EFFECTS OF TIDAL MOVEMENT ON THE FEEDING OF WINTER FLOUNDER PSEUDOPLEURONECTES AMERICANUS (WALBAUM) IN LONG POND, CONCEPTION BAY, NEWFOUNDLAND BRANDY COVE, NEW BRUNSWICK

BARBARA F. WELLS

EFFECTS OF TIDAL MOVEMENT ON THE FEEDING OF WINTER FLOUNDER *Pseudopleuronectes americanus* (Walbaum) IN LONG POND, CONCEPTION BAY, NEWFOUNDLAND AND BRANDY COVE, NEW BRUNSWICK

A Thesis
Presented to
the Department of Biology
Memorial University of Newfoundland

In Partial Fulfillment
of the Requirements for the Degree
Master of Science

by
Barbara F. Wells

March, 1974

Abstract

Tidal movements and feeding in winter flounder were found to be strongly correlated in Brandy Cove, N.B. during the summer feeding period of this species. Tidal amplitude at the study site was six to seven times larger than for other coastal areas. Stomachs of fish moving inshore were empty or contained only smal quantities of prey whereas stomachs of those leaving the intertidal zone were full with fresh, intertidal prey. Fish caught in the subtidal zone at high tide fed as much as those in the intertidal zone but fed on subtidal and intertidal prey in contrast to intertidal feeders which fed, generally, only in that zone. Prey consumed support the classification of these fish as polychaete-mollusc-crustacean feeders.

Winter flounder studied in Long Pond, Newfoundland displayed tidal movement across the bottom of the shallow subtidal zone and into the narrower intertidal zone. They ate considerably less than those in deeper water in Conception Bay. The poor feeding on the shallow ground in Long Pond was due to a poor standing crop and diversity of benthos. It is concluded that the shallow water feeding is controlled by three interacting parameters, which in order of importance are: temperature, tides, and surf conditions. Food taken by shallow water fish corresponded with the benthos known to occur there and differed from that taken by fish from the bay. Constancy of diet among fish on the shallows showed little exchange with fish from the deeper ground on either a daily or monthly basis. An apparent relationship between tidal movement and feeding in Long Pond was found and over a 12 hr cycle was similar to tidal feeding observed in some North Sea flatfishes.

Peak consumption of 2% body weight per tidal cycle was the same in both areas (New Brunswick, Newfoundland) and indicated that P. americanus was a moderate consumer of energy in contrast to some European flatfishes which consume 4-5% of body weight.

Movement in Brandy Cove and Long Pond is considered to be a feeding migration. While feeding in the pond was less significant than that in Brandy Cove, postlarvae, immature and adult winter flounders were consistently seen in the intertidal zone of the pond.

In areas of large tidal range, gradually sloping beaches and coarse to fine sediments, the intertidal zone may serve as an important feeding ground and should be protected from human disturbance in order to maintain or improve our flatfish stocks.

Dedicated to:

Edith

Martha

Molly

Sadie

Sam

And the great SEA which shapes so many lives.

Acknowledgements

Sincere thanks are expressed to Dr. D. H. Steele and Dr. A. V. Tyler for suggesting this project, supervising the summers of field work, and giving their knowledgeable advice and patience during its development. I am also indebted to Mr. A. Sreedharan for statistical advice and computer programming; Messrs. Harry Sampson and David McBurney assisted in the diving in St. Andrews, while Mr. Frank Cunningham cheerfully helped with the photography. In Newfoundland, Mr. Scott Strong and Miss Joan Crane rendered their knowledgeable and safe diving practices during field work and worked far beyond the call of duty. Appreciation is expressed to all those who gave of their time in various ways toward the completion of this project. Charlene Dyer, Guelph, Ontario kindly typed the thesis.

Dr. A. W. H. Needler of the Huntsman Marine Laboratory provided working space in 1971 and 1973 to continue this project, and the Marine Sciences Research Laboratory, Logy Bay, gave facilities for analyzing the materials.

This work was carried out with the financial assistance of the Fisheries Service, Department of the Environment, St. Andrews, N.B. and the provincial government of Newfoundland.

Appreciation is also expressed to Drs. John Sprague and Sue Corey for their help in many small ways.

Table of Contents

List of Figures

List of Tables

List of Appendices

Introduction

The influence of large tides on animal life and activity in the Bay of Fundy can be seen within the smaller bays and islands along the shoreline of New Brunswick and Nova Scotia. Fish move inshore as the intertidal zone becomes available to them on the flood tide (Tyler, 1971). Pelagic migrations of fish and mammals take place as their food supplies move with the tidal currents within the bays. The movement of tides exerts an important biotic influence on productivity in an area where the effects of temperature on growth are already felt.

In Newfoundland, where large amplitudes are unknown and movements may be wholly subtidal, onshore movements of certain species have been known among fishermen in local outports but not reported in the literature. Annually, fishermen set traps on the west coast of the province, for example, to take advantage of this knowledge. Children and adults alike can be seen fishing from public wharves near the outports on the flood tide. Certain residents also seine the beaches for food during high tide (J. Payne, pers. comm.).

This study presents information on the tidal movement of winter flounders, the effects of such movement on feeding, and the importance of intertidal zones as accessory feeding areas to growth in flatfish. Feeding in the intertidal zone or shallow subtidal zone bordering it was compared with feeding on deeper subtidal grounds in Newfoundland and New Brunswick. That area of seabed between the tide lines alternatively exposed and submerged twice daily was considered to be the intertidal zone. Its area varied with the slope of the shoreline and height of tides; being larger in New Brunswick and smaller in Newfoundland. The area of seabed which remained permanently submerged below the lowest spring tide was considered subtidal. Guidelines set by Stephenson and Stephenson (1972) and Storer and Usinger (1965) were followed.

Winter flounders are day-active (McCracken,1963; Olla et al., 1969; Tyler, 1971). Since they feed mainly during daylight hours (Medcof and MacPhail, 1952; Pearcy,1962; Thomas, MS 1970; Wells et al.,1973) they may be classified as visual feeders.

Closely related flatfishes have also been reported as day-active: Paralichthys dentatus (Olla et al.,1972) and Scophthalmus maximus (De Groot,1971). Similarly, reports have either (1) directly classified several species as visual feeders or (2) shown that they depend upon sight more than smell while feeding: P. dentatus (Olla et al.,1972), S. maximus (Bateson, 1890; Scheuring, 1921; Pipping,1927 a,b), Pleuronectes platessa (Steven; Jones, 1952; Verheijen and De Groot, 1967). This has also been shown for Pleuronectes flesus (Bateson, 1890; De groot, 1971) and Limanda limanda (Steven,1930). As the diurnal activity and feeding of winter flounders and related species have been well documented, tidal movements in Newfoundland were studied during daylight only in contrast to other studies (Gibson,1973).

Literature Review

The ecology and locomotor activity of fish normally living in the intertidal zone have been reported by several authors (Beebe, 1934; Aronson,1951; Williams,1957; Gibson,1967; Green,1971). In Europe, tidal influence on fish production of commercially important species has prompted studies of intertidal movements of those normally resident in the subtidal zone. Edwards and Steele (1968) showed the density of plaice at low water mark to be higher than that for high tide in the same location, indicating onshore movement with the flooding water. In the Danish Wadden Sea, heavy concentrations of North Sea plaice and dab were found between 0 and 5 m by Johansen (1908; 1913), Garstang (1909), and Bruün (1927). From August to October, concentrations of the two substocks from the English spawning grounds and German WaddenSea (Lübert, 1925) aggregated outside the waddens at ebb tide. Then, they spread over the grounds in search of preyduring flood tide (Bückmann,1934: Smidt, 1951). During flood tide, numbers of fish as high as 2000-6000/ hr were taken by trawl.

Four studies are known for the Northwest Atlantic and two of these were carried out to investigae fish behaviour. In Connecticut, Merriman (1947) found that 6 of 13 fish species seined on a rocky beach displayed intertidal movement. A feeding migration was excluded due to the impoverished nature of the beach, although no quantitative sampling was made, and movement was ascribed to the escape of smaller fish from larger subtidal predators. De Sylva et al. (1962) studied the distributions of fishes in the shore zone of the Delaware River estuary and compared these to species collected in deeper water.

Pearcy (1962) briefly mentioned the occurrence of lyoung flatfish in the intertidal zone of the Mystic River estuary. In Delaware, Paralichthys dentatus, the summer flounder was seined intertidally at varying stages of the tide. It was taken during hours 3, 5, and 6 of flood tide and hour 3 of the ebb tide. Winter floudners were also capture. Collections of these fish seined intertidally controlled frequencies of winter flounder that were evenly distributed over each hour of the tidal cycle. However, no indication was given of the slope and width of the beach, tidal amplitude, or sampling area (length x width) of intertidal and subtidal zones studied. Evaluation of the intertidal zone of the Delaware estuary for comparison with beaches in this investigation was thus difficult. The above two studies were more quantitative than that of Merriman (1947) but dealt with fishes found in warmer temperate water of the mid-Atlantic Bight.

On the Canadian coast, only one study has been carried out. Tyler (1971) characterized the times of maximal movements, size ranges, and duration of stay for nine demersal fishes. Winter flounder were shown to have the most finite pattern in relation to time of the tide. Inshore movement reached its highest peak between 0.5 and 2.5 hr flood when 89% of the migrant fish had moved. Fish remained in the intertidal zone for 6-8 hr and then moved to the subtidal zone again between 2.5 and 0.5 hr ebb.

These studies established that both pelagic and benthic species show tidal movement, the intertidal zone is occupied for several hours and movement in many regions is related to feeding migrations. However, little is known of the contribution made by this area to the gain in body weight of the fishes which feed upon it, or its usefullness to their population in general, especially in eastern Canada. Although intertidal benthos studies have been made and we can draw on the similarities of European literature (Moore, 1972; McIntyre and Murison, 1973) our understanding of the value of intertidal areas in terms of caloric energy and biomass of prey populations is limited.

Methods and Materials

Choice of Sites

Long Pond, on Conception Bay, was the lagoon chosen for study in Newfoundland. It was located 21.6 km SSW of the city of St. John's (Fig. 1 and 2). It was chosen as it was considered to be similar to other inlets which have breeding populations of winter flounders along the coast from Labrador to Georgia (Saila, 1961a; Perlmutter, 1939). Long Pond was known to have a moderately large flounder population which was present from September to June. It was easily accessible from both shore and the city of St. John's. Its working area was small and protected from the rough water conditions characteristic of Conception Bay. The volume exchange, shape, and depth of the partially landlocked basins assured that flow velocity and tidal amplitude would occur with enough force to be detectable by the flounders.

Information had previously been collected on the sediments, benthos, water chemistry, morphometry (Christie, 1966) and dominant fish population (Kennedy, 1964) of the pond. All factors except the flounder population had been studied in detail in the eastern basin. The fish population had been characterized for the western basin alone. Diving surveys in the western basin revealed that sediment distribution was similar for both basins, and fish, mainly the winter flounders, were known to live throughout the pond. Continuity of benthos was found to be similar by comparison of food eaten by the fish in the western basin (Kennedy, 1964) with fauna collected in benthic

Figure 1. Aerial view of Long Pond, Newfoundland (center, right) showing the harbour in summer with Kelly's Island in Conception Bay in the background. Other barachois ponds along the east shore of the bay are shown.

Figure 2. Bathymetry (ft(m)), collection areas, and distribution of Zostera marina beds in Long Pond, Nfld. Scale = 1: 40,000. Map 4285 from the Canadian Hydrographic Service.

Depth in meters. Underlined figures indicate depth at mean high tide in the intertidal zone. Tidal transects marked by stations at ends with # 0 and 12 for T1 and #0 and 7 for T2. Water sampling stations marked by asterisks near tidal transects and tuna wharf.

CONCEPTION
BAY
10
BUOY
2
4
#12
3.5
TUNA WHARF
6
BASIN
.6
PIER
7
7
TIDAL TRANSECT
6
.6
.3
.3
TIDAL TRANSECT #0
#7
55°W
50°N
NFLD.
Long Pond
LONG POND
METER
800
FEET
500
ZOSTERA BED
.3
low water neap
FISH SAMPLING AREA

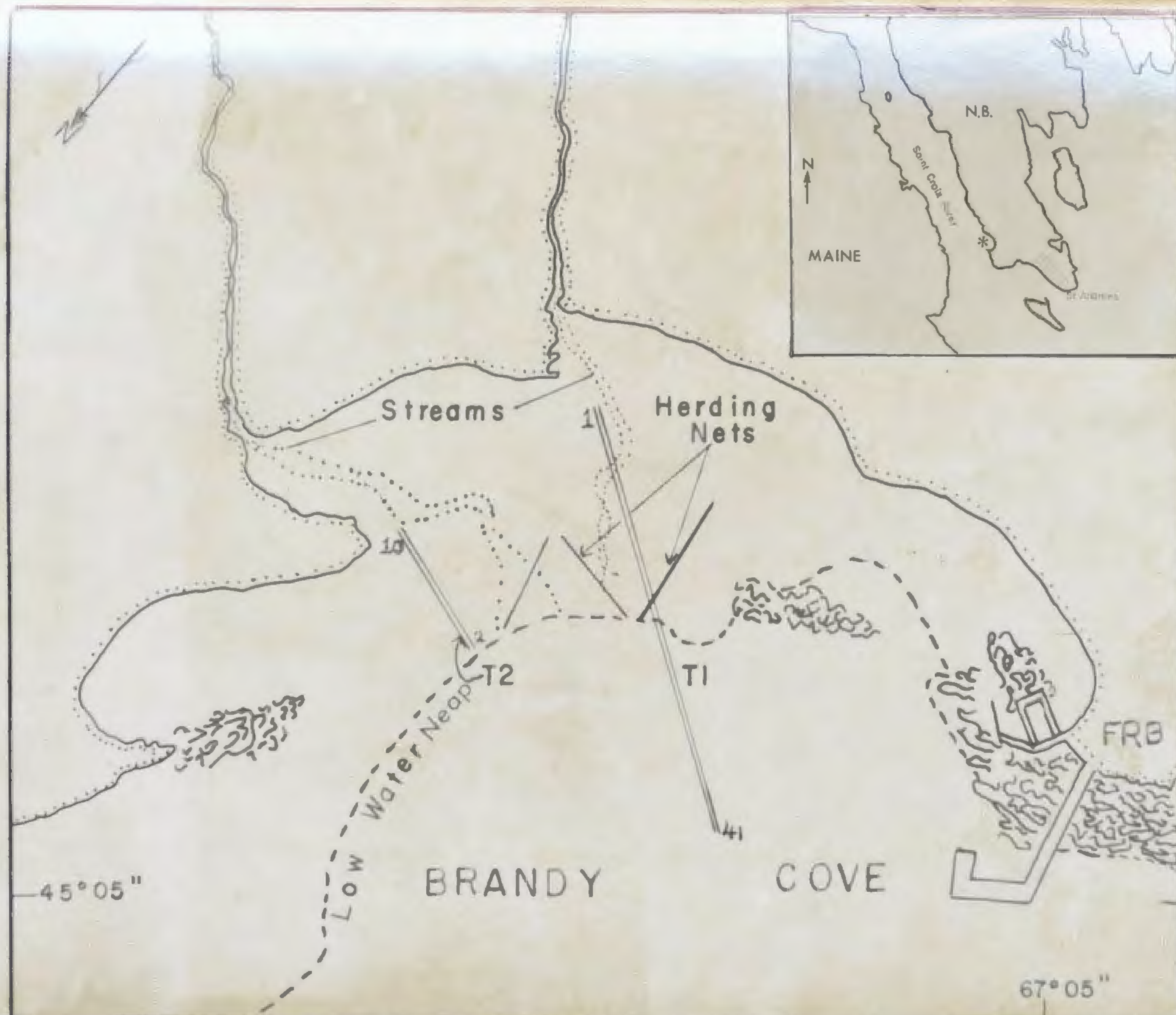
surveys of the eastern basin (Christie, 1966). Similarity of the two habitats allowed an approximation of conditions on each side for which data were available from the other. The two basins were extensions of one environment connected by a shallow gravel channel.

New Brunswick

Brandy Cove was chosen for a comparative study site as previous observations had established the tidal movements of winter flounders and other benthic fishes at this location (Tyler, 1971). Situated at the eastern mouth of the St. Crois River, Passamaquoddy Bay (Figs. 3 and 4), it is subjected to a maritime climate characterized by narrow temperature fluctuation and heavy summer fogs (Putnam, 1949). In the niche-habitat classification of Light et al. (1957), it is a protected rocky shore with tidal flats. Exposure and submergence of the intertidal zone is shown in Figure 4.

With its long axis running nearly due north-south, Brandy Cove is located on a peninsula jutting into the bay. As Colinvaux (1965) described the cove and surrounding area "... The tidal range is (about) 9 m, and the salinity is somewhat reduced from that of the open Bay of Fundy. The boundary between sea and land is sheer cliff... The intertidal substrate is mainly shelving sandstone, sand, and coarse gravel with boulders.... (Wherein) the upper sublittoral slopes steeply."

Figure 3. Brandy Cove, N.B. showing transects T1 and T2 from which benthos samples were taken, herding nets employed in catching winter flounder and the proportions of intertidal to shallow subtidal zones studied.



N.B.
Saint Croix River
MAINE
N
St. Andrews
Streams
Herding
Nets
1
1a
T2
T1
41
Low Water Neap
BRANDY
COVE
FRB
45°05"
67°05"

Figure 4 (A). The intertidal zone of Brandy Cove showing the large forage area closed to winter flounder at low tide.

Figure 4 (B). Aerial view of Brandy Cove showing the expanse of intertidal zone opened to winter flounder at high tide.

Establishment of Transect at Long Pond

Figure 2 shows the location of two transects laid in Long Pond for the study of fish movement. The longer of these, T1, was used to follow movement across the length of the lagoon. The shorter of these, T2, was used to study movement across its width.

The transect T1 traversed the least disturbed area which was determined through preliminary surveys during March-April, 1971.

It consisted of 366 m of orange corline twine held in position by two cinder block anchors at each end and marked in twelve units of 30.5 m (100 ft) each. Lead sinkers weighing 454 g each and topped with plastic torpedo floats (John Leckie & Sons, Ltd., St. John's) marked each of the twelve counting units. Floats were numbered sequentially and served as stations at the ends of units where the divers stopped and recorded numbers of winter flounder/unit. Waterproof red wax pencil marked each float according to its position in the series 1,2,3,....12. During the first season of diving, plain floats were spray painted and dipped in urethane varnish. This treatment increased their visibility and decreased their fouling underwater. The transect was laid by releasing the line from a rotating wire wheel fixed across the stern of a motor boat. It was laid straight by maintaining a constant motor speed and central position between two shore objects. Dives were also made to straighten individual units of line when required. As the twine was laid, galvanized washer rings were added to hold it on bottom between the one pound (454 g) sinkers. The beginning of the transect lay in shallow water and its end lay in deeper water. It was laid over the least disturbed area of bottom as determined by observations made on surveys over the pond. Such surveys were made in March-April, 1971, to find areas of disturbance to the sediments. The sampling area was chosen on undisturbed bottom except for 6-7 m of station 3 where a small depression was created by a sliding yacht launch. The sampling area was characterized by Zostera marina, densely packed mud, sandy-mud, soft algae, and occasional rocks.

The shorter transect, T2, was laid of the same materials and by the same method as for the first transect. It was laid in a direction perpendicular to transect T1. It contained seven units, 16 m apart, and extended from the shallow anchor block of transect T1 to the center of the pond.

Both T1 and T2 had the same origin at station 0 which was the location of their cinder block anchors and the starting position of consecutive dives.

No stations were included in the intertidal zone for the second transect, T2, due to the many attempts to steal gear by local inhabitants, and its eventual loss during each of the two diving seasons. Movement of flounders into and from the intertidal zone was observed. But, only description of their occurrence in this zone is given since numbers were not recorded.

Counting of fish

The choice not to randomize the direction of swim when making counts was based on a consideration of possible bias in the two ways of moving along the transect. Since the fish saw as well in all directions due to their independent and rotational eye turrets, divers had no more time to approach and count if they began at the same end of the transect consistently or both ends randomly. Hence, any fright response resulting in a change of position, and thus distribution, would have occurred at nearly equal rates for the two patterns. My diving partner and I could count with a fairly strong assurance that distributions were not significantly affected by maintanence of either one pattern or the other. Bias introduced by either pattern were considered equal. Thus, one method was chosen and maintained throughout censusing. Divers swam from the shallow end of the pond to its deep end.

Frequencies of flounders were determined along T1 every 30.5 m (100 ft) unit, during serial tidal dives. Numbers were recorded on plexiglass slates by paired divers swimming on each side of T1. Days for observations were chosen from a list of possible days when daylight and tidal phase synchronized to allow clearest vision underwater. Schedules beginning no later than 0900 and ending by 2045 hours were used. The longest period of counting for a tidal phase ran 6-7 successive days, after which rotation of the cycle brought the second phase into daylight hours. The second phase ran for an equal period. Natural advancement of the tide, at an average daily rate of 45 min, indicated that nearly every day of a week could be used. Dives could be made only when other variables such as weather, personnel and condition of equipment were met. Dives were made every other hour following a general pattern of 2, 4, and 6 hours per tide or 1, 3, and 5 hours of the tide. Estimates of the time of tide inside the inlet were calculated from the Canadian Tide and Current Tables of 1971 and 1972 (Canadian Hydrographic Service). Correction factors of 60 minutes for daylight savings and 28 minutes for secondary port displacement were added to the predicted time of tide for St. John's, Nfld. The latter addition was the correction necessary for Holyrood, a secondary port on Conception Bay, nearest Long Pond. Preliminary tidal readings were made at the government pier during April and May (1971) to compare with predicted values. Tidal readings for a representative month of the year were made when both neap and spring tides occurred. These were also compared to those of St. John's harbour and Holyrood to find if a correction factor for the pond was needed. Readings to 0.3 cm (0.01 ft) were made at 30 minute intervals on a tide gauge supplied by the Water Resources Branch (Department of the Environment). The gauge was mounted in a protected location so that readings could be made with little or no disturbance on the water surface.

Possible sources of error in the counting procedure were the following: (1) counting the same individual twice if it (a) moved around and ahead of the diver or (b) crossed the transect line from one side or the other; (2) not counting individuals which moved into the area behind the diver; (3) inability to see all fish present. Generally these errors could be divided into two positive and two negative factors affecting frequencies. Although they operated at different times, they appear to have cancelled each other. For example, errors resulting from sources 1(a) and 2 above may have increased or decreased, respectively, the counting accuracy. Differences caused by error 1(a) were not important as the fish were generally in a resting state on the bottom and not engaged in swimming activity. This applied to dives before and after inshore movement and those prior to final ebb tide movement. For individuals crossing both sides of the transect the following corrections were made: (1) where both divers were parallel in position, the side from which a fish swam was given a count while that toward which it tended was not; (2) where the divers were angular in position to each other, the side from which a fish swam was counted and deletions were made for the opposite side when positions of the divers became parallel at the counting stations (floats). Ability of new divers to see buried or camouflaged fish was tested before actual sampling by selecting a small area for demonstration and description of fish in their mud habitat. This was followed by a comparison count in a defined area, and continued until enough competence was gained to begin final counting. Ability to see the fish was also affected by the swimming speed of the census. Slow speeds gave the divers more time to see the individuals in numerous habitat conditions and allowed more familiarity with the sampling area.

Sampling of Physical Environment - Newfoundland

Two sampling stations were established to follow the water characteristics of the deeper and shoal water feeding grounds. The first station was located in the sampling area used for monthly flounder collections, at the end of a tuna wharf extending into Conception Bay. The second was located at the main entrance point to the transect laid for tidal sampling inside the pond, and was covered by 0.5-1.5 m water depending on tidal amplitude.

Measurements of dissolved oxygen content, bottom water temperature, salinity and pH were made in these areas. Bottom water samples were taken with a modified Kemmerer Bottle as described by Welch (1948). Two samples were taken for each station on the last date of each month in winter (October-March), and semi-monthly on the middle and last dates of each month during summer (April-September). The first sample at each station was fixed for later determination of oxygen content according to the modified Winkler method (Strickland and Parsons 1960). This was done by adding equal amounts of manganous sulfate and alkaline iodide followed by concentrated sulfuric acid. Samples were transported to the laboratory and were either titrated directly or held in a darkened, cold chamber until used, always within 48 hours.

Bottom water temperatures were measured from the top of the Kemerer bottle or in the second sample of each set as water was fed into the bottle. In the shallows, the mercury bulb thermometer was also laid on the bottom and read as a check.

pH was read on a Corning Model 7 pH meter within two hours of sampling. Salinity was determined by conversion of density values from a hydrometer for both room temperatures (21-23 C) and 15 C readings. Dredge samples were not taken for examination of the fauna or soil distribution, as for St. Andrews, N.B., since an account of these factors had already been completed (Christie, 1966). Information on the sediments and general hydrography of Conception Bay was obtained from the Geology Department, Memorial University, and the Canadian Hydrographic Service (Department of Environment).

New Brunswick

Sea surface temperatures for Brandy Cove were taken from recordings at the Biological Station wharf situated adjacent to the subtidal sampling area. Values cover the period of June-August, 1971, and represent a seasonal regime typical of Passamaquoddy Bay.

Salinities at the 0, 10, and 30 meter depths were obtained from data of the E.E. Prince station #6 (Courtesy, Atlantic Oceanographic Group) located 1 km west of the cove at 45° N X $67^{\circ}5'$ W, in the center of the St. Croix River. Values at 0 and 10 m were assumed to be similar to those encountered by winter flounder in the intertidal zone which extends from 0-7 m. Those at 30 m were also similar to salinities encountered by fish living in the subtidal sampling zone.

Sampling of Benthos

Benthic organisms on the intertidal and subtidal ground were sampled with a standard 15.2 x 15.2 cm Ekman dredge. Two transects were established to sample the various sediments. Transect T1 was centered in the middle of the cove and extended from the higher intertidal zone across upper cobble rock, gravel, sand, and mud to the subtidal zone. The transect covered a distance of 135 m (420 ft), was positioned obliquely across a fish herding fence, and was marked by 1.4 kg brick station markers at 6 m intervals above low water mark. Subtidally, the transect was laid with 1.3 cm polypropylene rope, marked by black electrical tape and brick weights. Samples were obtained on the beach by pushing the dredge into the sediment as far as possible. Due to the coarseness of the sediment, it was necessary to measure each site into 15.2 x 15.2 cm squares, insert wooden pegs at the corners and dig the sample hole with a small square gardener's shovel. The sediment was then transferred to the dredge to ensure that a volume equivalent to that of the sampler was taken. The sides and bottoms of the sample holes were measured during the digging process and the dredge lowered into the holes until it became level with the top of the substrate. Transect T1 contained eleven intertidal and ten subtidal stations. Transect T2 covered a second area of beach for a length of 40.3 m (125 ft) on a clam bed of coarse sand. Its position was parallel to the northeast shore of the cove and adjacent to a freshwater stream. Five stations were marked with black electrical tape at 8.1 m intervals along the line. The samples were taken as previously described for the first transect. Sediments were transferred from the beach to the laboratory in plastic bags, preserved in 10% formalin, and stored cold until sieved. The sediments were then washed through a series of graduated wire sieves of mesh sizes 8.0, 4.0, 1.0, and 0.5 mm. Mud and silt deposits passing through the smallest sieve were allowed to settle in a white enamel pan covered with 2.5 cm anesthetic solution. The solution was made with MS-222 and relaxed the smallest organisms so they would crawl from the deposits and float. They were then visible against the pan colouring and could be removed. The mesh of the 0.5 mm sieve was also fitted to the top of this pan and allowed to stand for thirty minutes. This relaxed the minute Oligochaeta clinging tightly to the mesh and allowed them to be removed without damage. Organisms found in each sediment sample were then identified, counted, and weighed wet. Preservation was made with 10% formalin in 454 g jars for the larger organisms such as sea urchins, and with buffered 10% formalin in smaller vials for molluscs.

Depth recordings of all T1 stations and photographs of intertidal stations were taken. These aided in plotting the distributions of benthos once specific locations of prey items from flounder stomachs were known from locations of daily catches within the cove.

Measurement of Fish

In the lab, the fish were washed of clinging debris, blotted with paper towelling and weighed to the nearest 0.1 g. Total lengths were measured to the nearest millimeter from snout tip to the end of the longest caudal fin ray. Sex was determined by visual examination of the gonad following dissection. As sexual dimorphism was not readily apparent, externally, in young juveniles or adults except during the breeding season, the right gonad was preserved in 70% ethanol for reference. Gonads were observed twice; a second observation being made several months following the first; to compare results. Gonads which were too small to determine sex accurately, were dissected under a binocular microscope.

Otoliths were collected by cutting transversely across the top of the cranium and bending the head perpendicular to the body to expose the sagittal chambers. They were preserved in glycerin and read whole in a 1:1 glycerin-water mixture against a black background or microscope base. Ages were determined following methods of Kohler (1958) and Berry (1959).

Treatment of Stomach Contents

Dissections were made to obtain the alimentary canal. It was removed by cutting the pyloric sphincter and esophageal connection to the cardiac end of the stomach. In freshly caught fish, this connection was easily cut without loss of food from the stomach due to the rigid muscle wall of the lower esophagus where it joined this organ. When necessary, stomachs were tied with #50 cotton thread to prevent food loss and postmortem migration of parasites from the intestine. Digestive tracts were preserved in 80% ethanol for later examination of the stomach contents. At this time, the stomachs were separated from the intestine and a longitudinal cut made along their length. The volume of food was estimated visually as it lay in the organ, using the points system of Ball (1961) and De Groot (1971). This system was changed slightly from the original of Hynes (1950) and described approximate volume by employing rounded integers to indicate the nearest quarter fullness. Prey were sorted to phyletic or ordinal groups in 5 ml polystyrene cups, identified under dissecting and monocular microscopes and counted. Wet weights were determined to the nearest milligram, a procedure necessitated by the recurrence of minute larval forms. Occasionally, a photographic Nikon L-Ke microscope was used for determination of polychaete species by examining setal morphology. Prey were then placed in 1 dram vials and coded. Identification of contents was made using standard keys given in Appendix 11.

Sampling of Fish

Newfoundland

Monthly collections of winter flounders were taken while diving on Scuba or snorkel over two feeding grounds (Fig. 2): Long Pond and Conception Bay. These grounds differed from each other in depth and sedimentation. Samples were taken to compare the effects of tidal movements on feeding in flounders in the pond and differences between a shallow and a deeper water feeding ground. The shallow ground in Long Pond compared as closely as possible to the shallow intertidal zone of Brandy

Cove while the deeper ground in Conception Bay corresponded as closely as possible to the deeper subtidal zone in Brandy Cove. Table 12 (p. 100) presents the dates, depths, sample sizes and other information for the catches. Depth limits of the two grounds were chosen in reference to the following points: (1) preferred depths of the species (McCracken, 1954; Levings, 1973) within which patch concentrations occurred when flounders were offshore; and (2) depth of concentrations when flounders were inshore. Fish were speared over the eastern 1/2-1/3 of bottom in the western basin of Long Pond. Samples were taken during the last week of each month and as often as possible on the last day of the month to allow the sampling of water characteristics to coincide with that of feeding. Occasionally, collecting was extended to both sides of the shallows when sample size from the eastern half of the basin was insufficient.

The second sampling ground, in Conception Bay, consisted of a sand and shale-cobble bottom and had a depth range of 3.1-20 m. Its area was larger than that of the pond and since the flounders in this part of the bay were scattered more widely than those in the pond their concentrations were lower, as reflected during some months in the sample sizes. The sampling area included two rectangular areas (Fig. 2) with average depths of 4-13 m and maximum depths of 20 m. The first one, for primary collecting, contained five reference points used for surface and subsurface orientation. These points enabled divers to keep collections within relatively constant borders. Collections were made from August, 1971, to July, 1972. Cessation of feeding in winter flounder and other pleuronectids during winter and early spring has been recorded by many authors (Bigelow and Schroeder, 1953; De Groot, 1971; Kennedy and Steele, 1971; MacKinnon, 1973). Thus, samples for these months were not taken (Nov.-Mar.). Fish taken in the bay were collected in a burlap bag and immersed in a 1:1 solution of formalin and sea water, on shore. In the pond, fish speared in 1971 were transferred directly to a boat where the coeloms were injected with 10% formalin. Those speared in 1972 were treated in the same manner as samples from Conception Bay since formalin injection was not found to improve inhibition of digestion more than direct immersion immediately after capture. In the latter method, fish swallowed the solution into the stomach more quickly than it could be injected for an entire sample.

New Brunswick

Three samples of winter flounder were obtained by spearing under water using Scuba from July 8-August 5, 1971, in Brandy Cove, New Brunswick (Fig. 3) adjacent to the Fisheries Service Station, St. Andrews.

A record of catches appears in Table 1, which gives date, and depth of catch, daily sample size, and hour of the tide. Catches were scheduled to allow adequate time for food consumption under the supposition that this was their major activity following inshore movement. As the winter flounder occupied the intertidal zone for six to eight hours between inshore and offshore movement, fish in Sample 1 were caught on the ebb tide as they were (1) feeding on or (2) in the process of leaving that zone. These fish well be referred to as "migrants".

Date	Sample Size	Depth (m)	Catch Time	Tidal Hour	Tide
15.7.71	5	0.9- 7.5	0930-1030	3.60-4.60	Ebb
20.7.71	6	0.9- 7.5	1540-1640	4.42-5.42	Ebb
21.7.71	6	1.8- 4.5	1300-1345	0.83-1.58	Ebb
23.7.71	3	0.9- 7.5	1500-1600	1.33-2.33	Ebb
25.7.71	9	0.9- 7.5	1630-1745	1.50-2.50	Ebb
29.7.71	15	0.9- 7.5	1700-1830	0.60-2.17	Ebb
10.8.71	1	1.8- 4.5	1800-1900	1.60-2.60	Ebb

Intertidal Migrants

10.7.71	13	1.8- 2.4	1030-1110	2.38-3.00	Flood
12.7.71	13	1.8- 4.5	1115-1300	1.50-3.25	Flood
13.7.71	21	9.0-10.5	1130-1300	1.00-2.50	Flood
26.7.71	3	1.8- 7.5	1100-1200	1.50-2.50	Flood

Subtidal Pre-Migrants

8.7.71	8	1.8- 6.0	1330-1500	0.75-2.25	Ebb
9.7.71	10	1.8- 6.0	1400-1500	0.50-1.50	Ebb
19.7.71	3	9.0-10.5	1230-1300	2.35-3.25	Ebb
28.7.71	3	10.5-15.0	1445-1545	3.83-4.83	Flood
29.7.71	9	10.5-15.0	1445-1545	3.16-4.00	Flood
4.8.71	6	10.5-15.0	1300-1415	2.25-3.50	Ebb
5.8.71	2	10.5-15.0	1400-1445	2.42-3.16	Ebb

Subtidal Non-Migrants

Table 1. Record of Catches of three samples of winter flounder from Brandy Cove, N.B.

Two subtidal samples, consisting of fish that (1) remained subtidally and did not migrate with the flood, and (2) those which were subtidal prior to the turn of the tide but moved inshore, were taken at opposing times. The first of the two subtidal samples had 41 fish and will be referred to as "non-migrants". This distinguishes between the two behavioural types. The two subtidal samples were taken to find variations in prey consumption, which might have occurred as a result of differing responses to tides. Non-migrants were taken after inshore movement but before the offshore surge of the migrants; they represented the main stock in the St. Croix river which did not respond to the tide. Their catch period occurred during the six to eight hours when directional movements ceased and the two groups were separated.

Fewer but larger catches of pre-migrants were taken on the flood tide when they were concentrated in a small area between low water mark and the advancing tide line. Due to their pre-flood position, pre-migrants contained subtidal food in their stomachs, as in the non-migrants. As the rate of tidal advance controlled their movement over the intertidal zone, they could be found in a more restricted area. Following inshore movement, they became intertidal feeders and like non-migrants, spread over the remainder of the zone and required more time for sampling. Following capture of daily samples, the spinal cords of the fish were severed behind the head, coeloms slit and their bodies immersed in 20% formalin and sea water. In the laboratory, measuring and dissecting methods were the same for fish samples taken in both provinces as described above.

Results and Discussion

Physical Environment

Oxygen and Temperature

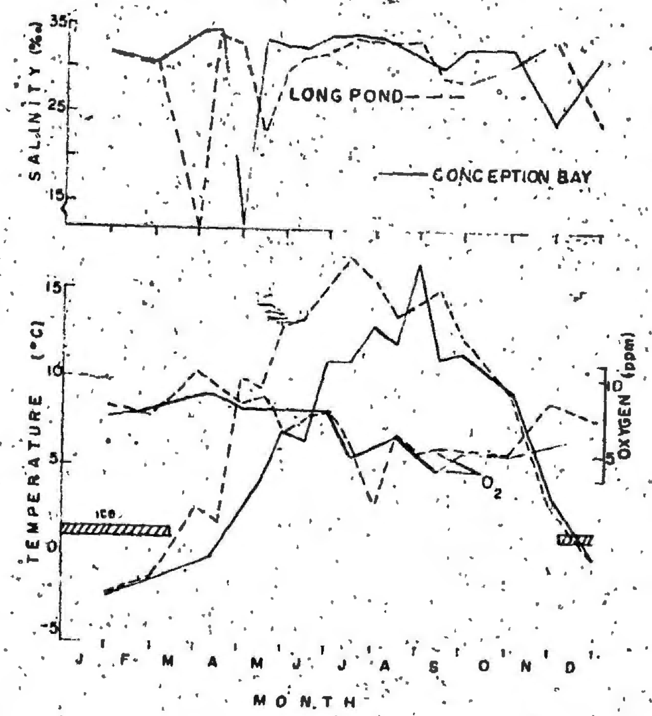
Long Pond

Figure 5 shows the winter monthly and summer semi-monthly records of oxygen and temperatures in Long Pond and Conception Bay. Bottom water temperatures in the pond ranged from -2.2 to 17.0 C and those in the bay ranged from -2.2 to 16.8 C. Water temperature in the western basin was found to be slightly higher than that in the eastern basin (Christie, 1966). Unlike temperature, trends in oxygen content of the bottom water in the western basin and the bay followed each other closely. Water was well supplied with oxygen from January through April (1972) and again during November and December. Supersaturation occurred in the pond on March 31, April 30, May 16, June 16, and June 30.

Temperature inside the pond reached a summer maximum before that in the bay. This compared with similar conditions found by Smidt (1951) on the Danish waddens. Following break-up of the ice cover in mid-March, seasonal warming began almost immediately in Long Pond and was enhanced by the shallow water column and dark mud bottom.

Temperature reached a seasonal peak of 17 C in Long Pond by mid-July. However temperature records kept during the days of fish counts showed that warmer water also occurred on certain days in the spring. This was, of course, dependent of weather conditions.

Figure 5. Temperature, oxygen, and salinity of the bottom waters of Long Pond and Conception Bay, Nfld. Readings taken monthly in winter and semi-monthly in summer (1972). Panel A = Salinity. Panel B = Temperature and oxygen. ------ = Long Pond. ———— = Conception Bay.



SALINITY (‰)
35
25
15
LONG POND
CONCEPTION BAY
TEMPERATURE (°C)
15
10
5
0
-5
ice
OXYGEN (ppm)
10
5
O_2
J F M A M J J A S O N D
MONTH

Seasonal warming in Long Pond occurred by sharp increases in water temperature separated by longer periods of stability. During late April, May, and June, values remained low to moderate for many days and then rose quickly after only two to three days of calm water and sunlight. Warming progressed at faster rates after the temperature reached 10 C. Below this value it cooled more quickly than from other levels of temperature.

Changes in oxygen and temperature were typical of a shallow lagoon and similar to those found in the Mystic River estuary (Pearcy, 1962) and the eastern basin of the pond (Christie, 1966). Lowest temperatures occurred in January. The widest range occurred over the intertidal flats (-2.2-21.0 C) where pan ice formed in winter and summer maxima were highest for the pond. The relation between temperature and oxygen in the western basin was slightly more complex than that in the eastern basin. The expected inverse relationship of the two parameters (Sverdrup et al., 1942) did not always occur when the bay and pond were compared. From April through May and mid-August through September, the concentration and per cent saturation of oxygen in the bottom water were greater in the Pond than in the Bay even though water was warmer in the pond (Fig. 5). Such conditions probably resulted from the effects of wind exposure on turnover and saturation of the shallow water inside the pond, even during warm weather. Effects of wind on this lagoon were comparable to those on freshwater ponds on the Avalon Peninsula (Davis, 1969). Winds of 15-25 mph often occurred during clear weather, and caused saturation here as well as in the surface waters of the bay.

Salinity

Long Pond

Salinity remained relatively uniform from May to October (Fig. 5) and ranged between 30.8 ‰ and 32.9 ‰ during periods of constancy. Salinity decreased to 11.9 ‰ during times of dilution. Variations in these values resulted from the interaction of wind, tide, and changes in precipitation. Wide fluctuation occurred in spring and early winter due to dilution of the water column by terrestrial runoff and seasonal precipitation. Melting snow produced haloclines which decreased visibility greatly. On March 31, for example, haloclines were observed where water currents encircled stable objects at the sampling stations. From May 1-15, haloclines which approached bottom were seen while counting winter flounders along transect T1. This change occurred not only over a wide vertical but wide horizontal distance (e.g. 290 m of 366 m of T1). It inhibited clear vision and required counting to be postponed until the mixing was completed.

Conception Bay

Except during periods of complete mixing and heavy precipitation, salinity of the bottom water normally ranged from 31.8 ‰ to 34.1 ‰. Only on two dates, April 30 and November 30, did it drop to low values of 12.7 ‰ and 23.9 ‰, respectively, because of spring runoff and melting snow.

Sediments

Distribution and characteristics of the sediments at the two Newfoundland study sites are discussed in Appendix I.

Temperature

Brandy Cove

Mean surface temperatures in Brandy Cove and Passamaquoddy Bay followed a seasonal cycle reaching a maximum in August and a minimum in February (Fig. 6B). From 1921-1947, the mean August temperature was 12.9 C and the February minimum was 0.2 C (Hachey and McLellan, 1948). In 1971, the mean August surface temperature was 14.0 C. A maximum of 16.0 C was recorded on August 1. Thus, the temperature regime experienced during July and August, 1971, was higher than the earlier 27-yr mean and compared more closely with the August maxima of 14.7 C and 14.8 C reported by Stephenson and Stephenson (1972) and McCracken (1954), respectively.

Table 2 gives the mean bottom water temperature at 3 depths in the cove during summer. Means were recalculated from McCracken (1954) who gave temperatures at various depths in both the bay and the St. Croix River from trawling surveys.

Depth	Month			
(m)	June	July	August	September
1- 4	11.3	12.6	14.8	15.5
11-14	7.2	10.1	13.0	13.8
26-30	7.3	10.2	12.4	13.4

Table 2. Average bottom water temperature (C) at three depths in Brandy Cove, N.B.

The June thermocline disappeared during late July and August. Warming at depths of 11-14 m occurred in equal increments from June to July and from July to August. Surface temperature progressed at the same rate during spring and summer in both Brandy

Cove and Conception Bay, but lagged two months behind Long Pond. For example, an average temperature of 9-10 C was recorded in Brandy Cove and Conception Bay in June but in Long Pond in April and early May. A mean range of 12.5-14.0 C occurred in the cove and bay in July but in the pond in May. Maxima of 13.5-16.0 C were recorded in cove and bay in August but in the pond in June.

It is interesting to note that bottom temperatures in Conception Bay exceeded those at the surface at Brandy Cove in August, indicating that the water column in the bay was warmer than in Brandy Cove. Water in Brandy Cove was colder because of tidal mixing and upwelling. These characteristics are common in Passamaquoddy Bay, where the water is not static long enough to warm up as it did by mid-summer in Conception Bay.

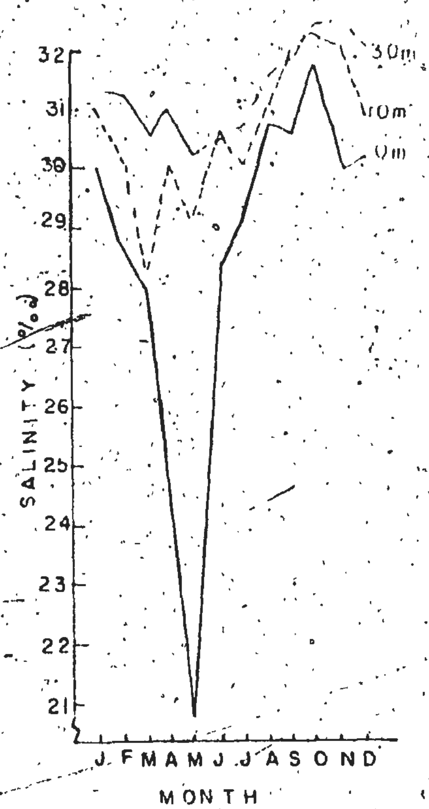
Salinity

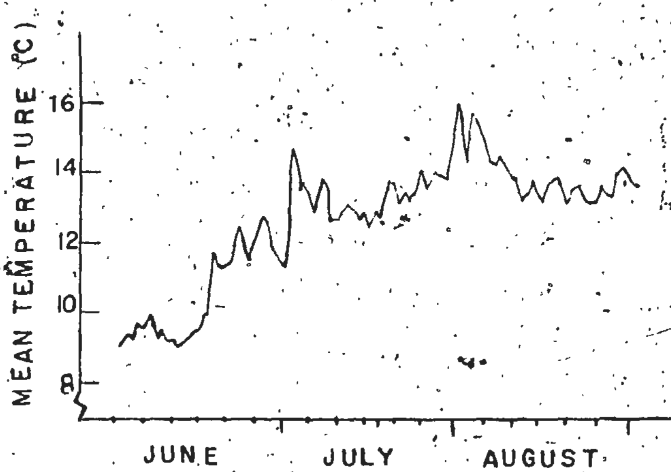
Brandy Cove

Lowest surface salinities occurred in April and May when values were 24.8‰ and 20.9‰, respectively. Values at 0, 10, and 30 m followed each other closely from January to March, but surface dilution was not extensive enough to penetrate to the 10 m level. Data for the 30 m curve were not taken in April and June and have been replaced by two values which were taken at 20 m to provide continuous plotting (Fig. 6A). Salinity at 20 m was very close to that at 30 m for other periods in the year and would be expected to be similar at this time of year. Runoff decreased salinity

Figure 6 (A) Monthly salinity values of the St.Croix River at 0, 10, and 30 m. Data from E.E. Prince station #6, 1 km west of Brandy Cove. Data courtesy of Atlantic Oceanographic Group.

Figure 6 (B) Mean surface water temperature of Brandy Cove, N.B. Data taken twice daily from wharf of the Fisheries Research Board Biological Station during the summer of 1971


30m
10m
0m
SALINITY (‰)
32
31
30
29
28
27
26
25
24
23
22
21
J F M A M J J A S O N D
MONTH


MEAN TEMPERATURE (°C)
16
14
12
10
8
JUNE
JULY
AUGUST

throughout the entire water column during May, while relatively dry weather from June to October caused an increase in salinity. In the river, maximum values occurred in October at all depths. During July and August, salinity ranged from 29.2-31.6‰ and compared with values given by Rowe (1970) and Tyler (1968) for Passamaquoddy Bay. Their ranges were 30.0-32.0‰ in mid-summer and typified the river at the deepest part.

Benthos

Long Pond

Observations on the Biota

Intertidal plant growth consisted primarily of *Fucus vesiculosus*. Subtidally, *Zostera marina* grew in bands parallel to shore (Fig. 2) and the crest of an underwater slope. *Chorda filum* was interspersed among bands of *Zostera marina*. Stations 2 and 3 of the tidal transect, laid for study of fish movement, crossed this band of eelgrass on the east side of the pond. Beyond the *Zostera* bands, the open bottom was covered by rolling clumps of *Pilayella littoralis*. *Laminaria digitata* was seen adhering to occasional rocks and anchors. Transient plants of *Agarum cibrosum* and *L. digitata* were seen drifting into deeper water as they were carried to the eastern basin by tidal currents from Conception Bay. Other algae, such as *Ulva lactuca*, *Polysiphonia flexicaulis*, *Dictyosiphon foeniculaceus*, and *Chondrus crispus*, were found in small quantity. Species of *Ascophyllum* and *Enteromorpha* were found clinging to wharves and floating in quiet areas. Beds of

Mytilus edulis covered the head of the pond in an area devoid of *Zostera marina*.

The following animals appeared in the basin at varying times between May and September: eel, *Anguilla rostrata*; skate, *Raja* sp.; herring, *Clupea harengus*; lobster, *Homarus americanus*; rock crab, *Cancer irroratus*; starfish, *Asterias forbesi*; and occasionally Queen crab, *Chionoecetes opilio*.

Asterias forbesi aggregated in a breeding colony across the transect T1 in May and June, but dispersed in July. It was the only localized area of asteroids inside the basin.

Littorinids were present in large concentrations intertidally and scattered individuals of *Polinices heros* were observed in the shallow subtidal zone of the pond.

The green sea urchin, *Strongylocentrotus droebachiensis*, reported by Acreman (1966) for the channel and Christie (1966) for the eastern basin, was not seen in the western basin. Between the transect and shore, *Pandulus montaguii*, *Littorina littorea*, *Balanus balanoides* and numerous post-larval and juvenile flounders (.5-20 cm) were present.

Faunal Communities

From a comparison of organisms sampled in the eastern basin (Christie, 1966) with prey eaten by flounders in the western basin (Kennedy and Steele, 1971; this study) it is believed that faunal communities in the two basins were similar. Diving observations on the general distribution of benthos and sediments also revealed this similarity between the two areas. Christie (1966) found one epifaunal and two infaunal communities. Elements comprising these communities were Amphipoda, Polychaeta, Cumacea, Gastropoda, and Pelecypoda. The animal community changed from infaunal, with low biomass to epifaunal, with a high biomass. The gradation from infauna to epifauna took place from soft to hard sediments and there was a corresponding increase in the frequency of species and numbers of each. The high standing crop of the epifaunal community, Mytilus-Littorina, was restricted to a small area and made up only 4.4% of the bottom surface area. However, much of the large food resource of this small community was not harvestable by flounders due to the large size of Pelecypoda comprising the groupings in this association.

The two infaunal communities (Macoma-Mya; Polycirrus-Mya) covered the remaining bottom area of the eastern basin and only supported 56.3% of the total standing crop. Christie (1966) found that numbers of species per sampling area was low compared to other localities (Mare, 1942; Sanders, 1962; Peer, 1963). Infaunal communities sampled in mud at the center of the eastern basin fluctuated seasonally with changes in their life cycles, but little permanent change was found on a yearly basis. He reported an impoverished epifauna of only six species due to the absence of firmer substrata on which these larger organisms could attach themselves.

Similar communities were seen in the western basin. Infauna consisted of an unidentified polychaete-Macoma association. Epifauna consisted of Littorina and Mytilus. Numbers of organisms were more abundant in areas where Zostera marina grew, particularly in the spring of 1971. This corresponded to observations by Holmes (1949) and Christie (1966) that abundance increases in areas of increased plant cover. As soil and benthos were removed semi-annually from the deep end of the western basin, its contribution to the food supply was negligible. Thus, its bottom area is precluded from consideration in this discussion.

Diving observations suggested that the mud habitat had a lower biomass when compared to the sand habitat.

Approximately 50% of the bottom area of the shallows in the western basin was sandy with the other half composed of mud and silt. It may be assumed that the proportion of epifauna inhabiting the larger bottom area of coarse sediment, in the western basin, provided a slightly higher biomass of animals than that in the eastern basin. As well, infauna in the western basin would be less abundant than that in the eastern basin, since its surface area was smaller.

Fauna known to occur in Long Pond are listed in Appendix 2. Suffixes applied to each species indicate the source of the record for that species and are: 1-Christie (1966), 2-Kennedy (1964), 3-Acreman (1966), 4-(1+2) and 5-the present study.

Conception Bay

Benthic marine algae of Newfoundland coastal waters have been described by numerous authors (Wilce, 1959; Taylor, 1957; Mathieson et al., 1969; Himmelman, 1970; South, 1970). The more common Rhodo-, Chloro-, and Phaeophyta discussed from these reports appears in Table 3. For each species, the zone

Level of Abundance	Species	Zone	Sediment Location
	Phaeophyta:		
very abundant	*Fucus vesiculosus*	intertidal	protected rock
less abundant	*Fucus distichus v.edentatus*	low intertidal	protected bedrock
common	*Fucus distichus v.distichus*	high intertidal	spray zone, HW pool
common	*Pilayella littoralis*	inter- & subtidal	epiphytic on fucoids
abundant	*Alaria esculenta*	low inter- shallow subtidal	exposed bedrock faces
common	*Desmarestia viridis*	subtidal	stable rock & cobble
very abundant	*Scytosiphon lomentaria*	low inter- & subtidal	bedrock faces
very common	*Chordaria flagelliformis*	inter- & subtidal	protected shorelines
less common	*Dictyosiphon foeniculaceus*	low tide - subtidal	epiphytic on fucoids
common	*Saccorhiza dermatodea*	inter- & subtidal	tidal pools
very abundant	*Ascophyllum nodosum*	intertidal	exposed bedrock
common	*Polysiphonia lanosa*	inter- & subtidal	epiphytic on ?
common	*Agarum cribrosum*	subtidal	exposed bedrock faces
scattered, common	*Halosaccion ramentaceum*	subtidal	cobble on crustose corallines
	Rhodophyta:		
common	*Chondrus crispus*	low inter-deep subtidal	bedrock, below fucoids
very common	*Corallina officinalis*	low inter-deep subtidal	protected, smooth rock
rare	*Ahnfeltia plicata*	low inter-deep subtidal	under fucoids & *Alaria*
less common	*Ptilota serrata*	subtidal	seaward bedrock faces
rare	*Euthora cristata*	"	and associated with
rare	*Phycodrys rubens*	"	*Agarum*
	Chlorophyta:		
uncommon	*Ulva lactuca*	subtidal	
common	*Enteromorpha* sp.	intertidal-subtidal	near fresh water efflux
seasonally abun-	*Monostroma* sp.	intertidal	tidal pools
dant	*Urospora* sp.	subtidal	boulders, large rocks

Table 3 . Partial List of Macrophytes found in Conception Bay, Newfoundland. Species given represent more dominant forms open to predation of the benthos found within the bay.

or depth of average occurrence, type of sediment, habitat and level of abundance are given. The level of abundance indicates a visual estimate taken underwater. For an explanation of this method, see Mann(1972). Only the more common macrophytes occurring along the east coast of the bay are listed to show these available to predation by the larger fauna. The species listed cover the coastline from Cape St. Francis to Holyrood on the east side of Conception Bay. Long Pond is located along this shore.

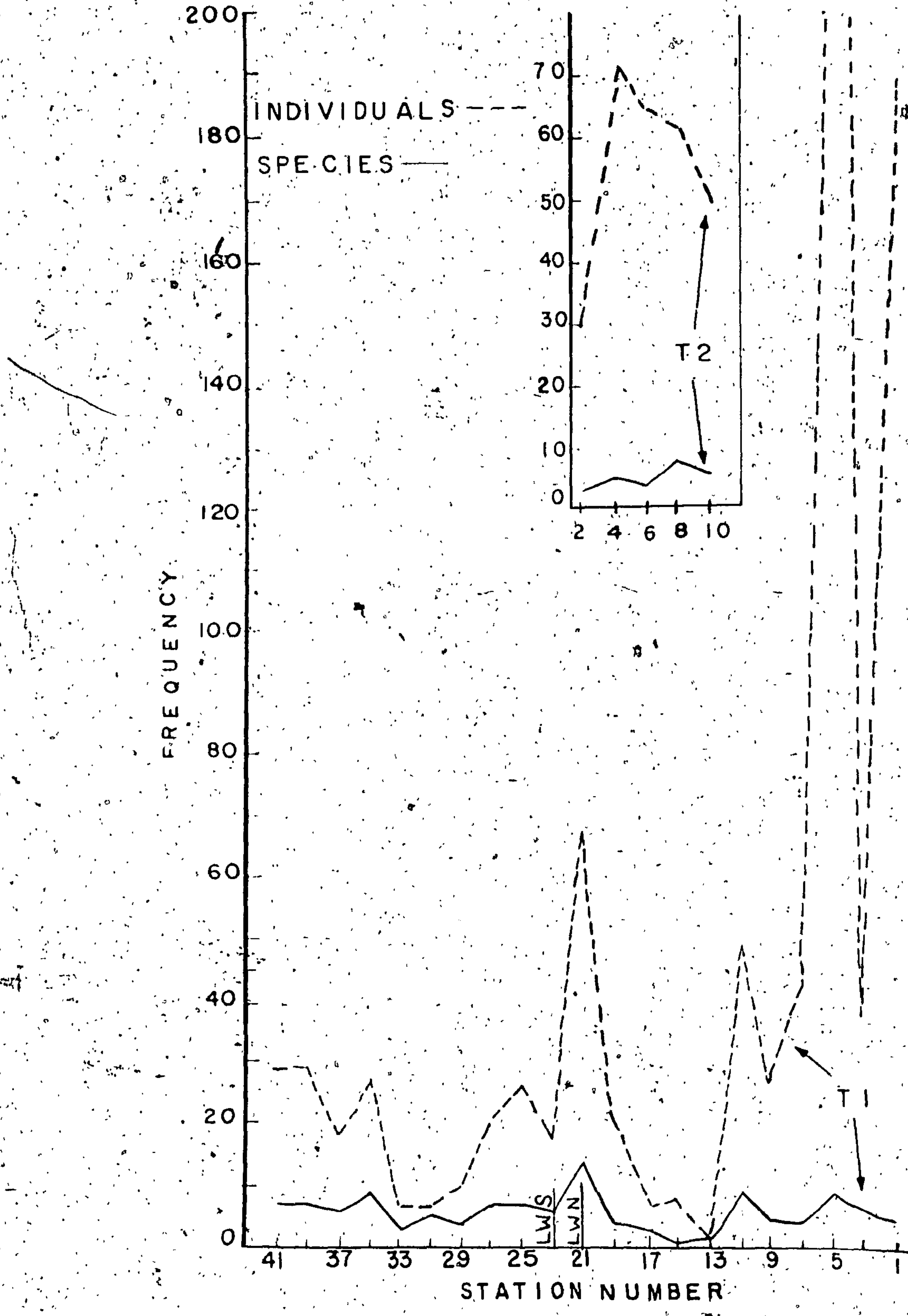
The benthic fauna is similar to that reported for other areas around the island of Newfoundland. It differs only in relative numbers of certain species which thrive under the more protective coastline of the bay. Appendix 3 is a list of benthic and macrofaunal species of five phyla known to occur in Conception Bay. Species listed occur either as annual residents (Tyler, MS 1968) or temporary migrants during some phase of their life cycle. It was compiled from my own data and information in Frost (1940), Kennedy (MS 1964), Himmelman (MS 1970), Coady (MS 1973) and Downer (MS 1973). Pelagic and microfaunal species which appear only infrequently in the winter flounder diet are excluded.

Brandy Cove

Algae, Amphipoda, and infaunal Pelecypoda were more numerous in the intertidal zone than other groups of organisms sampled. Larger epifauna, such as Asteroidea, Echinoidea, Anthozoa and Decapoda, were scarce as a result of the increased degree of shelter from the coast. Numbers of organisms on the beach and in the shallow subtidal zone are listed in Appendix 4. Two frequencies for each of two categories - abundance and species variation - are given/station to show differences between dead and live individuals of molluscs.

Fewer than half of the intertidal stations had mean frequencies lower than the mean of the transect which was 56.7 individuals/station or 2520/m^2. Maximum abundance occurred at stations 1 and 5 with 179 and 563 organisms per sample, respectively. Abundance and fluctuations in numbers increased with decreasing depth in the intertidal zone (Fig. 7). Subtidally, the number of species was slightly higher and more constant than intertidally. Numbers of organisms were greatest in the most shallow T1 stations; decreased through the middle part of the zone; and increased again just before low water neap (LWN). Abundance of organisms around low water has been reported elsewhere (McIntyre and Murison, 1973) and was also found along transect T2. Numbers reached a peak at station 4 just above low water line on this transect (Fig. 7).

The distribution of animals was closely related to substrate hardness and type of habitat. Since species diversity was inversely proportional to homogeneity of the sediment, the distributions are partially explicable. More organisms were found in the extreme low and high intertidal zone where gravel, pebbles, cobble rock, boulder, and shelving sandstone ledge with tide pools provided a wider variety of niches than did the sand of the mid-intertidal zone. Rocky substrate covered stations 1-7 and 21 of T1 and all of those along T2. Thus, 8444, 1644, 25020, 1866, and 2977 organisms/m^2 were found at


INDIVIDUALS
SPECIES
FREQUENCY
STATION NUMBER
T 2
T 1
LWS
LWN
0
20
40
60
80
100
120
140
160
180
200
41
37
33
29
25
21
17
13
9
5
1
0
10
20
30
40
50
60
70
2
4
6
8
10

the T1 stations, respectively, and a mean of $2485/m^2$ was seen at T2 stations. These were peak numbers and the biomass values corresponded similarly with a high of $4546\ g/m^2$ wet weight at low water for station #21 and $1864\ g/m^2$ wet weight at station #5 (Appendix 4, and Fig.7). The upper part of T1 was colonized by algae, amphipods, nereids, and pelecypods. Table 4 illustrates the distribution of organisms in the T1 samples.

Beyond station 7, the soil changed to sand and extended to #19. This area is considered to be the mid-intertidal zone at this location in Brandy Cove. It was here that numbers declined to a low of $89/m^2$ at #13. At station 15, 355 individuals belonged to one species only and biomass fell to 1 g from there to #19.

Throughout the sand flat, only relatively coarse material was present and comprised 92% (dry weight) of the soil sample at station #19, 87% at #15, and 79% at #9. The homogeneity of the sand habitat compared to the border of rocks above was thus partly accountable for the drop in numbers. Large epifauna were scarce over the sand flat due to the lack of suitable substrate for attachment. Algae and species associated with the cobble-ledge substrate above the sand flat phased out; while low, filamentous, green and brown species of algae appeared. Nereis virens declined in abundance. Peloscolex benedeni increased steadily along T1 toward the low water mark. An oligochaete complex of Peloscolex and Clitellio, consumed by the flounder, was represented only by Peloscolex in the mid-to-low intertidal (Table 4). Its

Species	Station Number: Cobble-Pebble					Sand Flat					Bedrock			Sand Surface over Gravel Mixture							
	1	3	5	7	9	11	13	15	17	19	21	23	25	27	29	31	33	35	37	29	41
Balanus balanoides			31		24	37							10								
Gammarus oceanicus	78	19	108	34																	
Nereis virens	5	1	6	6	1								1								
Mytilus edulis	100	13	411								33		3								
Monostroma sp.	1	1																			
Acrosiphonia arcta	1																				
Macoma balthica	4		1																		
Fucus sp.		1																			
Pilayella littoralis		1																			
Polychaeta			1																		
Enteromorpha intestinalis			1		1	1	1														
Lunatia triserata				1		1															
Ascophyllum nodosum																					
Lunatia heros				1		1	1														
Peloscolex benedeni					1	2		8	5	16	4										
Micrura sp.						1					3										
Cricotopus sp.										2											
Enoplus sp.											7										
Thais lapillus											4										
Heteronemertea											3										
Chondrus crispus											1										
Buccinum undatum											1										
Rhodymenia palmata											1										
Cistenides gouldii											1	2									
Nemertea												1									
Phascolosoma sp.												1									
Ammotrypane aulogaster													1	2							
Harmothoe imbricata														1							
Acmaea testudinalis											1	1	1	2		1					
Nephtys incisa						3	3		1	1		9	8	11	4	1	1	3			2
Cladophora sp.				1	1	1	1		1	1	1										
Leptocheirus pinguis												3			2	3	4	10	1	1	3
Scoloplos armiger													2	1	3			4	5	16	17
Eteone longa														2				1			
S. groebachiensis															1	1	2		2	1	1
Lumbrineris fragilis																		4	7	6	4
Clymenella torquata																		1		1	
Ninoe nigripes																		1			
Terebelloides stroemi																		1			
Syllis gracilis																		1			
Yoldia sp.																			1		1
Glycera capitata																			1		
Casco bigelowi																				1	
Mya arenaria																			1	3	

Table 4. Distribution and numbers of organisms per T1 Ekman Dredge sample from Brandy Cove, N.B. Numbers are for a 0.0225 cm^2 sampler.

distribution in Brandy Cove coincided with that reported elsewhere (Moore, 1905; Brinkhurst, 1965b; Cook and Brinkhurst, 1973).

In the low and mid tide zone broad bands of small green and brown algae grew adjacent to the transect. Among them were Acrosiphonia, Monostroma, Enteromorpha, Cladophora, Ulothrix, and Pilayella. Pilayella littoralis was seen to have the widest distribution from HWN to LWN throughout the summers of 1971 and 1972. It grew profusely in freshwater runoffs of pebble bottom or attached to fucoid holdfasts. Acrochaetium grew upon the rhodophyte Ceramium in scattered places, while Ascophyllum often dominated Fucus of the mid-intertidal.

Station #21 was found to be profusely covered with Mytilus, and contained more species (14), organisms and biomass than stations of the mid-intertidal. Species were transitional between the mid-intertidal and the subtidal zone. Ten species did not appear elsewhere on the transect and included Cistenides, Buccinum, Enoplus and Micrura. Peloscolex diminished in quantity, and its distribution stopped here. Similar groupings of species were found on T2, where Oligochaeta, Nematoda, and Nemertea were found. The polychaete, Pygospio elegans, occurred only on T2 but not along T1.

Subtidally, polychaetes became more important on T1, and sea urchins substantially raised biomass values of the subtidal samples. There was poor variety among other groups except for the polychaetes. There included 11 species. Some of these were Ninöe, Clymenella, Terebelloides and Syllis.

Transect T2

Species distribution was similar along transect T2 but composition differred because polychaetes and echinoids were absent. Algae, Nematoda, Nemertea and Gastropoda dominated. Mya arenaria and Macoma balthica were important. Their dense populations formed a wide clam bed that extended into and beyond the second stream outflow. These two species are important food sources for fish (Medcof and MacPhail, 1952; Steele, et al., 1968). Numbers (Appendix 4) peaked at station #8, similar to that in the upper intertidal of T1 (Fig. 7). However the T2 area was generally less diverse.

Interspersed among the clams were nematodes, oligochaetes and Lunatia. The most abundant was Peloscolex benedeni which seemed to follow the distribution of Mya over the clam bed and into decomposing sediment of the second stream.

Statistical Comparison of Brandy Cove Intertidal and Subtidal Zones

Along T1, numbers of species, biomass, and individuals were not significantly different in the two zones. The number of T1 intertidal samples was nearly equal to the number of subtidal samples as was the number of species per station (6) in each zone. Application of both parametric and non-parametric tests revealed no significant difference in the results at the traditional 1 and 5% levels of either biomass or numbers along T1. That no difference in biomass occurred was foreseen (Appendix 1). However, the absence of a large difference between means in the number of individuals in the two zones was surprising. This was due to an extremely large variance surrounding the intertidal mean. The subtidal variance was narrow about its mean because of a more uniform distribution of numbers. Consequently, the subtidal standard deviation was less than its mean. However, the distribution of numbers intertidally was abnormal, skewed to the left compared to the subtidal distribution, and resulted in extreme variance with a standard deviation twice the size of its mean. This affected the ability of any test to show a difference if it existed. It was caused by a wide range of frequencies in the first five stations of T1, where organisms clumped in a line perpendicular to low water and were uniform in distribution parallel to it in relation to substrate changes. Thus, although intertidal abundance of organisms was five times greater than that subtidally, the beach did not provide significantly more benthos (t=0.21) as prey for flounder. Its biomass was slightly lower than that subtidally although not significantly, and its variety was equivalent. The Randomization Test, T-Test, and Mann-Whitney U Test were employed in this analysis. The results were similar for each test; significance between the 5% and 10% levels, and closest to 8%. It would seem, then, the intertidal area studied is as important as the shallow subtidal in offering comparable species, numbers, and weights of organisms as prey.

The Relation of Brandy Cove to Other Areas

Faunistically, Brandy Cove and its adjacent shoreline of Passamaquoddy Bay are one of the richest regions in eastern Canada. Literature searches concomitant with dredge sampling indicated that of several regions both to the north and south, this area had one of the widest varieties of species between Newfoundland and New York. Table 5 compares shallow water benthic surveys over this geographic range. The total number of species cited from each source is considered typical for its corresponding site. Information on the number of intertidal and subtidal biota, biomass determined by type of study, and abundance per square meter has been listed so that comparisons can be made. Columns 3,6,7, and 8 of Table 5 illustrate the difficulties in comparing the studies due to their widely varying methods. Total numbers of species known for Long Pond have been determined from composite listings of four workers in that area. However, Christie (1966) is used in reference to the first complete benthos survey there. Authors have been shown as "various" to cover all original identifications and collectors who contributed to the list of fauna of Brandy Cove from 1912-1973, as most records have not been published or a complete survey made. In numbers of species, Brandy Cove is endowed with 182 reported between 1912 and 1973, compared to Bideford River, Prince Edward Island (159) and Long Pond, Newfoundland (101). The depth ranges and sieve sizes were the same in each of these studies. Numerical abundance and biomass estimates of the three sites will then be comparable. Based on total lists of the Bay nearby, this number is expected to rise minimally to 220 for the cove following more thorough sampling and completion of the area records. Species for Brandy Cove are shown in Appendix 5.

Author	Year	No. Stn.	Locality (north-south)	Total No. Known Species	Maximum Depth (m)	No. Samples	Sieve Size	No. Intertidal Flora/Fauna	No. Subtidal Flora/Fauna	Mean Subtidal Biomass (g. dry weight/m^2)	Mean Intertidal Biomass (g. dry weight/m^2)	Mean Number Organisms/m^2 Subtidal Zone (S)	Mean Number Organisms/m^2 Intertidal Zone (I)	Maximum Abundance Organisms/m^2 by Zone
Christie	1966	6	Long Pond, Nfld.	101	4.6	62+	0.5	2/4	13/82	97.5	–			–
Thomas	1970	637	Bideford, PEI.	159	4.0	7000+	0.5	20/9	16/114	20.1	2173.1	10252 (S)		29859 (S)
Thomas	1970	8	Bideford, PEI.	79	3.0	160	0.5		7/72					
Wells	1973	26	Brandy Cove	61	9.0	26	0.5	9/26	2/24			844 (S)	4012 (I)	25020 (I)
Various	1912-73	---	Brandy Cove	182	20.	---	var	37/84	5/128					
Hanks	1964	78	Sheepscot, Me.	—	16.	78+	1.5		–/108			1500 (S)		
Stickney	1959	---	Sheepscot, Me.	173	20.	24	1.5	18/31	11/113					
Young & Rhoades	1971	7	CapeCodBay, Mass.	–	42. 42.	7	1.0		–/118			15410 (S)		30150 (S)
Sanders	1960	1	BuzzardsBay, Mass.	–	19.	24	0.2		–/79	12.2		8985 (S)		15622 (S)
Sanders	1958	19	BuzzardsBay, Mass.	–	20.	19	0.5		–			4430 (S)		12576 (S)
Sanders	1962	6	Barnstable Hbr, Mass.	–	0.0	14+	0.75	0/82	–	38.9			181000 (I)	355000 (I)
Sanders et.al.	1956	8	Long Island, N.Y.	135	31.	36+	1.0		–/135	54.6		16446 (S)		46404 (S)

Table 5. Comparison of Benthos Studies for Coastal Marine Localities: Newfoundland to New York.

The distribution of many species is contiguous and extends up the beach in the cove where it may not elsewhere, due to the differences in tidal amplitude. The 182 species are divided into 121 intertidal species compared to 49 at the mouth of the Sheepscot River, 29 at Bideford River estuary, and 6 at Long Pond. With 128 subtidal fauna, Brandy Cove stands intermediate between Long Pond and Long Island, for which Sanders (1956) found 135 subtidal species in Greenwich Bay. This intermediate rank seems to result from the addition of more short-lived Virginian forms and a phasing out of the boreo-arctic component in the latter area. At the same time, Brandy Cove is higher in rank than areas north of Long Island. The Sheepscot River compares almost equally with Brandy Cove with a total of 173 species. Prince Edward Island, Maine, and Massachusetts, all of which rank lower than Brandy Cove, seem to have similar numbers of subtidal species: 114, 113, and 118 respectively. Having a less diverse fauna, Buzzard's Bay compared poorly not only to Brandy Cove but Cape Cod Bay and all areas to the north. Sanders (1960) found a poor overturn in production, few subtidal species (79), and a low mean biomass at one station intensively studied in Buzzard's Bay. Abundance of organisms for the station was only 8,985/m^2 and a maximum of 15,622/m^2 only slightly exceeded the mean in Cape Cod Bay which was 15,410/m^2. A lower overall mean of 4,430/m^2 and a maximum number of 12, 576/m^2 were found in a related survey for the entire Bay (Sanders, 1958).

As few intertidal surveys have been reported, a direct comparison to Brandy Cove's intertidal zone is difficult.

One survey in Barnstable Harbor, Mass. (Sanders, 1962) revealed 82 species living on a sand flat. Material analyzed in Brandy Cove consisted primarily of macrofauna, except for the two meiofaunal classes of Nematoda and Oligochaeta (Mare, 1942). All other meiofauna and microfauna were excluded. If these lower trophic levels (Moore, 1931; Gray and Rieger, 1971; Harris 1972 a,b,c) were excluded, the Barnstable estimate would be decreased considerably. Thus, Mills (1967) found only 42 intertidal macrofaunal species there at Station E in 1960.

The cove appears to be relatively poor in subtidal and intertidal flora despite its relative richness of fauna (Colinvaux, 1966). Species of the flora found in the intertidal and shallow subtidal are shown in Appendix 6, grouped according to their characteristic vertical distribution at this location. As far as possible, species found at each level of the two zones, are listed only once. Some from the intertidal zone may grow subtidally for short distances, thus increasing that list by 5 or 6. The algae of the Acadian Peninsula have been studied in detail by MacFarlane (1952). Mann (1972) can be consulted for comparison of the abundance, variety, and biomass between the two shore zones found typically at Brandy Cove. While Colinvaux (1966) holds the flora to be poorly developed, the cove was found to have more species than Long Pond, Bideford, or Sheepscot. The 20 floral species from Bideford include only three algae. The remainder were estuarine angiosperms.

The variety of fauna found at the cove is due to the interaction of moderate climate, tidal range, and estuarine location (Bousfield, 1960). Large amplitude tides create long hours of solar warming on the exposed beaches, which also warm the sea water column by releasing heat at high water. Ice-free bay water decreases the danger of frost and ice abrasion, while heating of the soft sediments in summer prevents their freezing up in winter (Rowe, 1970). Estuarine species are present, and the beach expanses are such that many species which elsewhere are subtidal, also colonized the intertidal zone. Thus, _Diastylis_ species, _Casco bigelowi_, _Maera danae_, _Anonyx nugax_, _Pontoporeia femorata_, _Corophium crassicorne_, and _Clymenella torquata_ (Bousfield, 1960, 1973; Mangum, 1964) are found in the lowest and highest parts of the tidal zone in Passamaquoddy Bay and many are to be seen in the cove. Some, such as _Mysis stenolepis_, are distributed abundantly only in this region, yet are rather scarce along the remaining shoreline outside Passamaquoddy Bay. Others, such as _Bathyporeia quoddyensis_, have developed peculiarly in the Fundy area and are not found outside of it.

Colinvaux (1966) provides a description of these phenomena for algae which apply equally well to the fauna.

Tidal Characteristics of the Study Sites

From November through February seasonal maxima of the tidal oscillations created 1.6 m tides in Long Pond compared to the average summer level of 0.78-1.1 m; while at Brandy Cove the large tides ranged to 8.7-9.1 m.

Sverdrup et al. (1942) discussed the oscillations peculiar to the Bay of Fundy, where the largest known tides occur. Brandy Cove is subjected to these. A major factor in their creation is that, as in many bays, an increase is caused by narrowing of the shoreline or funnelling and shoaling of the bottom, amounting to a fourfold increase in range. Such increase has been found where the co-oscillating tide dominates as in the Adriatic Sea (DeFant, 1925). While resonance brings about larger amplitude, there is some loss in height due to drag as oceanic waves move inland. An incoming wave loses height toward Minas Basin and when reflected from the extreme head of the Bay, is smaller as an outgoing wave. The character of the outgoing wave, thus, changes from that of the ingoing wave, but the total effect is not great. As part of the Bay of Fundy, Passamaquoddy Bay has two features: (a) cotidal lines can be drawn across the Bay horizontally showing equal time of occurrence for each tidal phase in the direction of progress (b) tidal currents are strongest at half tide. Tidal current at the mouth of the Bay of Fundy was estimated to be only 82 cm/sec (Marmer, 1926) while that in L'etite Passages ranged to 308 cm/sec. Slower current in the first case was due to the large cross sectional area of of the Bay mouth proportional to its own surface area. The larger tidal range in the second case was due to a smaller cross sectional area at the mouth of Passamaquoddy Bay in proportion to its surface. Its four deep and narrow entrances create fast rip tides from the large volume which must be funnelled in and out to the nearby ocean. This larger tidal range also exposes wide intertidal areas compared to those exposed in Newfoundland for the same stage of tide.

Newfoundland tides show smaller inequality and range than those in New Brunswick. Their amplitude varies around the island being larger on the south coast and generally smaller on the east coast. Tides of 2.1 m are known in Placentia Bay but only 0.9-1.2 m at St. John's.

Surface tidal currents over the sampling area in Conception Bay were stronger during ebb tide from the surface to a depth of 3 m. Currents were weaker below 4 m on the ebb tide and during flood tide. On neap tides, currents were estimated to run between 51.4 and 102-105 cm/sec, but when very weak approximated the speeds reported for Placentia Bay (Trites, 1969).

Tidal Movements of Winter Flounder in Long Pond

Statistical Analysis

Frequency histograms of the daily counts are shown in Figs. 8-12. For these, mean numbers of fish per 61 m of transect are graphed against time of tide. Changes within units as well as between them are given with a corresponding graph of the same tidal phase. Tidal curves were not taken on the same day but are representative of the same phase of tide. Data pertaining to these curves are shown in Appendix 7 which gives differences in the time of occurrence, range, and span of time over which the tide occurred for the shallows of the pond. Information relating to Long Pond tides and diving counts appear in Table 6.

The Chi-squared Test (Alder and Roessler, 1966; Davies, 1970) and the Komorogov-Smirnov Test (Siegel, 1956) were used to measure differences between the observed hourly distributions and expected random distributions of each set of observations. For each of the two tidal phases, the hypothesis of no difference between the distribution of fish with changing hour of tide was tested and showed either the presence or absence of movement related to tide.

Although for any significant Chi-square dependence of the variates is shown, an exact casual relation may not be established. Chi-square values from the tidal counts are compared with tabular values at the 1 and 5% levels of significance in Table 6.

Table 6. Hours of diving observations, tidal characteristics, and comparison of calculated and tabular χ^2 for observed distributions of winter flounder.

Date	Tide	Time of H.W.*	Hour of Census	Calculated χ^2	df	Tabular χ^2 0.05	0.01
1971							
May 20	Flood	1733	2,5,6	79.51	22	33.92	40.29
May 24	Flood	2053	1,3,	93.51	11	19.68	24.72
May 28	Ebb	1128	3,5,1	87.90	22	33.92	40.29
1972							
May 3	Ebb	1128	1,3,5	69.50	22	33.92	40.29
May 9	Flood	1753	1,3,5	104.84	22	33.92	40.29
May 10	Flood	1843	1,3,5	84.94	22	33.92	40.29
May 15	Ebb	1018	1,3,5	43.06	22	33.92	40.29
May 15	Flood	2238	1,3,5	74.78	22	33.92	40.29
May 16	Ebb	1103	2,4,6	69.54	22	33.92	40.29
May 17	Ebb	1148	2,4,6	14.42	11	19.68	24.72
May 23	Flood	1748	1,3,5	83.16	22	33.92	40.29
May 25	Flood	1913	1,3,5	49.67	22	33.92	40.29
Vertical Movements							
1972							
May 30	Ebb	1003	1,3,5	27.17	12	21.03	26.22
May 30	Flood	2213	1,3,5	16.61	12	21.03	26.22
May 31	Ebb	1038	1,3,5	32.94	12	21.03	26.22
Horizontal Movements							

H.W.=High Water, (NST). Observations made before H. W. on flood tide and following it on ebb tide.

All but two series of distributions showed significant changes with time of tide along the transect at the traditional 5% levels for the Chi-square Test. Changes were not significant on May 17 and 30, 1972. May 17 should have compared similarly to that on May 16 but did not, for although a decline in numbers occurred, each hourly distribution contained frequencies that were uniform across the bottom of the pond. The same feature of uniformity per hourly distribution occurred on May 30 during the third hour of flood tide even when an increase in fish moving toward shore occurred. Fifty-seven per cent of the horizontal transect stations during third hour flood had 13 flounder, each, and more than 1.4 of the classes had low frequencies. These features of the data for the three sets of observations on May 30 made detection on a station by station basis impossible from the χ^2 test. An absence of change on May 17 reflected the strong effect of habitat on behaviour of the flounder. Those along one unit moved in the opposite direction to those in adjacent units, and group movement was dissociated with scattering in various directions when divers appeared. The erratic movement of individual fish was apparently caused by the effect of severe weather on the shallow water column both on this and previous days. Conditions were poor enough during this week of observations to cause an unexpected blizzard of 11.0 cm (4.4 in) of snow on May 16. High winds and choppy water apparently frightened these fish and as the tide declined numbers in the middle units of the transect increased rather than decreased. The last daily census was aborted for counts could not be taken accurately along some units due to surface chop, supersaturation and silting of the water. These reduced visibility such that the fish could not be seen.

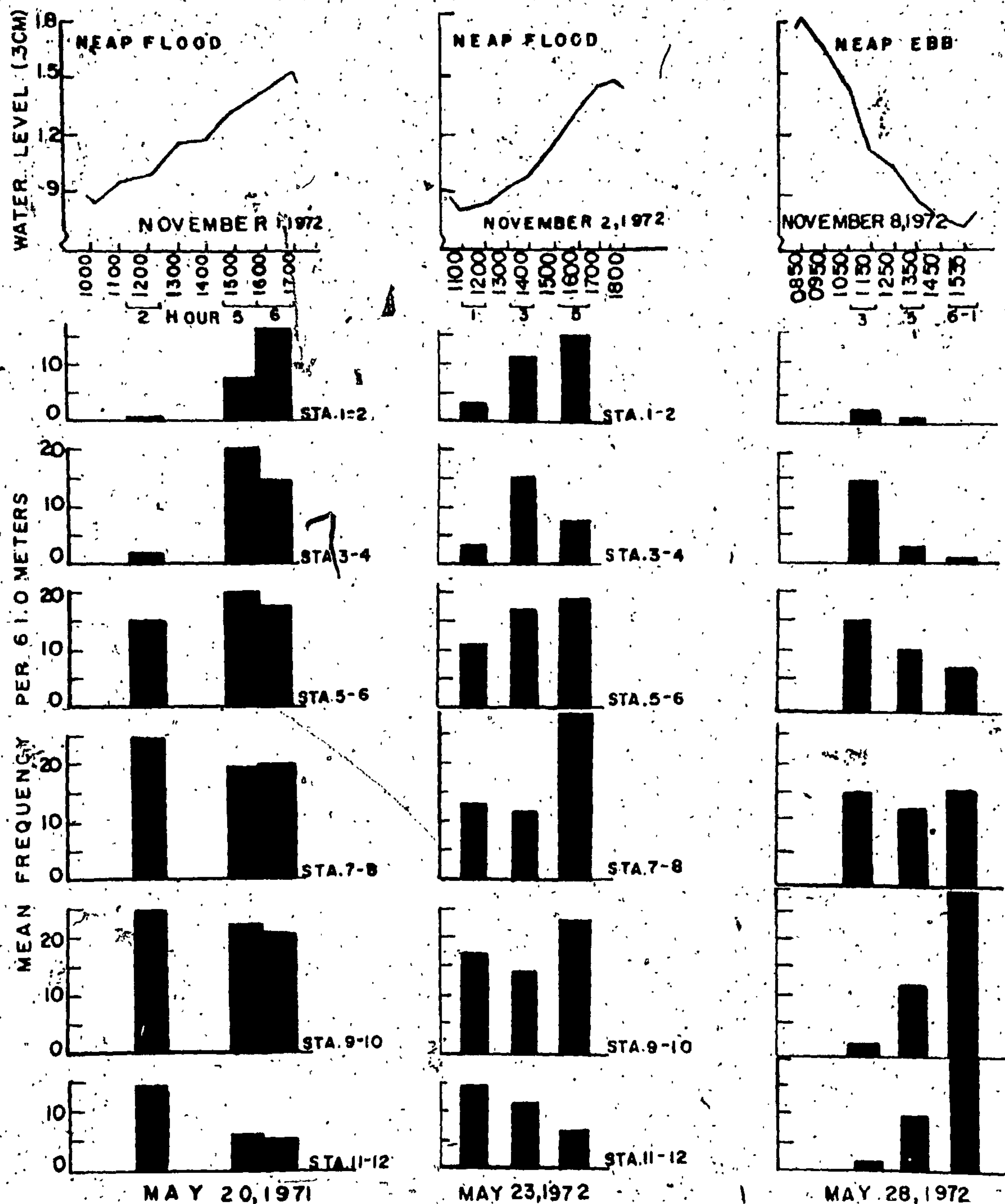
Due to the lower power efficiency and weaknesses of the χ^2 Test (Siegel, 1956) the Komorogo-Smirnov Two Sample Test was applied. This was (1) a nonparametric equivalent to the χ^2 statistic and (2) applicable to the statistical model. Its advantage lay in the sensitivity to class frequencies when more than 20% have (f) less than 5 and pooling is undesirable. Df may be higher and the feature of ordered magnitude within distributions could be used in contrast to the Chi-Square Test. This test has a higher power-efficiency than the T-Test, χ^2 Test, or Median Test. The maximum value of the difference was calculated for sets of daily observations and was significant at 5% for all except the May 17 results.

The May 30 result confirmed an expectation that fish had actually moved into the intertidal zone as was the case for their reverse movement from it on the same day.

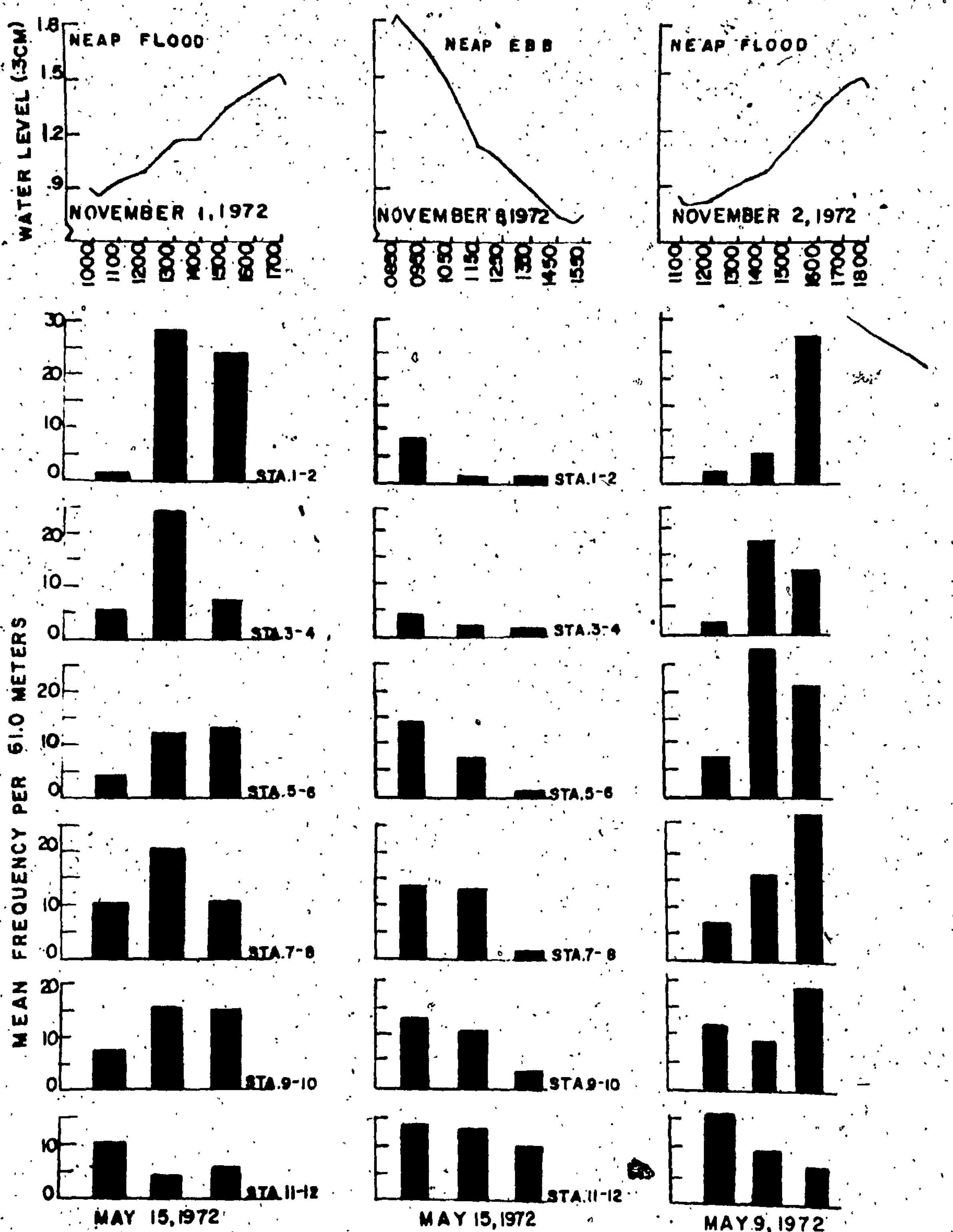
Daily Change in Location with Time

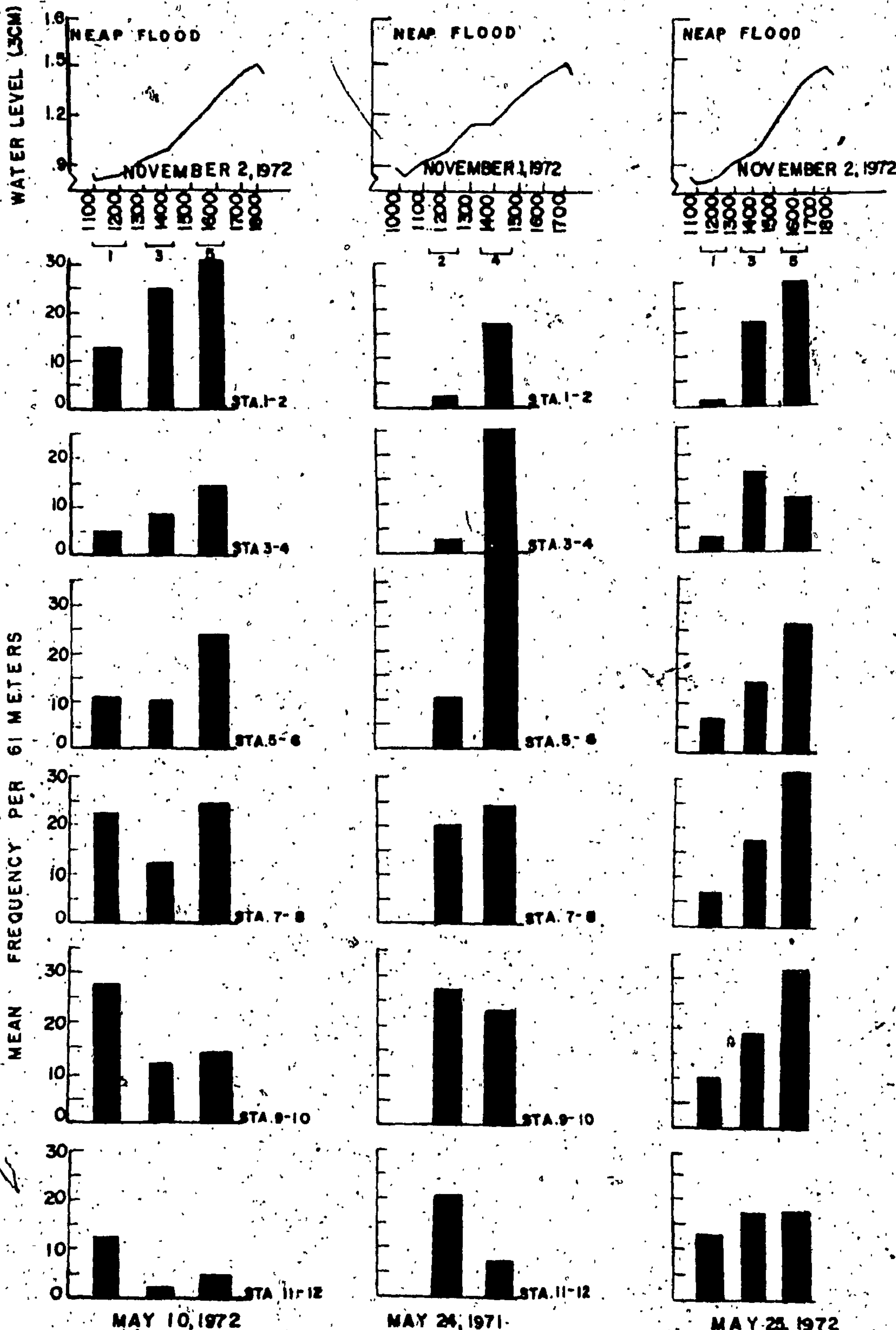
To clarify certain features found throughout the sampling (Figures 8-12) those pertaining to May 20 only, shall be discussed in some detail to aid in analyzing material presented. Similarities and contrasts are made for the remaining counts, where possible, throughout these results. Here, May 20 is treated as an example. On May 20, increases in numbers of fish (Figure 8) were found on the flood tide from the

Figures 8-11. Frequency histograms of mean numbers of winter flounder per paired transect units at different tidal phases in Long Pond. Means calculated from frequencies of 100 ft.(30.5m) units taken 2 at a time.



WATER LEVEL (.3CM)
NEAP FLOOD
NOVEMBER 1,1972
1000 1100 1200 1300 1400 1500 1600 1700
2 HOUR 5 6
NEAP FLOOD
NOVEMBER 2,1972
1100 1200 1300 1400 1500 1600 1700 1800
1 3 5
NEAP EBB
NOVEMBER 8,1972
0850 0950 1050 1150 1250 1350 1450 1530
3 5 6-1
MEAN FREQUENCY PER 61.0 METERS
STA.1-2
STA.3-4
STA.5-6
STA.7-8
STA.9-10
STA.11-12
MAY 20,1971
MAY 23,1972
MAY 28,1972


WATER LEVEL (.3CM)
1.8
1.5
1.2
.9
NEAP FLOOD
NOVEMBER 1, 1972
1000
1100
1200
1300
1400
1500
1600
1700
NEAP EBB
NOVEMBER 8 1972
0850
0950
1050
1150
1250
1350
1450
1530
NEAP FLOOD
NOVEMBER 2, 1972
1100
1200
1300
1400
1500
1600
1700
1800
MEAN FREQUENCY PER 61.0 METERS
30
20
10
0
STA.1-2
STA.3-4
STA.5-6
STA.7-8
STA.9-10
STA.11-12
MAY 15, 1972
MAY 15, 1972
MAY 9, 1972


WATER LEVEL (.3CM)
NEAP FLOOD
NOVEMBER 2, 1972
NEAP FLOOD
NOVEMBER 1, 1972
NEAP FLOOD
NOVEMBER 2, 1972
STA. 1-2
STA 3-4
STA. 5-6
STA. 7-8
STA. 9-10
STA 11-12
MEAN FREQUENCY PER 61 METERS
MAY 10, 1972
MAY 24, 1971
MAY 25, 1972

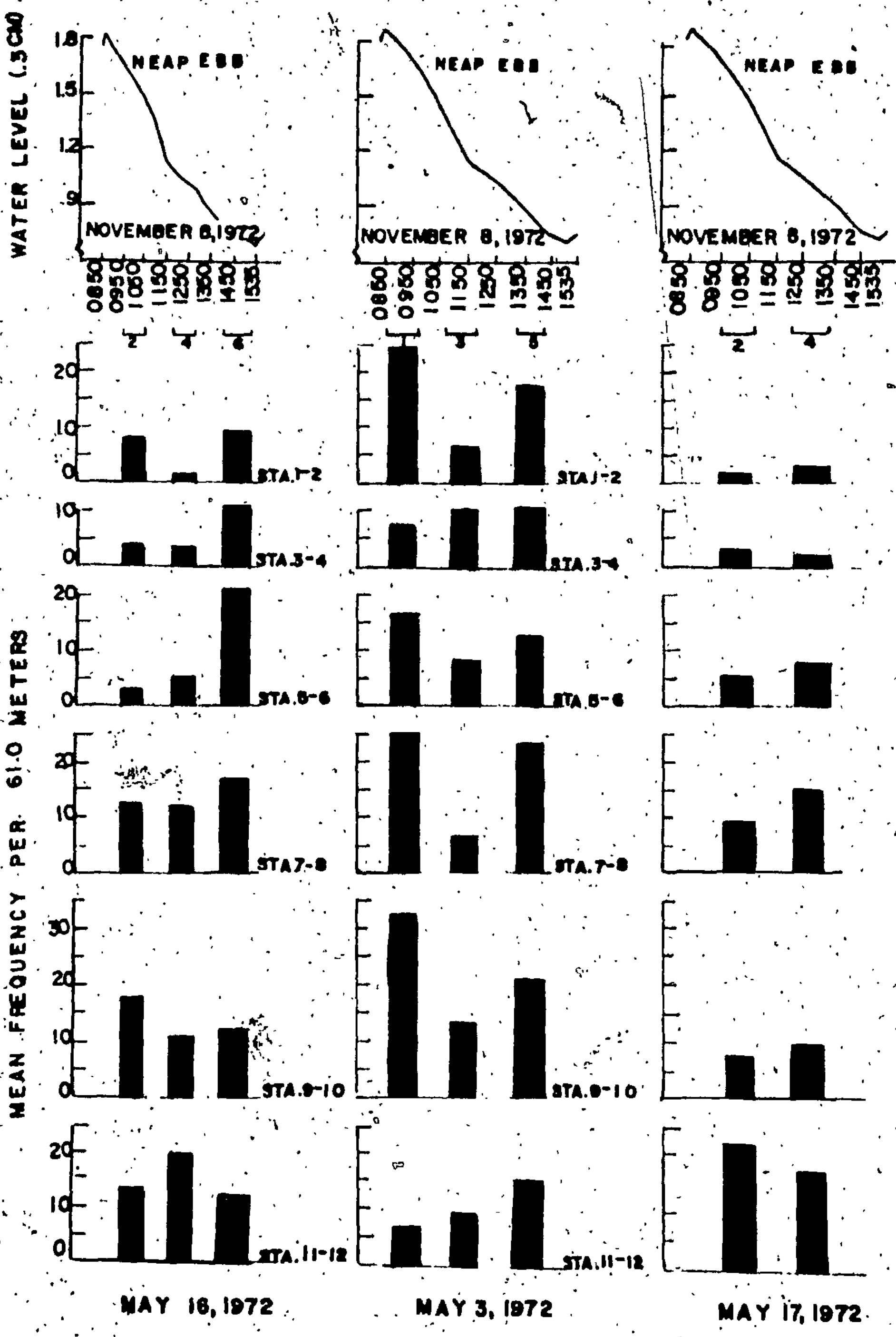
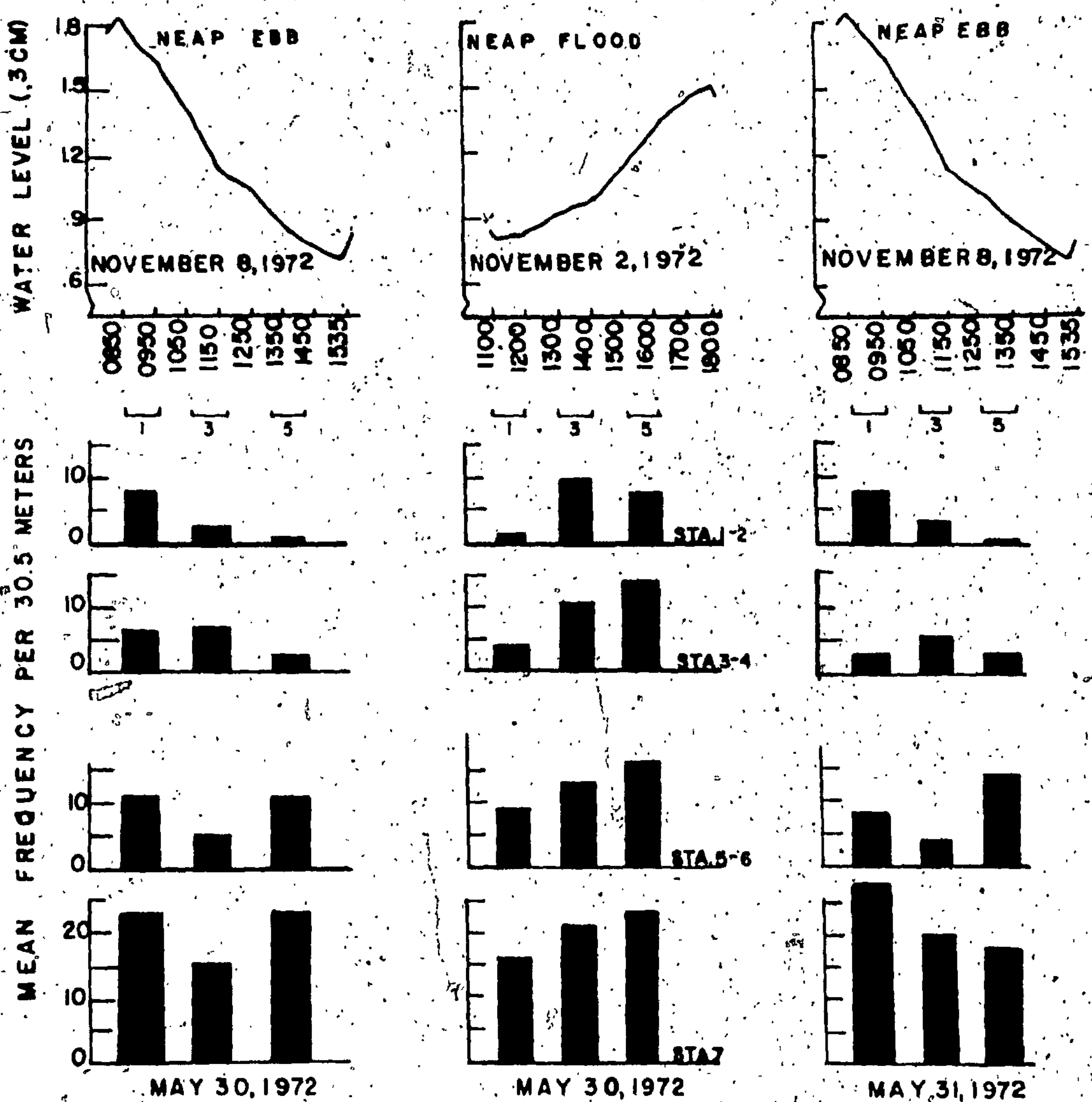

WATER LEVEL (.5CM)
NEAP EBB
NOVEMBER 8, 1972
0850
0950
1050
1150
1250
1350
1450
1535
MEAN FREQUENCY PER 61.0 METERS
STA.1-2
STA.3-4
STA.5-6
STA.7-8
STA.9-10
STA.11-12
MAY 16, 1972
MAY 3, 1972
MAY 17, 1972

Figure 12. Frequency histograms of mean numbers of winter flounder per paired transect units at different tidal phases in Long Pond. Means calculated from frequencies of 50 ft. (15.3 m) units taken two at a time.



WATER LEVEL (.3CM)
1.8
1.5
1.2
.9
.6
NEAP EBB
NOVEMBER 8, 1972
0850
0950
1050
1150
1250
1350
1450
1535
NEAP FLOOD
NOVEMBER 2, 1972
1100
1200
1300
1400
1500
1600
1700
1800
NEAP EBB
NOVEMBER 8, 1972
1
3
5
MEAN FREQUENCY PER 30.5 METERS
10
0
20
STA.1-2
STA.3-4
STA.5-6
STA.7
MAY 30, 1972
MAY 30, 1972
MAY 31, 1972

start of second hour to the end of the fourth hour, as shown by the 5th hour counts. Numbers were low in the paired units 1-2, 3-4, 5-6, and 7-8 during the first 1¼-1½ hours of tide. This occurred especially in the first 129 m (400 ft.) of transect, where means were 0.5 and 2.0 fish for units 1-2 and 3-4 respectively. Larger mean numbers were found for the middle of the transect where units 5-6 and 7-8 held 15.5 and 24.5 fish each. Units 9-10 contained more individuals at the far end of the pond, or an average of 25.0 fish. The center of aggregation around low water occurred in units 8, 9, and 10. Nature of the movement was found to vary and be dependent on the center of aggregation for the day concerned. As in many open field studies, much daily variation was found due to weather, plant camouflage and location, and size of increases and decreases in the tide.

The center of aggregation at low tide influenced (1) the length of time of overall movement, (2) the distance moved, and (3) starting time of movement. The center of concentration was found in one of four places relative to transect T1. Two involved the substrata in the sampling area, while two others did not. These were (1) the far shallow area of the inlet to the crest of an underwater slope, (2) the deep end, including the slope face and dredged basin, stations 11 and 12, (3) beyond the end of the transect in the channel, or (4) beyond the lateral limits of the sampling area. Fish could be concentrated in any of these areas, at the beginning of the flood tide. On

May 20, 24, and 28 fish were aggregated heavily in units 8, 9 and 10. Relatively high numbers were also found in unit 11 down the slope face to the bottom of the basin. For the majority of the other flood tides, the center of supply for tidal movement was in units 10 and 11. Flounder could have also come from beyond the sides of the transect or beyond station 12. This was found to be the case on May 9, 15, and 25, when the larger mid-tide increase in fish could not be accounted for by decreases from the far, deep end of the inlet and fish came from outside the immediate sampling area.

Large decreases in numbers of fish in units 8 through 12 accounted for much of the increase in the shallow end of the pond on May 20. The fifth hour count indicated a shift in numbers during hours 3 and 4 as the second hour census required nearly a full hour and no change was seen during that dive. A small scale movement apparently took place during the first hour of this tide, also, as units 7 and 8 contained relatively large numbers by the beginning of hour 2 with 21 and 28 fish each.

A decrease occurred in hours 5 and 6 along most of the transect (units 2-7, and 9). Frequencies in the other areas remained the same or increased nominally. Thus, fish numbers increased in the shallow, near the end of the lagoon, as the tide rose and decreased in the far, deep end. Movement of the central aggregation of fish was initiated by at least the end of second hour flood and continued until most fish had moved inshore by the end of the fourth hour. The last dive on May 20 indicated an increase occurred in unit 1 and again in 8 and 10 during 5th hour flood. The remaining units decreased slightly. It is felt that this decrease occurred as fish moved out of the sampling area and swam to either the right of the transect and into the center of the pond; or left of it, going inshore to the shallow subtidal and intertidal. Hourly variations also occurred as individuals moved back and forth along the transect, changing positions. While divers swam from shore to station 0 (anchor block) of transect T1, fish were seen on this strip of bottom during the hours surrounding high water. Approximately one half of this area was uncovered at low water, and covered on high water. The disappearance of fish from the intertidal and shallow subtidal at low water and reappearance at high water indicated a movement which was horizontal in direction across part of the pond. Movement across the width of the pond was known to occur from the sampling area toward shore as positions of individual fish between the two places were noted.

To more closely determine the progress of changes over a tidal cycle, counting was made during hours 2, 4, and 6. After one hour of tidal flow, a distribution similar to that of hour 2 was found.

Increases occurred from units 1-8 with decreases in 9 and 10. Increases in the shallow units were larger than could be accounted for by decreases in the deep end and showed fish from areas listed above had joined those in the sampling area.

The example of May 20 is compared to the remaining sets of fish counts in the following paragraphs.

Comparison of flounder frequencies for second hour flood on May 20 and 24, 1971 (Figures 8, 9) indicated equivalent numbers of fish and similar distribution patterns. Numbers of fish were also similar for the same portions of transect during equal tidal hours on these days. By coincidence, the total number of fish after 1 hr flood was 164 for both. For May 24, the distribution was similar to that of May 20th and the center of aggregation after low water occurred in units 8, 9, and 10, as well as in the basin. A shift in numbers with time occurred. Numbers changed rather rapidly from the end of second hour flood to the end of third hour flood as seen by counts at the start of fourth hour. Decreases were more evident in the dredged basin than before. Total numbers counted during the second dive were also higher than those counted during the first dive. The second dive took place at half flood.

Increases on May 24 in units 1-2 were similar to those of May 20th where the former had a mean of 1.5 fish and the latter 0.5. These rose to means of 16.5 and 16.0 respectively, after mid-flood. The pattern of distribution along the bottom was similar and compared with other flood tide patterns (Fig. 9, 10). Units 1, 2, 3, and 4 contained low numbers around low water. These frequencies were usually less than 5 fish/ 30.5 m (100 ft) and included four units, but the exact boundary changed by ± 1 unit. Numbers increased relatively quickly in the middle of the transect just beyond the shallow water units 1-4. The middle portion here included units 5, 6, 7, and 8 and was the same for both days. This was also the case for May 9, 1972. The middle section was characterized by numbers larger than those in the shallows but lower than those located in the last third of transect which lay in the most distant part of the shallows and deeper basin. Length of the middle portion of transect varied by one unit as described for the first portion containing low frequencies. The number of units in the middle portion usually remained constant at 4±1. Within narrow limits, mean numbers of fish in this middle portion of transect were of similar magnitude for the same stage of tide regardless of day. Frequencies ranged between 10 and 22, for most days at the beginning of the flood tide. For example, the mean of unit 5-6 on the second hour flood was 15.5 on May 20; 10.5 on May 24; 11.0 on May 10; and 11.5 on May 23. Means for units 7-8 similarly were 20.5 for May 24; 15.0 on May 28; 17.0 on May 10; 10.5 for May 15; and 13.5 for May 23, 1972.

A slight but consistent increase was evident for units 9, 10, and 11. Occasionally unit 12 was included in the last third of transect if fish concentrated in the basin. However, it contained low frequencies of flounder during most observations becuase of the absence of suitable plant cover and food supplies. Means of units 9, 10, and 11 were larger than in units 5, 6, and/or 7. Unit 8 appeared to vary and on some days could be grouped with 5-7, while on others with 9-11, depending upon daily variation.

At the time of slack water ± 2 hours the center of aggregation was indicated by mean frequencies of 20-30 each in units 9-10 and/or 11-12. Table 7 compares numbers of flounder from the third portion of transect T1 with those listed above for the middle or second portion. The observation established for order of magnitude in numbers in the middle portion of T1, held for those in the third portion. However, frequencies were larger in the third portion.

Date	Tide	Hour	Mean Frequency Station (9-10)	Mean Frequency Station (11-12)
20/5	Flood	2	25.0	14.5
24/5	Flood	2	27.0	20.0
28/5	Flood	1	30.0	19.5
10/5	Flood	1	27.5	12.5
16/5	Ebb	4	10.5	20.5

Table 7. Mean numbers of winter flounder found on third portion of T1 at slack water (± 2 hr) in Long Pond. Paired units with means ≥ 19.5 indicate centers of aggregation.

Dates listed in Table 7 show that fish concentrated in groups at the most distant end of the shallows and/or dredged basin. These aggregations provided the main supply of individuals which moved with the tide on the day indicated.

Summary of Trends in Flounder Distributions

A summary of the change in numbers of winter flounder over each hour of the tide cycle in the pond is shown in Fig. 13 and 14. For each unit, a mean from all frequencies of fish in that unit for each hour of the tidal phase was graphed. Such curves smooth out minor variations and differences found within the daily curves shown in Figures 8-12.

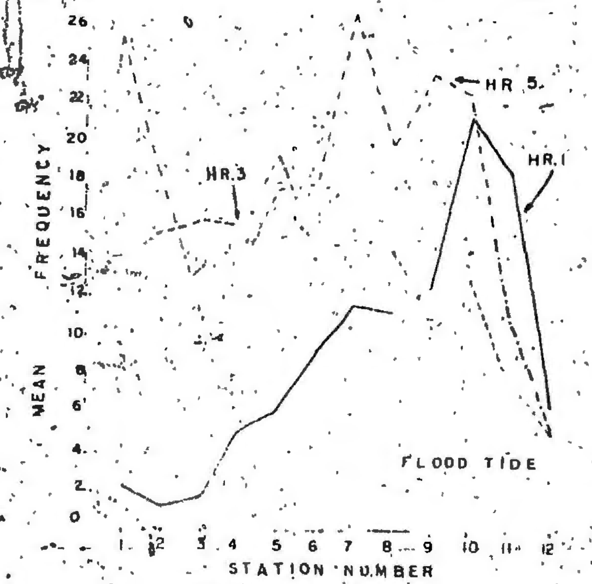
Comparison of the flood and ebb distributions by hour shows certain similarities between the 5th hr ebb and 1st hr flood, 1st hr ebb with 5th hr flood, etc. An average of 9.0 fish occurred in unit 1, for example, during the 1st hr flood following low water; while 9.9 fish occurred there during 5th hr ebb. Fifteen fish appeared in unit 1 at 5 hr flood and the mean of equal magnitude occurred for 1 hr ebb. Averages increased over the first four hours flood tide with maximum increase during hours 2 and 4. A slight decline occurred there after as fish left the sampling area and spread out or moved farther toward the head of Long Pond. Insufficient data for hours 2 and 6 of ebb tide made explanation of trends during these periods slightly more difficult, but gradual decline was evident. This decline occurred with less rapidity than that of the flood tide increases.

Figure 13 suggests that fish moved inshore in 3 groupings. Peak numbers of flounder found ~~in unit one at 5th hr~~ flood decreased during that hour until the start of 6th hr flood. It then increased again at 1 hr. ebb (low water) while the three groups spread out in units 1-2, 5, and 8-10.

At the beginning of 3 hr ebb, the concentration at units 8-10 broke into smaller sub-concentrations in units 4, 7, and 9. The high water aggregation had thus split and shifted. The one hr ebb concentration at unit 1 diminished as individuals moved into the shallower sand flats and intertidal zone. The three concentrations from 3 hr ebb began shifting toward the far end of Long Pond during the 4th hr of tide. Mean frequencies at the start of 5 hours ebb showed these to be displaced to the right on the axis. They concentrated in units 7, 9, and 11, on the average, after being at 4, 7, and 9, respectively.

It would appear, then, that during the last half of ebb tide a slow but steady change in distribution took place. P. americanus moved in small groups or waves toward the distant end of Long POnd through 5th hr ebb. At the start of 6 hr ebb the shift increased in pace until the majority of fish arrived at the crest of the slope. The slightly faster pace is seen in the distributions at the end of sixth hour (Fig. 14). As such a distribution is mirrored in the distribution recorded at the onset of first hour flood a look at Figure 13 will show the location of fish at the end of ebb tide (see hr 1). This can then be compared with the distribution after 5 hr ebb (Fig. 14) to observe the difference in pace during sixth hour ebb. The procedure is suggested since the single set of data recorded for the last hour of ebb tide is insufficient to be used as an average case.

Figure 13. Grand mean of all frequencies of winter flounder per unit of transect #1 per hour of flood tide in Long Pond. Means are for all sets of daily observations within a unit. Hr = Hour of Tide. Panel (A) with hours 1, 3, and 5, separated from Panel (B) with hours 2, 4, and 6.


HR. 5
HR. 1
HR. 3
MEAN FREQUENCY
FLOOD TIDE
STATION NUMBER

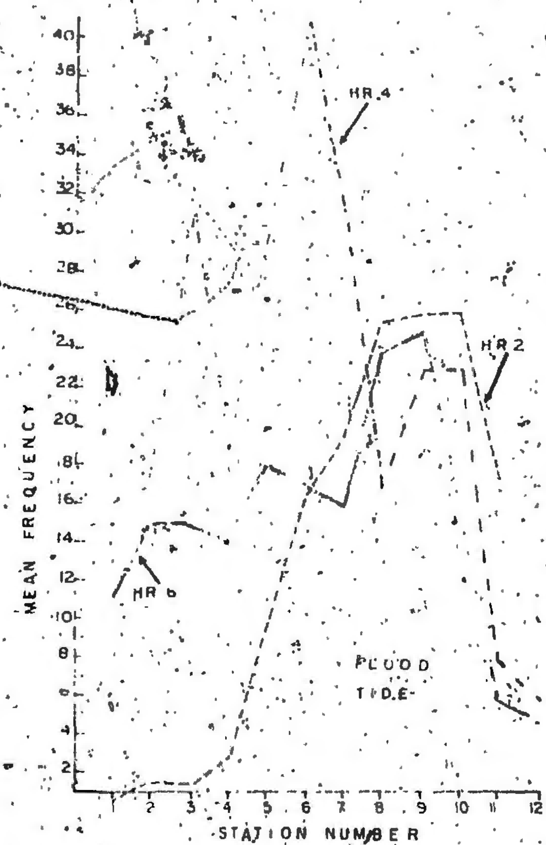
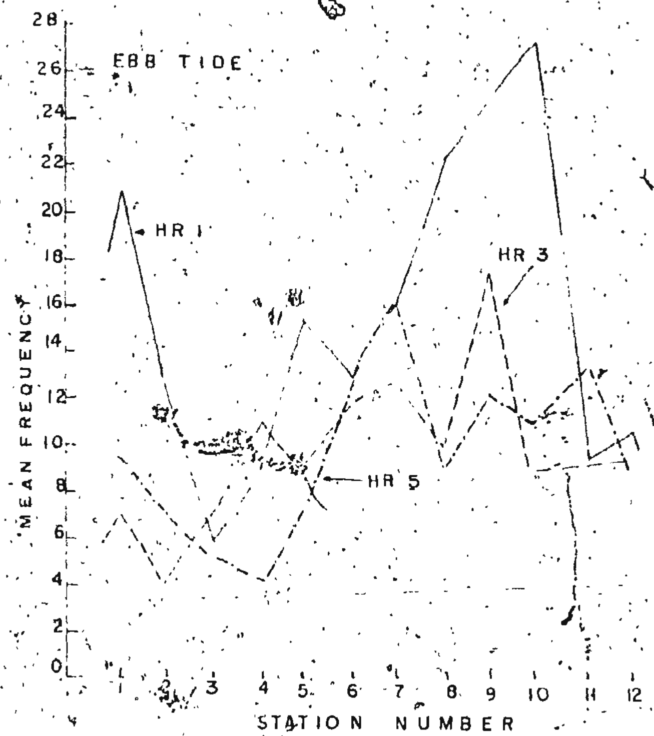
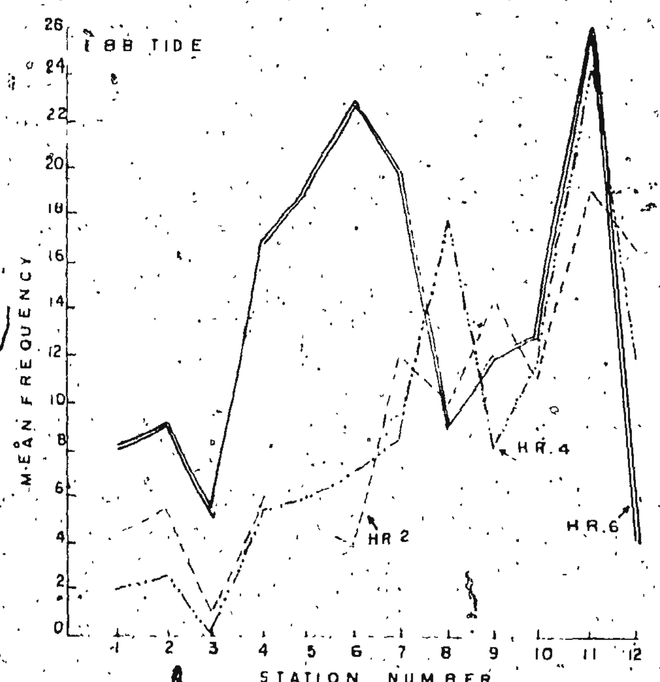

HR. 4
HR 2
HR 6
MEAN FREQUENCY
FLOOD TIDE
STATION NUMBER

Figure 14. Grand means of all frequencies of winter flounder per unit of transect T1, per hour of ebb tide, in Long Pond. Means are for all daily observations within a unit. Hr = Hour. Panel (A) with hours 1,3, and 5, separated from Panel (B) with hours 2,4, and 6.



EBB TIDE
MEAN FREQUENCY
STATION NUMBER
HR 1
HR 3
HR 5



EBB TIDE
MEAN FREQUENCY
STATION NUMBER
HR 2
HR 4
HR 6

Intertidal Feeding of Winter Flounder in Brandy Cove

Prey consumed by each of the three samples of winter flounder in Brandy Cove are listed in Tables 8-10. Feeding was assessed by measuring the wet weight of food consumed, frequency of occurrence of prey per stomach and per sample. Percentage composition of prey weight is given for each sample to allow comparison between samples on a more equal basis because of differing sample sizes. Samples of fish will be referred to as defined earlier: pre-migrants, migrants, and non-migrants. Pre-migrants were subtidal fish which responded to the tide and moved inshore between 0.5 and 2.5 hr flood. They were caught between low water and the advancing tide line. Migrants entered the intertidal zone and were caught while feeding on or in the process of leaving that zone. In contrast, non-migrants were those fish which did not respond to tidal flow and remained in the subtidal zone during high tide. Non-migrants were caught when directional movements ceased and they were separated from migrants.

Winter flounder caught in the intertidal zone were found to feed heavily with 95% of sample containing food. Eighty-one per cent of those containing food was filled to three-quarters or full capacity. Only 19% were 50% full or less. Volume of food in the stomach was estimated using fullness indices.

Intertidal migrants fed more than did subtidal non-migrants, although not significantly (Z=0.16), for a feeding

Table 8. Prey consumed by winter flounder in the Intertidal Zone

Species Name	Weight (g)	% Wet Weight	Frequency Occurrence	% Frequency	Frequency
Acrosiphonia arcta	36.0315	20.00	12	27.9	-
Peloscolex benedeni	24.0551	13.20	12	27.9	-
Gammarus oceanicus	23.6419	13.00	20	46.5	479
Enteromorpha intestinalis	23.2745	12.80	21	48.8	-
Cladophora sericea	13.4314	7.40	5	11.6	-
Nereis virens	8.5664	4.70	8	18.6	8
Gammarus lawrencianus	6.0294	3.30	9	20.9	426
Pilayella littoralis	5.9755	3.30	7	16.3	-
Amphithoe rubricata	5.7427	3.10	19	44.2	155
Ectocarpus siliculosus	5.0040	2.70	3	7.0	-
Mya arenaria	4.1507	2.30	12	27.9	51
Polydora sp. (& *P. elegans*)	3.8525	2.10	2	4.7	10
Littorina littorea	3.7651	1.80	3	7.0	38
Acmaea testudinalis	2.6122	1.40	2	4.7	11
Nephtys incisa	1.9889	1.10	8	18.6	17
Cricotopus sp.	1.6806	.92	34	79.1	809
Ulva lactuca	1.2352	.68	3	7.0	-
Clymenella torquata	1.0325	.57	5	14.7	33
Harmothoe imbricata	.9876	.54	3	7.0	6
Nemertea	.6395	.35	3	7.0	7
Glycera americana	.5587	.31	1	2.3	1
Edotea montosa	.4509	.25	5	11.6	31
Mytilus edulis	.4285	.24	11	25.6	56
Photidae	.4174	.23	8	18.6	3
Ammotrypane aulogaster	.3482	.19	3	7.0	8
Pholis gunnellus	.2477	.14	1	2.3	1
Jaera albifrons	.1943	.11	4	9.3	13
Leptocheirus pinguis	.1933	.11	4	9.3	11
Eteone longa	.1924	.11	7	16.3	85
Crangon septemspinosa	.1891	.10	1	2.3	1
Polydora sp. (*ciliata*)	.1641	.09	2	4.7	6
Chiridotea caeca	.1576	.09	1	2.3	2
amphipoda	.1160	.06	3	7.0	3
Cistenides gouldii	.0811	.04	1	2.3	1
Eulalia sp.	.0711	.04	1	2.3	1
Tharyx acuta	.0700	.04	1	2.3	26
Rhodymenia palmata	.0673	.04	2	7.0	-
Pygospio elegans	.0362	.02	11	25.6	15
Scoloplos armiger	.0264	.02	2	4.7	4
Nucula proxima	.0254	.01	1	2.3	1
Corophium volutator	.0221	.01	1	2.3	7
Phoxocephalus holbolli	.0165	.01	2	4.7	2
Hydrobia minuta	.0149	.01	3	7.0	6
Micrura sp.	.0116	.01	1	2.3	2
Nematoda	.0098	.01	3	7.0	4
Lunatia heros	.0095	.01	2	4.7	3
Fucus vesiculosus	.0092	.005	1	2.3	-
Polychaeta	.0076	.004	1	2.3	4
Macoma balthica	.0060	.003	1	2.3	2
Copepoda	.0059	.003	2	4.7	7
Neptunea decemcostata	.0055	.003	1	2.3	1
Dexamine spinosa	.0032	.002	1	2.3	1
Praxillella praetermissa	.0025	.001	1	2.3	1
Lumbrineris fragilis	.0004	.0002	1	2.3	1
Nainereis sp.	.0002	.0001	1	2.3	1
debris	4.9034	2.69	11	25.6	-

Table 9 Prey consumed by winter flounder in the subtidal zone. (Nonmigrant)

Species Name	Weight (g)	% Wet Weight	Frequency Occurrence	% Frequency	Frequency
Pilayella littoralis	37.3881	22.40	8	19.5	---
Leptocheirus pinguis	31.4412	18.80	22	53.7	1439
Enteromorpha intestinalis	23.9002	14.30	11	26.8	---
[illegible]	14.8930	8.90	2	4.9	---
Mya arenaria	10.4285	6.20	12	29.3	77
Lumbrineris fragilis	6.9980	4.20	6	14.6	8
Cladophora sp.	5.3298	3.20	4	9.8	---
Gammarus lawrencianus	3.8133	2.30	3	7.3	198
Nereis virens	2.6768	1.60	3	7.3	4
Harmothoe imbricata	1.7481	1.00	8	19.5	10
Ampithoe rubricata	1.1412	.68	3	7.3	18
Acrosiphonia arcta	1.1249	.67	1	2.4	---
[illegible]	1.1068	.66	6	14.6	49
Gammarus oceanicus	.8507	.51	7	16.8	31
Cerastoderma pinnulatum	.7232	.43	9	22.0	15
Cistenides gouldii	.7083	.42	9	22.0	13
Cricotopus sp. (*variabilis*?)	.6545	.39	5	12.2	40
[illegible]	.5201	.31	8	19.5	19
[illegible]	.4196	.25	1	2.4	2
Nucula proxima	.3119	.19	2	4.9	2
Balanus balanoides	.2451	.15	1	2.4	2
[illegible]	.2418	.14	2	4.9	3
Yoldia sp. (*sapotilla*)	.1537	.09	2	4.9	2
Nephtys incisa	.1400	.08	1	2.4	1
Caeco bigelowi	.1337	.08	2	4.9	4
Nereidae	.0928	.06	1	2.4	1
Nucula tenuis	.0809	.05	2	4.9	1
Ninoe nigripes	.0649	.04	1	2.4	1
Solemya borealis	.0643	.04	1	2.4	1
Cucumaria frondosa	.0640	.04	1	2.4	1
Aphroditoidea	.0597	.04	2	4.9	1
Nematoda	.0543	.03	3	7.3	29
Cirratulus cirratus	.0537	.03	1	2.4	1
Gemma gemma	.0535	.03	1	2.4	4
Macoma balthica	.0472	.03	1	2.4	1
Terebellides stroemi	.0423	.03	2	4.9	2
Littorina saxatilis	.0373	.02	1	2.4	5
Littorina littorea	.0336	.02	1	2.4	2
Thais lapillus	.0278	.02	1	2.4	1
Mytilus edulis	.0233	.01	5	4.9	9
Nemertea	.0232	.01	2	12.2	2
Syllis gracilis	.0225	.01	3	7.3	3
Phascolocephalus holbolli	.0212	.01	1	2.4	2
Unciola irrorata	.0212	.01	1	2.4	2
Maldanidae	.0151	.01	1	2.4	1
Strongylocentrotus droebachiensis	.0139	.01	1	2.4	1
Hydrobia minuta	.0087	.01	2	4.9	4
Polynoidae	.0067	.004	1	2.4	1
Scoloplos armiger	.0058	.003	1	2.4	1
Eudorella truncata	.0044	.003	1	2.4	1
Polydora sp.	.0029	.002	1	2.4	1
Spirorbis borealis	.0027	.002	1	2.4	2
Praxillella gracilis	.0011	.001	1	2.4	1
Unidentified Polychaeta	1.8207	1.09	9	22.0	
Debris	17.1711	10.28	11	26.8	

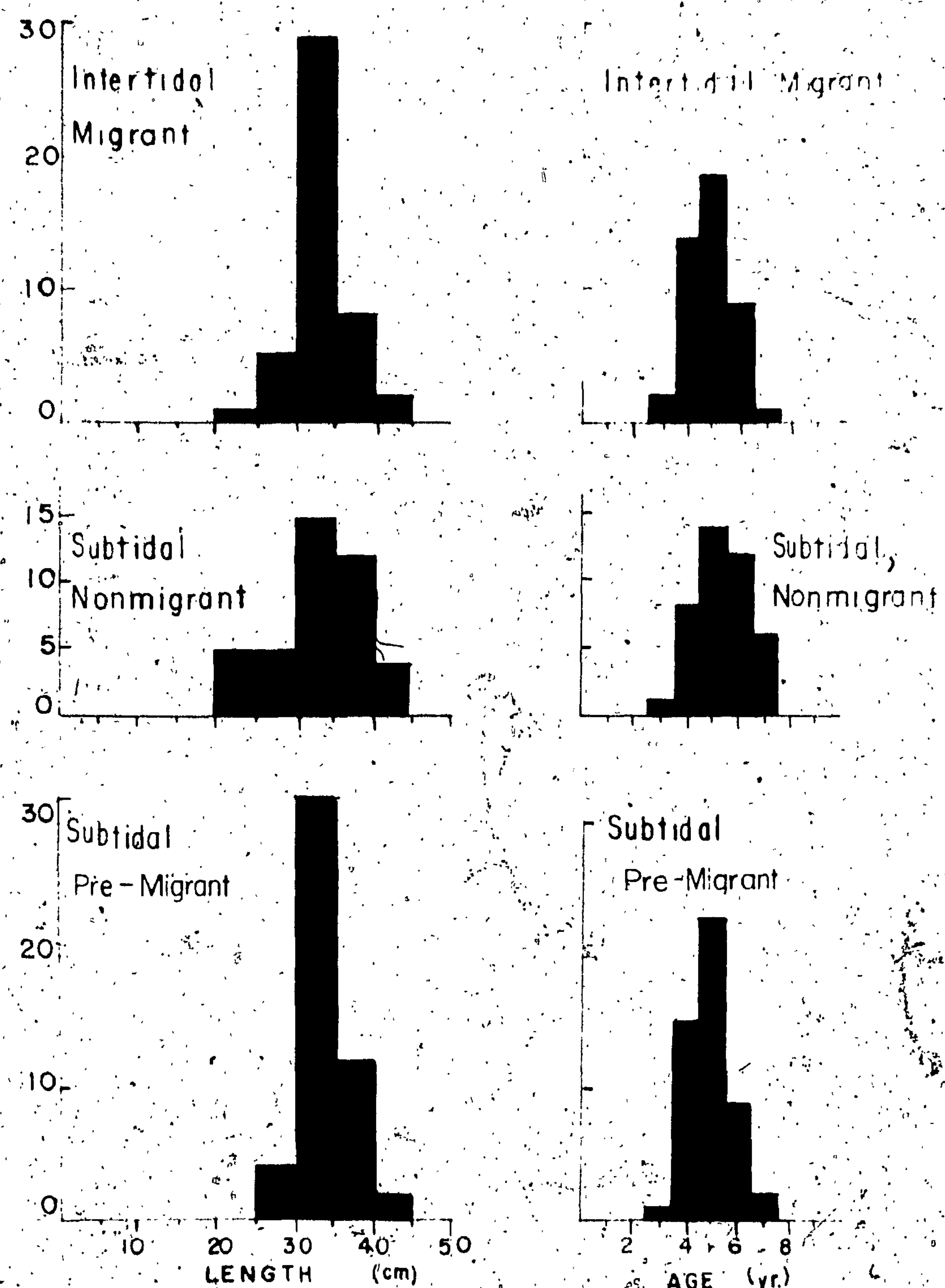
Table 10 Prey consumed by winter flounder in the subtidal zone (Migrant).

Species Name	Weight (g)	% Wet Weight	Frequency Occurrence	Frequency	Frequency
Acrosiphonia arcta	30.3093	34.4	19	38.7	-
Mya arenaria	17.9277	20.3	27	55.1	109
Nereis virens	15.3397	17.4	3	6.1	4
Enteromorpha intestinalis	7.7574	8.8	11	22.4	-
Acmaea testudinalis	2.9879	3.4	1	2.0	41
Cladophora sericea	2.3735	2.7	2	4.1	-
Leptocheirus pinguis	2.1327	2.4	18	36.7	59
Balanus crenatus	1.2000	1.4	1	2.0	-
Gammarus sp.	.6049	.69	6	12.2	33
Nephtys incisa	.5830	.66	3	6.1	7
Melita dentata	.4363	.50	2	4.1	14
Solemya borealis	.4203	.48	3	6.1	4
Cistenides gouldii	.3822	.43	2	4.1	4
Lumbrineris fragilis	.2650	.30	4	8.2	11
Schizothrix sp.	.3503	.40	1	2.0	-
Musculus discors laevigatus	.3470	.39	1	2.0	1
Ectocarpus siliculosus	.2966	.34	1	2.0	-
Yoldia sapotilla	.2676	.30	2	4.1	2
Nucula proxima	.2268	.26	2	4.1	3
Lunatia heros	.2650	.30	1	2.0	2
Ammotrypane aulogaster	.2644	.30	5	10.2	5
Gammarus oceanicus	.2191	.25	3	6.1	6
Casco bigelowi	.2009	.23	5	10.2	6
Crangon septemspinosus	.1729	.20	1	2.0	1
Cerastoderma pinnatulum	.1431	.16	3	6.1	3
Pelonscolex benedeni	.1417	.16	2	4.1	-
Rhodymenia palmata	.0934	.11	1	2.0	-
Amphithoë rubricata	.0928	.11	2	4.1	2
Crenella glandula	.0924	.10	2	4.1	2
Mulinia lateralis	.0894	.10	2	4.1	2
Hermonthoe imbricata	.0864	.10	2	4.1	2
Corophium volutator	.0672	.08	2	4.1	5
Gammarus lawrencianus	.0663	.08	1	2.0	13
Polynoidae	.0496	.06	1	2.0	1
(*Abra aequalis*?)	.0479	.06	1	2.0	3
Clymenella torquata	.0449	.05	2	4.1	2
Cricotopus sp. (*variabilis*?)	.0416	.05	2	4.1	16
Maldanidae	.0403	.05	2	4.1	1
Edotea montosa	.0320	.04	1	2.0	1
Mytilus edulis	.0219	.02	2	4.1	6
Scoloplos armiger	.0171	.02	1	2.0	1
Phoxocephalus holbolli	.0044	.002	2	2.0	2
Eteone longa	.0018	.005	1	4.1	2
Coniaga maculata	.0016	.002	1	2.0	1
Strongylocentrotus droebachiensis	.0010	.001	1	2.0	1
Hydrobia minuta	.0010	.001	1	2.0	1
Pleustidae	.0001	.0001	1	2.0	1

period of equal or similar duration. Fifty-six per cent had completely full stomachs compared to 46% of subtidal non-migrants. As well, numbers of non-migrant fish filled to 50% capacity or less were 2.2-2.5x higher than in the migrant sample. Differences between pairs of samples were tested using the T-Test for N>30 or the Z Test under the normal curve. Fifty-four benthic species comprising 2487 prey items were identified from stomachs of intertidal fish. This does not include total numbers of Oligochaeta or algae recorded by frequency of occurrence only. This was required by the high percentage of fragmentation that rendered whole body counts impracticable since the worms were too small, fragile, and densely tangled. No significant difference was found in the number of prey consumed by migrant and non-migrant fish which fed subtidally during high tide (Z=0.35). Migrants ate an average of 56.5 prey/fish and non-migrants, 54.4 prey/fish. However, both groups ate significantly more prey than did pre-migrant fish, which had an average of 8.4 prey/fish. This value was nearly seven times lower than either of the other means. The difference between pre-migrants and each of the other groups was significant beyond the 0.001% level (migrants vs. pre-migrants, Z=13.6, df=91; pre-migrants vs. non-migrants, Z=10.2, df=86).

Migrants consumed 188.26 g. of food which averaged 4.2 g/fish. This compared closely to the non-migrant average of 4.3 g. Again, both groups ate significantly more food than pre-migrant fish. Comparison of means of wet weight consumption yielded values which were significant at or beyond the

Figure 15. Age-length composition of winter flounder from three samples of Brandy Cove, New Brunswick.



30
20
10
0
Intertidal
Migrant
Intertidal Migrant
15
10
5
0
Subtidal
Nonmigrant
Subtidal,
Nonmigrant
30
20
10
0
Subtidal
Pre-Migrant
Subtidal
Pre-Migrant
10
20
30
40
50
LENGTH (cm)
2
4
6
8
AGE (yr.)

0.001% level (Fisher and Yates, 1943). Migrant fish compared significantly to pre-migrants with Z=3.75. This could be predicted due to the difference in feeding times and catch periods of the two samples. It was estimated that fish caught from the intertidal zone during ebb tide had been allowed sufficient time to eat if this was their major activity while inshore. The quantity, freshness, and order of prey in their stomachs showed that they had been feeding prior to capture. Pre-migrant stomachs were nearly empty when these fish entered the intertidal zone. This was shown by the smaller food intake of the pre-migrant sample upon entering the intertidal zone; in quantity (88 g.), number of prey (412) and species (47) compared to the non-migrant and migrant samples.

Thus, following separation, non-migrant and migrant feeders showed little or no difference in food consumption by eating similar amounts and number of prey. This was not surprising since individuals were taken from the same population and were closely matched in age-length composition (Figure 15). Their composition was similar to that reported earlier (Tyler, 1971) for the same stock and for Passamaquoddy Bay (Kohler et al., 1970).

Nine species made up 80% or more of the total weight in each of the migrant and non-migrant samples. In contrast, only four species eaten by pre-migrants made up this level as compared in Figure 16. This shows positions of the ten most important prey for the three samples based on per cent wet weight composition.

Figure 16. Per cent wet weight consumption of the ten most important prey species by winter flounder in Brandy Cove, N.B. Diet items of the three samples are as follows:

Intertidal Migrants

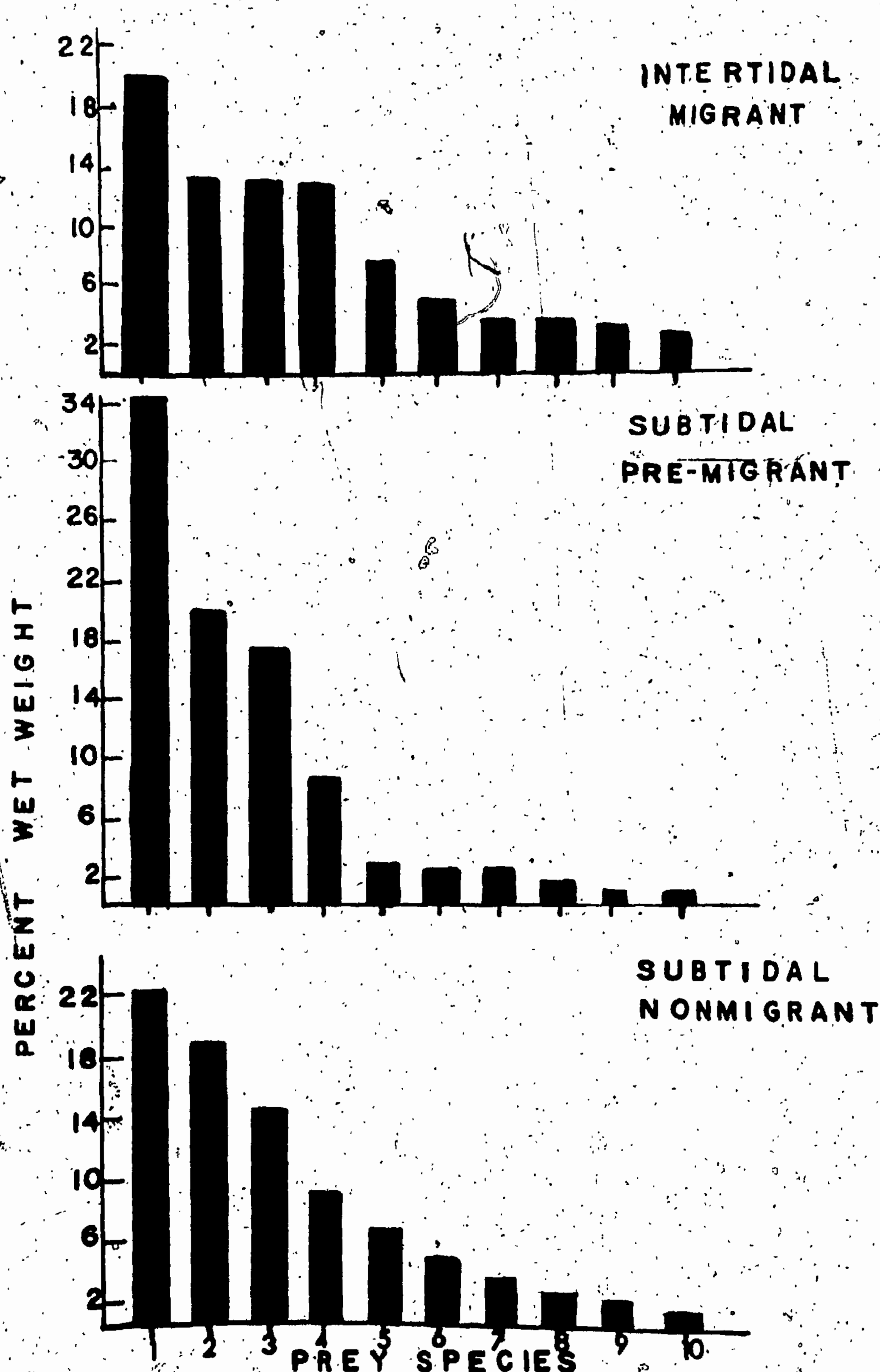
1. _Acrosiphonia arcta_
2. _Peloscolex benedeni_
3. _Gammarus oceanicus_
4. _Enteromorpha intestinalis_
5. _Cladophora sericea_
6. _Nereis virens_
7. _Gammarus lawrencianus_
8. _Pilayella littoralis_
9. _Amphithoe rubricata_
10. _Ectocarpus siliculosus_

Subtidal Pre-Migrants

1. _Acrosiphonia arcta_
2. _Mya arenaria_
3. _Nereis virens_
4. _Enteromorpha intestinalis_
5. _Acmaea testudinalis_
6. _Cladophora sericea_
7. _Leptocheirus pinguis_
8. _Balanus crenatus_
9. _Gammarus sp._
10. _Nephtys incisa_

Subtidal Non-Migrant

1. _Pilayella littoralis_
2. _Leptocheirus pinguis_
3. _Enteromorpha intestinalis_
4. _Peloscolex benedeni_
5. _Mya arenaria_
6. _Lumbrineris fragilis_
7. _Cladophora sericea_
8. _Gammarus lawrencianus_
9. _Nereis virens_
10. _Harmothoe imbricata_



INTERTIDAL MIGRANT
SUBTIDAL PRE-MIGRANT
SUBTIDAL NONMIGRANT
PERCENT WET WEIGHT
PREY SPECIES
22
18
14
10
6
2
34
30
26
1
2
3
4
5
6
7
8
9
10

While migrant and non-migrant fish showed similar feeding behaviour, the pre-migrants differed from non-migrants in having concentrated feeding effort on three or four species only. Some degree of selection was shown by the pre-migrants when the amount of food was considered in terms of such few prey tupes. This was not uncommon as selectivity has been found in plaice, lemon sole, cod, haddock and other demersal fishes. Ivlev (1961), Shoryigin (1931), and Larsen (1936) have shown that fish are discriminant feeders. They prey heavily on a few major species while adding minor supplements to the diet from other sources. Migrant fish also showed some degree of preference for certain food types.

The six most important intertidal prey which comprised 70% of the total weight of food were divided nearly equally among the algae, Annelida, and Amphipoda. Heaviest predation was on the small filamentous alga, Acrosiphonia arcta and the larger Enteromorpha intestinalis . The former was eaten by 28% of the migrants and the latter by 49%. Acrosiphonia was found in the high intertidal at station 1 on benthos transect T1 of Brandy Cove. Enteromorpha was found at stations 5, 9, 11, and 13 of the transect. These two algae together with Cladophora comprised 40% of combined stomach weights (Wells et al., 1973). Five of the top ten intertidal prey were algae.

Gammarus oceanicus was more important than G. lawrencianus or Amphithoe rubricata. This relationship was to be expected since Amphithoe rubricata occurred in lower abundance than either of the other two species. It showed that migrants moved into the highest parts of the intertidal zone. _G. oceanicus_ was distributed along the transect at stations 1, 3, 5, and 7, in the following frequencies: 78, 19, 108, and 34, respectively.

Damage caused by flounder predation on clam beds (_Mya arenaria_) in the St. Andrews area and similar localities (Medcof and MacPhail, 1952; Birkett and Wood, 1959; Edwards and Steele, 1968) was supported by these data. Clams and their siphons were found in 28% of the migrant fish and 55% and 29% of the pre-migrant and non-migrant samples respectively.

Annelida and Crustacea comprised 31% and 22%, respectively, of the intertidal species consumed. _Nereis virens_ was most heavily preyed upon by all three groups of fish, appearing sixth on the migrant list (Tables 8 to 10). Seventeen per cent of pre-migrant fish consumed 15.34 g. of _Nereis_ in the subtidal zone (Figure 16). This appeared to be a heavy level of predation on one polychaete and replaced that on a smaller, more divided scale between _Peloscolex benedeni_ and _Nereis_ found in the other two groups.

Peloscolex was the most important annelid to migrant and subtidal non-migrants. Ranking second in the former, and fourth in the latter groups, it was consumed more intertidally than in the subtidal zone at high tide (Table 10).

Joint interaction of predator-prey distribution and concentration affected prey selection among some benthos.

Clymenella torquata was consumed intertidally at rather low levels compared to Nereis, Nephtys incisa or Peloscolex despite its abundance in certain dense beds at the south end of the cove (Rowe, MS 1970). Clymenella distribution in the cove was one of high incidence in clumped beds. Peloscolex occurred abundantly but more uniformly than Clymenella and covered a larger area. Nereis and Nephtys were found in beds that were less dense than either of the first two and were as ubiquitous as the oligochaete (see Snow, MS 1971). Because of its small size, the numbers of Clymenella per unit area were very high compared to Nereis or Nephtys. Despite the advantage that small body size gave Clymenella in producing higher abundance per unit area, consumption of Clymenella was far less than expected when compared to its predation levels in deeper water of Passamaquoddy Bay (Tyler, 1968).

Subtidal Non-migrant Feeding

Five prey species comprised 70% of the food weights among subtidal non-migrant feeders. Pilayella littoralis replaced Acrosiphonia as the most heavily consumed alga, and with Entermorpha and Cladophora made up 40% of the total weight. Leptocheirus replaced G. oceanicus as the most important crustacean making up 18.8% of the prey consumed, but only 0.11% of the intertidal.

Species which appeared on both the non-migrant and migrant prey lists but ranked higher as subtidal prey were the following: Edotea montosa, Macoma balthica, Ammotrypane aulogaster, Nucula tenuis, Harmothöe imbricata, Mya arenaria, Cistenides gouldii, Lumbrineris fragilis, and Leptocheirus pinguis.

With the exception of Mya arenaria, these are known to occur wholly or predominantly in the subtidal zone. Mya was more important to subtidal non-migrants and made up 6.2% of their prey weights as compared to 2.3% intertidally. It occurred in benthos samples of both zones.

Lumbrineris fragilis constituted 4.2% of non-migrant prey weights but only 0.0002% of those intertidally. It occurred only subtidally at T1 stations 35, 37, 39, and 41.

Species which appeared only on the subtidal non-migrant list and were known for that zone only, were: Cerastoderma, Didemnum, Lepidochitin, Yoldia, Casco, Nucula, Solemya, Cirratulus, Strongylocentrotus, Gemma, Terebelloides, Ninoe, and Cucumaria (Table 9).

G. lawrencianus was more important than G. oceanicus to non-migrants. This was the reverse relationship held by these two species in the migrant sample. Cricotopus sp. chironomid similar to the Icelandic C. variabilis, was much less important subtidally than intertidally. In the former case, it was eaten by only 12% of the subtidal non-migrants, but in the latter, by 79% of the sample (Wells, et al., 1973).

Cistenides gouldii was more important in non-migrant predation and was known mostly for the subtidal zone.

Subtidal Pre-migrant Feeding

These fish contained subtidal prey similar to the non-migrant flounder. Acrosiphonia was as important to pre-migrants as to the migrant feeders. Mya and Nereis virens were most important to these fish than to either of the other samples. Comparable to non-migrants, pre-migrants consumed prey such as Leptocheirus pinguis, Balanus crenatus, and Nephtys incisa. Enteromorpha held a similar rank as in other samples. L. pinguis occurred subtidally at benthos stations 23 and 29-41, only. Eight of the twelve benthos samples which contained Nephtys incisa were not only subtidal but had the higher frequencies of occurrence for the two zones.

Winter Flounder Feeding in Newfoundland

Seasonal Trends in Long Pond and Conception Bay

The proportion of active feeders from Conception Bay was higher for fewer months of the feeding cycle than that from Long Pond (Fig. 17). The percentage of stomachs containing food was larger among Bay flounders, during April, May and September only. Despite this difference, flounders from the Bay consume more than the Pond flounders during all months except September (Table 10).

In April, May, August, and October, winter flounder from Conception Bay ate 3.5, 5.6, 6.7, and 8.1 times more food than did Long Pond flounder. Differences between mean monthly consumption of the two grounds appear in Figure 17A. Changes in the mean ratio of food for both total and feeding subsamples are compared. The small consumption level among Long Pond flounders was considered unity. Hence, the ratio

Month	Sample Size CBD	Sample Size LPS	% Full Stomachs CBD	% Full Stomachs LPS	Total Wet Weight Food (g) CBD	Total Wet Weight Food (g) LPS	Average Weight Food CBD	Average Weight Food LPS	Average Consumption Ratio	Total Adjusted Consumption (g) CBD	Total Adjusted Consumption (g) LPS	Mean Adjusted Consumption (g) CBD	Mean Adjusted Consumption (g) LPS*	Mean Adjusted Consumption Ratio CBD/LPS
April	15	34	87	79	62.38	40.99	4.19	1.21	3.5	129.60	40.99	4.80	1.52	3.2
May	29	13	86	69	141.12	11.27	4.87	.87	5.6	141.12	70.00	5.64	2.80	2.0
June	13	11	46	45	3.86	2.20	.30	.20	1.5	3.86	2.64	.65	.44	1.5
July	8	15	75	87	8.70	6.00	1.09	.40	2.7	14.17	6.00	1.09	.46	2.4
August	14	36	64	64	28.13	10.64	2.01	.30	6.7	71.99	10.64	3.13	.46	6.8
September	11	22	91	68	15.79	17.13	1.44	.78	1.8	23.70	17.25	1.58	1.15	1.4
October	16	21	56	55	23.25	3.88	1.45	.18	8.1	30.96	3.88	2.58	.32	8.1

Table 11. Sample size, total and mean wet weight consumption, and monthly ratios of feeding rate of winter flounder in Long Pond and Conception Bay. Values adjusted for equal size of feeding subsample only, marked by asterisk.

R-CBD/LPS. Adjustment for equal sample size was necessitated by wide differences in the monthly sample sizes of fish from the two grounds. Bay samples were often small. Sampling on this deeper ground was always hampered by poor weather and widely scattered fish.

As the feeding season progressed, the difference between wet weight consumption on the two grounds increased until, at the end of August, Bay fish had doubled the initial difference found in late winter. This increase occurred near the time of peak energy composition known for the flatfish body (MacKinnon, 1973).

During any one season, ratios followed each other closely. Only in May (Fig. 17A) was the difference in wet weight consumption greater due to the lack of proportional increase in mean food intake among Conception Bay fish as occurred in Long Pond. In May, mean intake of the feeding subsample increased threefold over that of the total sample in the pond. However, a similar increase was not observed in Conception Bay.

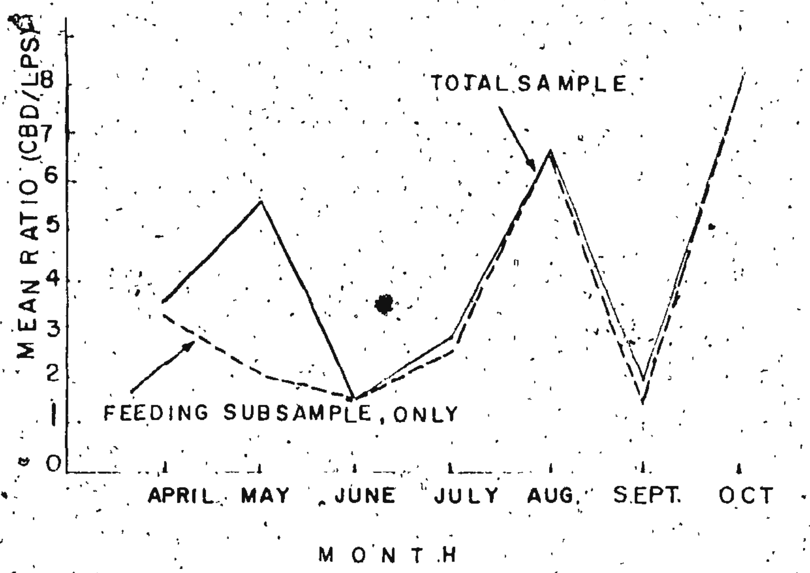
Feeding on both grounds was variable from month to month. Food intake was high in the spring, declined in early summer, increased in mid to late summer, and fell again in September. Levels were high in the autumn. Low values on both grounds were partly attributed to a late spawning period and small sized fish in June and early July (1972). Until this time, only two mature gonads had been found among the June fish and none were observed to be mature in fish sampled in April or May. While making fish counts in May, flounder with mature gonads were not seen. Spawning was delayed by at least one

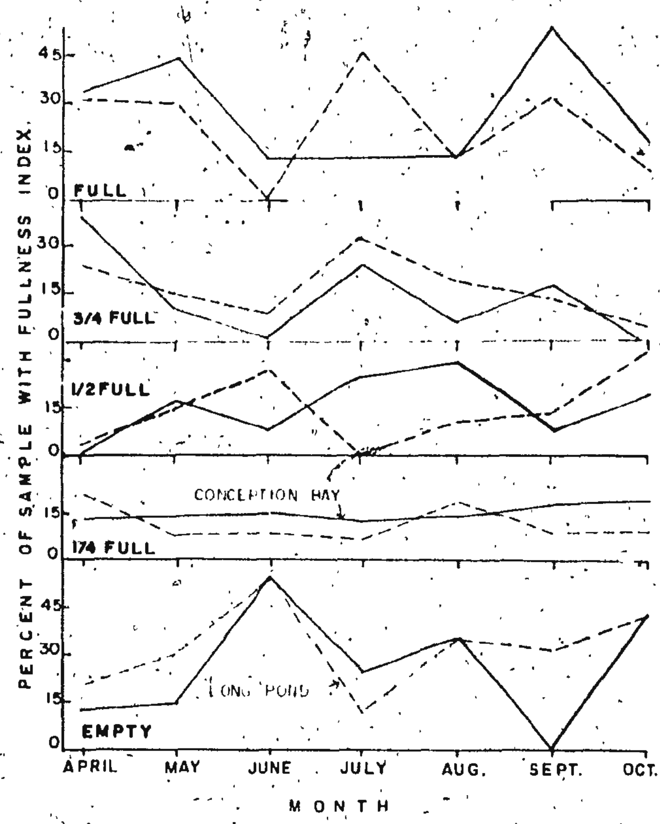
Figure 17 (A) Comparison of mean monthly consumption of winter flounder in Long Pond and Conception Bay, Nfld.

________ = Raw ratio of total feeding sample

-------- = Adjusted ratios of feeding subsample only.

Figure 17 (B) Fullness indices of feeding intensity of winter flounder from the two feeding grounds, Long Pond and Conception Bay.


TOTAL SAMPLE
FEEDING SUBSAMPLE, ONLY
MEAN RATIO (CBD/LPS)
APRIL MAY JUNE JULY AUG. SEPT. OCT
MONTH


PERCENT OF SAMPLE WITH FULLNESS INDEX
FULL
3/4 FULL
1/2 FULL
CONCEPTION BAY
1/4 FULL
LONG POND
EMPTY
APRIL MAY JUNE JULY AUG. SEPT. OCT.
MONTH

month due to the effects of lower than normal temperature on gonad development. Normally, flounder with ripe gonads do not feed or do so minimally as a result of suppression of the stomach walls by the enlarging gonads. Decreased feeding during winter generally, and during the pre-spawning period, specifically, causes the winter flounder to convert stored energy from the liver to the body for maintanence, until after spawning (Dunn, MS 1968). After spawning, feeding increased in Long Pond flounder rapidly. The value for July reflected that rise. After July it rose quickly in August when gonads were spent.

In April and May, Bay flounder consumed 3.5 and 5.6 times, respectively, the amount of food consumed in the Pond. In June and July, both groups showed low levels of food intake, due to delayed spawning, and the small body size of fish. Body size would have directly affected, and been proportional to, the quantity of food consumed. Flounder caught in July, for example, ranged in length from 15-30 cm. Missing from this sample were the larger 30-45 cm, 30-40 cm, and 30-35 cm length classes sampled in the pond in April, May, and June, respectively (Fig. 23). Similarly, the July sample from Conception Bay lacked the larger 40-45 cm and 55-60 cm flounder found in May and 30-35 cm fish taken there in April, May and June.

Feeding Intensity and Behaviour on the Two Grounds

More stomachs were filled to capacity over a longer period of the feeding cycle in Conception Bay (Fig. 17B). This also applied to the 50% and 25% levels. In contrast, fish from the Pond usually fed to only 75% fullness or not at all for more of the monthly samples than did winter flounder in Conception Bay.

This produced a larger total consumption in both adjusted and unadjusted Bay samples compared to Long Pond samples. Variations in feeding behaviour of winter flounder from the two grounds are compared in Fig. 17B and Appendix 8. The percentage of fish within a sample corresponding to each fullness index is given (Fig. 17B). Although differences in total food intake (Table 11) on the two grounds were due partly to differences in fish size (Fig. 23), variation in the behaviour of individuals during feeding was also important. Differences in behaviour were consistent for more than half of the study period. In April, May, July and September, the relative proportion of empty stomachs was two to thirty-two times higher among Pond fish than among Bay fish (Table 12). This occurred during 3 of the 4 months when temperatures were within a range which did not reduce or inhibit normal feeding and swimming activity (Table 12; McCracken, 1954). Reduced feeding levels during a temperature range of normal swimming activity pointed to other factors which controlled feeding more than temperature. Two of these were considered to be low food supply and possible effects of overcrowding.

Christie (1966) found an impoverished fauna of only six species on the mud bottom of the central station of the eastern basin. He estimated that this fauna contributed little to the food supply of animals higher in the food chain. Biomass estimates for the widely distributed infaunal communities, Macoma-Mya and Polycirrus-Mya, were not large compared to those in slightly more temperate regions. As well, energy

Long Pond Shallows

Date	Tide Span	Collection Time	Tidal Hour of Collection	Phase of Tide	No. Fish	Catch Hour on Tide (/0.01 hr)	Temp. (°C)	Full	75%	50%	25%	0%	Sediment	Depth Range (m)
								% of sample with % Full stomachs						
28.4.72	0853-1448	1330-1430	4 37- 5 37	Ebb	34	4.62-5.62	10.0	31	24	3	21	21	mud	0.6-2.1
28.5.72	0858-1443	1212-1255	3 17- 3 57	Ebb	13	3.28-3.95	10.0	31	15	15	8	31	mud	0.6-2.1
30.6.72	1103-1703	1520-1645	4 17- 5 42	Ebb	11	4.28-5.70	21.0	0	9	27	9	55	mud	0.6-2.4
25.7.72	0833-1448	1400-1500	5 27- 0 42	Ebb	16	5.60-0.72	15.5	47	33	0	7	13	mud	0.6-2.1
30.8.71	1443-2228	1615-1800	1 33- 3 17	Ebb	40	1.55-3.28	16.5	14	19	11	19	36	mud	0.6-2.7
23.9.71	1033-1653	1100-1200	0 27- 1 57	Ebb	27	0.45-1.95	12.3	32	14	14	9	32	mud	0.6-2.7
25.9.71	1138-1758	1500-1630	3 22- 4 52	Ebb		3.36-4.87	12.3						mud	
27.10.72	1348-2118	1600-1700	2 12- 3 12	Ebb	22	2.20-3.20	7.5	10	5	33	10	43	mud	0.6-2.4
13.10.72	0858-1518	1100-1130	2 02- 2 32	Fld.		2.03-2.53	7.5						mud	

Conception Bay

Date	Collection Time	Phase of Tide	No. Fish	Temp. (°C)	Full	75%	50%	25%	0%	Sediment	Depth Range (m)
					% of Sample with % Full Stomachs						
30.4.72	- -		15	2.0	33	40	0	13	13	sand,	2.4-7.5
28.5.72	1105-1155		31	4.0	44	10	17	14	14	shale	3.6-10.1
30.6.72	1635-1730		13	11.0	13	0	8	15	54	coral-	5.8-8.1
25.7.72	1200-1253		8	12.0	13	25	25	13	25	lime	7.5-9.0
31.8.71	1530-1630		16	16.8	14	7	29	14	36	algae	6.6-7.5
29.9.71	1005-1215		14	11.0	55	18	9	18		"	6.0-18.0
29.1072	1000-1030		16	6.0	19	0	19	19	43	"	6.0-8.0

Table 12. Monthly collections of winter flounder on two feeding grounds in Newfoundland waters. Collections arranged to show beginning of natural feeding cycle : spring to winter. Bottom types listed in order of dominance as observed underwater. Tidal data calculated from Tide and Current Tables (Canadian Hydrographic Service) for Long Pond. Fullness indices after the method of Ball (1961).

in the form of the less widely distributed but more diverse epifauna was not harvestable due to the oversized molluscs. Due to the similarity between the eastern and western basins, it is felt that the western basin offered comparably little fauna and/or biomass as a constant food supply. A similar conclusion was reached by Kennedy (1964) who showed that offshore movement was not coordinated closely with an "auto-selected temperature range" of 12-15 C proposed by McCracken (1963). Instead, movement was shown to be more closely related to the breeding and feeding cycle because fish left the pond after spawning; when feeding intensity began to rise.

The Diet Organisms

Numbers of species, diet items, wet weight consumption, and percentage composition of the six most important diet items followed similar trends on the two feeding grounds (Appendix 9).

Minimum and maximum food intakes in Long Pond preceded those in the Bay by one month. While the number of species, individuals, and total wet weight consumption were minimum in the pond in June, the percentage composition of the six most heavily consumed diet items was highest in that month. Wet weight consumption reached a minimum in June in Conception Bay, but also declined to its second lowest point in July. While variety of prey and numbers of individuals were minimum in July in the Bay, percentage composition of the six most heavily consumed items was at its maximum.

Mean monthly consumption was significantly larger in Conception Bay than in Long Pond (Z=6.88), as were the number of species (Z=5.60) and prey items (Z=5.28). This difference may be due partly to the larger size of fish in Bay samples (Fig. 23; Appendix 10) since weight of food consumed is proportional to stomach and body size, and flounders taken from the Bay were generally larger.

Monthly variation in numbers of species consumed in the pond seemed to be related more to smaller sizes of the fish in the summer samples than to changes in faunal composition. The smaller stomach volume and mouth sizes of the immature flounder, left after offshore migration of the adults, appeared to affect the kind, size, and amounts of food taken in the pond. Sizes and amounts of food were minimal. Monthly differences in diet variety among Bay flounder may have been related, in a similar way, to changes in fish (stomach) size.

The number of prey items was lower among flounders from the pond than among those from the Bay for four of the seven months. It was higher only during August and September. In July, flounder from the pond ate 51 prey items while those from the Bay ate 50 prey items, amounts not being significantly different. The six most heavily consumed diet items made up 63-96% and 86-97% of total food intake for Long Pond and Conception Bay flounders, respectively.

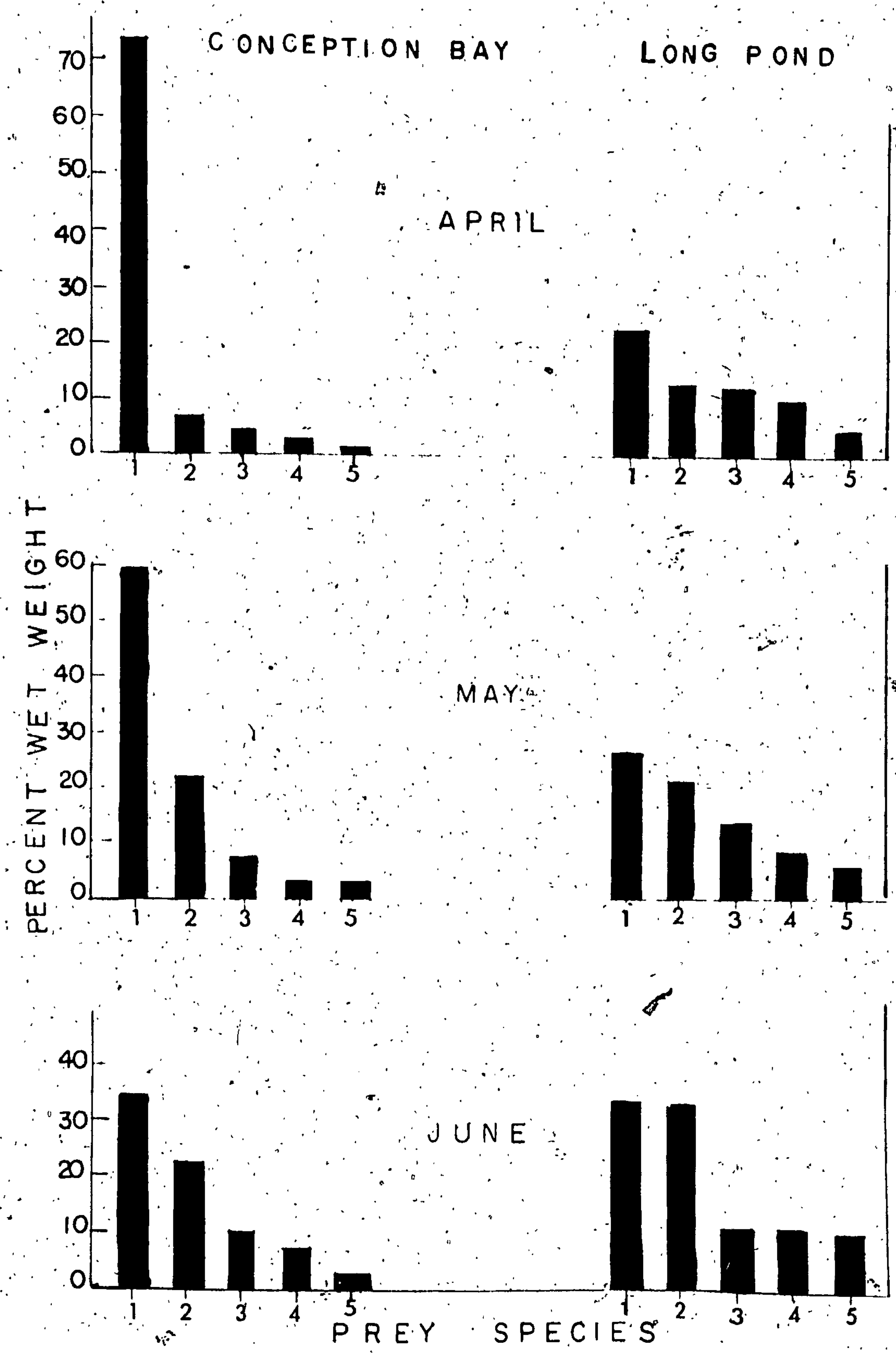
Early spring and mid-summer feeding on the shallows was characterized by a wider variety of prey organisms than that from the bay. In late spring and autumn, reverse conditions occurred.

Limpets, chitons, sea urchins, algae, and polychaetes were the most important prey taken from the deeper water feeding ground (Fig. 18). These species were either the most heavily consumed by wet weight or appeared most frequently among the first ten species. Acmaea testudinalis and Ischnochiton ruber appeared every month among Conception Bay fish and were the only two molluscan representatives among the top ten prey. Microcrustaceans were of little importance among Bay flounder and were not consumed on the shallows, except for one amphipod species in October. Echinoderms were less important than algae or polychaetes, but appeared consistently. These were eaten more frequently on the deeper feeding ground than on the shallows, reflecting the difference in substrate hardness and benthos.

Algae and polychaetes were more frequently consumed in Conception Bay. The former made up 30-50% of the first ten prey for five of the seven monthly samples. The frequent occurrence of algae was not unusual due to heavy growths of red, green, and brown species on rock outcroppings lining a shipping channel to the pond and on patches of cobble rock along the sea floor. Wet weight consumption on the deeper feeding ground ranged from 0-79%. Consumption of 46.5 g of Monostroma sp. by three fish in April accounted for 74% of the larger monthly intake of 79% in the bay. Of this, one fish contained 45 g. Algal intake on the shallows was less important, ranging from 2.7-46.9% per month. Monthly wet weights fluctuated widely on each ground but changes generally followed a similar pattern for both.

Figure 18. Per cent wet weight consumption of the five most important prey by winter flounder on the two Newfoundland feeding grounds. Diet items of the two sets of samples are:

Conception Bay	Month	Long Pond
1. Monostroma sp. 2. Nereis virens 3. Acrosiphonia arcta 4. Acmaea testudinalis 5. Ischnochitin ruber	April	1. Debris 2. Nereis virens 3. Nereis pelagica 4. Enteromorpha sp. 5. Desmarestia viridis
1. Strongylocentrotus droebachiensis 2. Nereis pelagica 3. Acmaea testudinalis 4. Ischnochitin ruber 5. Desmarestia viridis	May	1. Debris 2. Nereis virens 3. Lumbrineris fragilis 4. P. americanus (eggs) 5. Amphitrite sp.
1. Nereis virens 2. Desmarestia viridis 3. Ischnochitin ruber 4. Pilayella littoralis 5. Cistenides gouldii	June	1. Debris 2. Dictyosiphon foeniculaceus 3. Ectocarpus siliculosus 4. Nereis virens 5. Nereis sp.



CONCEPTION BAY
LONG POND
APRIL
MAY
JUNE
PERCENT WET WEIGHT
PREY SPECIES
0
10
20
30
40
50
60
70
1
2
3
4
5

Consumption of limpets, chitons, and the alga Schizothrix sp. was of interest. The latter genus is a primitive, colonial alga, composed of gelatinous sheaths of biflagellated cells and similar to Dinobryon in appearance. Its consumption required rasping of rock surfaces by the fish for the alga grows on such substrate surfaces.

Polychaeta were second in importance as a group for Bay fish, compared to molluscs, crustaceans, echinoderms, and algae. In September, 50% of the ten most heavily consumed prey were polychaetes.

In Long Pond, crustaceans and echinoderms were consumed in negligible quantities. However, the polychaetes and molluscs predominated. This was expected considering the fauna of its mud bottom (Christie, 1966), and the difference between it and the coarse, hard substrate of the bay. From April to October, the annelids comprised between 40 and 70% of the ten most heavily consumed prey, while molluscs made up to 40% of the same group per month. Weight consumption of the five most heavily consumed prey from April to June is illustrated in Fig. 18 for the two feeding grounds. Debris was most heavily consumed of any stomach item and is represented because of its unusual abundance. Debris comprised monthly proportions of 24, 26, 23, 26, 68, 14, and 36% by weight, respectively. It consisted of cigarette filters, barley seeds, pebbles, sand and dead plant fibers. Such values were higher than can be accounted for by accidental swallowing. Filling of the stomach could have been due to (a) lack of sufficient food material, (b) natural consumption of muddy materials for their organic or protein content, or (c) the need for gastric grinding materials during digestion. Absence of noticeable debris among stomach contents from Conception Bay seems to make the third possibility less plausible. This is because food caught in the mud sediment of the pond was softer than that caught in the bay and in least need of grinding.

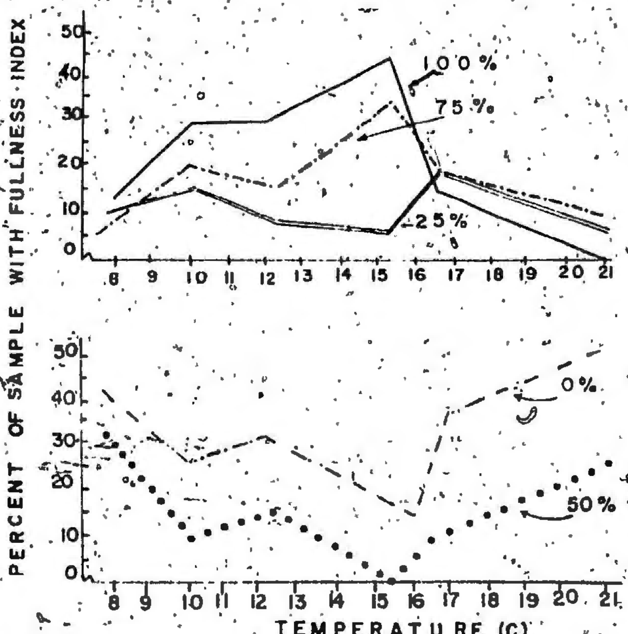
Feeding in Relation to Temperature

Long Pond

The influence of temperature on feeding of flounder in Long Pond is shown in Fig. 19. Degree of feeding is measured by the proportion of monthly samples which fall into each of five fullness index classes which indicate the volume of food in the animal's stomach. Samples with their corresponding indices are arranged by increasing temperature.

The influence of temperature on feeding was to be expected since both the mud bottom of the pond and its shallow depth enhanced rapid heating and cooling on a daily basis. During April and May, food consumption increased gradually from the winter period of partial or complete cessation of feeding. By the last week of April more than 50% of the fish were actively feeding to half or more of their full capacity. Feeding continued at this level within a temperature range 8.1-16.4 C (42-62 F), and reached a maximum between 10.0 and 15.5 C. This indicated that April, May, July, and September were best for feeding within the pond (see Table 12). Consumption declined sharply between 15.5 and 16.5 C and continued to decline until more than half of a monthly sample (55%) had empty stomachs. This percentage (55%) occurred in June. In April and May more fish were

Figure 19. Relation between temperature and feeding of winter flounder in Long Pond.



PERCENT OF SAMPLE WITH FULLNESS INDEX
100%
75%
25%
0%
50%
TEMPERATURE (C)

consuming food than in June, July, or August. During the latter months, feeding was of little importance since the majority of the population, including mature post-spawning adults and larger immatures, was offshore in Conception Bay.

In September, food intake attained levels reached in April and May, while in October it gradually declined toward a winter minimum.

Between 7.0 and 15.5 C, feeding to 50% fullness or more encompassed 48, 58, 60, and 80% of the samples corresponding to each temperature respectively. Fish in the pond followed an interesting pattern of food consumption. Those with empty and 1/2 full stomachs followed a similar pattern of increase and decrease in food intake over the temperatures studied. At the same time, those with 1/4, 3/4, and full stomachs followed a close pattern of increase or decrease throughout the same temperature range. While feeding indices followed a similar pattern within each group, the two groups opposed each other when graphed on the same scale. It is interesting that the same kind of separation of groups was found among winter flounder in Conception Bay as among fish in the pond.

Conception Bay

Table 13 presents the percentages of fish which correspond to the five indices of stomach fullness for temperatures 2.0-16.8 C. The relation between temperature and feeding in Conception Bay was not as strong as that in Long Pond. A larger proportion of fish consumed 50% or more of their stomach capacity at lower temperatures in the bay than in the pond. Peak feeding occurred at 2, 4 and 11 C, but primarily at 2 and 4 C.

The 50% and 0% indices behaved similarly over the temperature range sampled and showed the same kind of pattern as did the 50% and 0% indices for Long Pond. They also followed an opposing pattern to fish feeding at the 1/4, 3/4 and full capacities. Among flounders from this bay, all indices except the 25% index showed significant increases or decreases. However, the relationship between temperature and 25% fullness was nearly linear had an approximately zero slope.

Table 13. Percentages of flounders filling various fullness indices at temperatures 2.0-16.8 C. in Conception Bay. Samples with identical temperatures combined (11.0 C)

	Temperature C					
	2.0	4.0	6.0	11.0	12.0	16.8
Sample Size	15	31	16	27	8	16
Fullness Index (%)						
100	33	44	19	34	13	14
75	40	10	0	9	25	7
50	0	17	19	9	25	29
25	13	14	19	17	13	14
0	13	14	43	27	25	36

Tidal Feeding in Long Pond

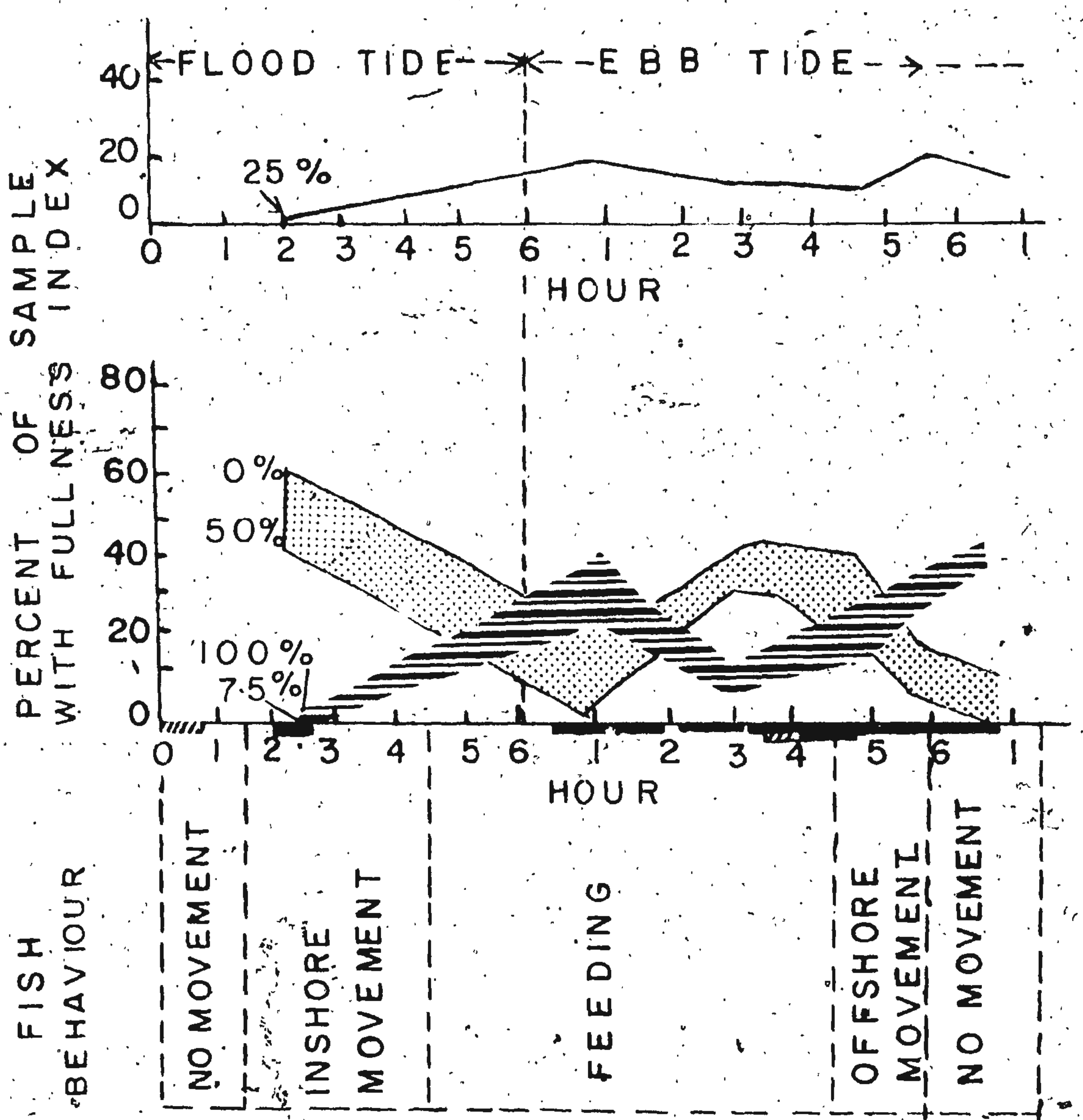
Table 14 presents catch data for samples taken from the two Newfoundland feeding grounds. The dates, depth ranges, sample sizes, tidal hour of catch, and temperature of bottom water at the time of sampling are shown. Tidal data were calculated from the Tide and Current Tables (Canadian Hydrographic Service). Sampling in the pond was a function of the location of the population during the year, and especially during the peak period of feeding. The majority of the flounders had returned to the pond by August 28, 1971. According to the fall movement reported by Kennedy (1964) that observed in August appeared to be early. Fish were speared from August, 1971, to July, 1972.

To show the natural onset and progression of the feeding cycle, samples which corresponded to temperatures 7.5 through 15.5 C are arranged by increasing hour of tide from low water to the next low water. The degree of food consumption among the samples could then be seen before and after changes in the distributions of flounder. Seven catches, covering consecutive time periods of a tidal cycle, are aligned in Fig. 20. Samples for which catch periods overlapped 50% or more of a tidal hour were averaged to prevent duplication. This was necessary only once for 4th hr ebb.

The time periods covered by collecting were: 2.0-2.5 hr flood, 0.5-2.0 hr ebb, 2.2-3.2 hr ebb, 3.3-4.9 hr ebb, 4.6-5.6 hr ebb, 5.6-6.0 hr ebb, and 0.0-0.72 hr flood.

Stomach fullness of the flounder are shown in Fig. 20. Three-fifths of the flounder caught between 2.0 and 2.5 hr flood had empty stomachs, while 40% were half full. The majority of fish were either not feeding or did so lightly at the onset of inshore movement. Few fish consumed food heavily during movement for stomach fullness remained at the same relative levels between 2.5 and 4.5 hr flood tide. A majority still had empty or half full stomachs. Food intake increased steadily from 4 hr flood to the middle of the second catch period. By 1.25 hr ebb, 60% of the fish ate 75% and 100% of

Figure 20. Stomach fullness of winter flounder in relation to time of tide in Long Pond, 1971-1972.


FLOOD TIDE
EBB TIDE
SAMPLE INDEX
40
20
0
25 %
0 1 2 3 4 5 6 1 2 3 4 5 6 1
HOUR
PERCENT OF SAMPLE WITH FULLNESS INDEX
80
60
40
20
0
0%
50%
100%
75%
0 1 2 3 4 5 6 1 2 3 4 5 6 1
HOUR
FISH BEHAVIOUR
NO MOVEMENT
INSHORE MOVEMENT
FEEDING
OFFSHORE MOVEMENT
NO MOVEMENT

their stomach capacity, instead of the 0% volume of food as in the early part of flood tide. Forty per cent were also divided equally into the 0% and 25% food capacities.

By half ebb tide, the number of heavy feeders decreased and those feeding lightly increased in number. The decrease in numbers of heavy feeders could be expected about this time in the tide cycle since the fish would have to digest part of their food before renewing ingestion. The number of fish with half full stomachs increased between 1.25 hr ebb and half ebb by 32%. This increase was reflected in a 41% decrease in numbers with fuller stomachs. An increase in numbers with empty stomachs was seen by a decrease in the proportion with 25% and 75% fullness. It appears that digestion rates among heavy feeders and their time of peak consumption on a preceding flood tide influences the time of a feeding slump on the ebb tide; a result shown by Karpevitch and Bokoff (1937) and De Groot (1971). Considering the amount of time required for the flounders to move inshore, reach full stomach capacity and the short time over which a decrease in food volume occurred (4-5 hr in this case) it appeared that the fish ate slowly until full.

Quantities of food consumed were also small enough to allow these fish to be classed as moderate feeders. Therefore, winter flounder seem to be continuously feeding on small meals. This finding is in agreement with observations made by Dunn (MS 1968). He commented "...Winter Flounder are physically and morphologically adapted to nearly continuous exposure to food functioning at their maximum only under these conditions... they keep near the bottom, feeding steadily on food as it presents itself. The digestive system forms a relatively small part of the fish's body and probably is adapted to the continuous procession of small meals".

From 3-5 hr ebb, numbers with empty stomachs remained steady. Fish that were half full decreased as those that were feeding heavily increased at the same rate as on the preceding flood tide. Flounders that were 25% full declined in numbers more slowly. This group of feeders maintained a slow and relatively insignificant rate of change throughout the tidal cycle.

During the last hour of ebb tide and first hour of flood tide, numbers of light feeders decreased. Heavy feeders reached proportions which were higher than the feeding peak of the preceding flood tide. Increases in the number of fish feeding at the heavier stomach capacities were steady from the time of the ebb tide slump in feeding to the time of low water, (Fig. 20). This indicated that feeding took place during ebb tide movement to the distant end of the pond.

By 0.72 hr flood no fish were half full; only 7% were 25% full, and the majority, 80%, were in the heavy fullness indices. The proportion of heavy feeders increased by 25%. Simultaneously, feeders in the moderate to light categories decreased by 25%.

At 2.0-2.5 hr flood, the fish were again in the reverse condition. Most of the heavy feeders were empty and/or only moderately full. A period of digestion lasting long enough to reverse the condition of fullness to that found in the first catch period followed the second feeding peak on ebb tide. For simplicity, if midpoints of the seven catch periods were used a 2.2 hr period of digestion is calculated. The drop in the percentage of fish with full or nearly full stomachs comprised 80% of the fish during this time of digestion. Those filling the lower indices of fullness increased by a net 80%. This was understandable since fish filling the heavier fullness indices digested their food and changed their standing on the scale of indices by shifting to the lower classes.

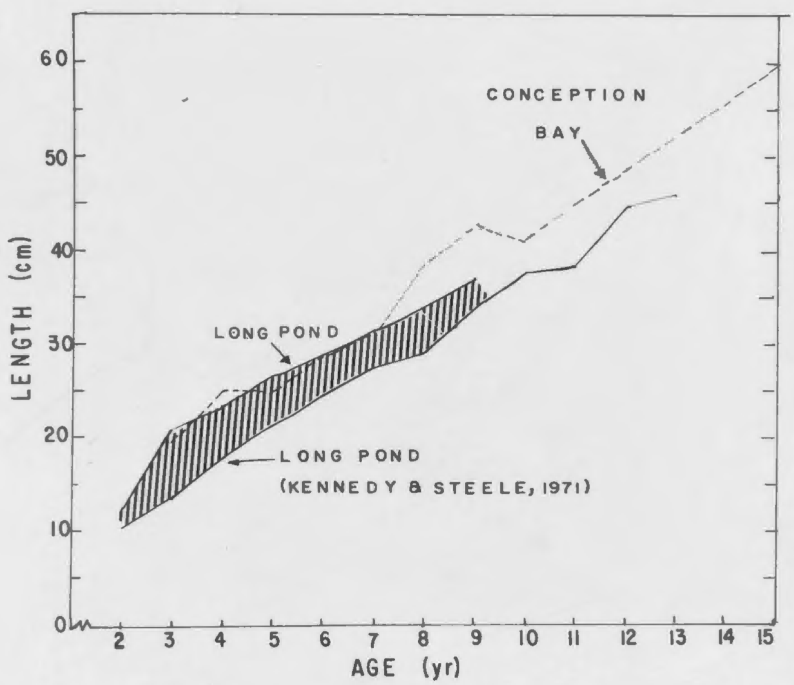
In summary, feeding of winter flounder in the pond showed some synchrony with the tidal cycle. Stomachs were empty or lightly full during inshore movement. They increased in fullness after movement and reached a peak at high water. After becoming full, a period of cessation followed while part of the food digested. A second increase occurred toward the end of ebb tide or early flood tide of the next cycle. Fish consumed food while moving to the distant end of the pond, but ate little or none during a change of distribution on the flood tide.

Growth on the Feeding Grounds

Figure 21 compares age-length data from the two sampling grounds in Newfoundland. The highest age class in Long Pond was nine years, while that in the bay was fifteen years. The shallow water population sampled from 1971-1972 had a faster growth rate than those speared in 1962-1963 (Kennedy and Steele, 1971) although those taken in the latter case were often older and larger.

Flounder from the bay had growth rates similar or equal to pond fish up to seven years, but grew faster beyond 7 years

Figure 21. Age-length relationship of winter flounder in Long Pond and Conception Bay. Comparison is made with previously recorded data.



60
50
40
30
20
10
0
LENGTH (cm)
CONCEPTION
BAY
LONG POND
LONG POND
(KENNEDY & STEELE, 1971)
2
3
4
5
6
7
8
9
10
11
12
13
14
15
AGE (yr)

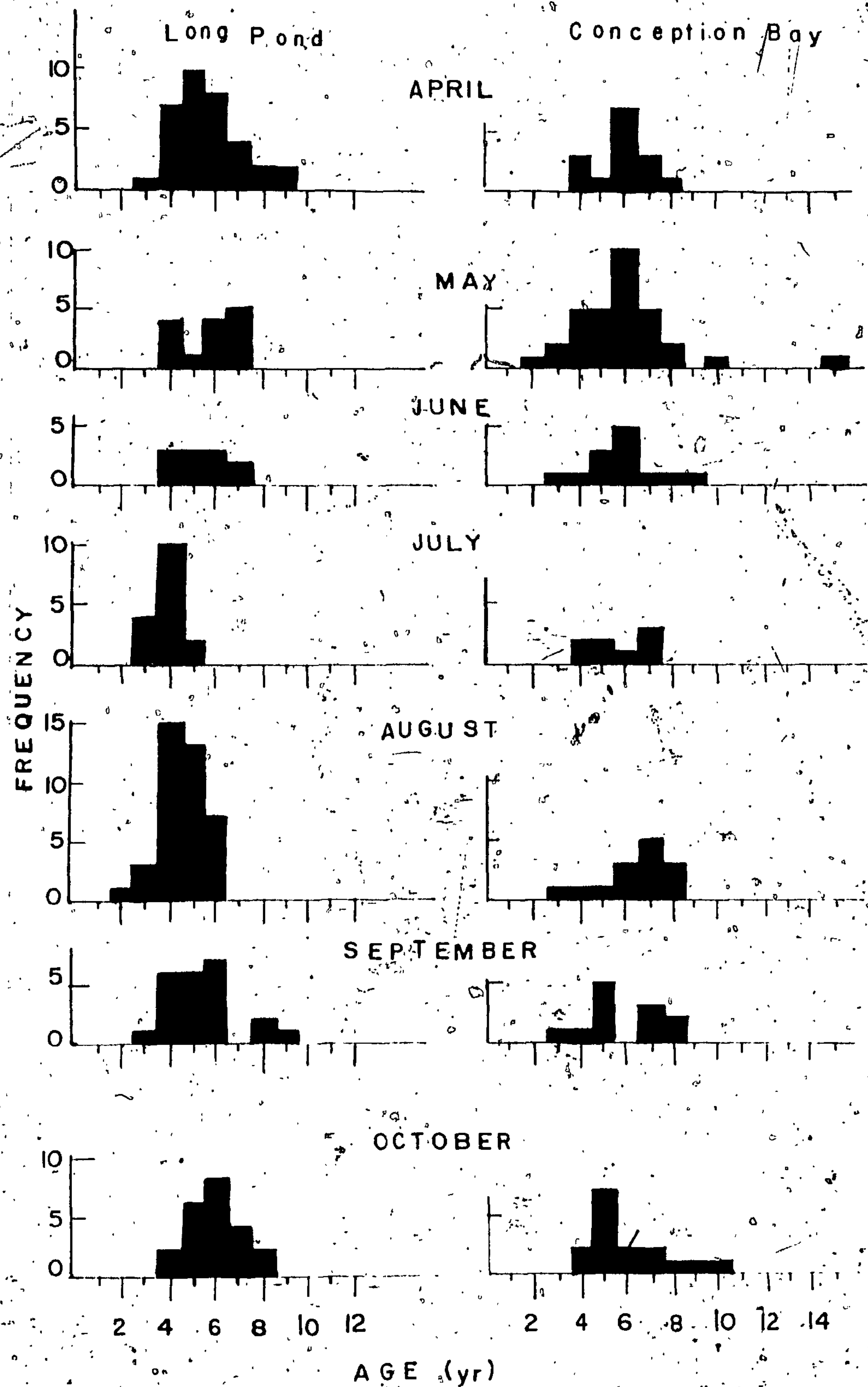
of age. Curves of mean length to age were calculated for all fish of the same age for the monthly samples on a feeding ground. For certain ages (e.g., 9) or months (e.g., July) insufficient numbers of fish caused an anomalous dip in the curves where this may not have normally occurred. The average of both groups of winter flounder gave the following length series for ages 2-10 and 15 years, as an indicator of general growth in the area: 12.2, 20.6, 24.1, 26.9, 28.7, 31.4, 36.3, 39.7, 41.0, and 59.3 cm, respectively.

Age and length composition changed little during the year in Long Pond (Appendix 10). The population was dominated by 4, 5, and 6 year old fish ranging in size from 15 to 35 cm (Fig. 22 and 23). Fewer and younger ages occurred in the summer due to the offshore movement of the adult population. From May to August, 8 and 9 year old fish were not found in the samples, and in July and August 6 and/or 7 year old individuals were not found. These reappeared by September and October to give the same length composition as that found in early spring. Post larval and yearling flounder were numerous; however, their small sizes evaded the sampling methods used.

Age frequencies and sex composition of the two sets of samples are given in Appendix 10. Larger samples taken in April, August, and September more closely approximate the population in the pond. Samples taken in May and October were largest for Conception Bay, but nearly all samples were small in size for this ground.

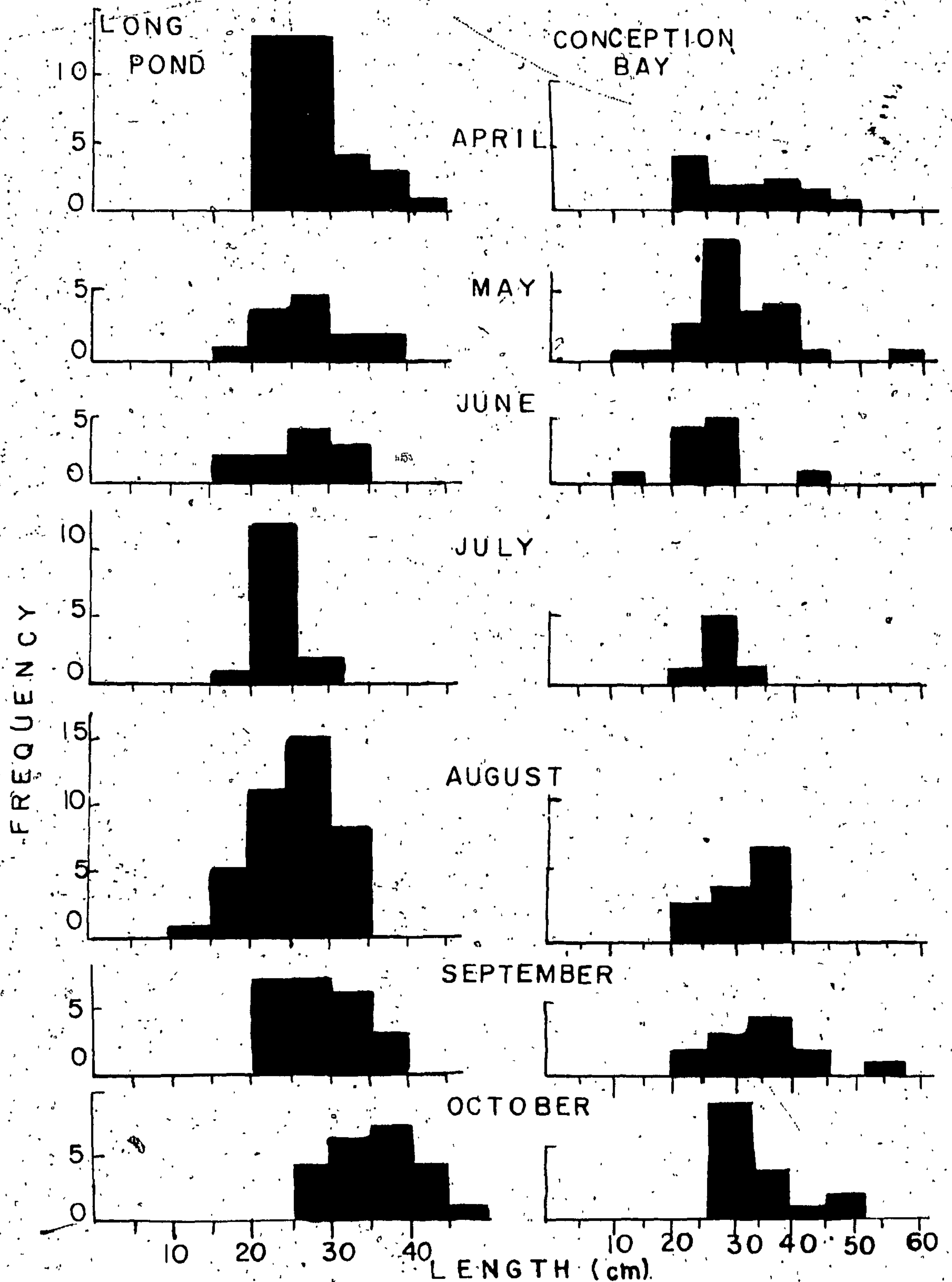
In April, twice as many females were present as males in Long Pond. This ratio became 1:1 in May and June when

Figure 22. Age composition of winter flounder on the two Newfoundland grounds.



Long Pond
Conception Bay
APRIL
MAY
JUNE
JULY
AUGUST
SEPTEMBER
OCTOBER
FREQUENCY
AGE (yr)
2 4 6 8 10 12
2 4 6 8 10 12 14

Figure 23. Length composition of winter flounder on the two Newfoundland grounds.



LONG POND
CONCEPTION BAY
APRIL
MAY
JUNE
JULY
AUGUST
SEPTEMBER
OCTOBER
FREQUENCY
LENGTH (cm)

breeding took place. Six times as many males were present in July. These were younger, immature fish which had not followed the bulk of the post-spawning adults into the bay. In the late summer and through the fall, males were more abundant than females due to their earlier movement into the pond ahead of ripening, adult females. The larger number of males in autumn corresponds with the situation found by Kennedy (1964) for the same period in the lagoon.

In Conception Bay, more females were present than males in the spring. In summer, the ratio became 1:1 and in the fall, females were again more abundant. Such changes in sex composition in the bay indicate some degree of mass movement inshore as well as farther offshore from the area. Whether both operate simultaneously or successively is unknown. Tagging studies are necessary before the results can be explained clearly. However, the autumn increase in females just offshore from the pond is probably due to the inshore movement of males to inlets, in preparation for overwintering and spawning.

In Conception Bay, age composition covered a wider range with fewer year classes dominating any one sample. Fish from 4-8 years were most frequent and consistent. From May to August, the classes missing from the pond were present in the bay samples.

General Discussion

Comparison of movement in Brandy Cove and Long Pond

Characteristics of the Long Pond movement differed from those of Brandy Cove in several respects and were a function of how the fish responded to tide.

Whereas Brandy Cove flounders began moving inshore after 0.5 hr flood those in Long Pond did not move until nearly 1.0-1.5 hr flood tide. Fish in Brandy Cove moved inshore, within 2 hours, and movement was completed by 2.5-3.0 hr flood. Those in Long Pond moved slower in "waves" or clusters of individuals. Movement occurred between 1 and 4 hr flood, and thus lasted about 1.5 hr longer, as well as being delayed by .5-1.0 hr. Since movement in the cove was more limited to a few hours before and after ebb tide (Tyler, 1971) it was similar to that of plaice at Loch Ewe, Scotland (Edwards and Steele, 1968) and the Danish Wadden Sea (Smidt, 1951). Nature of the movement was that it occurred as a surge in these three locations. Movement in Long Pond was not so restricted to a couple hours and, thus, was similar to that of plaice in Ardmucknish Bay (Gibson, 1973) where no surge occurred. Winter flounder, then, moved in differing ways in the two locations of the Northwestern Atlantic as did plaice for the two locations of the Northeastern Atlantic. Yet, although geographically the two species were widely separated, behaviourally they displayed similar patterns of movement.

Feeding in Brandy Cove occurred from about 3 hr flood to 3.5 hr ebb or more while in the pond it occurred from approximately 4 hr flood to 3.5 hr ebb before outward movement began. It must be remembered that this time schedule characterized the bulk of flounders which moved and that (1) within each phase of activity individuals varied and (2) the phases themselves varied in duration and time of initiation. Thus Brandy Cove flounders fed for a minimum period of 6-8 hours while in Long Pond they fed for 5.5 to 6.0 or 6.5 hr.

Offshore movement began by approximately 3.5 hr ebb at both study sites, and was mostly completed by 5.5 hr ebb tide. However, the surge in Brandy Cove which involved nearly 70% of the fish between 3.5 and 5.5 hr ebb did not occur in the pond.

While outward movement was initiated by 3.5-4.0 hr ebb in the pond, most flounders were observed to remain until nearly 5 hr ebb and then move out quickly during the last hour of the tide on most days. Thus, it seemed that these fish waited until the last possible moment before leaving. Differences in movement between the two locations are illustrated in Figure 24.

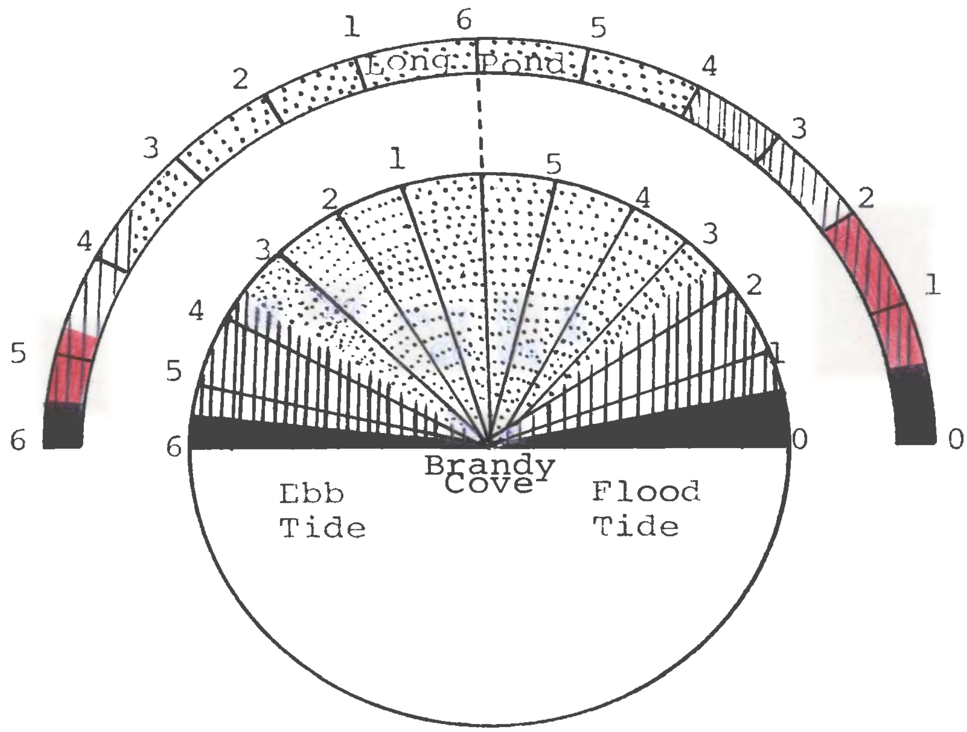
Consideration of factors causing orientation during movement

Bryne (1968), Poddubny (1969), and Gibson (1973) have reviewed at least eleven environmental cues proposed to be used by flatfish in making tidal movements. As flatfish are considered to need consistent physical and/or biotic cues to guide their movement, seven of these eleven have been rejected. This is because they were changeable and would confuse the fish which followed them. The seven spatial and temporal cues displayed too much variability in relation to depth to be followed consistently for long periods of time. These cues were: temperature, salinity, light intensity, photoperiod, sound, surface glitter pattern,

Figure 24. Comparison of tidal movements of winter flounders in Long Pond, Nfld, (arc) and Brandy Cove, N.B. (circle).

Legend

Stippled area	:	denotes time of exploration, feeding, etc. Distributions of fish dissociated at this time.
Hatched area	:	denotes time of movement in or outward from the intertidal zone. Distributions are opposing in pattern at this time.
Solid area	:	denotes time when no movement occurs. Fish concentrated in their ebb tide locations Distributions are the same or very similar at this time.
Coloured area	:	denotes time of pronounced movement in or out of the intertidal zone within th total time of movement (Hatched area).


Long Pond
Brandy Cove
Ebb Tide
Flood Tide
6
1
2
3
4
5
0

and turbulence. Of the four remaining cues, hydrostatic pressure was considered to be the most logical and consistent for fish to follow. These four cues were: depth contours, endogenous rhythm, tidal current and hydrostatic pressure. Pressure has the most reliability in allowing fish to maintain substrate position in relation to depth. As species of flatfish lacking a swimbladder (e.g. Pleuronectes platessa, Limanda limanda) react consistently to changing pressure (Blaxter and Tytler, 1972) it is possible that P. americanus also used this cue and that it was the attribute of depth which initiated movement.

In contrast, movement in Long Pond was felt to be intiated by water currents and then controlled by pressure, as the initial increase in depth of water at the change of tide was small compared to later increases in depth during hours 2 and 4.

The presence of winter flounder in the intertidal zone at high tide in Long Pond (personal observation) corresponded to their presence in the same zone in Brandy Cove. While Tyler (1971) studied movements in the latter location, presence of flounders there was observed as early as 1902 by Dr. Joseph Stafford, and later by Medcof and MacPhail (1952) who also found them at Belliveau Cove and Petpeswick, N.S. McCracken (1963) sampled the abundance of winter flounder in Brandy Cove in 1949 with set seine and beam trawl. Olla et al. (1969) observed winter flounder in close to shore at Long Island. Pearcy (1962) mentioned their occurrence in the intertidal zone at high tide, as did De Sylva et al. (1962) in seine catches on the beach in the Delaware River shore zone. Intertidal movement of this species and others (Merriman, 1947) also corresponds with that reported for North Sea plaice, *P. platessa*; *S. maximus*; flounder, *P. flesus*; sand goby, *P. minutus*; and cod, *Gadus morhua*. The appearance of these species has been described for intertidal zones of the North Sea and adjacent northern waters by Linke (1939), Smidt (1951), Zenkevitch (1963), and Hancock and Urquhart (1965).

Relation of movements to feeding in Brandy Cove

Sampling in Brandy Cove showed that migrant fish had small amounts of food in their stomachs during the last half of ebb tide before entering the intertidal zone. Two feeding patterns were suggested by the effect of tide on their movement and feeding. The first was of fish feeding during flood tide in the intertidal zone and digesting prey over the following ebb tide while in the subtidal zone. The second was of fish feeding at a slow rate of ingestion while remaining subtidally.

Tyler (1971) found that 68 % of his "1970" migrant flounders entered the intertidal zone by 2.5 hr flood tide. Stomachs examined from fish in this study were full by 3 hr ebb. As fish taken just after high water were as full as those taken later on ebb tide when fish were leaving the zone, feeding took place during the last half of flood tide as well as during ebb tide.

Subtidal non-migrants could become migrants if their stomachs were nearly empty at low tide and their prey were consumed either on the flood tide of the previous twelve hour cycle or early on the ebb before inshore movement.

The feeding types described for Long Pond and Conception Bay flounder as heavy and light were similar to labels applied by

De Groot (1971) to "intensive" and "moderate' feeding pleuronectids in the North Sea. In his experiments, the weight of food taken to the body weight of the fish was expressed as a percentage and then rated for various species. European plaice would have to consume greater than 5.25% of their body weight to be intensive feeders. Moderate feeders ate less than this amount. Flatfish sampled in this study in both New Brunswick and Newfoundland were moderate feeders according to this criterion. They ate no more than 2% of their body weight as prey weight per tide. Intensity of feeding among P. americanus was lower than that among P. platessa, L. limanda, but was similar to Solea solea and P. flesus.

Relation of movements to feeding in Long Pond

A feeding "slump" was observed between high tide and mid-ebb tide among Long Pond flounder. This "slump" in stomach filling and its corresponding peaks were part of a cycle seen in other flatfishes. In his treatise on the interrelationships between morphology of the alimentary tract and feeding habits, De Groot (1971) found feeding to be controlled by photoperiod and temperature primarily and tide secondarily. Stomach analysis from trawl samples in the Texelstroom revealed a consistent pattern in four North Sea flatfishes listed above. Feeding was coordinated with tides such that stomachs were emptier at the beginning of a tide and fuller at mid-tide. A period of cessation followed. Digestion of some of the contents occurred during this period. Renewed feeding continued thereafter. Plaice of 20-25 cm followed this pattern filling their stomachs after an interval in which some of the food was digested. His data showed this period to be 2-3 hours on the average. Feeding continued in daylight but slowed in rate during the night. Food eaten at the first peak of intake in early morning, was not digested as a full unit meal before more was consumed. Enough was digested and passed from the stomach to the midgut to allow room for another meal intake. Flounders in this study required more time to reach a state of satiation but the patterns were similar.

Because of the small number and size of samples used in this comparison the apparent synchrony between feeding and tidal movement requires further study. Sampling of stomachs over each hour of the tidal cycle is necessary to confirm the suggestion.

Function of Long Pond flounder movement

While Brandy Cove flounder movements were related to the availability of food resources in the intertidal zone it is felt that in Long Pond, movement was not related solely to food. Feeding was probably a stimulus for the spring movements observed during the seven or eight weeks between ice break-up and offshore migration. Water had warmed enough to stimulate swimming and some feeding by juveniles and immatures. Feeding intensity of all age groups, though, would have been lower compared to later summer feeding by the entire stock and involved fewer fish for (1) the majority of the population would not have consumed much food prior to spawning in late spring and (2) temperatures were usually reduced until the end of May. It is felt that food was not as strong a primary stimulus as in Brandy Cove.

Available evidence (Christie, 1966; Kennedy, 1964) indicated that Long Pond had a small food supply. A poor variety of food which could be consumed by animals higher in the food chain was present. A low standing crop covered much of the bottom surface area. Reduced levels of food consumption in the pond allowed survival but poor growth.

The flounders made seasonal movements to and from the lagoon which allowed the best use of both areas in summer and winter. Movement showed that offshore migration was not coordinated with "auto-selected" temperatures of 12-15 C (McCracken, 1963), but closer to times of spawning and feeding. Corresponding evidence was found in St. Margaret's Bay when movements to and from a deeper ground were not " triggered by a temperature response" (Levings, 1973). The pond was used for overwintering when gonads were recovering and ripening. Flounders left the inlet after spawning, when they fed intensively and could not obtain needed quantities of food inside the basin.

The effective number of months of active feeding inside the pond was reduced to three, despite their presence there ten months of the year. As well, the more important months for feeding were those in which they were not in the pond: late June, July, August, and/or September. This evidence supports the theory that food was not as important a cause of movement as in Brandy Cove, New Brunswick.

It must be remembered that in the cove, movements were directed intertidally whereas in Long Pond theywere directed from one end of the shallow subtidal zone to the other and the slope of the bottom was nearly zero, except for the dredged basin. Fewer fish entered the intertidal zone in the pond. Thus, essentially the same food supply was available to the population during both tides.

Value of the study in relation to society

The total intertidal area of Brandy Cove (Medcof and MacPhail, 1952) has been given. Mean numbers of flounders passing over a portion of that area have been found for a 12 hr tidal cycle (Tyler, 1971). Quantities of the most heavily consumed prey species were determined for an average tide when the fish were inshore (Wells et al. 1973). Caloric values of some infauna and substrate-surface eipfauna which are prey of flounders have been calculated either directly (Tyler, 1973) or indirectly for closely related species (Brawn et al. 1968; Paine and Vadas, 1969).

From these data and further studies, it will be possible to estimate densities of fish and calories consumed per acre. With the establishment of digestion rates and conversion efficiencies for the major prey species, the mean yield in fish production can be realized per acre of feeding ground. Yield in production is represented by the numbers of calories directed toward growth compared to calories consumed in the prey. Such information will extend our understanding of the nutrition and growth rates of a species which has a large potential for applied aquaculture both in the laboratory (Stickney and White, 1973) and in nature.

Since the present value of the intertidal zone is realized but its potential value in aquaculture remains undeveloped these zones should be protected from abuse and human intervention. Particularly, intertidal zones of medium to large acreage should be left in their natural state. Intervention in the form of tidal impoundments, hydroelectric dams, oil spills, bulldozing, sewage disposal, dumping, and retaining walls for silt must be stopped if productivity of our inshore fish stocks is to be maintained.

Conclusions

In New Brunswick, the intertidal zone is used as a feeding ground by P. americanus. It is used when flounders are onshore from April to October in this area of the Bay of Fundy. Its resources supplement food obtained subtidally. Numbers of fish moveing into and from the zone were large. In certain locations, abundance of organisms may be five to eitht times higher intertidally than subtidally. During spring, summer and fall, maximum use is made of the zone when the time of low water coincides with the onset of daylight. This allows the fish to move inshore between sunrise and approximately noon hour and feed through the day, since they are visual feeders. As the tidal phase (low water) loses synchrony with sunrise, inshore movement proceeds later and the feeding cycle is displaced to later hours in the day. With each day and loss of synchrony, the number of hours for feeding decreases as the time of low water rotates toward evening and the time of civil twilight. Intertidal feeding increased the energy supply available to the fish. Subtidal competition was reduced. The variety and quantity of food offered compensated for the inherent danger from predation of their inshore aggregations.

In Newfoundland, winter flounder were observed in the intertidal zone. Smaller sizes predominated there. Flounders displayed intertidal movement or movement across the bottom of the pond in relation to tome of the tide. An apparent relationship was found between feeding and movement. Although they appeared to feed in synchrony with the tide, food was not as important a stimulus in causing movement as in Brandy Cove, New Brunswick. Since an increase in depth is more perceptible in shallow water than deep water, very little increase would be required to stimulate the fish to move, particularly in a location like Long Pond. It is possible that pressure was more important than food since increases and decreases in surrounding pressure can be detected with 1-2%, amounting to addition of 0.2-0.3 m (8-10 in) water over the substrate.

Acreman, J. MS 1966. An investigation of the seasonal size of gonads and alimentary canal of the echinoid, Strongylocentrotus drobachiensis (O.F.Muller). B.Sc. (Hons.). Thesis Memorial Univ. St. John's, Nfld. 72 pp.

Alder, H.L. and Roessler, E.B. 1964. Introduction to Probability and Statistics. (3rd.ed.). W.H. Freeman and Co. San Francisco.

Aronson, L.R. 1951. Orientation and jumping behavior in the gobiid fish, Bathygobius soporator. Amer. Mus. Novit. No. 1486:1-22.

Ball, J.N. 1961. On the food of the brown trout of Llyn Tegid. Proc. Zool. Soc. Longon 137(4):599-622.

Bateson, W. 1890. The sense-organs and perception of fishes with remarks on the supply of bait. J. mar. biol. Ass. U.K. 1: 225-256.

Beebe, W. 1954. Notes on the gill-finned goby, Bathygobius soporator (Cuvier & Valennciennes). Zoologica 12:55-66.

Berry, R.J. MS 1959. Critical growth studies of winter flounder, Pseudopleuronectes americanus (Walbaum) in Rhode Island waters. M.S. Thesis. Univ. Rhode Island. 52 pp.

Berry, R.J., Saila, S.B., and Horton, D.B. 1965. Growth studies of winter flounder, Pseudopleuronectes americanus (Walbaum) in Rhode Island. Trans. Amer. Fish. Soc. 94(3):259-264.

Bigelow, H.B. and Schroeder, W.C. 1953. Fishes of the Gulf of Maine (1st.rev.). U.S. Fish Wildl. Serv., Fish .Bull. 74(3):1-577.

Birkett, L. and Wood, R.J. 1959. Shell and siphon regeneration on Mactra stultorum Linne (Lamellibranchiata). Nature 184:1075-76.

Blaxter, J.H.D. andTytler, P. 1972. Pressure discrimination in teleost fish. Symp. Soc. Exp. Biol. 26:417-443.

Bousfield, E.L. 1960. Studies on littoral marine arthropods from the Bay of Fundy. Nat. Mus. Can. Bull. 183:43-62.

____________. 1973. Shallow water Gammaridean Amphipoda of New England. Cornell Univ. Press, Ithaca, N.Y. 312 pp.

Brawn, V.M., Peer, D.L., Bentley, R.J. 1968. Caloric content of the standing crop of benthic and epibenthic invertebrates of St. Margaret's Bay, Nova Scotia. J. Fish. Res. Bd. Can. 25(9):1083-1091.

Brinkhurst, R.O. 1965. Studies on the NOrth American Aquatic Oligochaeta II. Tubificidae. Proc. Acad. Sci. Philadelphia 117:117.

Brückner, W.D. 1969. Post-glacial geomorphic features in Newfoundland, eastern Canada. Eclog. Geol. Helv. 62(2):417-444.

Bruün, A.F. 1927. Quantitative investigation of the 0-group and I-group of the Plaice, Turbot, Brill and Sole in the Skagerrak, Kattegat, and Belt Sea. Meddr. Kommn. Havunders, Ser. Fisk. 8(5).

Bryne, J. E. 1968. The effect of photoperiod and temperature on the daily pattern of locomotor activity in juvenile sockeye salmon (Onchorynchus nerka Walbaum).Ph. D. Thesis. Univ. British Columbia, Vancouver, B.C. 125 pp.

Bückmann, A. 1934. Uber die Jungschollenbevolkerung der deutscheun Wattenkuste der Nordsee. Ber. Deut. Wiss. Kommn. Meeres. N.S. 7(3):1-399.

Christie, P.M.P. MS 1966. Some aspects of the ecology of benthic invertebrates in Long Pond, Conception Bay, Nfld. M.Sc. Thesis, Memorial Univ., St. John's, Nfld. 165 pp.

Coady, L.W. MS 1973. Aspects of the reproductive biology of Cucumaria frondosa (Gunnrus, 1770) and Psoleus fabricii (Duber & Koren, 1946) (Echinodermata: Holothuroidea) in shallow waters of the Avalon Peninsula, Newfoundland. M. Sc. Thesis, Memorial Univ., St. John's, Nfld.

Colinvaux, L.H. 1966. Distribution of marine algae in the Bay of Fundy, New Brunswick, Canada. Proc. 5th. Int. Seaweed Symp. Halifax, N.S., August 25-28, 1965.

Cook, D.G. and Brinkhurst, R.O. 1973. Marine flora and fauna of the Northeastern U.S., Annelida: Oligochaeta. U.S. Dept. Comm. NOAA Tech. Rept. NMFS Circ. 374:1-23.

Copeland, G.G. 1912. On the temperature and densities of Passamaquoddy Bay waters and environs, with notes on allied subjects and the bearing of the same on the Oyster Industry. Contr. Can. Biol. (1906-1910): 281-294.

Craigie, G.H. 1916. Hydrographic investigations in the St.Croix River and Passamaquoddy Bay. Contr. Can. Biol. (1916):151-161.

Davies, R.G. 1970. Computer Programming in Quantitative Biology Acad. Press. London. 491 pp.

Davis, C. C. 1972. Plankton Succession in a Newfoundland lake. Int. Revue Hydrobiol. 57(3):376-395.

De Fant, A. 1925. Gezeitenprobleme des Meeres in Landnäbe. Probl. Kosmischen Phys. 6:1-80. (Not seen, cited in Sverdrup, Johnson, and Fleming, 1942).

De Groot, S.J. 1971. On the interrelationships between morphology of the alimentary tract, food and feeding behaviour in flatfishes (Pisces: Pleuronectiformes). Neth. J. Sea Res. 5(2): 121-196.

De Sylva, D.P., Falber, F.A. and Shuster, C.N. 1962. Fishes and ecological conditions in the shore zone of the Dealware River Estuary, with notes on other species collected in deeper water. Univ. Delaware Mar. Lab. Inform.Ser. Pub.No. 5:1-164.

Downer, D.F. MS 1973. A contribution to the biology of Amphiporeia lawrenciana in Newfoundland waters. M.Sc. Thesis, Memorial Univ. St. John's, Nfld.

Dunn, R.D. MS 1968. The effect of food supply on the fecundity of winter flounders, M.Sc. Thesis, Acadia Univ. Wolfville, N.S. 117 pp.

Edwards, R. and Steele, J.H. 1968. The ecology of 0-group plaice and common dabs at Loch Ewe. I. Population and Food. J.exp. mar. Biol. Ecol. 2:215-238.

Fisher, R.A. and Yates, F. 1943. Statistical tables for biological, agricultural and medical research. (2nd ed.) Oliver and Boyd Ltd. Edinburgh. 98 pp.

Frost, N. 1936. Reports: Faunistic Series, No. I. Amphipoda from Newfoundland waters with a description of a new species. Nfld. Dept. Nat. Res., Res. Bull. No. 3

Garstang, W. 1909. The distribution of plaice in the North Sea, Skagerrak, and Kattegat, according to size, age and frequency. Cons. perm. int. Explor. Mer., Rapp. et Proc. Verb. II.

Gibson, R. N. 1967. Experiments on the tidal rhythm of Blennius pholis. J.mar.biol. Ass.U.K. 47:98-111.

____________. 1973. The intertidal movements and distributionof young fish on a sandy beach with special reference to plaice (Pleuronectes platessa L.). J. exp. mar. Biol. Ecol. 12(9): 79-102.

Gosner, K.I. 1972. Guide to identification of marine and estuarine invertebrates: Cape Hatteras to the Bay of Fundy. Wiley-Interscience, John Wiley and Sons, Inc. New York. 693 pp.

Gray, J.S. and Rieger, R.M. 1971. A quantitative study of the meiofauna of an exposed sandy beach at Robin Hood's Bay, Yorkshire, J. mar. biol. Ass. U.K. 51:1-19.

Green, J.M. 1971. Field and laboratory activity patterns of the tidepool cottid Oligocottis maculosus Girard. Can.J.Zool. 49(2):255-264.

Hachey, H.B. and McLellan, H.J. 1948. Trends and cycles in surface temperatures of the Canadian Atlantic. J.Fish.Res.Bd.Can. 7(6):355-362.

Hanks, R.W. 1964. A benthic community in the Sheepscot River Estuary Maine. U.S. Fish Wildl. Serv. 63(2): 343-353.

Harris, R.P. 1972a. The distribution and ecology of the interstitial meiofauna of a sandy beach at Whitsand Bay, East Cornwall. J. mar. biol. Ass. U.K. 52:1-18.

__________. 1972b. Horizontal and vertical distribution of the interstitial harpacticoid copepods of a sandy beach. J. mar. biol. Ass. U.K. 52:375-387.

__________. 1972c. Seasonal changes in the meiofauna population of an intertidal sandy beach. J. mar. biol. Ass. U.K. 52:389-403.

Hempel, G. 1956. Studien zur Tagesperiodik der Aktivitat von Fischen II. Die Nahrungsaufnahme der Schoole, Kurze Mitt. Inst. Fischbiol. Univ. Hamburg. 6:22-37.

Himmelman, J.H. MS 1969. Aspects of the ecology of Strongylocentrotus droebachiensis in eastern Newfoundland. M.Sc. Thesis. Memorial Univ. St. John's, Nfld. 151 pp.

Holmes, N.A. 1949. The fauna of sand and mud banks near the mouth of the Exe Estuary. J. mar. biol. Ass. Plymouth 28 (1): 189-237.

Hynes, N.B. 1950. The food of freshwater sticklebacks (Gasterosteus aculeatus and Pygosteus pungitius) with a review of methods used in studies of the food of fishes. J. Anim.Ecol. 19(1):36-58.

Ivlev, V.S. 1961. Experimental Ecology of the Feeding of Fishes. (Transl. Douglas Scott) Yale Univ. Press. New Haven, Conn. 302 pp.

Johansen, A.C. 1908. Contributions to the biology of the plaice with special regard to the Danish plaice fishery. 3. On the variations in frequency of young in Danish waters, 1902-1907. Meddr. Kommn. Havunders., Ser. Fisk. 3(4):48.

__________. 1913. Contributions to the biology of the plaice with special regard to the Danish plaice fishery. 6. On the immigration of plaice to the west coast of Jutland. Meddr. Kommn. Havunders, Ser. Fisk. 4(4):1-26.

Karpevitch. A. and Bokoff, E. 1937. The rate of digestion in marine fishes. Russk. Zool.Zh. 16:28-44.

Kennedy, V.S. and Steele, D.H. 1971. The winter flounder (Pseudopleuronectes americanus) in Long Pond, Conception Bay, Newfoundland. J. Fish. Res. Bd. Can. 28(8):1153-1165.

Kennedy, V.S. MS 1964. Aspects of the biology of the winter flounder, Pseudopleuronectes americanus (Walbaum) in Long Pond, Conception Bay, Ndwfoundland, M.Sc. Thesis, Memorial Univ. St. John's, Nfld. 104 pp.

Kohler, A.C. 1958. The validity of otolith age determinations for haddock (Melanogrammus aegelfinus L.) from the Lockeport, N.S. area. J.Fish Res.Bd.Can 15(6):1229-1238.

Kohler, A.C., Fitzgerald, D.N., Halliday, R.G., Scott, J.S. and Tyler, A.V. 1970. Length-weight relationships of marine fishes of the Canadian Atlantic region. Fish. Res. Bd. Can. Tech. Rept. No. 164:1-200.

Krumbein, W.C. and Pettijohn, F.J. 1938. Manual of Sedimentary Petrography. Appleton-Century Co. New York. 549 pp.

Kruuk, H. 1963. Diurnal periodicity in the activity of the common sole, Solea vulgaris Quensel. Neth. J. Sea Res. 2(1):1-28.

Larsen, K. 1936. The distribution of the invertebrates in the Dybso-Fjord, their biology and their importance as fish food. Rept. Dan. Biol. Sta. 41:3-35.

Levings, C.D. 1973. Dominance and movements of winter flounder (Pseudopleuronectes americanus) at St. Margaret's Bay, Nova Scotia. Naturaliste Canadiene 100(4):337-345.

Light, S.F., Smith, R.F., Pitelka, F.A., Abbott, D.P. and Weisner, F.M. 1954. Intertidal invertebrates of the Central California Coast. Univ. California Press, Berkeley. 446 pp.

Lübert, H. 1925. Beobachtungen über den Schollenbestand in Amerikahafen in Cuxhaven in Jahre, 1922. Ber. Deut. Wiss. Kommn. Meeresforsch, N.S. 1:293-301.

Mac Farlane, C.I. 1952. A survey of certain seaweeds of commercial importance in southwest Nova Scotia. Can. J. Botany 30(1):78-97.

MacKinnon, J.C. 1973. Summer storage of energy and its use for winter metabolism and gonad maturation in American Plaice (Hippoglossoides platessoides). J. Fish. Res. Bd. Can. 29 (12):1749-1759.

Mangum, C.P. 1964. Studies on speciation in Maldanid polychaetes of the North American coast. II. Distribution and competition interaction of five sympatric species. Limnol. & Oceanogr. 9:12-26.

Mann, K. H. 1972. Ecological energetics of the seaweed zone in a marine bay on the Atlantic coast of Canada. I. Zonation and biomass of seaweeds. Mar. Biol. 12:1-10.

Mare, M.F. 1942. A study of a marine benthic community with special reference to the micro-orgamisms. J. mar. biol. Ass. U.K. 25:517-554.

Mathieson, A.C., Dawes, C.J. and Humm, H.J. 1969. Contributions to the marine algae of Newfoundland. Rhodora 71:110-159.

McIntyre, A.D. 1970. The range of biomass in intertidal sand, with special reference to the bivalve Tellina tenuis. J. mar. biol. Ass. U.K. 50:561-575.

McIntyre, A.D. and Murison, D.J. 1973. The meiofauna of a flatfish nursery ground. J. mar. biol. Ass. U.K. 53(1):93-118.

McCracken, F.D. MS 1954. Seasonal movements of winter flounder Pseudopleuronectes americanus from the east coast. Ph.D. Thesis, Univ. of Toronto, Toronto, Ont. 167 pp.

______________. 1963. Seasonal movements of the winter flounder, Pseudopleuronectes americanus (Walbaum) on the Atlantic Coast J.Fish. Res. Bd. Can. 20(2):551-586.

Medcof, C. and MacPhail, J.S. 1952. The winter flounder- a clam enemy. Fish. Res. Bd. Can. Prog. Rept. Atlan. Cstl. Sta. 52(118):3-7.

Merriman, D. 1947. Notes on the mid-summer ichthyofauna of a Connecticut beach at different tide levels. Copeia:281-286.

Mills, E.L. 1967. The community concept in marine zoology, with comments on continua and instability in some marine communities, a review. J.Fish. Res. Bd. Can. 26(6):1415-1428.

Moore, J.P. 1905. Some marine oligochaeta of New England. Proc. A.N.S. Philadelphia, Penn.

Moore, H.B. 1972. Aspects of stress in the tropical marine environment. In: Russell, F.S. and Yonge, M. (eds.) Advances in Marine Biology. 10:217-269.

Muus, B.J. 1967. Fauna of Danish estuaries and lagoons. Distributions and ecology of dominating species in the shallow reaches of the mesohaline zone. Meddr. Kommn. Danm. Fisk.- og. Havundersogelser. N. Y. Serie 5(1).

Olla, B.L., Wicklund, R. and Wilk, S. 1969. Behavior of winter flounder in a natural habitat. Trans. Amer. Fish. Soc. 98: 717-721.

Paine, R.T. and Vadas, R. I. 1969. Calorific values of benthic marine algae and their postulated relation to invertebrate food preference. Mar. Biol. 4(2):79-86.

Pearcy, W.G. 1962. Ecology of an estuarine population of winter flounder, Pseudopleuronectes americanus (Walbaum). Pt.I-IV. Bull. Bingham. Oceanogr. Collect. Yale Univ. 18(1):1-78.

Peer, D.L. 1972. Observations on mortalities of benthic organisms after contamination of the bottom of Long Harbour, Placentia Bay, Newfoundland with elemental phosphorus. In: Jangaard, P.M. (ed.). Effects of elemental phosphorus on marine life: Collected papers resulting from the 1969 pollution crisis, Placentia Bay, Nfld. Fish. Res. Bd. Can. Circ. 2:181-186.

Perlmutter, A. 1939. A biological survey of the salt waters of Long Island, 1938. I. An ecological survey of young fish and eggs identified from two-net collections. Suppl. 28th Ann. Rept. N. Y. State Conserv. Dept. 2:11-71.

Pipping,M. 1927a. Der Geruchssinn der Fische mit besonderer Berücksicktigung seiner Bedeutung für das Aufsuchen des Futters. Acta Soc. Sci. Fenn., B. 2(4):1-28. (Not seen, cited in De Groot, 1971).

__________. 1927b. Erganzende Beobachtungen über den Geruchssinn der Fische mit besonderer Berücksicktigung seiner Bedeutung für das Aufsuchen des Futters. Acta Soc. Sci. Fenn. B. 2(10):1-10. (Not seen, cited in De Groot, 1971).

Poddubny,A.G. 1969. Sonic Tags and Floats as a means of studying fish response to environmental changes and to fishing gear. F.A.O. Fish Rept. 62:793-801.

Putnam,D.F. 1940. The climate of the maritime provinces. Can. Geogr.J. 21:135-142.

Rowe,V.L. MS 1970. The reproductive biology and ecology of two maldanid polychaetes from Passamaquoddy Bay, New Brunswick. M.Sc. Thesis. Univ. Waterloo, Waterloo, Ont. 100 pp.

Saila,S.B. 1961a. A study of winter flounder movements. Limnol. & Oceanogr. 6:292-298.

Sanders,H.L. 1958. Benthic studies in Buzzard's Bay. I. Animal-Sediment Relations. Limnol. & Oceanogr. 3:254-258.

__________. 1960. Benthic studies in Buzzard's Bay. III. The structure of the soft bottom community. Limnol. & Oceanogr. 5(2):138-153.

Sanders,H.L., Goodsmit,E.M., Mills,E.L. and Hampson G.E. 1962. A study of the intertidal fauna of Barnstable Harbour, Massachusetts. Limnol. & Oceanogr. 7(1):63-79.

Sanders,H.L. 1968. Marine benthic diversity: a comparative study. Amer. Natl. 102:243-282.

Scheuring,P. 1924. A manual of harmonic analysis and prediction of tides. U.S. coast Geod. Surv. Spec. Pub. 98:1-416.

Shoryigin, A.A. 1939. Food and food preference of some Gobiidae of the Caspian Sea. (in Russian, English summary). Zool. Zh. Moscow 18(1): 27-53. (Not seen, cited in Ivlev, 1961).

Siegel, S. 1956. Nonparametric statistics for the behavioral sciences. McGraw-Hill Book Co., Inc. Toronto, 312 pp.

Slatt, R.M. 1972. Texture and composition of till derived from parent rock of contrasting textures: southeastern Newfoundland. Sediment. Geol. 7:283-290.

Smidt, E. 1951. Animal production in the Danish Waddensea. Meddr. Kommn. Danm.-og. Havundersogelser, Ser. Fish. 11(6): 1-1511.

Snow, D. MS 1972. The life history of a population of *Nereis virens* in St. Andrews, New Brunswick. M.Sc. Thesis, McGill Univ. 155 pp.

South, G.R. 1970. Checklist of marine algae from Newfoundland and the French Islands of St. Pierre and Miquelon. Tech. Rept. Mar. Sci. Res. Lab. No. 2.

Steele, J.H. 1968. Interrelations by a young plaice population with its invertebrate food supply. *In*: Animal Populations and their Food Supply: 375-387.

Stephenson, T.A. and Stephenson, A. 1972. *Life between Tidemarks on Rocky Shores*. W.H. Freeman and Co. San Francisco. 425 pp.

Stickney, R.P. 1964. Ecology of the Sheepscot River. U.S. Dept. Int. Fish Wildl. Serv. Spec. Sci. Rept.-(Fisheries) No.309: 1-21.

Stickney, R.R. and White, D.B. 1973. Flounder-A potential Aqua-culture Crop. Sea Frontiers 19(5):270-276.

Storer, T.I. and Usinger, R.L. 1965. *General Zoology* (4th ed.) McGraw-Hill Book Co. New York. 741 pp.

Strickland, J.D.H. and Parsons, T.R. 1972. A Practical Handbook of Sea Water Analysis (2nd ed.). Fish.Res.Bd. Can. Bull. 167:1-310.

Sverdrup, H.U., Johnson, M.W. and Fleming, R.H. 1961. *The Oceans: their Physics, Chemistry and General Biology*. Prentice Hall Inc. Englewood Cliffs, N.J. 1087 pp.

Taylor, W.R. 1957. *Marine Algae of the Northeastern Coast of North America*. (2nd.ed.). Univ. Mich. Stud., Sci. Ser. 13, Univ. Mich. Press. Ann Arbor. 509 pp.

Thomas, M.L.H. MS 1970. Studies on the benthos of Bideford River estuary, Prince Edward Island. Ph.D. Thesis. Dalhousie Univ. Halifax, N.S. 364 pp.

Trites, R.W. 1973. *Effects of elemental phosphorus on marine life: Collected papers resulting from the 1969 pollution crisis, Placentia Bay*, Nfld. Fish.Res. Bd. Can. Circ. 2:1-313.

Twenhofel, W.H. 1939. *Priciples of Sedimentation*. McGraw-Hill Book Co., Inc. New York. 610 pp.

Tyler, A.V. 1971. Surges of winter flounder, *Pseudopleuronectes americanus* into the intertidal zone. J. Fish. Res. Bd. Can. 28:1727-1732.

__________. MS 1968. Food resource division in a community of marine fishes. Ph.D. Thesis, Univ. of Toronto, Toronto, Ont. 78 pp.

__________. 1973. Caloric values of some North Atlantic invertebrates. Mar. Biol. 19:258-261

Verheijen, F.J. and De Groot, S.J. 1967. Diurnal activity patterns of plaice and flounder (Pleuronectidae) in aquaria. Neth.J. Sea Res. 3(3):383-390.

Welch, R.S. 1948. Limnological Methods. The Blakiston Co., Toronto, 381 pp.

Wells, B.F. Steele, D.H. and Tyler, A.V. 1973. Intertidal feeding of winter flounders, *Pseudopleuronectes americanus* in the Bay of Fundy. J. Fish. Res. Bd. Can. 30(9):1374-1378.

Wilce, R.T. 1959. The marine algae of the Labrador Peninsula and northwest Newfoundland (Ecology and Distribution). Nat. Mus. Can. Bull. 158, Biol. Ser. 56:1-103.

Williams, G.C. 1957. Homing behavior of California rocky shore fishes. Univ. California Rubl. Zool. 59:249-254.

Young, D.K. and Rhoades, D.C. 1971. Animal-sediment relations in Cape Cod Bay: a transect study. J.Mar. Biol. 11(3):242-254.

Appendix 1

General Aspects of Geology of Study Sites in Newfoundland and New Brunswick

Long Pond

As a shallow harbour located on the southwest coast of Conception Bay, Long Pond may be defined as a lagoon as it is a semi-closed body of water connected with the sea by a narrow channel (Muus, 1967) and its freshwater supply is minimal and salinity constant.

Lying in a coastal belt of low rolling terrain the harbour was formerly a barachois pond with brackish water like those of Broad Cove, Topsail, Chamberlains, Manuels, Seal Cove, and Lance Cove. However, since 1965, the pond has become a saltwater lagoon after dyking and dredging operations opened it to Conception Bay. It is dredged regularly so that oil and talc freighters can use the pier near the seaward channel.

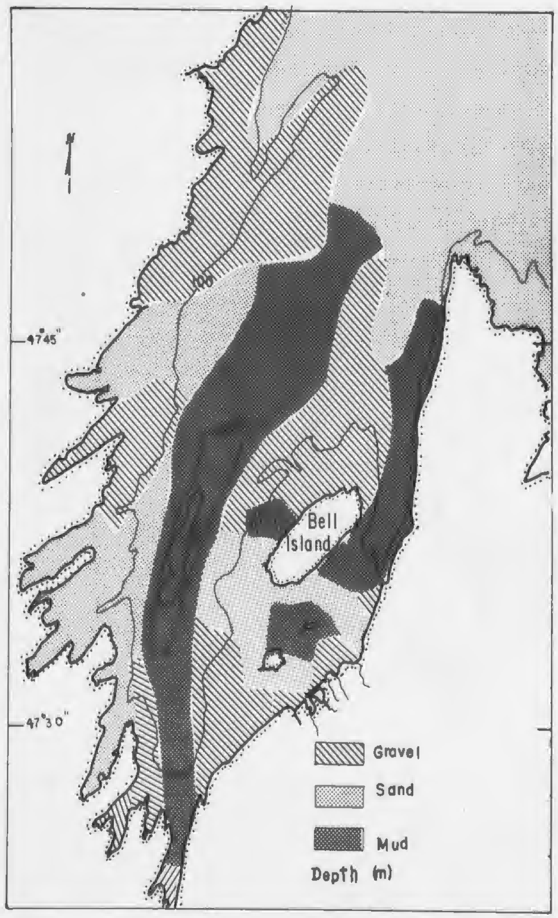
The coastal plain, alluded to above, is covered by glacial drift and deposits (Henderson, 1960). As a lagoon, the pond acts as a depositional basin for accumulation of sand and finer materials (mud) which wash down from surrounding land. The barachois beach at the distant end of the pond is composed of pebble and cobble with smaller fractions of other deposits such as sand. Its sand content varies between summer and winter, depending upon the severity of weather conditions and wave action. The pebble and cobble are derived from the reworking of glacial drift in the surrounding area of each bar by waves and currents (Brückner, 1969).

Conception Bay

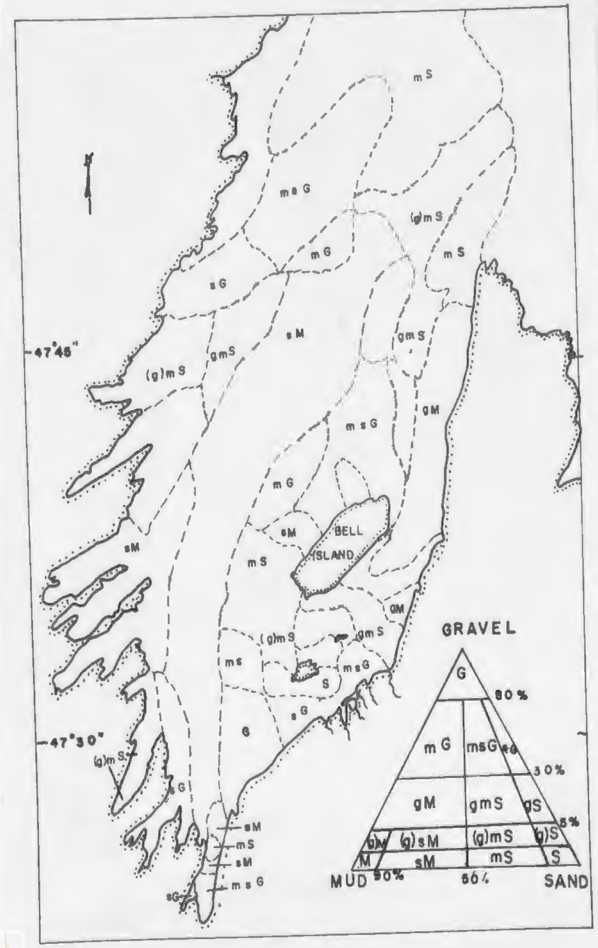
Soil texture and depth contours of this bay appear in Fig. 25. A deep mud trench in the center of the bay is bordered by fields of sand or cobble. The fields vary in size and depth due to the slope of bedrock and distribution of currents in each area. They form small to moderately large shoal grounds extending in parallel north-south direction on both the southeast and northwest ends of the bay.

The southeast ground extends from approximately Seal Cove northward to the 120 ft. contour and encircles Bell Island. The northwest ground extends from Feather Point east to the 200 ft. contour. It then broadens northward to the projecting 100 ft. contour in the head of the bay. The areas used for the sampling of winter flounder stomachs were located on gravelly sand with a slope of 1:10 (Map 4285, Canadian Hydrographic Service). Sediment taken at Station 79 were found to be typical of that found in the winter flounder sampling area. The bulk minerology consisted of feldspar and quartz, with clay made of mica and chlorite. No gravel was found, but soil consisted of sand, silt, and clay in a ratio of 75.1:20.9:4.0. Calcium carbonate was present as 1% and only as shell fragments. Both organic carbon and inorganic phosphorus were low. Of sixteen compounds and elements determined, five were important in gross composition and were: SiO_2=74%, Al_2O_3=12%, FeO=2.5%, Na_2O=2.9% and K_2O=2.3%.

Figure 25. Soil texture (A) and sediment fields (B) of Conception Bay and adjacent shoreline to Long Pond.



Bell Island
100
47°45"
47°30"
Gravel
Sand
Mud
Depth (m)



BELL ISLAND
47°45"
47°30"
GRAVEL
MUD
SAND
G
mG
msG
gM
gmS
gS
(g)sM
(g)mS
(g)S
M
sM
mS
S

St. Andrews

The rocks of St. Andrews are part of the Perry Group, which, unlike those that have undergone severe deformation and uplifting on the eastern shore of Passamaquoddy Bay, have undergone little transformation or metamorphosis. This group is made of shales, conglomerate, and siltstone, which are coarse, red to reddish-brown, and include gray strata with Devonian plant remains. Along the shoreline of the peninsula, dykes and sills are present and contain amygdaloid diabase. Known as "black granite", diabase is fine textured, dark in colour, and resembles basalt due to its igneous composition. Hard, tough and commonly used as crushed rock, it is widespread in occurrence. It consists of oxides of silicon, aluminum, iron, magnesium, and calcium in the following proportions by per cent weight: 50.5%, 15.4%, 7.9%, 5.8%, and 8.9%. This is based on average chemical analysis. These levels are in contrast to sediments of Conception Bay which contain silicon almost totally and only trace amounts of other elements. Sediments of St. Andrews contain nearly 24% less silicon, but much higher amounts of iron, magnesium, calcium, and lime. Lime, indicative of shallow water deposits, was 13 times more concentrated.

The beaches of the cove contain much red conglomerate and sandstone which erode continuously to form sandy, pebbly substrata of coarse texture. Brandy Cove, Navy Island, and Joe's Point consist of this composition. Cobble occurs at the south end and bedrock along the north shore in the cove.

Gritty, sandstone ledges surround the government wharf and foundation of the Biological Station. These occur in step fashion from the high intertidal to low subtidal. They end in the low subtidal and grade to muddy gravel laying over bedrock outcrops.

The intertidal zone extends from 1-7 meters on normal low tide and 8 meters on spring tides. Two ledges at the center and north side of the cove which are submerged at high water and exposed at low water, border this tide mark.

Sediments-Long Pond

Sediments of the western basin, the area under study, changed from a mud and sand bottom to a shore fringe of shale, and small rocks intertidally. Beyond this, glacial boulders are strewn to the edge of surrounding grasslands. Diving observations revealed that sediment distribution, amount of organic matter, and benthos were similar to those in the eastern basin (Christie, 1966). The channel between the two arms of the pond consisted of sand in a deeper trough with cleaner cobble along the edges of the shallow subtidal and intertidal zones. Soil and substrata in the channel had only small amounts of organic matter. In the western basin, sediments from the head to the center of the pond consisted of organic muds 1.6-2.2 m thick which graded into sandy mud in the shallow seaward end and dredged basin. From the baseline of the dredged basin to the shipping channel mud content appeared to diminish progressively, leaving higher proportions of sand. Colour of the sediment also changed along the length of the pond from the shallow to the deep end; where dredging has removed upper layers of soil and benthos. Silt and mud content appeared to be rather high in areas where Zostera marina grow in bands parallel to the shore and had root systems capable of accumulating sediment. Christie (1966) found that mud in the south arm and along the east shoreline of the eastern basin contained between 20 and 25% organic matter. Distribution of mud in the western basin was like that in the eastern basin. The exception was a small cove in the southwest corner of the study site which also had mud.

Sediments-Brandy Cove

Sediments from the benthos samples of transects T1 and T2 were analyzed to gain insight into possible effects of particle size on the benthos distribution in Brandy Cove. Samples from the higher intertidal zone were only approximate for stones and pebbles retained by the 8 mm sieve were removed during the sieving process. Equal amounts of soil from the 8, 4, 1, and 0.5 mm sieves and that passing through the 0.5 mm sieve were used to determine the per cent dry weight of each fraction, according to Shepard's (1954) system of nomenclature. Sediment samples were processed through courtesy of the Geology Department of this university. The central section of the beach and shallow subtidal was composed of sandy gravel. Mud was nearly absent. Sixty-three per cent of the intertidal samples had no mud or only traces (1 g.). Subtidally, mud occurred in more samples (60%) yet in small proportions ($\bar{X}$=2.47%/sample). Above mean low water, sandy gravel predominated in the higher intertidal stations 1-9. These were located in a region of cobble rock and sandstone ledges which leveled out to the mid-intertidal and lower intertidal where a sand flat stretched to LWN. Four of these five samples were situated adjacent to or within the freshwater efflux of Brandy Cove Brook. Nereis virens and G. oceanicus were abundant at stations 1 and 3. Subsurface rocks and debris found at these locations were absent at #5 where the proportion of sand increased and pebbles predominated. Gastropoda were numerous but the majority of individuals and 86% of the species were represented by dead or empty shells.

The remaining intertidal stations crossed a sand flat. Sand composition increased from 79% at #9 to 100% at #21. Station #9 contained no rock but some pebbles which were compacted below the surface. Coarse sand was observed over most of the tidal flat. This agrees with analyses made by Rowe (1970) on sediments of the mid-intertidal zone. Grain sizes at the south end of the beach ranged from 420 u to 710 u and fell into the coarse (500-1000 u) and medium (250-500 u) particle size classes.

Subtidally, grain sizes varied unevenly with depth showing a gradual decrease like that on the beach (Rowe, 1970), but they are not smaller than those in the intertidal zone.

Morphometry of Long Pond

The western basin is divided into an elongated, shallow mud flat and a deeper dredged basin. Mean width of the pond was 270 m while maximum length and width were 730 m and 317 m respectively (Chart 4285, Canadian Hydrographic Service). The larger part of the basin extended seaward from a broadened, island studied channel leading from Conway Brook.

The effect of stream influent on salinity was determined by estimation of freshwater drainage. Volume run-off was calculated as a percentage of that flowing from Broad Cove Brook, St. Philips. Stream flow data were available for this brook closest to Conway Brook. The comparison was based on proportional watershed areas of the two systems (Water Survey of Canada). Area of Conway Brook was 15.71 km^2 or 93% of Broad Cove Brook, producing an average daily volume of 2.04 m^3/sec in 1972. Maximum drainage occurred on November 12, 1972 when 25.03 m^3/sec flowed from the brook; or 12.4 times daily mean flow. Average daily discharge was small during the winter when the brook froze and in mid-summer when evaporation significantly decreased its flow. During these times, the flow exerted negligible dilution on salinity beyond the island studded channel.

Intertidal volume, area, and total volumes at mean high and low water were found by planimeter measurements of depth contours inside the pond. The number of tidal cycles needed to replace part or all of the system and thus possible effects of tide on currents could then be considered. Total area of the western basin was estimated to be 0.184 km^2. Volumes at mean high and low water were 256,389.9 m^3 and 115,236 m^3 respectively. This difference produced a tidal prism of

141,154 m^3 or 55% of high tide volume. Thus fewer than two tidal cycles were needed to flush a volume greater than or equal to its own and indicated that the basin drained its volume at least daily. The effect on currents by this amount of flushing was evident. The funnelling action of water entering from Conception Bay and its siphoning into the channel toward the east basin produced strong currents at certain stages of the tide.

Appendix 2

General list of biota known to occur in Long Pond, Newfoundland. Suffixed numbers indicate source of record numbered as follows: 1 = Christie (MS 1966), 2 = Kennedy (MS 1964), 3 = Acreman (MS 1964, 4 = Christie + Kennedy, 5 = the present study.

Coelenterata
Hydrozoa

Campanularia sp. 2

Nemertea
Cehpalothrix linearis 1

Mollusca
Amphineura

Ischnochitin ruber 2

Gastropoda

Acmaea testudinalis 4
Littorina littorea 4
Hydrobia minuta 2
Narsarrius trivittatus 5
Littorina saxatilis 5
Lacuna vincta 2
Buccinum undatum 2
Lunatia (heros) 2
Puncturella noachina 2
Lacuna pallidula neritoidea 2
Margarites helicinus 2
Nudibranchiata 2

Pelecypoda

Crenella faba 4
Mytilus edulis 4
Solemya borealis 5
Anomia simplex 1
Anomia aculeata 1
Macoma balthica 4
Hiatella arctica 4
Mya arenaria 4
Volsella modiolus 5
Cerastoderma pinnatulum 2
Mya truncata 2
Serripes groenlandicus 2
Clinocardium ciliatum 2

Annelida
Polychaeta

Lepidonotus squamatus 1
Harmothoe imbricata 1
Harmothoe extenuata 1
Scoloplos armiger 4,5
Scoloplos acutus 5
Pygospio elegans 1
Eteone heteropoda 1
Eteone longa 4
Eulalia viridis 4
Phyllodoce mucosa 4
Euchone elegans 1
Polycirrus phosphoreus 1
Cistenides gouldii 4
Nereis virens 4
Nereis pelagica 4
Nephtys caeca 1
Polydora (gracilis?) 2
Arenicola marina 2
Pholoe minuta 1
Phyllodoce maculata 5
Polydora websteri 5
Lumbrineris fragilis 5
Amphitrite sp.
Sabellidae 2
Cirratulidae 2
Maldanidae 2

Arthropoda
Crustacea

Cyclopoida 5
Harpacticoidea 2
Cirripedia
Balanus balanoides 4

Cumacea
Diastylis rugosa 1

Amphipoda
Lamprops fuscata 1
Phoxocephalus holbolli 1
Gammarus lawrencianus 1
Photis reinhardti 1
Ischyocerus anguipes 1
Dexamine spinosa 1
Monoculodes tuberculatus 1
Corophium bonelli 1
Caprella septentrionalis 4
Calliopius laevisculus 5
Leptocheirus pinguis 5

Decapoda

<u>Crangon septemspinosus</u> 1
<u>Cancer irroratus</u> 2
<u>Pagurus acadianus</u> 2

Insecta
<u>Cricotopus</u> sp. 2,5

Echinodermata
Asteroidea

<u>Asterias forbesi</u> 1
<u>Asterias vulgaris</u> 2

Echinoidea

<u>Echinarachnius parma</u> 2
<u>Strongylocentrotus droebachiensis</u> 3,4

Ophiuroidea
<u>Amphipholus squamatus</u> 5

Amphiuridae 2

Flora
=====

Cyanophyta
Cyanophyceae

<u>Schizothrix</u> sp. 5

Chlorophyta
Chlorophyceae

<u>Monostroma</u> sp. 5
<u>Ulva lactuca</u> 5
<u>Acrosiphonia arcta</u> 5
<u>Enteromorpha</u> sp. 5

Phaeophyta
Phaeophyceae

<u>Laminaria</u> sp. 5
<u>Desmarestia viridis</u> 5
<u>Sphacelaria</u> sp. 5
<u>Ectocarpus siliculosus</u> 5
<u>Dictyosiphon foeniculaceus</u> 5
<u>Pilayella littoralis</u> 5
<u>Polysiphonia flexicaulis</u> 5

Spermatophyta
Angiospermae
<u>Zostera marina</u> 1
<u>Scirpus ameriacanus</u> 1

Appendix 3

List of fauna known to occur in Conception Bay, Newfoundland. List is abbreviated and general in nature.

Coelenterata

Metridium dianthus
Obelia geniculata
Halocynthia pyriformis

Nemertea
Cephalothrix linearis

Mollusca
Gastropoda

Puncturella noachina
Acmaea testudinalis
Margarites helicinus
Lacuna pallidula neritoidea
Littorina littorea
Littorina obtusata
Littorina saxatilis
Hydrobia minuta
Natica clausa
Polinices heros
Buccinum undatum
Nassarius trivittatus
Thais lapillus
Veluntina laevigita

Pelecypoda

Solemya borealis
Hiatella arctica
Mytilus edulis
Mya arenaria
Volsella modiolus
Crenella glandula
Macoma balthica
Placopecten magellanicus
Anomia simplex
Anomia aculeata
Sispula polynyma
Zirfaea crispata
Clinocardium ciliatum

Annelida
Polychaeta

Phyllodoce maculata
Phyllodoce mucosa
Eteone longa
Eteone trilineata
Eteone heteropoda
Eulalia viridis
Lepidonotus squamatus
Harmothoe extenuata
Harmothoe imbricata
Nereis virens
Nereis pelagica
Amphitrite affinis
Polycirrus eximus
Cistenides gouldii
Fabricia sabella
Eusyllis tubifex
Arenicola marina
Ophelia radiata
Scoloplos armiger
Myxicola infundibulum
Spirorbis borealis
Nephtys caeca
Euchone elegans
Pholoe minuta
Syllis gracilis
Lumbrineris fragilis
Glycera capitata
Pherusa plumosa
Clymenella torquata
Aricidea suecica
Pygospio elegans
Cirratulus cirratus
Dodecaceria concharum
Cirratulidae
Sabellidae
Spionidae

Arthropoda

Crustacea

Cyclopoida
Cirripedia

Balanus balanoides

Cumacea
Diastylis rugosa
macrocuma

Isopoda
Edotea montosa
Idotea balthica
Jaera albifrons

Amphipoda

Jaera ischiosetosa
Phoxocephalus holbolli
Amphiporeia lawrenciana
Amphithoe rubricata
Calliopius laeviusculus
Unciola irrotata

Monoculodes tuberculatus
Gammarellus angulosus
Corophium bonelli
Hyale nilsonni
Gammarus oceanicus
Gammarus lawrencianus
Gammarus obtusata
Gammarus setosus
Gammarus duebeni
Caprella monocera
Jassa falcata
Ischyocerus anguipes
Orchestia platensis
Hippolytidae
Stegocephalidae

Decapoda

Pandalus montaguii
Pagurus acadianus
Carcinus maenas
Cancer irroratus
Hyas araneus
Homarus americanus

Echinodermata
Holothuroidea

Psolus fabricii
Cucumaria frondosa
Chirodotea laevis

Echinoidea

Strongylocentrotus droebachiensis
Echinarachnius parma

Asteroidea

Asterias vulgaris
Henricia sanguinolenta
Crossaster papossus
Solaster endeca
Leptasterias polaris

Ophiuroidea

Ophiura robusta
Ophiopholis aculeata

Chordata
Pisces

Chondrichthyes
Raja radiata
Raja ocellata
Myoxocephalus scorpius
Myoxocephalus octodecimspinosus
Pseudopleuronectes americanus
Stichaeus punctatus
Ulvaria subbifurcata
Pholis gunnellus
Macrozoarces americanus
Anarhinchas lumpus

Appendix 4.

Station Depth (m)	Station Number	Numbers of Individuals per .0225 m^2	Numbers of Species per .0225 m^2
Transect T-1			
4.3	1	190	7
5.0	3	37	7
5.3	5	563	9
5.6	7	42	4
5.6	9	27	5
5.6	11	49	9
5.6	13	2	2
5.9	15	8	1
5.9	17	7	3
5.9	19	20	4
6.5	21	67	14
6.5	23	17	6
6.8	25	26	7
6.8	27	20	7
7.1	29	10	4
7.4	31	7	5
7.4	33	7	3
7.8	35	27	9
8.1	37	18	6
8.4	39	29	7
8.7	41	29	7
		1202	

Station Number	Numbers of Individuals per .0225 m^2	Numbers of Species per .0225 m^2
Transect T-2		
10	50	6
8	62	8
6	65	4
4	72	5
2	30	3
	279	

Appendix 4. Numbers of Individuals and Species found on two transects of Brandy Cove, New Brunswick. Numbers are for a 3375 cm^3 Ekman Dredge.

Appendix 5

List of fauna known to occur at BrandyCove, N.B.

Porifera

Halichondria panicea
Cliona celata
Polymastia robusta

Coelenterata
Hydrozoa

Sertularia pumila
Clava squamata
Laomedea dichotoma
Laomedea longissima
Campanulina lacerata
Tubularia larynx
Bougainvillia superciliaris

Scyophozoa
Obelia sp.
Aurelia aurita
Haliclystus sp.
Lucernaria sp.
Sarsia tubulosa
Rhizogeton fusiformia

Anthozoa

Duva multiflora
Opercularia lacerata

Platyhelminthes

Notoplana sp.

Nemertea

Micrura sp.

Ectoprocta

Bugula sp.
Cryptosula sp.
Sachizoporella sp.

Brachiopoda

Terebratulina sp.

Mollusca
Amphineura

Tonicella marmarea
Ischnochitin ruber

Gastropoda

Buccinum undatum
Colus stimpsoni
Littorina littorea
Littorina saxatilis
Littorina obtusata
Lunatia triserata
Lunatia heros
Lora sp.
Neptunea decemcostata
Thais lapillus
Cingula aculeus
Hydrobia minuta
Lacuna vincta
Dendronotus frondosus
Acanthodoris pilosa
Acmaea testudinalis

Pelecypoda

Nucula tenuis
Mya arenaria
Yoldia sapotilla
Mytilus edulis
Nucula proxima
Macoma balthica
Cerastoderma pinnatulum
Solemya borealis
Anomia aculeata
Zirfaea crispata
Placopecten magellicanus
Nuculana sp.
Volsella modiolus

Annelida
Polychaeta

Nereis virens
Nephtys incisa
Clymenella torquata
Polydora sp.
Eteone longa
Glycera capitata
Lumbrineris fragilis
Eteone lactea
Terebelloides stroemi

Cistenides gouldii
Pygospio elegans
Harmothoe imbricata
Naineruis sp.
Eulalia sp
Tharyx acuta
Scoloplos armiger
Praxillella gracilis
Praxillella praetermissa
Glycera americana
Ammotrypane aulogaster
Ninoe nigripes
Cirratulus cirratus
Spirorbis spiralis
Lepidonotus squamatus
Aphrodite aculeata

Arthropoda
Copepoda

Oithona sp.
Calanus sp.

Cirripedia

Balanus balanoides

Mysidacea

Mysis stenolepis
Praunus flexuosus
Neomysis americanus

Cumacea

Diastylis sculpta
Diastylis quadrispinosus
Oxyurostylis smithi
Lamprops quadriplicata

Isopoda

Jaera albifrons
Chiridotea caeca
Edotea montosa
Eurdorella truncata

Amphipoda

Lipinia emarginata
Gammarus obtusatus
Leptocheirus pinguis
Pontoporeia femorata
Casco bigelowi
Amphithoe rubricata
Corophium voluntator
Gammarus lawrencianus
Dexamine spinosa
Ampelisca sinipes
Monoculodes tesselatus
Maera danae
Melita dentata
Caprella linearis
Lafystius sturionis
Stenopleustes gracilis
Anonyx nugax
Syrrhoe crenulata
Phoxocephalus holbolli
Unciola irrorata
Photidae

Euphausiacea
Meganyctiphanes norvegica

Decapoda

Spirontocaris spinosus
Pagurus acadianus
Cancer irroratus
Homarus americanus

Insecta
Cricotopus (variabilis?)

Echinodermata
Asteroidea

Asterias vulgaris
Asterias forbesi
Crossaster papossus
Solaster endeca

Ophiuroidea

Amphipholis squamatus
Ophiura robusta
Gorgoncephalus arctica

Echinoidea

Strongylocentrotus droebachiensis

Holothuroidea

Cucumaria frondosa

Chordata -
Urochordata

<u>Molgula manhattensis</u>
<u>Halocynthia pyriformis</u>
<u>Boltenia ovifera</u>
<u>Didemnum albidum</u>

Appendix 6

General list of algae known to occur at Brandy Cove, N.B. (1965-72)

Zone A (High Intertidal zone)	General Location
Rivularia atra	-in irregular band at top of zone
Enteromorpha micrococca	-below Rivularia and with Fucus spp.
Fucus spiralis	-mixed in with E. miccrococca
Ulothrix flacca	-high intertidal in early spring,
Cladophora sericea	in pools, upper interttidal
Ralfsia verrucosa	
Dumontia incrassata	
Hildenbrandia prototypus	
Porphyra minuta	
Lithothamneae	

Zone B (Mid-intertidal zone)	
Fucus vesiculosus	-throughout intertidal
Ascophyllum nodosum	-dominates F.vesiculosus in middle
Enteromorpha linza	of zone
Enteromorpha intestinalis	-growing in certain freshwater streams
Enteromorpha prolifera	" " " " "
Gomontia polyrhiza	" " " " "
Elachistea fusciola	" " " " "
Pilayella littoralis	" " " " "
Choreocolax polysiphonia	" " " " "
Polysiphonia lanosa	" " " " "
Ulva sp.	

Zone C (Low intertidal zone)

Monostroma grecillei
Petalonia fascia
Scytosiphon lomentaria
Ceramium rubrum
Achrochaetium sp.
Chondrus crispus
Gigartina stellata
Rhizoclonium tortuosum
Bangia fuscopurpurea
Spongomorpha arcta
Phycodrus rubens
Chorda tomentosa
Ulothrix (flacca)
Polysiphonia unceolata
Rhodymenia palmata
Diatomacea

Subtidal Zone D

Agarum cibrosum
Desmarestia viridis
Phycodrys rubens
Plumaria elegans
Lithothamneae

Type tide	Date 1972	Depth span (feet)	Tidal phase	St. John's expected	Hourly span Hr.	Min.	Long Pond expected	Long Pond observed	Hourly span Hr.	Min.	Depth span (feet)	Holyrood expected
Neap	1.11	1.9-3.7 (1.8)	Flood	1015-1635	6	20	1029-1649	1015-1700	6	45	2.8-5.1 (2.3)	1043-1703
Neap	2.11	1.7-3.8 (1.7)	Flood	1115-1725	6	10	1129-1739	1100-1735	6	35	2.7-4.9 (2.2)	1143-1753
Neap	8.11	4.9-1.5 (3.4)	Ebb	0815-1450	6	35	0829-1504	0850-1535	6	45	6.1-2.4 (3.7)	0843-1518
Spring	22.11	5.2-.6 (4.6)	Ebb	0805-1440	6	35	0819-1454	0824-1425	6	00	7.4-2.4 (5.0)	0833-1508
Spring	23.11	.8-4.0 (3.2)	Flood	1525-2115	5	50	1539-2129	1525-2125	6	05	1.9-6.9 (5.0)	1553-2143

Appendix 7 Comparison of tide levels and hours of tidal cycles for three Newfoundland ports.

Fullness Index	APRIL CBD	APRIL LPS	MAY CBD	MAY LPS	JUNE CBD	JUNE LPS	JULY CBD	JULY LPS	AUGUST CBD	AUGUST LPS	SEPTEMBER CBD	SEPTEMBER LPS	OCTOBER CBD	OCTOBER LPS
	%	%	%	%	%	%	%	%	%	%	%	%	%	%
4 (100%)	33(5)	31(11)	44(13)	31(4)	13(3)	- -	13(1)	47(7)	14(2)	14(5)	55(6)	32(7)	19(3)	10(2)
3 (75%)	40(6)	24(8)	10(3)	15(2)	- -	9(1)	25(2)	33(5)	7(1)	19(7)	18(2)	14(3)	- -	5(1)
2 (50%)	- -	3(1)	17(5)	15(2)	8(1)	27(3)	25(2)	- -	29(4)	11(4)	9(1)	14(3)	39(3)	33(7)
1 (25%)	13(2)	21(7)	14(4)	8(1)	15(2)	9(1)	13(1)	7(1)	14(2)	19(7)	- -	9(2)	19(3)	10(2)
0 (0%)	13(2)	21(7)	14(4)	31(4)	54(7)	55(6)	25(2)	13(2)	36(5)	36(13)	18(2)	32(7)	43(7)	43(9)

Appendix 8 Percentages of monthly samples of winter flounder with feeding indices 0-100%. CBD= Conception Bay Deeper Ground. LPS= Long Pond, Shallower Ground. Actual frequencies in brackets.

Appendix 9.

Monthly stomach lists of prey consumed by Long Pond and Bay flounder.

APRIL PREY LIST (NFLD.)

Long Pond

Species Name	Wet Weight	% Wet Weight	Frequency Occurrence	% Frequency Occurrence	Number Prey Items
Nereis virens	5.2493	12.80	9	26	15
Nereis pelagica	5.0513	12.30	6	18	7
Enteromorpha sp.	4.0579	9.90	1	3	-
Desmarestia viridis	1.7859	4.40	3	9	-
Mytilus edulis	1.1308	2.80	4	12	12
Mya truncata	.9621	2.30	1	3	2
Nereis sp.	.9450	2.30	2	6	2
Ulva lactuca	.5660	1.40	1	3	-
Cistenides gouldii	.5601	1.40	4	12	4
Mya arenaria	.4805	1.20	5	15	7
Pseudopleuronectes americanus (eggs)	.3856	.94	1	3	-
Cerastoderma pinnatulum	.2360	.59	1	3	2
Sphacelaria sp.	.1621	.39	2	6	-
Macoma balthica	.1319	.32	2	6	3
Ectocarpus siliculosus	.1120	.27	1	3	-
Phyllodoce maculata	.0892	.22	5	15	7
Lacuna vincta	.0821	.20	3	9	17
Harmothoe imbricata	.0820	.20	2	6	2
Polychaeta	.0728	.17	1	3	3
Oligochaeta	.0645	.16	1	3	1
Polydora websteri	.0606	.15	7	21	13
Calliopius laeviusculus	.0521	.12	1	3	1
Monostroma sp.	.0511	.12	1	3	-
Solemya borealis	.0489	.12	1	3	1
Eteone sp.	.0371	.10	6	18	8
Scoloplos armiger	.0293	.07	2	6	2
Hydrobia minuta	.0282	.07	5	15	10
Eteone longa	.0278	.07	2	6	2
Schizothrix sp.	.0272	.07	1	3	-
Littorina littorea	.0227	.06	1	3	1
Ischnochitin ruber	.0224	.05	1	3	1
Diastylis rugosa	.0161	.05	1	3	1
Margarites helicinus	.0101	.03	1	3	1
Pygospio elegans	.0026	.01	1	3	9
Leptocheirus pinguis	.0005	.001	1	3	1
Acmaea testudinalis	.0005	.001	1	3	1
Cyclops sp.	.0003	.001	3	9	33
Debris	9.8251	23.90	11	32	-

MAY PREY LIST FOR CONCEPTION BAY

Species Name	Weight (g)	% Wet Weight	Frequency Occurrence	% Frequency	Frequency
Strongylocentrotus dröebachiensis	83.6430	59.29	2	6.8	9
Nereis pelagica	31.1583	22.09	5	17.2	21
Acmaea testudinalis	10.5360	7.47	9	31.0	97
Ischnochitin ruber	4.0425	2.87	6	20.7	38
Desmarestia [illegible]	3.6849	2.61	5	17.2	–
Nereis virens	2.5791	1.79	2	6.8	2
Nereis sp.	1.0211	.72	2	6.8	2
Schizothrix sp	.8284	.59	1	3.4	–
Cladophora sp.	.5061	.36	1	3.4	–
Cistenides gouldii	.3557	.25	3	10.3	4
Dictyosiphon	.2277	.16	1	3.4	
Hiatella arctica	.2061	.15	1	3.4	1
Sabellidae	.1630	.12	1	3.4	1
[illegible] pilularis	.1538	.11	1	3.4	4
Macoma balthica	.1411	.10	4	13.8	5
P. americanus (eggs)	.1338	.09	1	3.4	–
Cyclops sp.	.1080	.08	3	10.3	175
Littorina littorea	.1006	.07	1	3.4	1
Cancer irroratus	.0522	.04	1	3.4	1
Ophiura robusta	.0231	.02	1	3.4	3
Monoculodes sp.	.0131	.01	2	6.8	13
(Sari..)	.0121	.01	1	3.4	1
Mytilus edulis	.0067	.004	1	3.4	1
Hydrobia minuta	.0056	.004	3	10.3	3
[illegible] holbollii	.0050	.004	4	13.8	8
Eteone longa	.0040	.003	1	3.4	1
Phyllodoce maculata	.0021	.001	1	3.4	1
Corophium bonelli	.0019	.0013	1	3.4	1
Diastylis rugosa	.0009	.001	2	6.8	6
[illegible]halidae	.0001	.0001	1	3.4	1
Pholoe minuta	.0001	.0001	1	3.4	1
Photidae	.0001	.0001	1	3.4	1
Debris	1.4069	1.00	2	6.8	–

MAY PREY LIST FOR LONG POND-MANUELS

Nereis virens	2.3539	20.89	2	15.4	4
[illegible] fragilis	1.5339	13.61	1	7.7	1
P. americansus (eggs)	1.4970	8.43	1	7.7	–
Amphitrite sp.	.9499	5.12	1	7.7	1
Nereis sp.	.5755	3.35	1	7.7	1
Mytilus edulis	.3773	2.64	3	23.1	3
Nereis pelagica	.2977	2.03	1	7.7	6
Littorina obtusata	.2288	1.13	1	7.7	2
[illegible] siliculosus	.1272		1	7.7	1
Lacuna vincta	.1035	.92	1	7.7	2
Dictyosiphon foeniculaceus	.0933	.83	–		1
Hydrobia minuta	.0375	.33	2	15.4	3
Margarites helicinus	.0270	.24	1	7.7	1
Macoma balthica	.0143	.13	1	7.7	1
Phyllodocidae	.0105	.09	1	7.7	1
Corophium bonelli	.0030	.03	1	7.7	1
Eteone sp.	.0019	.01	1	7.7	1
Gammaridea	.0012	.01	1	7.7	1
Algae [illegible]	.0932	.83	1	7.7	–
Debris	2.9430	26.11	3	23.1	–

JUNE PREY LIST FOR NFLD.

Conception Bay

Species Name	Wet Weight (g)	% Wet Weight	Frequency Occurrence	% Frequency Occurrence	Number Prey Items
Nereis sp.	1.3330	34.52	1	7.7	1
Desmarestia viridis	.8624	22.34	1	7.7	1
Ischnochiton ruber	.3647	9.75	2	15.4	2
Pilayella littoralis	.2549	6.60	1	7.7	-
Cistenides gouldii	.0820	2.12	1	7.7	1
Amphipholis squamata	.0793	2.05	2	15.4	2
Strongylocentrotus droebachiensis	.0755	1.93	1	7.7	1
Syllis gracilis	.0691	1.79	1	7.7	1
Cerastoderma pinnulatum	.0351	.93	3	23.1	5
Unciola irroratus	.0271	.70	3	23.1	8
Polysiphonia flexicaulis	.0250	.65	1	7.7	-
Hiatella arctica	.0235	.61	3	23.1	3
Harmothoe imbricata	.0221	.55	2	15.4	2
Ophiura robusta	.0150	.39	1	7.7	1
Asterias sp.(forbesii?)	.0119	.32	1	7.7	1
Lepidonotus squamatus	.0114	.30	1	7.7	1
Acmaea testudinalis	.0101	.26	1	7.7	1
Phoxocephalus holbolli	.0083	.21	2	15.4	4
Polynoidae	.0080	.21	1	7.7	1
Eulalia viridis	.0035	.09	1	7.7	3
Macoma balthica	.0025	.06	1	7.7	4
Lumbrineris fragilis	.0009	.02	1	7.7	1
Corophium bonelli	.0009	.02	1	7.7	5
Amphipoda	.0006	.01	1	7.7	1
Cyclops sp.	.0001	.002	1	7.7	1
Ectocarpus siliculosus	.0001	.002	1	7.7	-
Debris	.5280	13.67	2	15.4	-

Long Pond

Species Name	Wet Weight (g)	% Wet Weight	Frequency Occurrence	% Frequency Occurrence	Number Prey Items
Dictyosiphon foeniculaceus	.7094	32.30	1	9.1	
Ectocarpus siliculosus	.2248	10.24	2	18.2	-
Nereis virens	.2099	9.57	2	18.2	2
Nereis sp.	.1718	7.83	2	18.2	2
Enteromorpha sp.	.0480	2.19	1	9.1	-
Acrosiphonia arcta	.0471	2.14	1	9.1	-
Hiatella arctica	.0285	1.30	1	9.1	1
Mytilus edulis	.0073	.33	1	9.1	1
Polydora websteri	.0071	.32	2	18.2	2
Macoma balthica	.0053	.24	1	9.1	1
Scoloplos sp.?	.0008	.04	1	9.1	1
Debris	.7352	33.52	3	27.3	-

Conception Bay

JULY PREY LIST (NFLD.)

Species Name	Wet Weight (g)	% Wet Weight	Frequency of Occurrence	% Frequency Occurrence	Number Prey Items
Osteichythes	2.7887	32.05	1	12.5	1
Ischnochitin ruber	1.7939	20.68	2	25.0	14
Acmaea testudinalis	1.7648	20.28	3	37.5	12
Strongylocentrotus drobachiensis	1.7299	19.88	2	25.0	19
Ulva lactuca	.2018	2.32	1	12.5	-
Asterias sp.	.1710	1.79	1	12.5	1
Harmothoe imbricata	.0618	.71	1	12.5	1
Cladophora sericea	.0579	.67	1	12.5	-
Monostroma sp.	.0559	.64	1	12.5	-
Polysiphonia flexicaulis	.0504	.58	1	12.5	-
Phyllodoce maculata	.0122	.14	1	12.5	1
Nereis virens	.0057	.07	1	12.5	1
Cistenides gouldii	.0015	.02	1	12.5	1
Polychaeta	.0002	.002	1	12.5	1

Long Pond

Species Name	Wet Weight (g)	% Wet Weight	Frequency of Occurrence	% Frequency Occurrence	Number Prey Items
Nereis virens	3.2530	54.22	6	40.0	7
Nereis sp.	.5200	8.67	1	6.7	2
Nereis pelagica	.1673	2.79	1	6.7	2
Enteromorpha sp.	.1404	2.34	1	6.7	-
Pilayella littoralis	.0710	1.18	1	6.7	-
Mytilus edulis	.0644	1.07	1	6.7	1
Pholoe minuta	.0612	1.02	2	13.3	4
Eteone longa	.0572	.95	4	26.7	5
Polydora websteri	.0402	.67	7	46.7	10
Eteone sp.	.0199	.33	1	6.7	1
Leptocheirus pinguis	.0111	.18	2	13.3	4
Mytilus edulis	.0084	.14	2	13.3	2
Harmothoe imbricata	.0079	.13	2	13.3	2
Hydrobia minuta	.0042	.07	1	6.7	1
Pelecypoda	.0042	.07	1	6.7	1
Lacuna vincta	.0009	.01	2	13.3	3
Pygospio elegans	.0003	.005	1	6.7	2
Spionidae	.0001	.002	1	6.7	3
Polychaeta	.0357	.59	1	6.7	1
Debris	1.0357	25.54	2	13.3	-

Conception Bay

AUGUST PREY LIST (NFLD.)

Species Name	Wet Weight (g)	% Wet Weight	Frequency of Occurrence	% Frequency Occurrence	Number Prey Items
Dictyosiphon foeniculaceus	7.9256	28.17	3	21.4	--
Strongylocentrotus droebachiensis	4.8968	17.41	1	7.1	1
Polysiphonia flexicaulis	3.4759	12.36	1	7.1	----
Ulva lactuca	3.2781	11.65	1	7.1	--
Acmaea testudinalis	2.5759	9.16	2	14.3	40
Ceramium rubrum	1.5539	5.52	1	7.1	--
Carcinus maenas	.7873	2.80	1	7.1	40
Acrosiphonia arcta	.4834	1.72	1	7.1	--
Ischnochiton ruber	.1914	.68	2	14.3	2
Polychaeta	.0650	.23	1	7.1	1
Cistenides gouldii	.0364	.13	2	14.3	2
Hyas truncata	.0353	.13	1	7.1	1
Ectocarpus siliculosus	.0283	.10	1	7.1	-
Harmothoe imbricata	.0196	.07	1	7.1	2
Ensis directus	.0190	.07	1	7.1	1
Corophium bonelli	.0100	.04	2	14.3	4
Mytilus edulis	.0056	.02	1	7.1	-
Eteone longa	.0034	.01	2	14.3	4
Gammaridea	.0024	.01	1	7.1	1
Amphipholus squamatus	.0007	.002	1	7.1	1
Calliopius laeviusculus	.0002	.001	1	7.1	2
Chironomidae	.0001	.0003	1	7.1	1
Debris	2.7360	9.73	3	21.4	-

36

Long Pond

Species Name	Wet Weight (g)	% Wet Weight	Frequency of Occurrence	% Frequency Occurrence	Number Prey Items
Dictyosiphon foeniculaceus	.6636	6.24	2	5.6	-
Strongylocentrotus droebachiensis	.5689	5.35	1	2.8	1
Acmaea testudinalis	.3371	3.17	1	2.8	6
Macoma balthica	.3022	2.84	2	5.6	3
Nereis pelagica	.2088	1.96	1	2.8	2
Mytilus edulis	.2034	1.91	2	5.6	2
Phyllodoce maculata	.1528	1.44	2	5.6	9
Ischnochiton ruber	.1520	1.43	1	2.8	2
Nereis sp.	.1488	1.40	1	2.8	1
Cistenides gouldii	.1393	1.31	1	2.8	1
Enteromorpha sp.	.1384	1.30	-		1
Bostrichobranchus pilularis	.0689	.65	2	5.6	6
Harmothoe imbricata	.1561	.43	1	2.8	1
Lacuna vincta	.0446	.42	2	5.6	2
Nereis virens	.0385	.36	1	2.8	1
Polysiphonia flexicaulis	.0383	.27	1	2.8	-
Polydora websteri	.0270	.25	2	5.6	3
Mya arenaria	.0244	.23	1	2.8	1
Eteone longa	.0220	.21	3	8.3	3
Corophium bonelli	.0216	.20	3	8.3	30
Amphipholis squamatus	.0194	.18	1	2.8	1
Scoloplos acutus	.0150	.14	1	2.8	1
Ceramium rubrum	.0100	.09	1	2.8	-
Hydrobia minuta	.0060	.06	1	2.8	1
Phyllodocidae	.0057	.06	1	2.8	1
Phyllodoce sp.	.0026	.02	1	2.8	1
debris	7.2405	68.08	13	36.1	-

Conception Bay

SEPTEMBER PREY LIST

Species Name	Wet Weight (g)	% Wet Weight	Frequency of Occurrence	% Frequency Occurrence	Number Prey
Bostrichobranchus pilularis	7.9505	50.34	9	81.8	263
Strongylocentrotus drobachiensis	2.4009	15.20	1	9.1	1
Acmaea testudinalis	1.9397	12.28	1	9.1	12
Stylarioides plumosa	1.8273	11.57	1	9.1	1
Euchone elegans	.1629	1.03	1	9.1	1
Cistenides gouldii	.1375	.87	4	36.4	7
Pagurus acadianus	.0664	.42	1	9.1	1
Cerastoderma pinnulatum	.0574	.36	2	18.2	2
Clymenella torquata	.0404	.26	1	9.1	2
Harmothoe imbricata	.0202	.13	1	9.1	1
Scoloplos armiger	.0186	.12	1	9.1	2
Edotea montosa	.0180	.11	1	9.1	2
Crenella glandula	.0138	.09	5	45.5	11
Phoxocephalus holbolli	.0104	.07	2	18.2	3
Spionidae	.0103	.07	1	9.1	2
Diastylis rugosa	.0103	.07	4	36.4	5
Glycera capitata	.0055	.03	1	9.1	1
Corophium bonelli	.0053	.03	1	9.1	2
Eteone longa	.0033	.02	1	9.1	1
Scolopl s acutus	.0022	.01	1	9.1	1
Phyllodoce mucosa	.0015	.01	1	9.1	1
Macoma balthica	.0011	.01	1	9.1	1
Aricidea suecica	.0009	.01	1	9.1	1
Pygospio elegans	.00[illegible]	.01	1	9.1	1
Amphipoda	.00[illegible]	.001	1	9.1	1
Polychaeta	.02[illegible]	.17	2	18.2	5
Debris	1.0609	6.72	3	27.3	-

Long Pond					
Mytilus edulis	4.8785	28.48	8	36.4	35
Nereis virens	4.8377	28.24	7	31.8	10
Desmarestia viridis	2.9482	17.21	1	4.5	-
Macoma balthica	.9579	5.59	4	18.2	6
Neomacrius trivittatus	.4264	2.49	2	9.1	3
Nereis sp.	.3237	1.89	2	9.1	2
Littorina saxatilis	.1070	.62	1	4.5	1
Scoloplos armiger	.0626	.37	2	9.1	3
Polydora websteri	.0572	.33	4	18.2	11
Oligochaeta	.0491	.29	1	4.5	1
Cistenides gouldii	.0363	.21	1	4.5	1
Eteone longa	.0300	.18	2	9.1	2
Nereis pelagica	.0053	.03	1	4.5	1
Hydrobia minuta	.0040	.02	1	4.5	1
Corophium bonelli	.0001	.001	1	4.5	1
Debris	2.3618	13.79	8	36.4	-

OCTOBER PREY LIST (WELD.)

Conception Bay

Species Name	Wet Weight (g)	% Wet Weight	Frequency of Occurrence	% Frequency Occurrence	Number Prey
Ischnochiton ruber	8.9584	38.52	2	12.5	14
Ectocarpus siliculosus	6.4450	27.72	3	18.8	-
Acmaea testudinalis	2.7016	11.62	4	25.0	24
Chiridotea laevis	2.2072	9.49	1	6.3	12
Cistenides gouldii	1.0997	4.73	4	25.0	15
Strongylocentrotus drobachiensis	1.0080	4.33	1	6.3	1
Dictyosiphon foeniculaceus	.3516	1.51	1	6.3	-
[illegible]	.1779	.77	1	6.3	-
Pilayella littoralis	.0930	.40	1	6.3	-
Gammarus (lawrencianus)	.0495	.21	1	6.3	1
[illegible] robusta	.0333	.14	1	6.3	1
Hiatella arctica	.0303	.13	1	6.3	1
Corophium bonelli	.0293	.13	1	6.3	17
Polychaeta	.0184	.08	1	6.3	1
Caprella [illegible]	.0111	.05	1	6.3	1
[illegible]	.0075	.03	1	6.3	1
Cirratulus cirratus	.0074	.03	1	6.3	1
Phoxocephalus holbolli	.0074	.03	1	6.3	6
Lacuna vincta	.0063	.03	3	18.8	5
Scoloplos armiger	.0053	.02	1	6.3	1
[illegible] tuberculatus	.0033	.01	1	6.3	1
Spionidae	.0014	.01	1	6.3	1
Dexamine spinosa	.0009	.003	1	6.3	2
Cyclops sp.	.0001	.0004	3	18.8	?

Long Pond

Species Name	Wet Weight (g)	% Wet Weight	Frequency of Occurrence	% Frequency Occurrence	Number Prey
Algae	1.0649	27.41	1	4.8	-
Nereis virens	.3737	9.62	4	19.2	8
Polydora websteri	.3656	9.41	6	28.6	55
Littorina littorea	.3287	8.46	1	4.8	2
Mytilus edulis	.1465	3.77	1	4.8	2
Macoma balthica	.1366	3.52	2	9.5	2
Eteone longa	.0486	1.25	4	19.2	8
Phyllodoce mucosa	.0116	.30	2	9.5	2
Nereis pelagica	.0087	.22	2	9.5	3
Amphipoda	.0050	.13	1	4.8	1
Corophium bonelli	.0013	.03	1	4.8	1
[illegible]	.0007	.02	1	4.8	1
Cirratulidae	.0003	.01	1	4.8	1
Scoloplos sp.	.0001	.002	1	4.8	1
Debris	1.3921	35.84	3	14.3	-

MONTH	04/72		05/72		06/72		07/72		08/72		09/72		10/72	
Age	S	D	S	D	S	D	S	D	S	D	S	D	S	D
1														
2									12.2					
3	20.2			20.6		11.9	20.6		22.5	22.1	22.0	25.0		
4	25.3	28.0	22.6	25.8	21.2	23.4	22.1	26.1	24.4	22.8	23.7	22.0	23.1	26.7
5	24.9	22.0	26.4	28.9	28.9	24.3	23.3	25.4	26.0	20.8	28.4	25.1	29.8	27.8
6	28.2	29.3	27.9	23.6	26.0	23.4		28.0	28.8	32.8	31.2	-	29.4	30.8
7	31.4	37.2	30.0	33.9	33.0	25.0		25.0		30.8	-	34.8	31.0	32.6
8	31.5	47.8		40.1		29.2				33.5	32.4	40.0	37.5	41.7
9	37.7					41.5					36.7			42.7
10				42.0										39.9
11														
12														
13														
14														
15				59.3										

Age-Length Composition of Winter Flounder from two feeding grounds in Newfoundland waters. Growth Rate as age/month to corresponding length. S = shallow, D = deeps.

1972 | 1971

	April				May				June				July				August				September				October			
	Long Pond		Bay		Long Pond		Bay		Long Pond		Bay		Long Pond		Bay		Long Pond		Bay		Long Pond		Bay		Long Pond		Bay	
	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F
	12	22	6	9	6	8	11	20	5	6	7	6	12	2	4	4	24	16	6	8	15	8	2	10	9	13	6	10
	Age	f	Age	f	Age	f	Age	f	Age	f	Age	f	Age	f	Age	f	Age	f	Age	f	Age	f	Age	f	Age	f	Age	f
	2		2		2		2		2		2		2		2		2	(1)	2		2		2		2		2	
	3	(1)	3		3		3	(2)	3		3	(1)	3	(4)	3		3	(3)	3	(1)	3	(1)	3	(1)	3		3	
	4	(7)	4	(3)	4	(4)	4	(5)	4	(3)	4	(1)	4	(10)	4	(2)	4	(15)	4	(1)	4	(6)	4	(1)	4	(2)	4	(2)
	5	(10)	5	(1)	5	(1)	5	(2)	5	(3)	5	(3)	5	(2)	5	(2)	5	(14)	5	(1)	5	(6)	5	(5)	5	(6)	5	(7)
	6	(8)	6	(7)	6	(4)	6	(10)	6	(3)	6	(5)	6		6	(1)	6	(7)	6	(3)	6	(7)	6		6	(8)	6	(2)
	7	(4)	7	(3)	7	(5)	7	(5)	7	(2)	7	(1)	7		7	(3)	7		7	(5)	7	0	7	(3)	7	(4)	7	(2)
	8	(2)	8	(1)	8		8	(2)	8		8	(1)	8		8		8		8	(3)	8	(2)	8	(2)	8	(2)	8	(1)
	9	(2)	9		9		9	-	9		9	(1)	9		9		9		9		9	(1)	9		9		9	(1)
	10		10		10		10	(1)	10		10		10		10		10		10		10		10		10		10	(1)
							15	(1)																				

Appendix 10. Age—Sex Composition of Winter Flounder from Newfoundland feeding grounds.

Appendix 11

Classification keys used in the identification of prey of winter flounder.

Abbott, R.T. 1954. American Seashells. D.Van Norstrand. Toronto. 541 pp.

Barrett, J. and Yonge, C.M. 1970. Collins Pocket Guide to the sea shore. Collins Clear Type Press. London.

Bousfield, E.L. 1960 Canadian Atlantic sea shells. The Queen's Printer. Ottawa. 72 pp.

________. 1962. Studies on the littoral marine arthropods from the Bay of Fundy region. Bull. Nat. Mus. Can. 183:42-62.

Brinkhurst, R.O. and Jamieson, B.G.M. 1971. Aquatic Oligochaeta of the world. Univ. Toronto Press. Toronto. 860 pp.

Cook, D.G. 1969. The Tubificidae (Annelida, Oligohcaeta) of Cape Cod Bay with a taxonomic revision of the genera Phallodrilus Pierantoni, 1902, Limnodriloides Pierantoni, 1903/ and Spiridon Knollner, 1935. Biol. Bull. mar. biol. Lab. Woods Hole. 136(1): 9-27.

Fauvel, P. 1927. Polychaetes Sedentaires. Faune de France. 16:1-494.

Fordham, M.G.C. Aphrodite aculeata. XXVII. In: Herdman, W.A. and Johnstone, J. (eds). L.M.B.C. Memoirs on Typical British Marine Plants and Animals. Hodder and Stoughton Ltd. London.

Gould, A.A. 1870. Report on the invertebrata of Massachusetts. (2nd ed) W.G. Binney (ed.) Wright and Potter, Boston. 542 pp.

Grainger, E.H. 1966. Sea Stars (Echinodermata:Asteroidea) of arctic North America. Fish.Res.Bed.Can. Bull. 152:1-70.

Kirkegaard, H.B. 1969. A quantitative investigation of the central North Sea Polychaeta. Spolia Zool. Mus. Hauniensis. 29. Norlundes Bogrrykkeri. Copenhagen.

Kunkel, B.W. 1918. The Arthrostraca of Connecticut. State Geol. Natl. Hist. Soc. Harford. 261 pp.

Mason, W.T. MS 1968. An introduction to the identification of chironomid larvae. U.S. Dept. Interior. Cincinnati, Ohio. 89 pp.

Miner, R. W. 1950 Field Book of seashore life. G.P.Putnam's Sons. New York. 888 pp.

Morris, P.A. 1951 A field guide to the shells of our Atlantic and Gulf coasts. Houghton Mifflin. Co. Boston. 236 pp.

Pettibone, D.H. 1963. Marine Polychaete Worms of the New England region. I. Aphroditidae through Trochochaetidae. U.S. Mus. Natl. Hist., Smiths. Insti. Bull. 227:1-356.

________. 1956. Marine Polychaete Worms from Labrador. Proc. U.s. Mus. Natl. Hist., Smiths. Insti. Bull. 105(3361):531-584

Pickavance, J.R. and Cook, D.G. 1971. Tubifex newaei. n. sp. (Oligochaeta, Tubificidae) with a preliminary appraisal of the genus. Can. J. Zool. 49(2):249-254.

Pimental, R.A. 1967. Invertebrate Identification Manual. Reinhold Publ. Co., New York. 150 pp.

Pratt, H.S. 1935. A manual of the common invertebrate animals exclusive of insects. Blakiston and Sons. Philadelphia. 854 pp.

Rogers. J.E. 1936. The shell book. Doubleday, Page, and Co. Boston.

Saether, O.A. 1969. Some Nearctic Podonominae. Diamesinae, and Orthocladiinae (Diptera: Chironomidae) Fish. Res. Bd. Can. Bull. 170:154.

Sars, G.O. 1895. An account of the Crustacea of Norway. I. Amphipoda I[2]. Plates. Alb Cammermeyers Forlag. Christiania and Copenhagen.

Smith, R.I. 1964. Keys to marine invertebrates of the Woods Hole region: A manual for the indentification of the more common marine invertebrates. Contr. No.11 Syst-Ecol. Prog. mar. biol Lab. Woods Hole. Spaulding Co., Inc.

Stebbing, T.R.R. 1906. Amphipoda I. Gammaridea. Berlag von R. Friedlander und JSohn. Berlin.

Thomas, J.G. 1940. Pomatoceros, Sabella, and Amphitrite. XXXIII. In: Herdman, W.A. and Johnstone, a. (eds.). L.M.B.C. Memoirs n Typical British Marine Plants and Animals. Hodder and Stoughton Ltd. London.

Appendix 12 A.

Date	Tide	Tidal HOur	1	2	3	4	5	6	7	8	9	10	11	12
20.5.71	Flood	2	0	1	2	2	16	15	21	28	24	26	15	14
		5	9	16	21	19	21	21	26	13	31	13	6	6
		6	17	15	15	14	18	17	16	24	25	16	6	5
24.5.71	Flood	2	1	2	1	4	3	18	18	23	28	26	20	20
		4	16	17	31	19	29	41	31	17	23	23	8	6
28.5.71	Ebb-Flood	3	2	3	15	15	17	16	15	15	8	7	6	6
		5	0	1	3	3	11	10	14	12	11	11	9	9
		1	0	0	0	3	6	8	15	15	30	30	20	19
3.5.72	Ebb	1	35	16	3	13	17	16	19	31	28	37	5	8
		3	17	8	6	15	9	8	7	6	17	9	12	7
		5	16	20	13	9	9	16	34	13	23	19	26	5
9.5.72	Flood	1	4	1	2	3	4	9	9	5	6	18	16	7
		3	2	10	12	22	37	19	21	10	10	9	11	7
		5	35	19	9	15	21	21	33	22	26	22	9	5
10.5.72	Flood	1	4	1	2	8	9	13	20	14	16	39	20	5
		3	23	27	6	11	13	7	14	11	7	19	4	0
		5	29	33	12	15	17	11	27	22	16	31	8	1
15.5.72	Ebb	1	7	10	3	5	14	14	13	14	8	18	14	13
		3	2	1	1	3	2	12	16	10	10	11	10	16
		5	3	1	0	1	2	0	1	2	3	3	6	14
15.5.72	Flood	1	0	3	14	7	3	6	11	10	5	9	17	2
		3	29	28	34	14	17	8	17	24	14	16	4	5
		5	23	15	8	7	16	11	10	12	14	15	10	2
16.5.72	Ebb	2	6	10	2	6	5	3	15	10	22	15	17	10
		4	2	1	0	7	5	6	7	17	8	13	25	16
		6	8	9	5	17	19	23	20	14	12	13	20	4
17.5.72	Ebb	2	3	1	0	6	5	5	9	10	7	7	21	23
		4	2	4	0	4	7	8	10	19	8	10	27	8
23.5.72	Flood	1	5	1	1	5	9	14	8	19	13	21	28	1
		3	13	9	13	17	13	21	11	13	13	16	15	8
		5	19	11	5	10	20	18	41	17	25	21	10	3
25.5.72	Flood	1	1	1	1	5	6	8	8	6	7	13	20	6
		3	20	15	16	17	12	16	16	19	19	19	20	14
		5	38	12	10	12	11	15	30	33	30	34	22	13

Frequencies of Winter Flounder per Hour Tide per Day-
Long Pond, Conception Bay, Nfld., 1971-72.

Appendix 12 B.

Date	Tide	Tidal Hour	Station Number 1	2	3	4	5	6	7
30.5.72	Ebb	1	10	6	7	6	13	11	23
		3	2	3	3	11	3	7	15
		5	0	2	4	1	10	12	13
		1	2	0	2	5	7	11	16
30.5.72	Flood	3	13	6	13	8	13	13	21
		5	5	10	14	13	15	17	33
		1	7	10	0	6	6	10	28
31.5.72	Ebb	3	2	4	5	6	2	6	20
		5	0	1	2	4	10	18	18

Frequency of Winter flounder per Hour Tide per Day
Long Pond, Conception Bay, Nfld., 1971-72.