, *Myoxocephalus octodecemspinosus* (Mitchill), *M. scorpius* (Linnaeus), *Hippoglossoides platessoides* (Fabricius) and *Ammodytes* spp. were collected above 200 m. Average species richness for all collections in Fortune Bay was 1.5.

In Bay d'Espoir *Melanostigma atlanticum* and *Benthosema glaciale* were distributed throughout the water column during day and night (Fig. 7) and both juveniles and adults were collected. Only one species, *Pollachius virens* (Linnaeus), was represented solely by juvenile specimens (Table 2). However, as in Fortune Bay, most species in Bay d'Espoir were collected sporadically and in low numbers. Average species richness for the collections was 4.2 and the greatest number of species (7) occurred at day, between 500 and 600 m and at night between 200 and 300 m.

Most species collected from Bay d'Espoir were not collected from Fortune Bay. Only four species, *Benthosema glaciale*, *Cyclothone braueri* Jespersen & Taning, *C. alba* Brauer, and *Sebastes* spp. were collected from both fjords. To determine if catch rates for these species were significantly different between the fjords, a Mann-Whitney U-Test was performed. *C.alba* and *Sebastes* spp. were not included in the analysis because there was not more than one record of occurrence from each fjord. The results of the test showed that catch rates of *B. glaciale* were significantly greater in Bay d'Espoir than in Fortune Bay ($U_s = 0.0$, $n = 15,12$, $p < 0.0001$) although there was no significant difference in catch rates of *C. braueri* between the fjords.

Overall, the degree of similarity between the fjord faunas was found to be 1.8 using the PS index. The low value obtained in comparing the fish faunas of

Bay d'Espoir and Fortune Bay reflects the differences in species composition between the fjords.

4.1.1.2 Regional Comparisons

The fish faunas of Bay d'Espoir and Fortune Bay were compared with those of the Hermitage, Laurentian and St. Pierre Channels to examine the relationship between the fjord faunas and those of the adjacent regions. The comparison showed that the fish faunas in all five regions were dominated by one or two abundant species (Table 4). Only four species, *Benthosema glaciale*, *Cyclothone alba*, *C. braueri*, and *Mallotus villosus*, were collected from more than two regions while most species were recorded in only one region. *Melanostigma atlanticum*, the most abundant species in Bay d'Espoir, was not collected from any other region sampled.

The most abundant species in the Laurentian and Hermitage Channels was *Benthosema glaciale*, which was collected in all regions except St. Pierre Channel. *B. glaciale* was prominent in Bay d'Espoir, ranking second in overall abundance, but in Fortune Bay comprised less than 1 % of the fish fauna. *Mallotus villosus* was the most abundant fish in Fortune Bay and St. Pierre Channel and ranked second in abundance in Hermitage Channel. *M. villosus* was not collected in Bay d'Espoir or Laurentian Channel.

PS values were calculated to compare the overall degree of similarity among the fish faunas of all regions (Table 5). The fauna of Bay d'Espoir was most similar to those of the Hermitage and Laurentian Channels and almost totally dissimilar to those of Fortune Bay and the St. Pierre Channel. The fauna in

Fortune Bay was highly similar to that of the St. Pierre Channel, although this comparison is based on a single sample from the St. Pierre Channel. The Hermitage Channel fauna was moderately similar to those of all regions.

4.1.2 Macrozooplankton Fauna

The macrozooplankton fauna in Bay d'Espoir was characterized by five common species (Table 6). These were, listed in order of decreasing abundance, *Thysanoëssa raschii* (M. Sars), *T. inermis* (Krøyer), *Sagitta elegans* Verrill, *Meganyctiphanes norvegica*, and *Eukrohnia hamata* (Mobius). These species occurred in all of the collections and accounted for 98.4 % by number and 87.4 % by weight of the fauna sampled. The six species, *Pasiphaea multidentata*, *Sergestes arcticus* Krøyer, *S. maxima* (Conant), *T. longicaudata* (Krøyer), *Boreomysis arctica* (Krøyer), and *Tomopteris helgolandica* Greeff, occurred in at least 70 % of the collections although in low numbers relative to the common species. Most of the remaining species were patchy in distribution and were collected in low numbers (see coefficient of dispersion values given in Appendix C). Two species, *Pandalus montagui* Leach, and *Gennadas elegans* (Smith), occurred only in the deepest day collection while seven species, including *Boreomysis tridens* G.O. Sars, *Mysis mixta* Lilljeborg, and *Pseudomma truncatum* S.I. Smith, were collected only at night (Fig. 8). Average species richness for the macrozooplankton collections from Bay d'Espoir was 13.6.

Seven species were common in the macrozooplankton collections from Fortune Bay (Table 6). These were, in order of decreasing abundance, *Thysanoëssa raschii*, *Sagitta elegans*, *T. inermis*, *Meganyctiphanes norvegica*, *Parathemisto gaudichaudii* (Guerin), *Eukrohnia hamata*, and *T. longicaudata*.

These species occurred together in all fifteen collections, accounting for 98.8 % and 93.9 % of the macrozooplankton fauna, by number and weight, respectively. Several other species occurred consistently although in low densities. These were *Halirages fulvocinctus* (M. Sars), *Parathemisto abyssorum* Boeck, *Mysis mixta*, *Clione limacina* (Phipps), and *Tomopteris helgolandica*. As in Bay d'Espoir, most macrozooplankters in Fortune Bay were patchy in distribution with coefficients of dispersion much greater than one (see Appendix D).

Catch rates by depth strata (both years combined) for macrozooplankters collected from Fortune Bay are shown in Fig. 9. High catch rates were obtained for all common species, at all depths sampled, both day and night. Nine species were collected only at night, and the mysid, *Boreomysis nobilis* (G.O Sars), occurred in much greater numbers at night than day. Most species of amphipods and mysids were collected in the upper 200 m at night and, with the exception of *Boreomysis arctica* and *Parerythrops obesa* (G.O. Sars), all occurred above 300 m. Average species richness was 14.0 and species richness tended to increase with depth and also at night. This trend could not, however, be verified statistically because of the small number of samples collected from any given depth stratum.

4.1.2.1 Between Fjord Comparisons

To compare the macrozooplankton faunas between the fjords three separate species groups were identified. The first group contained those animals which were collected from one fjord but not the other. *Pasiphaea multidentata* and *Boreomysis arctica* have been included in this group because they were collected in large numbers from Bay d'Espoir (n = 438 and n = 510, respectively) compared to one individual of each species collected from Fortune Bay. Eleven species collected in Fortune Bay were not collected from Bay d'Espoir, and nine species in Bay d'Espoir were not collected from Fortune Bay (Table 7). Species collected only from Fortune Bay primarily belonged to the amphipod and mysid groups, while those recorded only from Bay d'Espoir were mostly decapod shrimp and pelagic polychaetes. None of these species were common members of the macrozooplankton fauna in either fjord. However, three species from Bay d'Espoir, *Pasiphaea multidentata*, *Sergestes arcticus* and *Boreomysis arctica* and one species from Fortune Bay, *Boreomysis nobilis*, were represented by greater than 300 individuals.

The second species group contained those animals which were collected from both fjords but in low numbers (Table 8). Four of the eight species belonging to this group were amphipods, although all groups excluding euphausiids and pteropods were represented. None of the species belonging to this group were common members of the macrozooplankton fauna in either fjord.

The third group of animals contained those species which were recorded from both fjords and for which greater than 30 individuals were enumerated, when sorting and splitting the samples, in at least one of the fjords. Twelve species of macrozooplankton were placed in this group (Table 9). To determine if catch rates for these species were significantly different between fjords, a Mann-Whitney U-Test was performed. Catch rates for 8 of the 12 (66.7 %) species in this group were found to be significantly different between fjords (Table 9). Six species, *Parathemisto gaudichaudii*, *P. abyssorum*, *Sagitta elegans*, *Thysanoëssa longicaudata*, *Mysis mixta* and *Clione limacina*, were more abundant in Fortune

Bay, while *Eukrohnia hamata*, and *Sagitta maxima*, were more abundant in Bay d'Espoir. Four species, *Meganyctiphanes norvegica*, *T. inermis*, *T. raschii* and *Tomopteris helgolandica* showed no significant difference in relative abundance between the two areas. *T. raschii* was the most abundant species collected from both Bay d'Espoir and Fortune Bay, while *T. inermis* and *M. norvegica* were among the top four ranked species in both fjords.

Overall, the value of PS between fjords for the macrozooplankton faunas was 56.7. This value was high compared to that of the fish faunas (PS = 1.8).

4.2 Structure and Organization of the Fjord Faunas

4.2.1 Fish Fauna

A number of parameters were investigated to assess the relative importance of physical versus biological processes in structuring the fjord faunas. These parameters included the degree of spatial and temporal variability in species composition, both within and between years, and the between year variability in species composition, catch rates and biomass of the fjord fish faunas.

To measure the within and between year variability in species composition and species rank order of abundances, Spearman rank correlation coefficients and PS indices were used. Both the Spearman rank correlation coefficients (Fig. 10) and the PS indices (Fig. 11) indicated that collections from Bay d'Espoir were more similar to one another within and between years than were those from Fortune Bay. In Bay d'Espoir, Spearman rank correlation coefficients showed a significant positive correlation in species ranks for 48 of the 66 (72.7 %) station pairs compared. Of these 25 were within year comparisons while 23 (34.8 %) were between year comparisons. This high degree of similarity was reflected in the mean (.71) value of Spearman rank correlation coefficients for all stations and the narrow range of values (.48 - .99). In Fortune Bay, species ranks showed a significant positive correlation for only 6 of the 66 (9.1 %) station pairs compared and the central tendency was towards a negative correlation. The mean correlation value for all stations was lower in Fortune Bay (.03) than in Bay d'Espoir and the range of values was much larger (-.30 - +1.0). Similar results were obtained using PS indices (Fig. 11). In Bay d'Espoir the mean value of PS (74.7) was significantly greater ($U_s = 538.0$, $n = 66,66$, $p < 0.0001$) than the mean value of PS (18.1) in Fortune Bay. Overall, PS values in Bay d'Espoir ranged from 34.5 to 95.7 compared to 0 to 100 in Fortune Bay. PS values in Fortune Bay were highly dependent upon the presence or absence of capelin at any given station. Forty-eight of the 66 (72.7 %) station pairs in Fortune Bay shared no species in common and the few highly similar stations were those at which large numbers of capelin were collected. Following the removal of capelin from the data set the mean value of PS in Fortune Bay further decreased to $PS = 7.8$ with overall values ranging from 0 to 66.7. However, given that only 22 fish other than capelin were collected from the fjord the significance of the PS values is unclear. The dominance of capelin in the Fortune Bay fish fauna with respect to other indices is discussed on page 60.

Although these results suggest that the fauna in Bay d'Espoir was spatially and temporally more homogeneous than that of Fortune Bay, differences in the scale of sampling between fjords must be taken into consideration. Samples in Bay d'Espoir were collected only from the deep central basin of the fjord and the maximum distance between station pairs was approximately 8 km. In contrast, samples were collected throughout Fortune Bay and the maximum distance between station pairs was approximately 95 km. To determine if the apparent heterogeneity in the fish fauna of Fortune Bay was merely a reflection of the sampling scale, values of PS against distance were plotted for all of the station pairs compared in each fjord (Fig. 12). In Bay d'Espoir, a Pearson product-moment corellation was calculated using transformed data (PS values were transformed using $\arcsin(p)^{1/2}$ where $p = PS/100$, distance values were transformed using $\log_{10}$) and the results indicated that there was a significant negative correlation between PS values and distance in that fjord ($r = -.41$, $n = 66$, $p < 0.001$). A similar transformation failed to normalize the frequency distribution of PS and distance values in Fortune Bay and therefore a Spearman rank correlation coefficient was calculated using the raw data. The results of this test showed that there was also a significant negative correlation between PS values and distance in Fortune Bay ($r = -.46$, $n = 66$, $p < 0.0001$). Given that spatial autocorrelation of PS values with distance was observed in both fjords, this relationship may be an inherent property of sampling on all scales. Therefore to evaluate the degree of variability between the fjord faunas, PS values were compared for only those samples from both fjords collected over similar spatial scales. This should provide an unbiased indication of the relative degree of homogeneity in the fjord faunas.

To make this comparison 16 station pairs separated in distance by less than 10 km were selected from all station pairs in Fortune Bay. In Bay d'Espoir, 10 data sets, each containing 16 station pairs, were randomly generated from all station pairs within the fjord. In all cases, values of PS against distance were plotted, and a representative plot for Bay d'Espoir and the plot for Fortune Bay are shown in Fig. 13. A Mann-Whitney U-Test was used to compare the mean value of PS for each of the 10 data sets from Bay d'Espoir with the mean value of PS in Fortune Bay (Table 10). Although there was no significant difference in the mean value of PS between the fjords (Table 10), this was likely due to the high variability of PS values in Fortune Bay. It is apparent from inspection of the data (Fig. 13) that there was a greater degree of homogeneity in the fish fauna of Bay d'Espoir, and in all cases the range of PS values in Bay d'Espoir was more restricted than in Fortune Bay (Table 10). In Fortune Bay, samples separated in distance by less than 2 km could be totally dissimilar (Fig. 13). The results of this analysis suggest that although the sampling scale did influence the observed degree of similarity among collections from both fjords, the observed heterogeneity in the fish fauna of Fortune Bay was real and persisted even over small spatial scales. However, as previously stated, PS values in Fortune Bay were heavily dependent upon the presence or absence of capelin in the collections.

A comparison of the between year variation in species composition, catch rates and biomass further suggested that the fish fauna in Bay d'Espoir was temporally less variable than that in Fortune Bay. Although only six of thirteen (46 %) species collected from Bay d'Espoir occurred in both years, PS between collections in 1982 and 1983 was high (PS = 91.5). This was due to the dominance of the fauna by *Melanostigma atlanticum* and *Benthosema glaciale* for which catch rates between years remained nearly constant (Table 11). Overall, the total number collected per hour was similar between years and although the total weight collected per hour increased in 1983, this was primarily attributed to an increased number of *Nezumia bairdii* in the 1983 collections and between year differences in the length frequencies of *Melanostigma atlanticum*. Differences did occur in the number of species and individuals of *Cyclothone* collected between years in Bay d'Espoir. Five species of *Cyclothone* were collected in 1982 compared to only two species in 1983, and catch rates for *C. braueri* and *C. microdon* were lower in 1983. However, *Cyclothone* spp. did not constitute a major component of the fjord fauna in either year of sampling.

In Fortune Bay, only two of 11 (18 %) species, *Mallotus villosus* and *Cyclothone braueri* were collected in both years and catch rates for the dominant species, *Mallotus villosus*, increased from 2.1 in 1982 to 78.9 in 1983 (Table 12). The total number and weight of fish collected per hour also increased in 1983 (Table 12). Overall, PS between years was low (PS = 43.6) in comparison to Bay d'Espoir.

Length frequency histograms were constructed for the dominant fish species in each fjord to assess the potential of the fjord assemblages to be self-sustaining. For Bay d'Espoir, length frequency histograms are presented for *Melanostigma atlanticum* (Fig. 14) and *Benthosema glaciale* (Fig. 15). A length frequency histogram of *Mallotus villosus* collected in 1983 (Fig. 16) is presented for Fortune Bay. Due to the small number of specimens collected in 1982 a length frequency histogram could not be constructed.

The length frequency histograms for *Melanostigma atlanticum* and *Benthosema glaciale* show that specimens collected from Bay d'Espoir in both years covered a wide range of sizes, and modes, suggestive of individual year classes, were evident in the data. The largest specimen of *B. glaciale* measured 83.4 mm SL, while the largest specimen of *M. atlanticum* measured 140.0 mm TL. These specimens are at the upper size range recorded for each species and suggests that adults of both species were present in the fjord. In contrast, only juvenile specimens of *Mallotus villosus* were collected in both years from Fortune Bay and in 1983 a single mode was present in the data, centered near 58.0 mm SL (Fig 16). Based on the work of Templeman (1948) on the length-age relationship of capelin in southern Newfoundland bays, it would appear that the capelin collected from Fortune Bay were spawned the previous summer.

4.2.2 Macrozooplankton Fauna

The fjord macrozooplankton faunas were also examined to investigate how they were influenced by physical and biological processes. The parameters examined were similar to those used for the fish faunas.

Species rank order abundances were found to be highly similar among stations within both Bay d'Espoir and Fortune Bay. In Bay d'Espoir, Spearman rank correlation coefficients showed a significant positive correlation ($p < 0.001$) in the rank abundance of species for all 45 station pairs compared, both within and between years (Fig. 17). Similarly, species ranks in Fortune Bay showed a significant positive correlation ($p < 0.001$) for 101 of 105 (96.2 %) station pairs compared, while species ranks at the remaining four stations (3.8 %) showed a significant positive correlation at $0.01 > p > 0.001$ (Fig. 18). In Bay d'Espoir the mean value of Spearman rank correlation coefficients was 0.76 with values ranging from 0.62 - 0.91, compared to a mean value of 0.68 in Fortune Bay and overall values ranging from 0.45 - 0.94. Although species rank order of abundances were highly consistent among all stations within both fjords, there were fluctuations in the relative abundances of individual species within and between years. Within year variability among stations was apparent in the patchy distribution of most macrozooplankters (see Appendices C and D) while between year variability in species relative abundances was evident when overall catch rates from 1982 and 1983 were compared (Tables 13 and 14).

The variability in species relative abundances was also reflected in PS values calculated among all stations within each fjord. PS values showed there to be less variability in the Fortune Bay fauna (Fig. 19) compared to that in Bay d'Espoir (Fig. 20). The mean value of PS in Fortune Bay (66.86) was significantly higher ($t = -4.44$, $df = 148$, $p < 0.001$) than in Bay d'Espoir (52.28) and the range of values more restricted. PS values were plotted against the distance between station pairs (Fig. 21) and Pearson product-moment correlations were calculated using transformed data (see page 36) to determine if the variables were spatially autocorrelated. There was no significant correlation between PS values and the distance between station pairs in either Bay d'Espoir ($r = .13$, $n = 45$, $p > 0.05$) or Fortune Bay ($r = -.13$, $n = 105$, $p > 0.05$).

Several euphausiids and the chaetognath *Sagitta elegans* comprised a large proportion of the macrozooplankton faunas of both fjords (see Table 6). Given that euphausiids and *S. elegans* undertake diurnal vertical migrations (e.g. Pearre 1973, Sameoto 1976b, Mauchline 1980), PS values were compared for only those station pairs collected at similar times in both fjords (Table 15). A Mann-Whitney U-test was used to compare PS values and the results showed there was no significant difference in mean PS values between fjords when samples collected at similar times were compared.

The overall value of PS between years and the lower variability in species composition suggests that the macrozooplankton fauna in Fortune Bay was more similar between years than that in Bay d'Espoir. In Fortune Bay, PS between years was high (84.1) and 24 of 33 (73 %) species were collected in both years (Table 14). In contrast, PS between years in Bay d'Espoir was low (17.0) and only 15 of 29 species (52 %) were collected in both years (Table 13). However, catch rates for some species in both fjords differed greatly between years. In Fortune Bay, *Meganyctiphanes norvegica* was collected in much greater numbers in 1983, while in Bay d'Espoir, catch rates for *Thysanoessa raschii* showed a dramatic increase in 1983. In Bay d'Espoir there was a corresponding sixteen fold increase in the total macrozooplankton biomass in 1983 compared to a 2.4 fold increase in Fortune Bay. However, this does not take into account the miscellaneous zooplankton, consisting primarily of copepods and gelatinous zooplankters. The percentage of the total zooplankton biomass comprised by the macrozooplankton in each fjord is given in Table 16. Overall, macrozooplankton accounted for a greater percentage of the total zooplankton biomass in Bay d'Espoir than in Fortune Bay although there was considerable between year variability. In 1982, the miscellaneous zooplankton comprised a greater proportion of the total zooplankton biomass in both fjords and in Fortune Bay accounted for 43.8 % of all zooplankton collected. Both fjords showed a similar gross increase in macrozooplankton biomass from 1982 to 1983.

4.2.3 Community Parameters

Several community parameters, species diversity and evenness and catch per unit effort (CPUE), were measured for both the fish and macrozooplankton faunas to see how values compared between Bay d'Espoir and Fortune Bay (Table 17). Average species richness values are also provided in Table 17. These community parameters, with the exception of CPUE, provide a different picture of the fjord faunas depending upon whether you examine the fish or the macrozooplankton assemblages. Comparing the fjord fish faunas, average species richness, species diversity and evenness were all greater in Bay d'Espoir than in Fortune Bay. In contrast, species diversity and evenness for the macrozooplankton faunas were greater in Fortune Bay than in Bay d'Espoir, while average species richness values were similar. CPUE of both fishes and macrozooplankters was greater in Bay d'Espoir than in Fortune Bay.

4.2.4 Biomass Size Spectra

The biomass size spectra, the percentage of the total fish and macrozooplankton biomass (not including the miscellaneous zooplankton) contained in $\log_2$ wet preserved weight size classes, and the number of species per size class, were calculated for Bay d'Espoir and Fortune Bay in 1983 (Fig. 22). Most of the biomass in Bay d'Espoir was concentrated in a single size class (-5 to -4), with lesser amounts, between 2 and 14 %, distributed among seven other size classes. A greater proportion of the biomass in Bay d'Espoir was concentrated in larger (> 0) size classes than in Fortune Bay due to the increased numbers of fish (e.g. *Benthosema glaciale*, *Melanostigma atlanticum*) and decapod shrimp (e.g. *Pasiphaea multidentata*, *Sergestes arcticus*) in the fauna. However, most of the faunal biomass in both fjords was contained in size classes less than zero.

In Fortune Bay, the fauna was largely distributed between two size classes. Although a greater number of species occurred in smaller size classes ($<$ -3) than in Bay d'Espoir, they did not account for a relatively greater proportion of the total biomass. Overall, there was little difference in the shape of the biomass size spectrum of Fortune Bay compared to that of Bay d'Espoir.

4.2.5 Taxonomic Group Composition

The percentage of the total fish and macrozooplankton biomass (not including the miscellaneous zooplankton) comprised by each of the major taxonomic groups was examined for Bay d'Espoir and Fortune Bay to determine how the partitioning of biomass compared between fjords. The biomass in both fjords consisted largely of euphausiids (Fig. 23), with the remaining biomass composed primarily of decapod shrimp, chaetognaths and fish. Amphipod and mysid species were more abundant in Fortune Bay, than in Bay d'Espoir and accounted for a greater percentage of the total fish and macrozooplankton biomass. Chaetognaths also accounted for a greater percentage of the biomass in Fortune Bay, although the contributions from fish and decapod shrimp were lower than in Bay d'Espoir. Two groups, pteropods and polychaetes, did not contribute substantially to the total biomass of the fauna in either fjord and, compared to the euphausiid biomass, the percentage of the total biomass comprised by all other groups was trivial. A Mann-Whitney U-test indicated there was no significant difference in the distribution of species ($U_s = 27.0$, $n = 8,8$, $p > 0.05$) or biomass ($U_s = 26.0$, $n = 8,8$, $p > 0.05$) among groups between fjords.

DISCUSSION

5.1 Species Distributions and Water Mass Affinities

5.1.1. Fish Fauna

The species composition of mesopelagic fishes in Bay d'Espoir was different from that in Fortune Bay. When the distribution patterns and water mass affinities of the most abundant species were considered, this difference could be related to the temperature and salinity characteristics of the deep water masses. This agrees with the initial prediction regarding the composition of the fjord faunas which was based on the difference in local oceanographic conditions between the two fjords.

The most abundant species in Bay d'Espoir, *Melanostigma atlanticum*, did not occur in Fortune Bay. *M. atlanticum* is mesopelagic, and has previously been collected in low numbers along the continental shelf edge, in the Laurentian Channel and in the Gulf of St. Lawrence (McAllister and Rees 1964). McAllister and Rees (1964) report the greatest collections of *M. atlanticum* off eastern Canada in depths of 275 to 360 m and at temperatures of 3.0 to 5.2°C and salinities of 33.4 to 34.7 °/oo. This coincides with the depths and the water properties of MSW in the Laurentian Channel (McLellan 1957; de Young 1983) and the Gulf of St. Lawrence (El-Sabh 1977), and suggests that the species is associated with this water mass. However, the absence of *M. atlanticum* in the MSW mass of the Laurentian and Hermitage Channels indicates that the abundance of individuals in the deep outer basin of Bay d'Espoir may also be a function of depth.

The large numbers of *Mallotus villosus* collected in Fortune Bay, are most likely associated with the cold water temperatures and shallower depths in the fjord. *M. villosus* has a northern circumpolar distribution (Jangaard 1974) and is commonly found at depths between 0 and 300 m in coastal areas (Kljukanov and McAllister 1979). Off eastern Canada, *M. villosus* is distributed from Ungava Bay to as far south as Maine (Leim and Scott 1966), in the continental shelf region where cold LCW is found. The association of this species with cold, neritic waters could account for its occurrence in Fortune Bay, and its absence from the deep outer basin of Bay d'Espoir.

Only four species, *Benthosema glaciale*, *Cyclothone alba*, *C. braueri* and *Sebastes* spp. were collected from both fjords. *B. glaciale* was abundant in Bay d'Espoir but rare in Fortune Bay, while *C. alba*, *C. braueri*, and *Sebastes* spp. were collected in low numbers from both fjords. *C. alba* and *C. braueri* are typically bathypelagic, oceanic species (Witzell 1979). The low numbers recorded in the present study may have resulted because individuals of these species were advected into the fjords from offshore populations, suggesting they were only transient members of the fauna. However, low numbers are not necessarily indicative of transience and futher sampling is required to determine whether these species are expatriate or resident within the fjords. Similarily, the significance of the low numbers of *Sebastes* spp. in collections from both fjords is not readily apparent.

Small numbers of *Benthosema glaciale* were collected from Fortune Bay.

This can be interpreted in terms of the water properties of the LCW. *B. glaciale* is a sub-polar temperate species, widely distributed throughout the northern Atlantic Ocean (Halliday 1970; Gjösaeter 1973; Nafpaktitis *et al.*1977). Although temperatures as low as 0°C are within the species' tolerance limits, it is most abundant in temperatures of 4 to 16 °C (Halliday 1970). This range of temperatures includes those of the deep MSW mass in Bay d'Espoir.

The greater water depth in Bay d'Espoir may also have been a factor in the collection of large numbers of *Benthosema glaciale*. However, this does not seem sufficient to account for the low numbers collected from Fortune Bay which, although considerably shallower than Bay d'Espoir, should be sufficiently deep to satisfy the bathymetric requirements of the species. The large number of *B. glaciale* collected from Hermitage Channel where the maximum depth is less than in Fortune Bay but where warm MSW is found below 150 m (de Young 1983) suggests that water properties, and not depth, are the reason for the paucity of *B. glaciale* in Fortune Bay.

It is likely that both the depth differential between the fjords and the greater degree of access across the deep outer sill are responsible for the restriction of *Paraliparis copei*, *P. garmani* Burke, and *Nezumia bairdii* to Bay d'Espoir. *P. garmani* and *P. copei* occur in the continental slope region, sometimes close to the bottom, but foraging at mesopelagic depths (Wenner 1979). Substrate type may also be important for *N. bairdii* which is common over mud substrates and occurs in deep waters along the North American continent, north of the Straits of Florida (Leim and Scott 1966; Marshall and Iwamoto 1973). Although *N. bairdii* is demersal (Leim and Scott 1966), it did occur in pelagic trawls in Bay d'Espoir.

This is not unknown in macrourids; *Coryphaenoides rupestris* Gunnerus, has been collected considerable distances above the bottom (Haedrich 1974), and some species are thought to forage at pelagic depths (Haedrich and Henderson 1974). In Bay d'Espoir, *P. copei*, *P. garmani*, and *N. bairdii* may be regular members of the mesopelagic fauna.

5.1.2 Macrozooplankton Fauna

The greater similarity between the invertebrate macrozooplankton faunas of the fjords is not surprising considering that all of the species collected, with the exception of *Sagitta decipiens* Fowler, and possibly *Boreomysis nobilis*, have amphi-Atlantic distributions and occur in sub-temperate to arctic regions. Broad latitudinal ranges are common for North Atlantic boreal species (Briggs 1970). Wigley and Burns (1971) found that in the U.S. Atlantic coastal region only warm-temperate and tropical mysids were indigenous; all subarctic and boreal species had amphi-Atlantic distributions.

There were some differences in species composition between the fjords, with several macrozooplankters occurring only in Bay d'Espoir or in Fortune Bay. In some cases the occurrence of a species in a given fjord can be interpreted in terms of the water properties of the deep water mass. For example, *Boreomysis nobilis*, an arctic-subarctic mysid (Tattersall 1951; Wright 1972; Judkins and Wright 1974), occurred only in Fortune Bay, while *Sergestes arcticus*, *Pasiphaea multidentata*, and *Boreomysis arctica*, occurred only in Bay d'Espoir. *S. arcticus* is a relatively warm-water pelagic shrimp (Squires 1965) which commonly occurs between depths of 250 to 550 m and at temperatures of 3.5 to 4.5°C (Squires 1966). *P. multidentata*, also a pelagic shrimp, is most abundant between depths of 200 to 380 m at temperatures of 5 to 6 °C (Squires 1965, 1966). *P. multidentata* has previously been collected in the Laurentian Channel, Hermitage Channel, and Cabot Strait at water temperatures of 4.8 to 5.5°C (Squires 1965), but not in regions where LCW occurs. *B. arctica* is mesopelagic (Fosså 1985), and common throughout the boreal Atlantic (Tattersall 1951). In the Gulf of St. Lawrence, *B. arctica* is restricted to the deep water mass characterized by temperatures of approximately 4°C and salinities of 33.2 to 34.4 °/oo (Wright 1972). This agrees with the collection of *B. arctica* from the MSW mass in Bay d'Espoir.

Some of the observed difference in the species composition between the fjords is due to the occurrence of suprabenthic animals in the pelagic fauna. Nine of the eleven species which occurred only in Fortune Bay were either gammarid amphipods, mysids, or semi-demersal shrimp, all suprabenthic species commonly found in association with the substrate (Brunel *et al.* 1978; Fosså 1985). These animals stay close to the bottom during the day and migrate into the water column at night (Brunel *et al.*1978). In Fortune Bay, suprabenthic animals were mostly collected in pelagic trawls at night or in deeper daytime collections. Diurnal migrations have been observed in mysids (Fosså 1985; Kaartvedt 1985), amphipods (Sainte-Marie and Brunel 1985), and decapod shrimp (Barr and McBride 1967; Apollonio and Dunton 1969). For mysids, it appears that the proportion of the population that migrates and the extent of the migration is species-specific (Kaartvedt 1985).

In Fortune Bay, the water depth is much shallower than in Bay d'Espoir (see section on topography) and vertically migrating suprabenthic species would have been more susceptible to collection because sampling was closer to the bottom. Although suprabenthic species (e.g. *Boreomysis tridens*, *Mysis mixta*, and *Pseudomma truncatum*) were collected in Bay d'Espoir, they were a much smaller component of the mesopelagic fauna in comparison to Fortune Bay. Suprabenthic species accounted for 0.01 % of the total number and weight of all macrozooplankton collected from Bay d'Espoir compared to 0.9 % by number and 5.76 % by weight of the macrozooplankton collected from Fortune Bay. However, suprabenthic species were not a major component of the macrozooplankton fauna in either fjord and their inclusion as a component of the pelagic fauna is evident only in the overall species composition and species richness. If supposed suprabenthic species are removed from the data set the overall value of PS for the macrozooplankton faunas between the fjords increases by only 0.4 (from PS = 56.7 to PS = 57.1).

The low density and typically oceanic distributions of the remaining species (e.g. *Nematobrachion boöpis* (Calman), and *Nematoscelis megalops* G.O. Sars in Fortune Bay, and *Gennadas elegans*, *Tomopteris cavalli* Rosa, *T. planktonis* Apstein, and *T. septentrionalis* de Quatrefages in Bay d'Espoir), may indicate they were expatriates. These species accounted for only a fraction of the macrozooplankton faunas in both fjords as did most of the species which occurred only in Bay d'Espoir or in Fortune Bay.

It was also predicted that species occurring in both fjords would differ in relative abundance, with cold-water species more abundant in Fortune Bay and warm-water species more abundant in Bay d'Espoir. This was the case for several species; *Sagitta elegans*, *Thysanoëssa longicaudata*, *Parathemisto abyssorum*, *P. gaudichaudii*, *Clione limacina* and *Mysis mixta*, were all more abundant in Fortune Bay. *S. elegans* is predominantly a cold water, arctic-subarctic species (Bieri 1959; Harding 1966; Alvariño 1965) although it can also occur in temperate regions (Tiselius and Peterson 1986). *S.elegans* is commonly found in coastal or mixed coastal and oceanic waters (Fraser 1957; Tokioka 1979; Cheney 1985a), and in the Slope Water region, its occurrence is associated with intrusions of low salinity coastal waters (Cheney 1985a). *T. longicaudata* is a subarctic-boreal species (Dunbar 1964; Jones 1969) commonly found in the colder waters of the Labrador and Irminger Currents (Lindley 1977). *P. abyssorum* is an arctic-subarctic species (Dunbar 1964, Harding 1966), and in the northern hemisphere, *P. gaudichaudii* is predominantly sub-arctic in distribution (Dunbar 1964). *C. limacina* is an arctic-boreal species (Morton 1957), which in the western North Atlantic occurs in the cold waters of the Labrador Current (Mileikovsky 1970). The fact that these species were all more abundant in Fortune Bay than in Bay d'Espoir is ascribed to their association with cold, low salinity, arctic and sub-arctic waters.

Eukrohnia hamata and *Sagitta maxima* were more abundant in Bay d'Espoir than in Fortune Bay. Both chaetognaths are abundant in surface waters of the Arctic and Antarctic Oceans (Alvariño 1965), and Harding (1966) regards *E. hamata* as an excellent indicator of southward flowing currents of Arctic origin in the North Atlantic Ocean. However, both *E. hamata* and *S. maxima* occur in deeper waters at low latitudes (Bieri 1959; Alvariño 1965; Harding 1966). They are common members of the Slope Water chaetognath assemblage (Cheney 1985a) at mesopelagic depths (Cheney 1985b). *E. hamata* and *S. maxima* are clearly able to tolerate the range in temperatures and salinities occurring in both Bay d'Espoir and Fortune Bay. The factors which caused their greater abundance in Bay d'Espoir are unknown, but it seems unlikely that this was due entirely to the deep water properties.

Similarily, several factors are also thought to have contributed to the greater abundance of *Mysis mixta* in Fortune Bay. In the Gulf of St. Lawrence, Wright (1972) reports that specimens of *M. mixta* were collected between water depths of 30 to 135 m with the center of abundance occurring between 45 and 85 m. Temperatures at most collection sites ranged from 0 to 1 °C and salinities ranged from 31 to 32 ‰. *M. mixta* also undertakes pronounced nocturnal migrations (Wigley and Burns 1971; Wright 1972). In the present study small numbers of *M. mixta* occurred throughout the water column in Fortune Bay and individuals were collected in the upper 100 m at night. It is likely that the greater sampled abundance of *M. mixta* in Fortune Bay can be attributed to both the shallower depth and the water properties of the fjord.

Four species, *Thysanoëssa raschii*, *T. inermis*, *Meganyctiphanes norvegica* and *Tomopteris helgolandica*, had similar catch rates in Bay d'Espoir and Fortune Bay. The three euphausiid species were common members of the macrozooplankton faunas in both fjords, and *T. raschii* was the most abundant species of macroozooplankton collected from both Bay d'Espoir and Fortune Bay.

Thysanoëssa raschii, *T. inermis* and *Meganyctiphanes norvegica* are all widely distributed (Einarsson 1945; Mauchline and Fisher 1967, 1969; Lindley 1977, 1980, 1982; Mauchline 1980) and occur regularly in coastal waters and deep fjords (Mauchline and Fisher 1969; Matthews 1973; Jörgensen and Matthews 1975;

Lindley 1977, 1980; Falk-Petersen and Hopkins 1981; Mauchline 1984). The adults undertake diurnal migrations to the surface layers at night (Mauchline 1984). In the Gulf of St. Lawrence these species regularly migrate through waters where temperatures change by as much as 15 C° (Sameoto 1976b). Thus, it is not surprising that the difference in the deep water properties between the two fjords had little affect on their distribution or relative abundances.

Sameoto (1976a) identified sound scattering layers in the Gulf of St. Lawrence composed primarily of *Thysanoëssa raschii*, *T inermis* and *Meganyctiphanes norvegica* and found that the presence of the layers was strongly correlated with chlorophyll *a* concentration. This was attributed to the animals seeking out the higher food concentrations (Sameoto 1976a). It is possible that within Bay d'Espoir and Fortune Bay the distributions of *T. raschii*, *T. inermis*, and *M. norvegica* are related to patchy phytoplankton distributions, as catch rates for all species were highly variable. Productivity in fjords is generally h[illegible] (Brattegard 1980) and may be comparable with levels of production in confluent coastal waters (Matthews and Heimdal 1980; Eilertsen and Taasen 1984). However, there are no data on phytoplankton distributions or primary productivity specifically for Bay d'Espoir or Fortune Bay.

The pelagic polychaete, *Tomopteris helgolandica* was also equally abundant in both fjords. *T. helgolandica* is widely distributed, occurring in the North Sea and off eastern Europe, off Newfoundland, in the Sargasso Sea, and off South America (Støp-Bowitz 1948). *T. helgolandica* is commonly found in coastal waters and most frequently inhabits the upper 100 m of the water column (Støp-Bowitz). Given the similar near-surface water properties of both fjords above sill depth, this may account for the comparable catch rates of *T. helgolandica* in Bay d'Espoir and Fortune Bay. However, *T. helgolandica* was not a common member of the macrozooplankton fauna in either fjord.

5.2 Environmental Stability

5.2.1 Temporal and Spatial Homogeneity

The structure and variability of the mesopelagic fish assemblages appeared to be influenced by the relative degree of mixing which accompanied deep water renewal in the fjords. In Bay d'Espoir, where the deep water mass was relatively homogeneous, there was less temporal or spatial variation in species composition and in relative abundances both within and between years. Although biomass estimates were greater in 1983, this is attributed primarily to the increased numbers of *Nezumia bairdii*, and to between year differences in length frequencies of *Melanostigma atlanticum* and *Benthosema glaciale*. In contrast, species composition, species rank order abundances, and the overall biomass of mesopelagic fishes were highly variable both spatially and temporally in Fortune Bay, coincident with the dynamic nature of deep water renewal in that fjord. Although differences in the scale of sampling did influence the degree of similarity between station pairs within fjords, following removal of the sampling bias the degree of variabilty remained higher among samples collected from Fortune Bay.

The results of this study are similar to those obtained by McGowan (1977), Loeb (1979) and Barnett (1983) in comparisons of faunal assemblages between two regions of contrasting oceanography in the Pacific Ocean. In a comparison of copepod assemblages between a stable environment, the North Pacific central gyre, and a dynamic environment, the California Current, McGowan (1977), found a nearly constant species list in the gyre assemblage, and a highly variable one in the California Current. Loeb (1979) compared larval fish assemblages between the same areas and, based on cumulative frequency curves and species diversity and equitability, concluded that the larval fish assemblage in the gyre was more structured than that in the current. Barnett (1983), found that samples of mesopelagic fishes collected from the California Current had a greater variability in both species composition and relative abundances than did samples collected from the North and South Pacific central gyres. Although the biomass of mesopelagic fishes in the gyres was found to be similar among stations within years there were between year differences (Barnett 1983), a situation similar to that observed in the overall biomass of mesopelagic fishes between years in Bay d'Espoir.

Based on the observed constancy in biological and physical properties, McGowan (1974, 1977), McGowan and Walker (1979) and Barnett (1983) have concluded that the North Pacific central gyre exemplifies a highly structured, biologically regulated ecosystem, while the California Current is regarded to be an advective, or open ecosystem (McGowan 1977). In the present study, the uniformity of the fish fauna and the homogeneous properties of the deep water mass in Bay d'Espoir suggest that the faunal assemblage there was regulated by *in situ* biological processes. In contrast, the high variability in the composition and abundance of fishes in Fortune Bay suggests that the assemblage there was primarily influenced by advective processes. Although this study has emphasized physical processes in Fortune Bay, advective processes can also be biological in nature. Dayton and Hessler (1972) suggest that a disturbance caused by locally intense predation may have the same effect on the community structure of an ecosystem as a physical perturbation. Although it is possible that the lack of a structured fish faunal assemblage in Fortune Bay is the combined effect of biological and physical processes, an investigation of biological advective processes is beyond the scope of this study.

The length frequency data for *Benthosema glaciale* and *Melanostigma atlanticum* provide further evidence that the fish assemblage in Bay d'Espoir was biologically regulated. In both years, *B. glaciale* collected in Bay d'Espoir covered a wide range of sizes and exceeded by 15.4 mm the maximum size of 68-mm recorded for the species in the northwest Atlantic (Halliday 1970). In the present study, individuals were not aged but modes were apparent in the length frequencies (Fig. 15). These closely matched those obtained by Halliday (1970) for *B. glaciale* from the Slope Water region. A comparison of length frequencies indicated that individuals ranging in age from one to four years, and possibly older, were present in the fjord.

In the northwest Atlantic, *Benthosema glaciale* mature between 50 to 60 mm in length (Nafpaktitis *et al.* 1977). Part of the population may initially spawn at age 2 and all do so by age 3 (Halliday 1970). In Bay d'Espoir, most fish were believed to be age 2 or older (applying Hallidays' growth data, i.e. SL $>$ 44 mm), which means that a large postion of the population consisted of potential spawners. A cursory examination of several large females revealed gonads with developing eggs. Although no larvae or fish aged 0+ were collected, this is likely due to the time of sampling. Halliday (1970) reports that in the western North

Atlantic *B. glaciale* spawn in early spring, while Gjösaeter (1981) reports that in Norwegian fjords and adjacent seas *B. glaciale* spawn mainly during the summer.

There are no studies on age and growth of *Melanostigma atlanticum* for comparison with the Bay d'Espoir population. *M. atlanticum* collected from the fjord reached the maximum length recorded for the species by McAllister and Rees ~~(1964), and~~ length frequencies in both years were tri-modal (Fig. 14). Although larvae were not collected, there is evidence that *M. atlanticum* spawns demersally (Markle and Wenner 1979) and larvae of *M. pammelas* are reported to be benthic during the first year of life (Robison and Lancraft 1984). A similar behaviour could account for the absence of larvae of *M. atlanticum* in the pelagic collections from Bay d'Espoir.

The wide range of sizes in *Benthosema glaciale* and *Melanostigma atlanticum*, and the similar catch rates between years, makes it unlikely that these individuals were expatriates advected into Bay d'Espoir from more offshore populations. Rather, it seems plausible that they represent viable fjord populations. In the case of *M. atlanticum*, the large numbers collected in Bay d'Espoir and its absence from all other areas sampled strongly suggests a localized fjord population.

Only juvenile *Mallotus villosus* were collected from Fortune Bay. Adult *M. villosus* typically overwinter offshore, moving inshore during late spring and early summer to spawn (Jangaard 1974). The individuals collected in Fortune Bay may be offspring of the stock which overwinters on the St. Pierre and Green Banks (Jangaard 1974), and migrates into the fjord to spawn in June and early July (Templeman 1948). The movements and distribution of juvenile capelin are not well known. At present it is uncertain whether the juvenile capelin collected from Fortune Bay remain in the fjord year round, or whether they are a seasonal member of the fjord fish fauna.

Although the fish assemblage in Bay d'Espoir appeared to be regulated primarily by biological processes, the difference in the number of *Cyclothone* species and in the catch rates of *C. braueri* and *C. microdon* between years indicate that the fauna was at least partially influenced by advection. Intrusions of oceanic water into adjacent coastal areas such as fjords can alter the composition of the resident fauna. This may occur either through the recruitment of new individuals to existing populations (e.g. Matthews 1973) or through the introduction of new species or assemblages of animals (e.g. Rainville 1979; Sands 1980; Gardner 1982; De Ladurantaye *et al.* 1984). In Bay d'Espoir, species of *Cyclothone* comprised only a small percentage of the total number and biomass of fishes in the fjord and their overall influence on the fjord ecosystem was probably minimal.

In contrast to the results obtained for the fish assemblages, varied results were obtained for the macrozooplankton faunas of the fjords. Some parameters, such as the high degree of similarity in species rank abundances, supported the initial prediction of Bay d'Espoir as a constant, biologically regulated ecosystem; others, such as the low overall value of PS between years, the large increase in the macrozooplankton biomass in 1983, and the between year differences in species composition, did not. In Fortune Bay, the high degree of similarity in species rank order of abundances, the high overall value of PS between years, and the constancy of the species composition between years contradicted the results obtained for the fish assemblages and were inconsistent with the concept of the fjord as an ecosystem regulated by advective processes. Although mean PS values among station pairs in Fortune Bay were not significantly greater than those in Bay d'Espoir when samples collected at similar times were compared, if the fjord macrozooplankton faunas were responding to environmental conditions in a manner similar to the fish faunas one would expect that the mean PS values in Bay d'Espoir would be greater than those in Fortune Bay.

Compared to the fishes, there is a probably a strong seasonal component to the macrozooplankton fauna, and both fjords contained large numbers of neritic species (e.g. *Thysanoëssa raschii*, *T. inermis*, *Meganyctiphanes norvegica* and *Sagitta elegans*). These species may respond primarily to seasonal fluctuations in environmental conditions which are short-term compared to the frequency of deep water renewal in the fjords. In general, the shorter life span of the macrozooplankters may facilitate their more immediate response to short term or seasonal events which might occur at lower trophic levels, such as phytoplankton blooms and fluctuating zooplankton populations. Hopkins (1981) stated that there is generally greater stability at higher trophic levels in plankton communities, and that large-scale changes in phytoplankton standing crop and production at spring blooms are buffered in successive links of the food chain as the rate of reproduction decreases.

I suggest that both the fish and macrozooplankton faunas in Bay d'Espoir and Fortune Bay provide a reflection of environmental conditions within the fjords, but for different time intervals. I believe that the fish faunas provide a reflection of more long-term environmental conditions within the fjords while the macrozooplankton faunas more accurately reflect the seasonal or more short-term environmental variability.

5.2.2 Species Richness, Diversity and Evenness

How measures of community structure, such as species diversity, relate to the environmental stability of an ecosystem is a topic of much discourse. A general assumption has been that stable ecosystems are biologically regulated and characterized by a high diversity, while unstable ecosystems are physically regulated and have a low diversity (Pielou 1975; Rainer 1981). However, this relationship is by no means straightforward. While some studies have shown that biological interactions act to increase diversity (e.g. Gray 1978), others have found the opposite (e.g. Caswell 1976; Day 1977). The frequency and duration of the environmental perturbation also appear to be important. Connell (1978) concludes that the high diversity of trees in tropical rain forests and corals on tropical reefs is maintained by perturbations of intermediate frequency and intensity. Extreme deviations in either direction are accompanied by a decrease in diversity (Connell 1978). However, Rainer (1981) suggests that frequent, small-scale perturbations may act to stabilize community structure by continually eliminating species unable to withstand more dramatic changes in environmental conditions.

Further problems arise in applying concepts derived mostly from studies in terrestrial or marine benthic ecosystems to pelagic ecosystems. In terrestrial ecosystems, species diversity increases with higher productivity and greater living space, but in pelagic ecosystems high productivity does not always result in a higher diversity, because it is often associated with upwelling and a physically dynamic environment (Angel 1979). Theories which successfully explain the maintenance of community structure and diversity in sessile ecosystems cannot account for the high species diversity observed in the North Pacific central gyre (McGowan and Walker 1985), nor can theories of spatial and temporal niche separation or resource partitioning (McGowan and Walker 1979).

Species diversity and eveness indices and average species richness were all greater for the mesopelagic fish fauna in Bay d'Espoir than in Fortune Bay. These results appear to be in keeping with the concept of Bay d'Espoir as biologically regulated (i.e. a stable ecosystem with a high species diversity, H' = 1.02) and Fortune Bay as physically regulated (i.e. a variable ecosystem with a low species diversity, H' = 0.24). The greater value obtained for average species richness in Bay d'Espoir (4.2) compared to Fortune Bay (1.5) is also in keeping with this concept. Angel (1979) suggests ~~that~~ increased species richness can result from long-term stability, or environmental predictability. However, the low species diversity in Fortune Bay appears to be associated with the patchy distribution of capelin, *Mallotus villosus*, in that fjord. If capelin are removed from the analysis both the diversity (H' = 2.26) and evenness (E = 0.14) indices increase. However, once capelin are removed from the data set in Fortune Bay the number of fish decreases from 592 to 22. Given the small number of specimens and the low average species richness of the fauna (1.5 including capelin, 1.2 following their removal) the significance ot these indices is unclear.

The measures of species diversity and evenness, and average species richness in the present study are for one instant in time and there is no indication of how these parameters may change temporally or spatially. These results do not conclusively negate nor confirm that the fish fauna in Bay d'Espoir was predominantly regulated by biological processes while that in Fortune Bay was predominantly regulated by physical processes. However, a more extensive study of these parameters and how they relate to environmental stability in the fjords may provide some useful information.

In comparison to adjacent oceanic areas, the fish faunas of both Bay d'Espoir and Fortune Bay were characterized by a low species richness, diversity and evenness (Table 17). Even in the faunally depauperate Newfoundland Basin (McKelvie 1985), average species richness of midwater fishes is three times greater than was observed in the present study. Similarly, diversity indices were nearly three times lower than those measured by Jahn and Backus (1976) for midwater fish faunas in the Slope Water, Gulf Stream, and Northern Sargasso Sea, which all had values closer to 3.0. Backus *et al.* (1977) calculated diversity indices for myctophid fish collected from 17 faunal provinces of the Atlantic Ocean. The diversity index of $H' = 0.23$ (H in their terminology) which they calculated for the Atlantic Subarctic Province closely matched the diversity index ($H' = 0.2$[illegible] calculated for the fish assemblage in Fortune Bay. In Bay d'Espoir, the diversity index ($H' = 1.02$) was most similar to the value of $H' = 1.10$ which they calculated for the Northern Gyre province of the North Atlantic Temperate Region (Backus *et al.* 1977).

Indices of species diversity and evenness, for the macrozooplankton faunas were greater in Fortune Bay than in Bay d'Espoir while average species richness was comparable in both fjords. If the fjord faunal assemblage was biologically regulated in Bay d'Espoir and physically regulated in Fortune Bay, the species diversity and evenness, and species richness of the macrozooplankton fauna should be greater in Bay d'Espoir than in Fortune Bay. The high value obtained for average species richness in Fortune Bay is ascribed to the suprabenthic component of the pelagic fauna in that fjord. This is supported by the apparent increase in species richness observed in the macrozooplankton fauna at night and with depth. However, the higher species diversity of macrozooplankters in Fortune Bay is not due to the presence of suprabenthic species and following their removal from the data set the diversity index decreases by only 0.03 (H' = 1.46). Rather, it appears that the lower species diversity in Bay d'Espoir resulted from the great abundance of *Thysanoëssa raschii* (which accounted for 85 % of the total number of macrozooplankters) in the fjord fauna. Catch rates for *T. raschii* were highly variable in Bay d'Espoir and a particularily large catch (n = 119108) occurred at station 1416. By removing this large patch of *T. raschii* from the data set, the diversity index nearly doubles in value from H' = 0.69 to H' = 1.30, a value more comparable to that in Fortune Bay (H' = 1.49). Diversity indices, because they take into account species relative abundances, can be influenced by patchy macrozooplankton distributions. Many macrozooplankton species are known to form patchy aggregations (Omori and Hamner 1982) and catch rates for most macrozooplankters in both Bay d'Espoir and Fortune Bay were highly variable (see Appendices C and D). It appears that the low diversity index in Bay d'Espoir largely resulted from the patchy distribution of *T. raschii* in that fjord.

The low species diversity and species richness of the faunal assemblages in Bay d'Espoir and Fortune Bay were typical of results for temperate coastal or estuarine regions where diversity is low and the fauna is dominated by one or two species (e.g Malone 1977; Haedrich 1983). Hopkins (1981) found the zooplankton community in Balsfjorden, Norway, to be species poor and dominated in both number and biomass by only a few species. In both Bay d'Espoir and Fortune Bay, the mesopelagic fish and macrozooplankton faunas were characterized by a small number of very abundant species and the biomass consisted primarily of euphausiids.

In the present study, the biomass of both fishes and macrozooplankters was higher in Bay d'Espoir than in Fortune Bay. These results are surprising given the oceanography of the two fjords. Timonin (1971) found that areas of relatively stable water stratification were characterized by a low biomass and high species diversity while biomass was higher and diversity was lower in regions of upwelling. The replacement of deep water in Fortune Bay with upwelled MSW from Hermitage Channel represents an input of nutrient rich water into the fjord (de Young 1983), and upwelling regions are typically characterized by high productivity (e.g. Boje and Tomczak 1978; Bernal and McGowan 1981). In 1982, macrozooplankton accounted for only 56.2 % of the total zooplankton biomass collected in Fortune Bay compared to 83.1 % in Bay d'Espoir, although the proportions were more similar in both fjords in 1983 (85.5 % in Fortune Bay compared to 96.1 % in Bay d'Espoir). This suggests that the proportion of the zooplankton biomass in Fortune Bay comprised by the smaller sized zooplankters such as copepods, fluctuates between years. This may be related to upwelling of MSW in the Hermitage Channel and deep water renewal in Fortune Bay and could account for the disparity in biomass estimates between the two fjords.

5.2.3 Biomass Size Spectra

The biomass size spectra indicated there were no major differences in size structure between the fjord faunas, despite differences in the species composition. According to Grassle and Sanders (1973), species inhabiting areas subject to unpredictable perturbations should be opportunistic, with high reproductive rates and short life spans. Given the variable nature of the ecosystem in Fortune Bay, it was expected that a greater proportion of the fauna there would consist of smaller, shorter-lived and more opportunistic species, than in Bay d'Espoir. Although a greater number of species were distributed in smaller size classes in Fortune Bay, these did not contribute more to the overall biomass. Conversely, larger individuals did not predominate in the Bay d'Espoir fauna.

Size spectra in both fjords also spanned a similar range of size classes, suggesting that the two fjords do not differ markedly in trophic organization. Matthews and Bakke (1977) found that in Korsfjorden, Norway, the species composition of micro- and macrozooplankton changed on a monthly basis, although the proportion of herbivores, carnivores and omnivores remained the same. They concluded that there could be considerable flexibility in the composition of species within zooplankton communities before marked effects in the trophic structure were evident. Although animals were not grouped according to trophic organization in the present study, the similarity in the size spectra, despite differences in the species composition, may indicate a similar degree of flexibility in trophic organization within the fjords.

Nutrient concentrations in the MSW are approximately two times greater than in the LCW (de Young 1983). Renewal of deep water in Fortune Bay by MSW thus represents an input of nutrient rich water and, depending upon the time of renewal, this could generate considerable phytoplankton production in the fjord. Roman *et al.* (1985) found that opportunistic species of calanoid and cyclopoid copepods were able to exploit high levels of phytoplankton production in warm-core Gulf Stream rings. Copepods, because of their small size and short generation time, may be the opportunistic species which were expected to be present in Fortune Bay but were not included in the present study. Hopkins (1981) found that copepods were the dominant taxa of the zooplankton fauna in Balsfjorden, Norway, and accounted for over 99 % of all zooplankters in the fjord. The large proportion of the total zooplankton biomass comprised predominantly of copepods (i.e. the miscellaneous zooplankton) in Fortune Bay in 1982, supports this hypothesis.

It is possible that the apparent similarity in size spectra between fjords occurred because smaller size fractions of the fauna such as copepods and microzooplankton, were excluded from the study, or because generation times of the species examined were long relative to the frequency of the perturbations (deep-water renewal) in Fortune Bay.

5.3 Origin of the Fjord Faunas

The mesopelagic fish and invertebrate macrozooplankton faunas in Bay d'Espoir and Fortune Bay are a mixture of indigenous, neritic and oceanic species. It is possible that many of the more common species, characteristic of the fjord faunas, have viable resident populations. Supporting evidence is, however, indirect and only presented for *Benthosema glaciale* and *Melanostigma* *atlanticum* in Bay d'Espoir. The characteristic species are generally those with ubiquitous distributions in the western North Atlantic, and their use as indicators of possible faunistic links between the fjords and external water masses is limited. However, in both Bay d'Espoir and Fortune Bay, there are a number of fish and macrozooplankton species whose presence was indicative of a link with offshore waters.

The fish fauna of Bay d'Espoir was similar to that of the Laurentian and Hermitage Channels. This is not surprising given that MSW is carried from offshore to the Bay d'Espoir-Fortune Bay region by this route. The similarity among the faunas is due primarily to the abundance of *Benthosema glaciale* in all three areas. The fish fauna of Fortune Bay was similar to that of the St. Pierre Channel, due to the abundance of juvenile *Mallotus villosus* in both areas, and essentially dissimilar to those of the Laurentian Channel and Bay d'Espoir. LCW is transported to Fortune Bay primarily through the St. Pierre Channel and this would account for the similarity of those faunas.

Hermitage Channel was the only area where the faunal composition was similar to both warm-water (Bay d'Espoir and Laurentian Channel) and cold-water (Fortune Bay and St. Pierre Channel) regions. This is due to the presence of both *Benthosema glaciale* and *Mallotus villosus* in Hermitage Channel. Geographically, Hermitage Channel is intermediate to all of the regions sampled; with respect to water masses, MSW is present below 150 m and LCW is present at shallower depths. In the present study, Hermitage Channel appears to constitute an ecotone, an area of faunal mixing, between the two independent sources of the fjord faunas, the Laurentian and St. Pierre Channels. McKelvie (1985) found the

Slope Water region to be an ecotone between the cold-water Newfoundland Basin, and the warm-water Gulf Stream.

The fish fauna in Bay d'Espoir was derived, at least in part, from the Laurentian and Hermitage Channels while that of Fortune Bay was derived from the St. Pierre and Hermitage Channels. However, the proportion of the fauna which may have originated from these external channels relative to that produced locally within the fjords remains unknown.

The area surrounding Bay d'Espoir is mostly shallow continental shelf, with the Hermitage and Laurentian Channels providing the only deep-water link between the fjord and the offshore continental slope region. The presence in the fjord of typically oceanic species such as *Cyclothone* spp., *Sagitta decipiens*, *Gennadas elegans*, *Tomopteris cavalli*, *T. planktonis* and *T. septentrionalis* suggests the reality of a faunistic link.

Some species, such as *Cyclothone alba*, *C. pallida* Brauer, *C. pseudopallida* Mukhacheva, and *Sagitta decipiens*, are indicative of a faunal link with more southerly oceanic waters. In the Atlantic, *C. alba* is regarded as a tropical species, while *C. pallida* and *C. pseudopallida* are subtropical-tropical species (Badcock 1982); all are bathypelagic (Witzell 1979). *Sagitta decipiens* is commonly found at mesopelagic depths in the Northern Sargasso Sea, although it occurs as an expatriate in the Slope Water region (Cheney 1985a, 1985b). The presence of these species in Bay d'Espoir indicates that there exists a route whereby fauna from deep, oceanic regions to the south is transported into the fjord. Given that species of *Cyclothone* do not migrate vertically (Kobayashi 1973; Badcock and Merrett 1976, 1977), nor does *S. decipiens* (Cheney 1985b), the deep MSW of the Hermitage and Laurentian Channels would provide the most likely route.

Studies investigating the mesopelagic fish fauna of the Scotian Shelf-Slope Water region have noted many tropical and subtropical species (Nafpaktitis 1968; Halliday and Scott 1969; Jahn and Backus 1976; Markle *et al.*1980; Backus and Craddock 1982). The abundance of these southerly species in the Slope Water fauna has generally been attributed to northward dispersion by the Gulf Stream (Nafpaktitis 1968; Halliday and Scott 1969; Markle *et al.*1980), including the formation of warm-core rings which provide a virtually continual input of water from the Northern Sargasso Sea and Gulf Stream into the Slope Water region (Backus and Craddock 1982). It is possible that some species (e.g. *Cyclothone* spp.) collected in Bay d'Espoir were initially transported from more southerly populations to the Slope Water region, and from there to Bay d'Espoir via the deep MSW mass. If this is the case, there is a potential for any number of subtropical oceanic species to occur sporadically in the fjord fauna. However, as observed in the present study (e.g. *Cyclothone* spp. and *Sagitta decipiens*), these species would probably have little impact on the overall fjord fauna and would unlikely be persistent.

The presence of an arctic amphipod, *Parathemisto libellula* (Lichtenstein), in Bay d'Espoir suggests that fauna is also transported into the fjord in the surface flowing LCW. *P. libellula* is regarded as a good indicator of Arctic water (Dunbar 1964) and may be transported by the Labrador Current as far south as the Gulf of Maine (Bigelow 1926). In addition to *P. libellula*, other predominantly arctic or subarctic species such as *P. abyssorum*, *P. gaudichaudii*, *Hyperia medusarum* (O.F. Müller), and *Hyperoche medusarum* (Krøyer) were collected in small numbers in the fjord.

In Fortune Bay, there also appeared to be a small, offshore, warmwater component in the mesopelagic fauna, indicated by the presence of *Cyclothone alba*, *C. braueri*, *Sagitta decipiens* and *Nematobrachion boöpis*. Given the bathymetric and temperature preferences of the above species, it is possible that fauna may be transported into the fjord when deep-water renewal takes place and upwelled MSW flows over the western sills. However, the exact mechanism is unknown and further sampling, particularly at the time when deep water renewal with MSW occurs, is required.

SUMMARY AND CONCLUSIONS

A comparison of the mesopelagic faunas between Bay d'Espoir and Fortune Bay showed the species composition of fishes to be almost totally dissimilar while the macrozooplankton faunas were largely the same. There appeared to be a well-established fish assemblage in Bay d'Espoir, characterized by *Melanostigma atlanticum*, *Benthosema glaciale*, and the periodic occurrence of oceanic meso- and bathypelagic species such as *Cyclothone braueri* and *C. microdon*. In comparison, the fish fauna in Fortune Bay was depauperate and more typical of the neritic, continental shelf region. There were no species which could be regarded as characteristic of the fjord fauna.

The macrozooplankton fauna in both fjords was predominantly neritic containing large numbers of the euphausiids *Thysanoëssa raschii*, *T. inermis*, and *Meganyctiphanes norvegica*, and the chaetognath *Sagitta elegans*. These species were the four most abundant macrozooplankters collected in both Bay d'Espoir and Fortune Bay. There were differences in the species composition of macrozooplankters between the fjords, although these were generally species which occurred in low numbers and comprised only a small fraction of the fjord faunas.

In both the fish and macrozooplankton faunas there was evidence that, for some species, the observed distributions could in part be attributed to the different water properties and sources of deep water between the fjords. Some species (e.g. *Benthosema glaciale, Melanostigma atlanticum, Pasiphaea multidentata, Sergestes arcticus*) were associated with the relatively warm MSW in Bay d'Espoir, while others (e.g. *Mallotus villosus, Boreomysis nobilis, Parathemisto abyssorum*) were associated with the relatively cold and fresh LCW in Fortune Bay. However, the distributions of many species appeared to be limited by temperature and salinity only in a broad geographical sense, and within these confines, other factors may have been important in determining their distribution on a smaller scale. For some macrozooplankters (i.e. *Thysanoëssa raschii, T. inermis,* and *Meganyctiphanes norvegica*), primary productivity may have influenced local distribution patterns, while bottom depth and substrate type were probably important for the suprabenthic amphipod, mysid and shrimp species, and for demersal fishes.

The structure and persistence of the mesopelagic fish assemblages in the fjords were related to the static condition of the deep water mass. The faunal assemblage in Bay d'Espoir appeared to be regulated primarily by biological processes, despite some evidence of advection. In Fortune Bay the regulatory mechanisms appeared to be physical. Similar results were not obtained for the macrozooplankton fauna which was thought primarily to reflect short-term seasonal changes in environmental conditions, rather than long-term events such as the frequency of deep water renewal.

Species diversity and evenness, and average species richness of mesopelagic fishes was higher in Bay d'Espoir than in Fortune Bay, although for the macrozooplankton faunas, species diversity and evenness and average species richness were higher in Fortune Bay than in Bay d'Espoir. These indices did not provide conclusive evidence regarding the mechanisms which might be important in structuring the fjord faunal assemblages. Species diversity and evenness, and average species richness, were low in both fjords compared to oceanic areas.

There was no apparent difference in the size structure of the faunal assemblages between the two fjords. Both size spectra covered a similar range of size classes. Although smaller sized animals were more abundant in Fortune Bay they accounted for little of the total fish and macrozooplankton biomass. In Bay d'Espoir larger animals were not more prominent as was predicted on theoretical grounds. It is possible that the similarity in size spectra was due to the particular portion of the size spectrum examined, or that the generation time of the species examined was long relative to the frequency of the perturbations in Fortune Bay. By including smaller animals such as copepods and microzooplankton, the biomass size spectra might display different characteristics.

The fish fauna in Bay d'Espoir was derived, at least in part, from the Laurentian and Hermitage Channels while that in Fortune Bay was derived from both the St. Pierre and Hermitage Channels. Hermitage Channel, situated intermediate between Bay d'Espoir and Fortune Bay, constituted an ecotone between the warm-water and cold-water regions.

A small portion of the mesopelagic fauna in both fjords was derived from the offshore continental shelf region. This faunal link was stronger in Bay d'Espoir than in Fortune Bay, and was attributed to the onshore transport of MSW from the Slope Water region. Warm-water oceanic species were also collected from Fortune Bay although the exact mechanism whereby these species were transported into the fjord is unknown. Fauna may be transported into the fjord via deep water renewal during the winter months.

This study provides the first comprehensive examination of pelagic faunas in deep Newfoundland fjords. The results have shown that there were differences between the faunal assemblages of Bay d'Espoir and Fortune Bay although the degree to which the faunas differed varied considerably between the fish and macrozooplankton assemblages. This implies that the conclusions one reaches and the perceptions one develops of an ecosystem may depend on the group selected for study. If this is true, it suggests that there may be no universal ecological laws. Conclusions obtained from one particular group of animals if applied to a different group or to an entire ecosystem may lead to erroneous interpretations.

Many aspects of the faunal assemblages in Bay d'Espoir and Fortune Bay still need to be examined. The present study has compared the mesopelagic fish and macrozooplankton faunas between fjords only during the spring/early-summer period, and data are needed to determine how the assemblages compare seasonally and over extended time periods. In addition, studies to determine quantitatively how the fjord faunas are influenced by advective processes, including the proportion of the fauna that is locally produced compared to that derived from outside recruitment, are essential to obtaining a comprehensive understanding of the structure and persistence of the resident faunal assemblages.

Finally, studies have shown that levels of primary production as well as the size spectrum of primary producers can influence both the abundance and composition of species at higher trophic levels (e.g. Mathews and Heimdal 1980) and there are currently no estimates of primary productivity, or data regarding the species and size composition of primary producers in the two fjords. Future studies in this area should greatly enhance our understanding of the structure and dynamics of species assemblages at higher trophic levels in Bay d'Espoir and Fortune Bay.

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Table 1. Station data for all collection sites. * indicates stations where the fishing depth was estimated by assuming a wire angle of 45°. Station data for latitude, longitude, bottom depth and time refer to the start of the tow. Tows are classified as dawn "Da", day "D", dusk "Du", or night "N", based on the time of collection.

Area	Station	Date (D/M/Y)	Latitude (°N)	Longitude (°W)	Bottom Depth (m)	Fishing Depth (m)	Time (local)
Bay d'Espoir	1205	6/05/82	47 42.15	56 08.2	786	*283	2250 N
	1206	7/05/82	47 39.85	56 07.89	550	*424	0012 N
	1207	7/05/82	47 41.2	56 07.9	770	*566	0620 D
	1208	7/05/82	47 40.32	56 07.8	749	*636	1800 D
	1209	7/05/82	47 41.88	56 08.05	768	*495	1921 Du
	1210	7/05/82	47 39.9	56 07.7	760	*354	2100 N
	1211	7/05/82	47 41.52	56 08.04	770	*212	2210 N
	1416	7/06/83	47 40.95	56 08	490	250	0250 N
	1419	7/06/83	47 41.72	56 08.20	765	475	0617 D
	1420	7/06/83	47 41.21	56 08.02	767	500	0823 D
	1423	8/06/83	47 40.59	56 04.14	385	270	0014 N
	1424	8/06/83	47 42.02	56 08.20	785	230	0203 N
	1425	8/06/83	47 42.0	56 08.20	780	500	0346 N
	1426	8/06/83	47 42.75	56 08.34	780	555	0539 D
Fortune Bay	1204	6/05/82	47 08.6	55 54.8	325	*283	0505 Da

Table 1. Continued

Area	Station	Date (D/M/Y)	Latitude (°N)	Longitude (°W)	Bottom Depth (m)	Fishing Depth (m)	Time (local)
Fortune Bay	1213	8/05/82	47 21.18	53 33.78	336	*318	0810 D
	1215	8/05/82	47 23.95	55 27.59	400	*424	2015 Du
	1218	11/05/82	47 18.3	55 41	333	*212	2255 N
	1403	4/06/83	47 05.7	56 03.8	305	210	0530 D
	1404	4/06/83	47 11.1	55 52.9	322	190	0818 D
	1405	4/06/83	47 12.73	55 48.77	270	240	0943 D
	1406	4/06/83	47 26.24	55 21.95	305	230	1307 D
	1408	4/06/83	47 37.3	55 16.7	460	230	1648 D
	1409	4/06/83	47 38.76	55 24.52	505	190	1926 D
	1410	4/06/83	47 41.2	55 25.1	520	200	2146 N
	1411	6/06/83	47 20.71	55 36.29	385	190	0041 N
	1412	6/06/83	47 21.47	55 34.32	382	120	0140 N
	1413	6/06/83	47 22.11	55 32.20	370	260	0241 N
	1414	6/06/83	47 22.41	55 30.10	425	50	0341 N
Laurentian Channel	1200	5/05/82	46 33.5	57 52.8	448	*354	0435 N
	1400	3/06/83	46 16.94	58 00.47	455	340	1237 D
	1401	3/06/83	46 15.70	58 02.58	455	320	1433 D

Table 1. Continued

Area	Station	Date (D/M/Y)	Latitude (°N)	Longitude (°W)	Bottom Depth (m)	Fishing Depth (m)	Time (local)
Laurentian Channel	1402	3/06/83	46 14.02	58 04.71	455	300	1552 D
Hermitage Channel	1201	5/05/82	47 15.6	56 42.6	380	*318	1345 D
	1216	10/05/82	47 29.19	56 24.65	380	*283	0343 N
	1217	11/05/82	47 01.3	57 16.98	325	*283	0054 N
	1427	9/06/83	47 07.08	57 01.51	340	180	1942 D
	1428	9/06/83	47 14.60	56 45.77	365	210	2300 N
	1429	10/06/83	47 20.75	56 35.18	370	212	0121 N
	1430	10/06/83	47 32.91	56 23.62	260	185	0358 N
St. Pierre Channel	1434	12/06/83	46 40.39	54 55.11	235	175	0244 N

Table 2. Total number and catch rate of all fishes collected in Bay d'Espoir.

FAMILY Species	Total Number	Number Hr^{-1}
CHAULIODONTIDAE		
Chauliodus sloani Bloch & Schneider	1	0.08
GADIDAE		
**Pollachius virens*(Linnaeus)	1	0.08
GONOSTOMATIDAE		
Cyclothone alba Brauer	1	0.08
C. braueri Jespersen and Taning	16	1.30
C. microdon (Günther)	20	1.63
C. pallida Brauer	1	0.08
C. pseudopallida Mukhacheva	1	0.08
LIPARIDAE		
Paraliparis copei Goode & Bean	12	0.98
P. garmani Burke	2	0.16
Paraliparis sp.	1	0.08
MACROURIDAE		
Nezumia bairdii(Goode and Bean)	6	0.49
MYCTOPHIDAE		
Benthosema glaciale (Reinhardt)	359	29.19
SCORPAENIDAE		
Sebastes spp.*	2	0.16
ZOARCIDAE		
Melanostigma atlanticum Koefoed	490	39.84
Total	913	74.23

* juvenile specimens only

Table 3. Total number and catch rate of all fishes collected in Fortune Bay.

FAMILY Species	Total Number	Number Hr^{-1}
AMMODYTIDAE		
**Ammodytes* spp.	2	0.20
COTTIDAE		
**Myoxocephalus octodecemspinosus* (Mitchill)	1	0.10
**M. scorpius* (Linnaeus)	1	0.10
**Myoxocephalus* sp.	1	0.10
GONOSTOMATIDAE		
Cyclothone alba Brauer	1	0.10
C. braueri Jespersen & Taning	6	0.60
Cyclothone spp.	2	0.20
LIPARIDAE		
Careproctus longipinnis Burke	1	0.10
Liparis tunicatus Reinhardt	1	0.10
MYCTOPHIDAE		
Benthosema glaciale (Reinhardt)	3	0.30
OSMERIDAE		
**Mallotus villosus* (Müller)	570	57.10
PLEURONECTIDAE		
**Hippoglossoides platessoides* (Fabricius)	1	0.10
SCORPAENIDAE		
**Sebastes* spp.	2	0.20
Total	592	59.30

* juvenile specimens only

Table 4. Rank abundance of juvenile and adult fishes collected from all regions; LC = Laurentian Channel, HC = Hermitage Channel, BD = Bay d'Espoir, FB = Fortune Bay, SP = St. Pierre Channel. + indicates species that represented less than 1 % of the total number.

Species	LC	HC	BD	FB	SP
Ammodytes spp.		3		+	
Anarhichas lupus		+			
Benthosema glaciale	1	1	2	+	
Careproctus longipinnis				+	
Chauliodus sloani			+		
Cyclothone alba	4		+	+	
C. braueri	2	+	4	2	
C. microdon			3		
C. pallida			+		
C. pseudopallida			+		
Cyclothone spp.	+			+	
Hippoglossoides platessoides				+	+
Lumpenus maculatus					+
Liparis tunicatus				+	
Mallotus villosus		2		1	1
Melanostigma atlanticum			1		
Myoxocephalus octodecemspinosus				+	
M. scorpius				+	
Myoxocephalus sp.				+	
Nezumia bairdii			6		
Paraliparis copei			5		
P. garmani			+		
Paraliparis sp.			+		
Pollachius virens			+		
Protomyctophum arcticum	3				
Sebastes spp.		+	+	+	

Table 5. **Percent similarity matrix for fish faunas of all regions; LC = Laurentian Channel, HC = Hermitage Channel, BD = Bay d'Espoir, FB = Fortune Bay, SP = St. Pierre Channel.**

	LC	HC	BD	FB	SP
LC	-	77.52	41.23	2.03	0.00
HC		-	40.18	20.59	25.90
BD			-	1.84	0.00
FB					97.92
SP					-

Table 6. The most abundant species of macrozooplankton collected in Bay d'Espoir and Fortune Bay and the percentage of the total number and weight of the macrozooplankton fauna that they comprised. N is the estimated total number collected. Species are arranged according to numerical abundance.

BAY D'ESPOIR

Species	N	% Total Number	% Total Weight (g)
Thysanoëssa raschii	174470	84.70	67.74
T. inermis	9807	4.76	3.95
Sagitta elegans	9153	4.44	0.83
Meganyctiphanes norvegica	4823	2.34	13.93
Eukrohnia hamata	4399	2.13	1.00
Total	202652	98.37	87.45

FORTUNE BAY

Species	N	% Total Number	% Total Weight (g)
Thysanoëssa raschii	45857	42.58	31.80
Sagitta elegans	32640	30.31	8.64
T. inermis	11752	10.91	10.76
Meganyctiphanes norvegica	6390	5.93	38.76
Parathemisto gaudichaudii	4913	4.56	2.77
Eukrohnia hamata	2792	2.59	0.82
T. longicaudata	2044	1.90	0.35
Total	106388	98.78	93.90

Table 7. Macrozooplankton species occurring only in Fortune Bay or Bay d'Espoir.

GROUP	Fortune Bay	Bay d'Espoir
AMPHIPOD	*Acanthostepheia malmgreni* *Halirages fulvocinctus* *Hyperoche medusarum* *Orchomenella minuta*	
EUPHAUSIID	*Nematobrachion boöpis* *Nematoscelis megalops*	
MYSID	*Erythrops erythropthalma* *Boreomysis nobilis* *Meterythrops robusta* *Parerythrops obesa*	*Boreomysis arctica* *Boreomysis tridens*
POLYCHAETE		*Tomopteris cavalli* *T. planktonis* *T. septentrionalis*
SHRIMP	*Pandalus borealis*	*Gennadas elegans* *Pasiphaea multidentata* *Pasiphaea tarda* *Sergestes arcticus*

Table 8. Macrozooplankton species occurring in low numbers in Fortune Bay and Bay d'Espoir.

GROUP Species	Fortune Bay No. Hr^{-1}	Bay d'Espoir No. Hr^{-1}
AMPHIPOD		
Hyperia galba	1.30	0.11
H. medusarum	0.20	0.11
Orchomenella pinguis	0.20	1.55
Parathemisto libellula	0.20	0.11
CHAETOGNATH		
Sagitta decipiens	0.20	0.55
MYSID		
Pseudomma truncatum	1.40	0.11
POLYCHAETE		
Tomopteris kefersteini	3.31	0.66
SHRIMP		
Pandalus montagui	0.20	0.11

Table 9. A comparison of catch rates for macrozooplankton collected from 10 trawls in Bay d'Espoir and 14 trawls in Fortune Bay. U_s is the Mann-Whitney statistic. p is the probability level corrected for ties. n.s. indicates there was no significant difference in the catch rate between fjords.

GROUP Species	U_s	p	Area of greatest abundance
AMPHIPOD			
Parathemisto gaudichaudii	0.0	0.0001	Fortune Bay
P. abyssorum	23.0	0.0029	Fortune Bay
CHAETOGNATH			
Eukrohnia hamata	38.0	0.0401	Bay d'Espoir
Sagitta elegans	30.5	0.0136	Fortune Bay
S. maxima	18.5	0.0009	Bay d'Espoir
EUPHAUSIID			
Meganyctiphanes norvegica	71.0	0.8244	n.s.
Thysanoëssa inermis	65.0	0.5791	n.s.
T. longicaudata	19.0	0.0019	Fortune Bay
T. raschii	72.0	0.8678	n.s.
MYSID			
Mysis mixta	25.5	0.0030	Fortune Bay
POLYCHAETE			
Tomopteris helgolandica	60.5	0.4148	n.s.
PTEROPOD			
Clione limacina	23.0	0.0033	Fortune Bay

Table 10. Comparison of the mean and range of Percent Similarity values for 16 stations in Fortune Bay separated by a distance of less than 10 km, and 10 groups of 16 station pairs randomly generated from all station pairs in Bay d'Espoir. U_s is the Mann-Whitney statistic. p is the probability level corrected for ties.

Area	Mean	Range	U_s	p
Fortune Bay	50.69	00.00 - 100.00		
Bay d'Espoir	76.62	62.15 - 93.63	106.0	0.5776
	75.62	47.43 - 95.70	104.0	0.5245
	68.52	34.26 - 89.20	113.0	0.7807
	79.25	54.14 - 94.11	102.0	0.4740
	76.40	45.10 - 95.70	107.0	0.6051
	76.36	54.07 - 94.11	108.0	0.6332
	70.39	39.36 - 93.63	112.0	0.7503
	71.67	39.36 - 95.20	109.0	0.6617
	70.90	34.36 - 95.70	110.0	0.6908
	73.63	39.36 - 95.03	108.0	0.6332

Table 11. Total number and weight of fish collected per hour in seven trawls from Bay d'Espoir in 1982 and 1983. - indicates species was not collected. / indicates data were unavailable.

	1982		1983	
Species	No. Hr^{-1}	Wt. Hr^{-1} (g)	No. Hr^{-1}	Wt. Hr^{-1} (g)
Benthosema glaciale	30.52	100.03	28.01	77.57
Chauliodus sloani	0.17	0.02	-	-
Cyclothone alba	0.17	0.01	-	-
C. braueri	2.60	0.10	0.15	0.01
C. microdon	3.12	0.24	0.31	0.03
C. pallida	0.17	0.01	-	-
C. pseudopallida	0.17	/	-	-
Melanostigma atlanticum	39.19	41.80	40.41	104.11
Nezumia bairdii	0.17	0.07	0.77	77.01
Paraliparis copei	0.69	3.12	1.22	1.17
P. garmani	-	-	0.31	0.16
Paraliparis sp.	0.17	2.83	-	-
Sebastes spp.	0.35	/	-	-
**Pollachius virens*	-	-	0.15	0.06
Total Hr^{-1}	77.51	148.88	71.33	260.11

* juvenile specimens only

Table 12. **Total number and weight of fish collected per hour in Fortune Bay from four trawls in 1982 and eleven trawls in 1983. - indicates species was not collected. / indicates data were unavailable.**

Species	1982 No. Hr^{-1}	1982 Wt. Hr^{-1} (g)	1983 No. Hr^{-1}	1983 Wt. Hr^{-1} (g)
**Ammodytes* spp.	-	-	0.28	0.01
Benthosema glaciale	1.06	0.57	-	-
Cyclothone alba	-	-	0.14	0.00
C. braueri	0.71	0.04	0.56	0.01
Cyclothone spp.	0.35	/	0.14	/
Careproctus longipinnis	0.35	3.16	-	-
**Hippoglossoides platessoides*	-	-	0.14	0.02
Liparis tunicatus	-	-	0.14	2.90
**Mallotus villosus*	2.12	3.48	78.88	66.15
**Myoxocephalus octodecemspinosus*	-	-	0.14	0.01
M. scorpius	-	-	0.14	0.01
Myoxocephalus sp.	-	-	0.14	0.01
**Sebastes* spp.	0.71	/	-	-
Total Hr^{-1}	5.29	7.24	80.70	69.13

* juvenile specimens only

Table 13. Total number and weight of macrozooplankton collected per hour in Bay d'Espoir from three trawls in 1982 and seven trawls in 1983. - indicates species was not collected. / indicates data were unavailable.

GROUP FAMILY Species	1982 No. Hr^{-1}	1982 Wt. Hr^{-1} (g)	1983 No. Hr^{-1}	1983 Wt. Hr^{-1} (g)
AMPHIPOD				
HYPERIIDAE				
Hyperia galba	-	-	0.15	0.00
H. medusarum	-	-	0.15	0.00
Parathemisto abyssorum	0.80	0.02	-	-
P. gaudichaudii	18.00	0.44	3.37	0.12
P. libellula	0.40	0.00	-	-
LYSIANASSIDAE				
Orchomenella pinguis	0.80	0.03	1.84	0.06
CHAETOGNATH				
Eukrohnia hamata	222.00	6.04	588.37	15.73
Sagitta decipiens	0.40	0.00	0.61	0.00
S. elegans	1058.80	13.18	995.82	9.90
S. maxima	7.20	0.30	111.58	7.67
EUPHAUSIID				
EUPHAUSIIDAE				
Meganyctiphanes norvegica	96.30	23.88	702.40	241.62
Thysanoëssa inermis	199.20	7.45	1424.85	68.30
T. longicaudata	11.20	0.11	90.00	1.14
T. raschii	70.80	1.25	26677.50	1219.23
MYSID				
MYSIDAE				
Boreomysis arctica	112.00	8.78	55.26	4.52
B. tridens	0.40	0.08	-	-
Mysis mixta	1.20	0.04	-	-
Pseudomma truncatum	0.40	/	-	-

Table 13. Continued

	1982		1983	
GROUP FAMILY Species	No. Hr^{-1}	Wt. Hr^{-1} (g)	No. Hr^{-1}	Wt. Hr^{-1} (g)
POLYCHAETE				
TOMOPTERIDAE				
Tomopteris helgolandica	1.20	0.02	29.39	1.07
T. cavalli	-	-	3.06	0.03
T. kefersteini	-	-	0.92	0.00
T. planktonis	-	-	1.38	0.00
T. septentrionalis	-	-	16.38	0.11
Tomopteris spp.	0.80	0.01	6.43	0.14
PTEROPOD				
CLIONIDAE				
Clione limacina	3.20	0.40	0.92	0.14
SHRIMP				
PANDALIDAE				
Pandalus montagui	-	-	0.15	0.10
PASIPHAEIDAE				
Pasiphaea multidentata	62.00	153.60	41.94	101.58
P. tarda	0.40	0.10	-	-
Pasiphaea spp.	20.00	0.71	4.59	0.62
PENAEIDAE				
Gennadas elegans	0.40	0.20	-	-
SERGESTIDAE				
Sergestes arcticus	19.20	17.43	42.55	38.74
Total Macrozooplankton Hr^{-1}	1904.40	234.09	30799.59	1710.84

Table 14. Total number and weight of macrozooplankton collected per hour in Fortune Bay from four trawls in 1982 and eleven trawls in 1983. - indicates species was not collected. / indicates data were unavailable.

GROUP FAMILY Species	1982 No. Hr^{-1}	1982 Wt. Hr^{-1} (g)	1983 No. Hr^{-1}	1983 Wt. Hr^{-1} (g)
AMPHIPOD				
CALLIOPIIDAE				
Haliragea fulvocinctus	12.71	0.28	6.99	0.30
HYPERIIDAE				
Hyperia galba	0.35	0.00	1.68	0.03
H. medusarum	-	-	0.28	0.03
Hyperoche medusarum	0.35	0.00	1.68	0.03
Parathemisto abyssorum	4.59	0.12	10.91	0.59
P. gaudichaudii	518.47	14.19	481.68	15.4[illegible]
P. libellula	-	-	0.28	0.0[illegible]
LYSIANASSIDAE				
Orchomenella minuta	0.35	0.00	0.42	0.01
O. pinguis	-	-	0.28	0.01
OEDICEROTIDAE				
Acanthostepheia malmgreni	1.06	0.23	2.24	0.23
CHAETOGNATH				
Eukrohnia hamata	244.94	2.26	293.43	5.36
Sagitta decipiens	0.71	0.01	-	-
S. elegans	1990.50	24.54	3870.07	56.08
S. maxima	3.88	0.23	4.90	0.52
EUPHAUSIID				
EUPHAUSIIDAE				
Meganyctiphanes norvegica	18.35	4.06	886.43	293.69
Nematobrachion boöpis	3.18	0.24	0.28	0.03
Nematoscelis megalops	0.71	0.03	-	-
Thysanoëssa inermis	645.88	13.67	1387.69	76.55
T. longicaudata	196.24	1.54	208.11	2.07
T. raschii	1838.12	40.63	5685.17	226.12

Table 14. Continued

GROUP FAMILY Species	1982 No. Hr^{-1}	 Wt. Hr^{-1} (g)	1983 No. Hr^{-1}	 Wt. Hr^{-1} (g)
MYSID				
MYSIDAE				
Boreomysis arctica	0.35	0.01	-	-
B. nobilis	30.35	8.80	92.17	15.45
Erythrops erythropthalma	2.47	0.02	0.42	0.01
Meterythrops robusta	2.82	0.18	0.84	0.03
Mysis mixta	8.47	0.55	4.48	0.43
Parerythrops obesa	3.88	0.25	-	-
Pseudomma truncatum	2.47	0.05	0.98	0.02
POLYCHAETE				
TOMOPTERIDAE				
Tomopteris helgolandica	1.06	0.01	4.62	0.20
T. kefersteini	0.35	0.00	4.48	0.00
Tomopteris spp.	1.06	0.00	0.56	0.00
PTEROPOD				
CLIONIDAE				
Clione limacina	5.65	0.56	3.78	0.36
SHRIMP				
PANDALIDAE				
Pandalus borealis	1.41	6.39	4.06	20.62
P. montagui	0.71	0.18	-	-
PASIPHAEIDAE				
Pasiphaea multidentata	-	-	0.14	0.37
Total Macrozooplankton Hr^{-1}	5304.71	119.14	12959.02	714.63

Table 15. A comparison of the mean value of Percent Similarity "$\bar{x}$PS" for macrozooplankton in Bay d'Espoir and Fortune Bay using only day station pairs and night station pairs from both fjords. sd is the standard deviation. n is the number of station pairs compared. U_s^* is the Mann-Whitney statistic. p is the probability level corrected for ties.

Time	Area	$\bar{x}$ PS	sd	n	U_s	p
Day	Bay d'Espoir	63.88	27.28	06	61.0	0.9071
	Fortune Bay	69.29	15.79	21		
Night	Bay d'Espoir	47.47	31.17	15	76.0	0.1300
	Fortune Bay	68.16	11.74	15		

Table 16. The amount of macrozooplankton "Macro Zoo", miscellaneous zooplankton "Misc. Zoo", and the total zooplankton "Tot Zoo", wet preserved weight biomass (g) collected from Bay d'Espoir[1] and Fortune Bay[2] in 1982, 1983, and overall, and the percentage of the total zooplankton biomass comprised by the macrozooplankton and the miscellaneous zooplankton.

	Bay d'Espoir			Fortune Bay		
	Macro Zoo	Misc Zoo	Tot Zoo	Macro Zoo	Misc Zoo	Tot Zoo
Total Wt. Hr^{-1} 1982	234.1	47.6	281.7	119.1	92.9	212.0
Total Wt. Hr^{-1} 1983	3736.1	152.3	3888.4	719.6	122.2	841.7
Totla Wt. Hr^{-1}	1886.5	97.0	1983.4	535.0	113.2	648.2
% Total Zooplankton Biomass 1982	83.1	16.9	100.0	56.2	43.8	100.0
% Total Zooplankton Biomass 1983	96.1	3.9	100.0	85.5	14.5	100.0
% Total Zooplankton Biomass	95.1	4.9	100.0	82.5	17.5	100.0

1 Stations 1419, 1420, 1424, 1426 not included
2 Station 1413 not included

Table 17. Selected community parameters for the fish and macrozooplankton faunas of Bay d'Espoir "BD" and Fortune Bay "FB". CPUE is catch per unit effort.

	Fish		Macrozooplankton	
Community Parameters	BD	FB	BD	FB
Average Species Richness	4.2	1.5	13.6	14.0
CPUE (g min^{-1})	3.47	0.86	21.70	9.09
Diversity (H')	1.02	0.24	0.68	1.49
Evenness (E)	0.14	0.02	0.03	0.11

Figure 1. The study site located off the southern coast of Newfoundland, Canada.

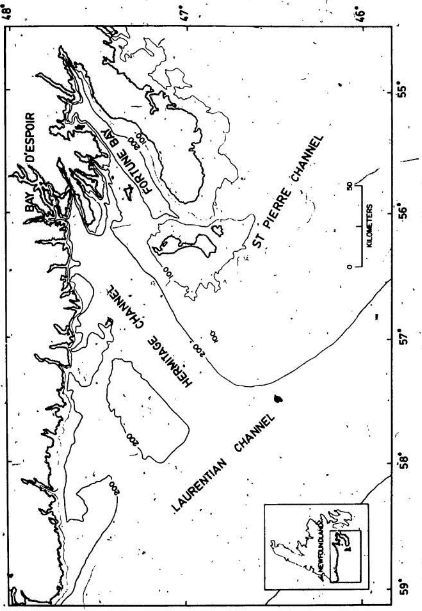

48°
47°
46°
55°
56°
57°
58°
59°
BAY D'ESPOIR
FORTUNE BAY
ST PIERRE CHANNEL
HERMITAGE CHANNEL
LAURENTIAN CHANNEL
100
200
0
50
KILOMETERS
NEWFOUNDLAND

Figure 2. Detailed chart of Bay d'Espoir.

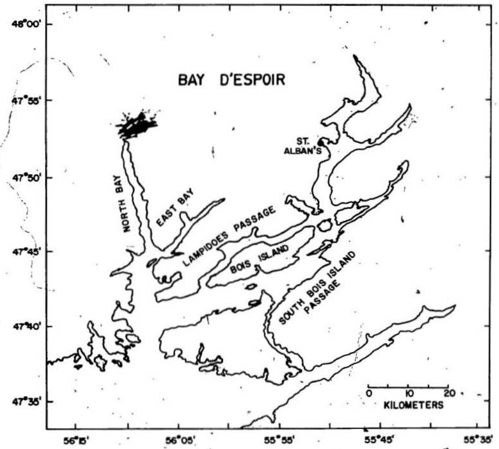
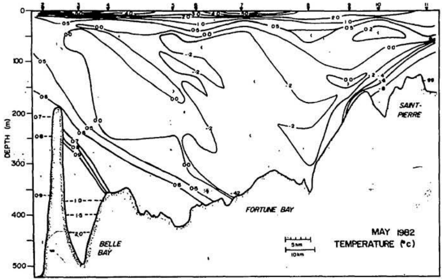

BAY D'ESPOIR
ST. ALBAN'S
NORTH BAY
EAST BAY
LAMPIDOES PASSAGE
BOIS ISLAND
SOUTH BOIS ISLAND PASSAGE
0
10
20
KILOMETERS
48°00'
47°55'
47°50'
47°45'
47°40'
47°35'
56°15'
56°05'
55°55'
55°45'
55°35'

Figure 3. Temperature (upper) and salinity (lower) profiles for Fortune Bay in May 1982 extending from the head of the fjord into the St. Pierre Channel. Station numbers are shown on top of the figures. Salinity is measured in practical salinity units. ">" and "<" symbols indicate that water temperatures were "greater than" or "less than" that of the surrounding isotherm. A dashed line indicates that isopleths were extrapolated from a single data point (from de Young 1983).


2
3
4
5
6
7
8
9
10
11
0
100
200
300
400
500
DEPTH (m)
0.5
0.0
-2
0.6
0.7
0.8
0.9
1.0
1.5
2.0
2.0
3.0
4.0
BELLE BAY
FORTUNE BAY
SAINT-PIERRE
5nm
10km
MAY 1982
TEMPERATURE (°c)

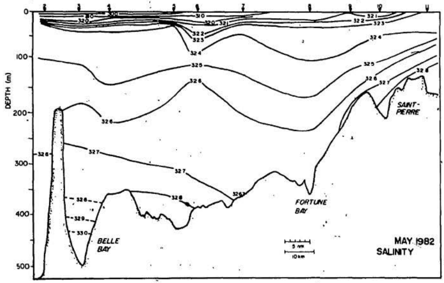
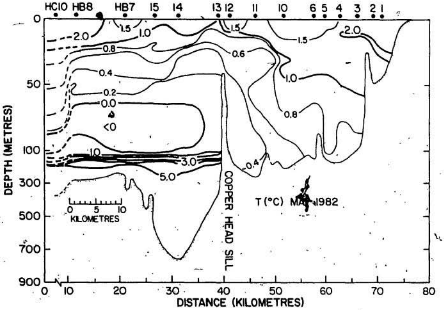

2
3
4
5
6
7
8
9
10
11
0
100
200
300
400
500
DEPTH (m)
300
310
320
321
322
323
324
325
326
327
328
329
330
BELLE BAY
FORTUNE BAY
SAINT-PIERRE
5 nm
10km
MAY 1982
SALINITY

Figure 4. Temperature (upper) and salinity (lower) profiles for Bay d'Espoir in May 1982 extending from the mouth of the fjord to the head of the eastern arm near St. Alban's. Station numbers are shown on top of the figures. Salinity is measured in practical salinity units. A dashed line indicates where isopleths have been extrapolated between stations. Distance is measured as the distance from the outermost station to the head of the fjord (from Richard and Hay 1984).


HC10 HB8 HB7 15 14 13 12 11 10 6 5 4 3 2 1
2.0
1.5
1.0
1.5
1.5
2.0
0.8
0.6
0.4
1.0
0.2
0.0
<0
0.8
1.0
3.0
0.4
5.0
COPPER HEAD SILL
T (°C) MAY 1982
0 5 10
KILOMETRES
DEPTH (METRES)
0
50
100
300
500
700
900
0 10 20 30 40 50 60 70 80
DISTANCE (KILOMETRES)

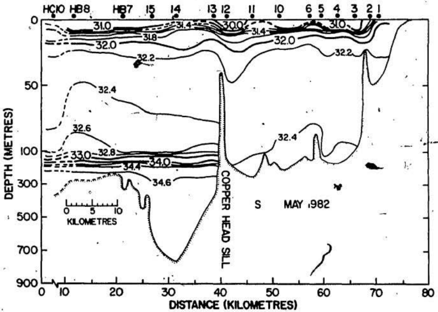

HC10 HB8 HB7 15 14 13 12 11 10 6 5 4 3 2 1
31.0
31.4
30.0
31.4
31.0
31.8
32.0
32.0
32.2
32.2
32.4
32.6
32.4
33.0
32.8
34.0
34.4
34.6
COPPER HEAD SILL
S MAY 1982
0 5 10
KILOMETRES
DEPTH (METRES)
0
50
100
300
500
700
900
0 10 20 30 40 50 60 70 80
DISTANCE (KILOMETRES)

Figure 5. Location of Isaacs-Kidd sampling stations in Bay d'Espoir and Fortune Bay in 1982 (◊) and 1983 (◆).

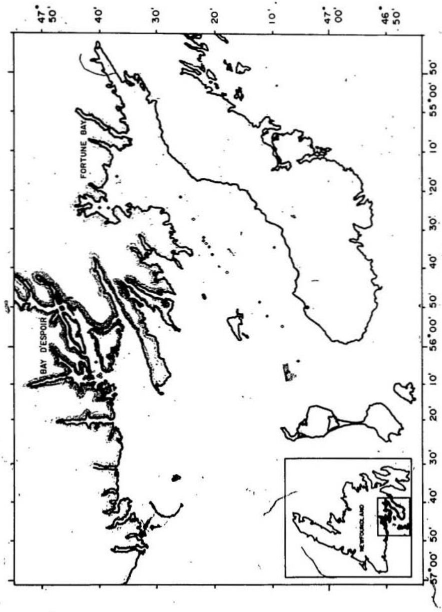

FORTUNE BAY
BAY D'ESPOIR
NEWFOUNDLAND
47° 50'
40'
30'
20'
10'
47° 00'
46° 50'
50'
55°00'
10'
20'
30'
40'
50'
56°00'
10'
20'
30'
40'
50'
57°00'

Figure 6. Catch rate by depth strata for fishes in day (□) and night (■) collections from Bay d'Espoir for 1982 and 1983 combined. n is the number of tows per depth stratum.

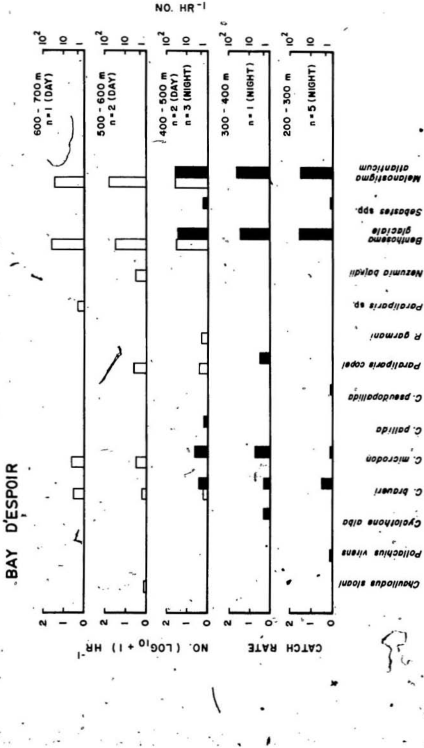

BAY D'ESPOIR
NO. HR⁻¹
CATCH RATE NO. (LOG₁₀ + 1) HR⁻¹
200 - 300 m
n = 5 (NIGHT)
300 - 400 m
n = 1 (NIGHT)
400 - 500 m
n = 2 (DAY)
n = 3 (NIGHT)
500 - 600 m
n = 2 (DAY)
600 - 700 m
n = 1 (DAY)
10²
10
1
0
1
2
Melanostigma atlanticum
Sebastes spp.
Benthosema glaciale
Nezumia bairdii
Paraliparis sp.
R. garmani
Paraliparis copei
C. pseudopallida
C. pallida
C. microdon
C. braueri
Cyclothone alba
Pollachius virens
Chauliodus sloani

Figure 7. Catch rate by depth strata for fishes in day (□) and night (■) collections from Fortune Bay for 1982 and 1983 combined. n is the number of tows per depth stratum.

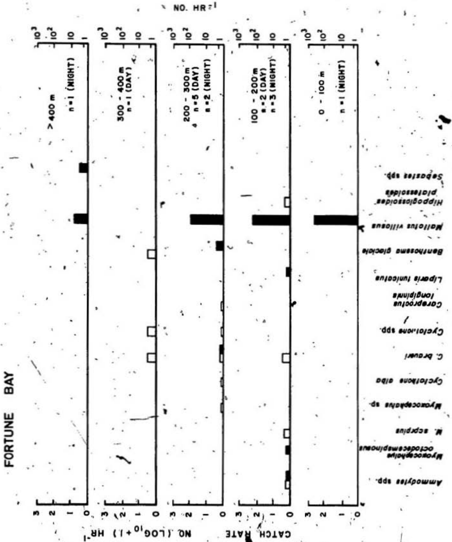

FORTUNE BAY
NO. HR⁻¹
CATCH RATE NO. (LOG₁₀ + 1) HR⁻¹
0 - 100 m n = 1 (NIGHT)
100 - 200 m n = 2 (DAY) n = 3 (NIGHT)
200 - 300 m n = 5 (DAY) n = 2 (NIGHT)
300 - 400 m n = 1 (DAY)
> 400 m n = 1 (NIGHT)
1
10
10²
10³
0
1
2
3
Sebastes spp.
Hippoglossoides platessoides
Mallotus villosus
Benthosema glaciale
Liparis tunicatus
Careproctus longipinnis
Cyclothone spp.
C. braueri
Cyclothone alba
Myoxocephalus sp.
M. scorpius
Myoxocephalus octodecemspinosus
Ammodytes spp.

Figure 8. Catch rate by depth strata for macrozooplankton in day (□) and night (■) collections from Bay d'Espoir for 1982 and 1983 combined. n is the number of tows per depth stratum.

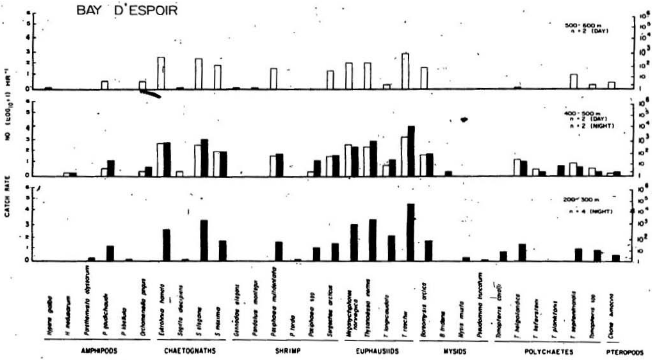

BAY D'ESPOIR
500-600 m
n = 2 (DAY)
400-500 m
n = 2 (DAY)
n = 2 (NIGHT)
200-300 m
n = 4 (NIGHT)
CATCH RATE NO (LOG10+1) HR-1
NO HR-1
0
1
2
3
4
5
6
1
10
10²
10³
10⁴
10⁵
10⁶
Hyperia galba
H medusarum
Parathemisto abyssorum
P gaudichaudii
P libellula
Orchomenella pinguis
AMPHIPODS
Eukrohnia hamata
Sagitta decipiens
S elegans
S maxima
CHAETOGNATHS
Gennadas elegans
Pandalus montagui
Pasiphaea multidentata
P tarda
Pasiphaea spp
Sergestes arcticus
SHRIMP
Meganyctiphanes norvegica
Thysanoessa inermis
T longicaudata
T raschii
EUPHAUSIIDS
Boreomysis arctica
B tridens
Mysis mixta
Pseudomma truncatum
MYSIDS
Tomopteris cavalli
T helgolandica
T kefersteini
T planktonis
T septentrionalis
Tomopteris spp
POLYCHAETES
Clione limacina
PTEROPODS

Figure 9. Catch rate by depth strata for macrozooplankton in day (☐) and night (■) collections from Fortune Bay for 1982 and 1983 combined. n is the number of tows per depth stratum.

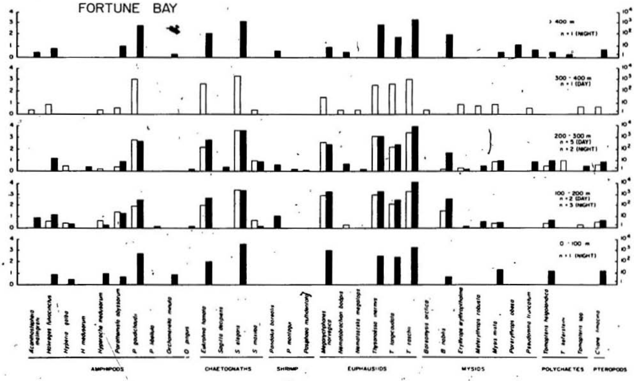
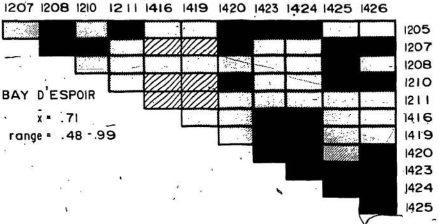

FORTUNE BAY
NO (LOG10 +1) HR-1
CATCH RATE
NO HR-1
> 400 m
n = 1 (NIGHT)
300 - 400 m
n = 1 (DAY)
200 - 300 m
n = 5 (DAY)
n = 2 (NIGHT)
100 - 200 m
n = 2 (DAY)
n = 3 (NIGHT)
0 - 100 m
n = 1 (NIGHT)
0
1
2
3
4
1
10
10²
10³
10⁴
Acanthostepheia malmgreni
Halirages fulvocinctus
Hyperia galba
H medusarum
Hyperoche medusarum
Parathemisto abyssorum
P gaudichaudi
P libellula
Orchomenella minuta
O pinguis
Eukrohnia hamata
Sagitta decipiens
S elegans
S maxima
Pandalus borealis
P montagui
Pasiphaea multidentata
Meganyctiphanes norvegica
Nematobrachion boopis
Nematoscelis megalops
Thysanoessa inermis
T longicaudata
T raschii
Boreomysis arctica
B nobilis
Erythrops erythrophthalma
Meterythrops robusta
Mysis mixta
Parerythrops obesa
Pseudomma truncatum
Tomopteris helgolandica
T kefersteini
Tomopteris spp
Clione limacina
AMPHIPODS
CHAETOGNATHS
SHRIMP
EUPHAUSIIDS
MYSIDS
POLYCHAETES
PTEROPODS

Figure 10. Graphical presentation of Spearman rank correlation coefficients for the abundance of fishes between stations in Bay d'Espoir (upper) and Fortune Bay (lower). Station numbers are shown along the outside of each matrix. Station numbers beginning with "12" indicate the 1982 collections while those beginning with "14" indicate the 1983 collections.


1207 1208 1210 1211 1416 1419 1420 1423 1424 1425 1426
1205
1207
1208
1210
1211
1416
1419
1420
1423
1424
1425
BAY D'ESPOIR
$\bar{x}$ = .71
range = .48 - .99

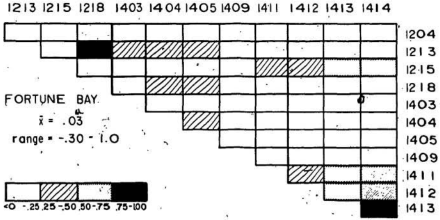
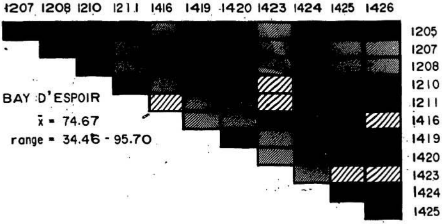

1213 1215 1218 1403 1404 1405 1409 1411 1412 1413 1414
1204
1213
1215
1218
1403
1404
1405
1409
1411
1412
1413
FORTUNE BAY
$\bar{x}$ = .03
range = -.30 - 1.0
<0 -.25 .25-.50 .50-.75 .75-100

Figure 11. Graphical presentation of percent similarity values for the abundance of fishes between stations in Bay d'Espoir (upper) and Fortune Bay (lower). Station numbers are shown along the outside of each matrix. Station numbers beginning with "12" indicate the 1982 collections while those beginning with "14" indicate the 1983 collections.


1207 1208 1210 1211 1416 1419 1420 1423 1424 1425 1426
1205
1207
1208
1210
1211
1416
1419
1420
1423
1424
1425
BAY D'ESPOIR
x̄ = 74.67
range = 34.46 - 95.70

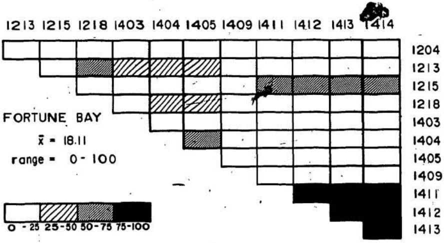

1213 1215 1218 1403 1404 1405 1409 1411 1412 1413 1414
1204
1213
1215
1218
1403
1404
1405
1409
1411
1412
1413
FORTUNE BAY
x̄ = 18.11
range = 0 - 100
0 - 25
25-50
50-75
75-100

Figure 12. Plots of percent similarity versus distance between station pairs for the fish fauna in Bay d'Espoir "a" and Fortune Bay "b". Note the change in distance scales between plots.

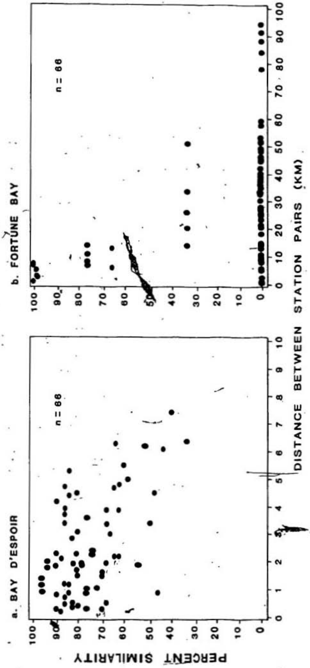

a. BAY D'ESPOIR
n = 66
b. FORTUNE BAY
n = 66
PERCENT SIMILARITY
100
90
80
70
60
50
40
30
20
10
0
0
1
2
3
4
5
6
7
8
9
10
20
30
40
50
60
70
80
90
100
DISTANCE BETWEEN STATION PAIRS (KM)

Figure 13. Plots of percent similarity versus distance for the fish fauna in Bay d'Espoir "a" and Fortune Bay "b" between station pairs separated in distance by less than 10 km.

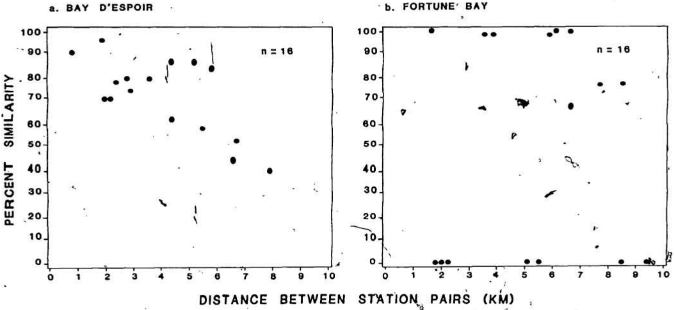

a. BAY D'ESPOIR
b. FORTUNE BAY
n = 16
n = 16
PERCENT SIMILARITY
100
90
80
70
60
50
40
30
20
10
0
0 1 2 3 4 5 6 7 8 9 10
DISTANCE BETWEEN STATION PAIRS (KM)

Figure 14. Length frequency distribution of *Melanostigma atlanticum* collected from Bay d'Espoir for 1982 (upper) and 1983 (lower).

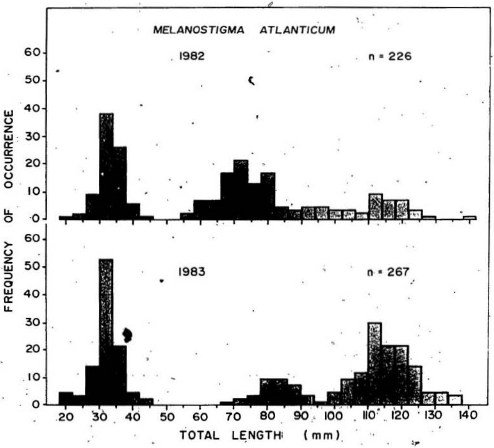

MELANOSTIGMA ATLANTICUM
1982
n = 226
1983
n = 267
FREQUENCY OF OCCURRENCE
60
50
40
30
20
10
0
20
30
40
50
60
70
80
90
100
110
120
130
140
TOTAL LENGTH (mm)

Figure 15. Length frequency distribution of *Benthosema glaciale* collected from Bay d'Espoir for 1982 (upper) and 1983 (lower).

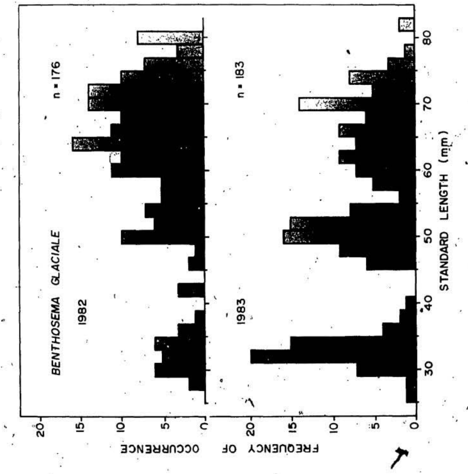

BENTHOSEMA GLACIALE
1982
n = 176
1983
n = 183
FREQUENCY OF OCCURRENCE
0
5
10
15
20
STANDARD LENGTH (mm)
30
40
50
60
70
80

Figure 16. Length frequency distribution of *Mallotus villosus* collected from Fortune Bay in 1983.

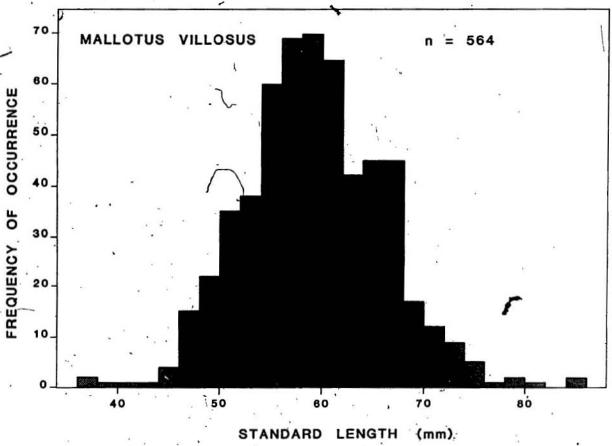

MALLOTUS VILLOSUS
n = 564
FREQUENCY OF OCCURRENCE
70
60
50
40
30
20
10
0
40
50
60
70
80
STANDARD LENGTH (mm)

Figure 17. Graphical presentation of Spearman rank correlation coefficients for macrozooplankton abundance between stations in Bay d'Espoir. Station numbers are shown along the outside of each matrix. Station numbers beginning with "12" indicate the 1982 collections while those beginning with "14" indicate the 1983 collections.

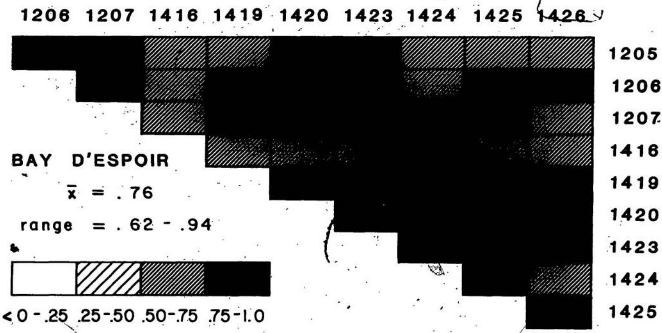

1206 1207 1416 1419 1420 1423 1424 1425 1426
1205
1206
1207
1416
1419
1420
1423
1424
1425
BAY D'ESPOIR
$\bar{x}$ = .76
range = .62 - .94
<0 - .25
.25-.50
.50-.75
.75-1.0

Figure 18. Graphical presentation of Spearman rank correlation coefficients for macrozooplankton abundance between stations in Fortune Bay. Station numbers are shown along the outside of each matrix. Station numbers beginning with "12" indicate the 1982 collections while those beginning with "14" indicate the 1983 collections.

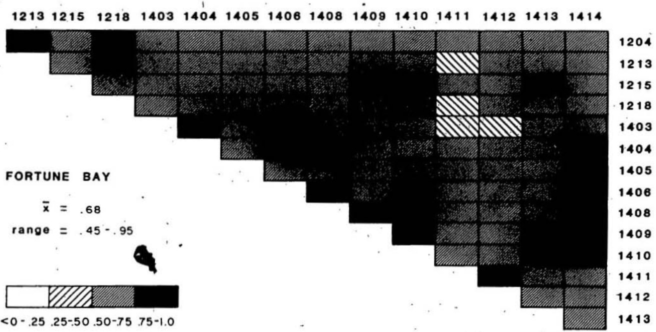
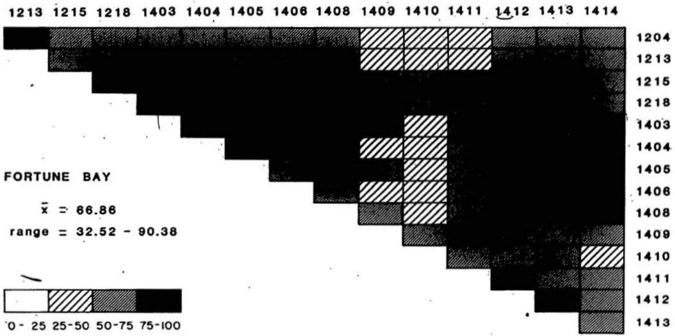

1213 1215 1218 1403 1404 1405 1406 1408 1409 1410 1411 1412 1413 1414
1204
1213
1215
1218
1403
1404
1405
1406
1408
1409
1410
1411
1412
1413
FORTUNE BAY
x̄ = .68
range = .45 - .95
<0 - .25 .25-.50 .50-.75 .75-1.0

Figure 19. Graphical presentation of percent similarity values for macrozooplankton abundance between stations in Fortune Bay. Station numbers are shown along the outside of each matrix. Station numbers beginning with "12" indicate the 1982 collections while those beginning with "14" indicate the 1983 collections.

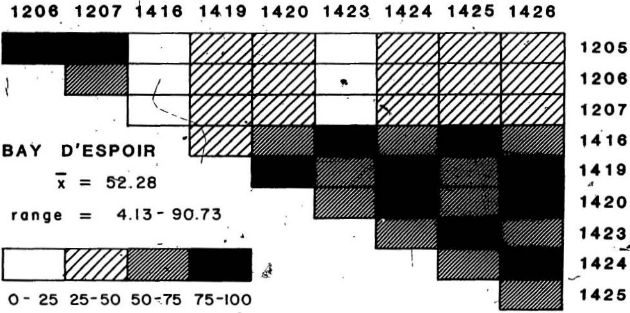


FORTUNE BAY

$\bar{x} = 66.86$

range = 32.52 - 90.38

Figure 20. Graphical presentation of percent similarity values for macrozooplankton abundance between stations in Bay d'Espoir. Station numbers are shown along the outside of each matrix. Station numbers beginning with "12" indicate the 1982 collections while those beginning with "14" indicate the 1983 collections.



	1206	1207	1416	1419	1420	1423	1424	1425	1426
1205	■	■	□	▨	▨	□	▨	▨	▨
1206		▩	□	▨	▨	□	▨	▨	▨
1207			□	▨	▨	□	▨	▨	▨
1416				▨	▩	■	▩	■	▩
1419					■	▩	■	▩	■
1420						▩	■	▩	■
1423							▩	■	▩
1424								▩	■
1425									▩

BAY D'ESPOIR

$\bar{x} = 52.28$

range = 4.13 - 90.73

□	▨	▩	■
0 - 25	25-50	50-75	75-100

Figure 21. Plots of percent similarity versus distance between station pairs for the macrozooplankton fauna in Bay d'Espoir "a" and Fortune Bay "b". Note the change in distance scales between plots.

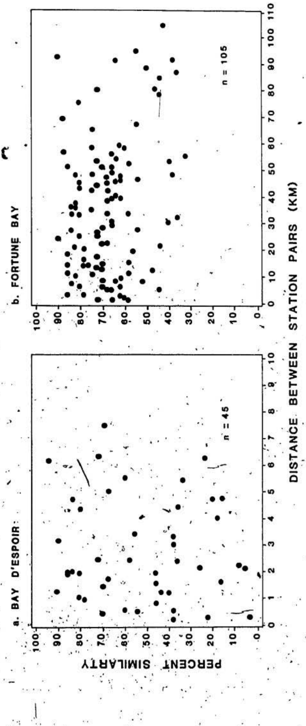
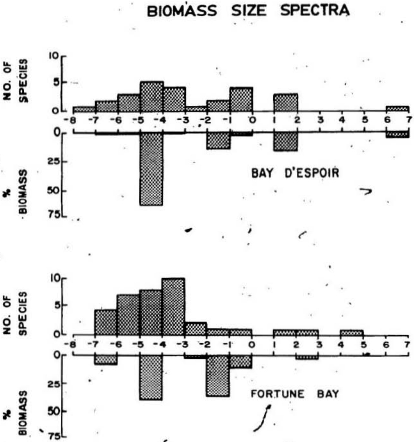

a. BAY D'ESPOIR
n = 45
b. FORTUNE BAY
n = 105
PERCENT SIMILARITY
100
90
80
70
60
50
40
30
20
10
0
0
1
2
3
4
5
6
7
8
9
10
0
10
20
30
40
50
60
70
80
90
100
110
DISTANCE BETWEEN STATION PAIRS (KM)

Figure 22. Biomass size spectra for Bay d'Espoir (upper) and Fortune Bay (lower) showing the number of species and the percentage of the fish and macrozooplankton wet preserved weight biomass in each $\log_2$ weight size class. Data are for 1983 only.


BIOMASS SIZE SPECTRA
NO. OF SPECIES
% BIOMASS
10
5
0
25
50
75
-8
-7
-6
-5
-4
-3
-2
-1
0
1
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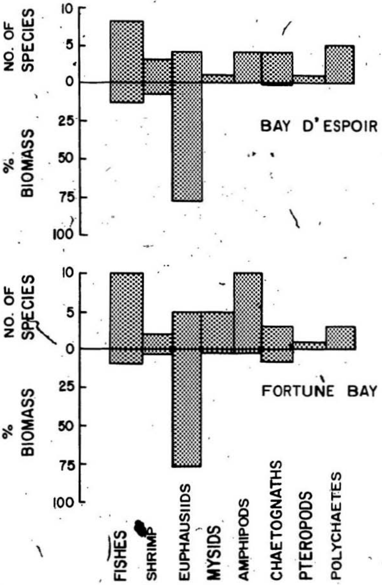
BAY D'ESPOIR
FORTUNE BAY

Figure 23. Taxonomic group composition for Bay d'Espoir (upper) and Fortune Bay (lower) showing the number of species and the percentage of the fish and macrozooplankton biomass in each of the faunal groups. Data are for 1983 only.

GROUP COMPOSITION



APPENDIX A. Species and number of individuals of larval fish collected from all regions in 1982 and 1983; LC = Laurentian Channel, HC = Hermitage Channel, BD = Bay d'Espoir, FB = Fortune Bay, SP = St. Pierre Channel.

Species	LC	HC	BD	FB	SP
Ammodytes spp.	16	87	8	50	1
Anarhichas lupus			1		
Argentina silus	3	1			
Cryptacanthodes maculatus			1		
Hemitripterus americanus				1	
Hippoglossoides platessoides		1			
Mallotus villosus				1	
Sebastes spp.	495	6	56	15	
Stichaeus punctatus				1	

APPENDIX B. Formulae used to calculate the population estimate variance, standard error, and fiducial limits for macrozooplankon species.

1. Population estimate:

$$\hat{N} = \bar{n}_c \, p^k,$$

where $\hat{N}$ is the best estimator of the actual number N, p is the probability of an organism being in the subsample after one split, k is the number of successive splits, and $\bar{n}_c$ is the mean number of animals counted in m subsamples ($m \geq 1$).

2. Variance:

$$\hat{\sigma}^2 = \bar{n}_c \, p^{-2k} \, (1 - p^k),$$

where $\hat{\sigma}^2$ is the best estimator of the variance σ^2 and $\bar{n}_c$, p and k are as defined above.

3. Standard deviation:

$$\hat{\sigma} = [n_c \, p^{-2k} \, (1 - p^k)]^{1/2},$$

where $\hat{\sigma}$ is the best estimator of the standard deviation σ and $\bar{n}_c$, p and k are as defined above.

4. 95 % fiducial limits:

$$(1.96\hat{\sigma}/m^{1/2}) + \hat{N} \geq N \geq \hat{N} - (1.96\hat{\sigma}/m^{1/2}),$$

where $\hat{\sigma}$, $\hat{N}$ and N and m are as defined above.

APPENDIX C. Mean, variance and coefficient of dispersion "C.D." for the number of macrozooplankters collected per hour, and the total number "N" for all species collected from Bay d'Espoir, 1982 and 1983 combined.

GROUP FAMILY Species	Mean No. Hr^{-1}	Variance	C.D.	N
AMPHIPOD				
HYPERIIDAE				
Hyperia galba	0.12	0.15	1.22	1
H. medusarum	0.10	0.10	1.00	1
Parathemisto abyssorum	0.23	0.53	2.31	2
P. gaudichaudii	7.62	202.26	26.54	67
P. libellula	0.12	0.13	1.15	1
LYSIANASSIDAE				
Orchomenella pinguis	1.37	2.80	2.04	14
CHAETOGNATH				
Eukrohnia hamata	494.42	59202.15	119.74	4399
Sagitta decipiens	0.48	0.94	1.95	5
S. elegans	1166.38	1130482.00	969.22	9153
S. maxima	74.96	4541.23	60.58	747
DECAPOD SHRIMP				
PANDALIDAE				
Pandalus montagui.	0.07	0.04	0.66	1
PASIPHAEIDAE				
Pasiphaea multidentata	50.73	366.67	7.23	429
P. tarda	0.12	0.13	1.15	1
Pasiphaea spp.	10.41	202.27	19.44	80
PENAEIDAE				
Gennadas elegans	0.10	0.10	1.00	1
SERGESTIDAE				
Sergestes arcticus	35.42	1027.44	29.01	326
EUPHAUSIID				
EUPHAUSIIDAE				
Meganyctiphanes norvegica	620.77	686536.40	1105.95	4823
Thysanoëssa inermis	1338.00	2888982	2159.18	9807
T. longicaudata	77.31	39431.00	510.05	616
T. raschii	26129.90	3.54E+09	135440.40	174470

APPENDIX C. Continued

GROUP FAMILY Species	Mean No. Hr^{-1}	Variance	C.D.	N
MYSID				
MYSIDAE				
Boreomysis arctica	69.53	2851.64	41.01	641
B. tridens	0.16	0.25	1.58	1
Mysis mixta	0.35	1.20	3.46	3
Pseudomma truncatum	0.12	0.13	1.15	1
POLYCHAETE				
TOMOPTERIDAE				
Tomopteris helgolandica	25.88	1995.33	77.10	195
T. kefersteini	0.63	1.04	1.66	6
T. cavalli	2.93	85.66	29.27	20
T. planktonis	1.10	12.14	11.02	9
T. septentrionalis	11.31	339.69	30.04	107
Tomopteris spp.	5.16	151.17	29.31	44
PTEROPOD				
CLIONIDAE				
Clione limacina	1.40	8.32	5.94	14

APPENDIX D. Mean, variance and coefficient of dispersion "C.D." for the number of macrozooplankters collected per hour, and the total number "N" for all species collected from Fortune Bay, 1982 and 1983 combined.

GROUP FAMILY Species	Mean No. Hr^{-1}	Variance	C.D.	N
AMPHIPOD				
CALLIOPIIDAE				
Halirages fulvocinctus	9.46	159.37	16.84	86
HYPERIIDAE				
Hyperia galba	1.29	3.33	2.58	13
H. medusarum	0.17	0.45	2.61	2
Hyperoche medusarum	1.50	7.00	4.66	13
Parathemisto abyssorum	9.97	294.20	29.50	91
P. gaudichaudii	454.09	167795.30	369.52	4913
P. libellula	0.21	0.32	1.49	2
LYSIANASSIDAE				
Orchomenella minuta	0.51	2.97	5.80	4
O. pinguis	0.21	0.31	1.50	2
OEDICEROTIDAE				
Acanthostepheia malmgreni	2.00	14.74	7.38	19
CHAETOGNATH				
Eukrohnia hamata	309.74	178432.3	576.06	2792
Sagitta decipiens	0.27	1.07	4.00	2
S. elegans	3189.34	6941076	2176.33	32640
S. maxima	4.35	91.72	21.07	46
DECAPOD SHRIMP				
PANDALIDAE				
Pandalus borealis	3.47	59.68	17.18	33
P. montagui	0.23	0.39	1.66	2
PASIPHAEIDAE				
Pasiphaea multidentata	0.08	0.10	1.20	1
EUPHAUSIID				
EUPHAUSIIDAE				
Meganyctiphanes norvegica	703.88	796930.90	1132.19	6390
Nematobrachion boöpis	1.23	6.55	5.34	11
Nematoscelis megalops	0.23	0.39	1.66	2

APPENDIX D. Continued

GROUP FAMILY Species	Mean No. Hr^{-1}	Variance	C.D.	N
EUPHAUSIID				
EUPHAUSIIDAE				
Thysanoëssa inermis	1178.50	906742.00	769.41	11752
T. longicaudata	217.61	26848.64	123.38	2044
T. raschii	4855.52	32469503.00	6687.13	45857
MYSID				
MYSIDAE				
Boreomysis arctica	0.10	0.15	1.50	1
B. nobilis	87.34	72053.37	824.95	745
Erythrops erythropthalma	0.99	3.95	3.98	10
Meterythrops robusta	1.60	6.71	4.20	14
Mysis mixta	6.36	57.92	9.11	56
Parerythrops obesa	0.73	8.07	11.00	11
Pseudomma truncatum	1.21	6.46	5.35	14
POLYCHAETE				
TOMOPTERIDAE				
Tomopteris helgolandica	3.78	20.95	5.54	36
T. kefersteini	2.63	98.00	37.31	33
Tomopteris spp.	0.66	2.23	3.38	7
PTEROPOD				
CLIONIDAE				
Clione limacina	4.68	13.42	2.87	43