Géographie physique et Quaternaire

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Volume 60, numéro 1, 2006

URI : https://id.erudit.org/iderudit/016365ar
DOI : https://doi.org/10.7202/016365ar

Aller au sommaire du numéro

Éditeur(s)

Les Presses de l'Université de Montréal

ISSN

0705-7199 (imprimé)
1492-143X (numérique)

Découvrir la revue

Citer cet article

Dale, J. E. & Leontowich, K. (2006). Sediments and Biota of the Marine Coastal Zone of Igloolik Island, Nunavut. *Géographie physique et Quaternaire*, *60*(1), 63–80. https://doi.org/10.7202/016365ar

Résumé de l'article

Sédiments et invertébrés de la zone marine côtière de l'île d'Igloolik, Nunavut. Peu d'études menées dans l'arctique canadien combinent les données sur l'environnement physique marin et les invertébrés. Ceci est la première étude détaillée portant sur les conditions océanographiques et la distribution des sédiments et des invertébrés dans les zones intertidales et subtidales de l'île d'Igloolik, Nunavut. Les mesures océanographiques (température, salinité, oxygène dissous, turbidité) et l'échantillonnage des sédiments et des invertébrés ont été menées durant les étés de 1999 et 2002. Les zones intertidales reposent sur de la roche en place avec un mince placage de graviers faiblement triés, exempts d'invertébrés à cause des conditions environnementales rigoureuses. Quatre-vingt-seize espèces d'invertébrés marins ont été identifiées dans la zone sub-tidale de Turton Bay, une baie peu profonde qui se déverse au sud dans Hooper Inlet. La faible profondeur de la baie (<25 m) et son ouverture vers le sud signifie que l'eau est bien mélangée sur toute sa profondeur, pendant la période sans glace. Les variations d'espèces, d'abondance et de densité sont le résultat des conditions locales et de la nature du substrat. Les zones subtidales avec un substrat non consolidé possèdent une faune abondante et diversifiée tandis que celles au substrat consolidé présentent une variété d'espèces plus limitée. L'abondance et la diversité maximales des espèces se trouvent aux sites les plus profonds composés de sédiments fins, dominés par des espèces se nourrissant de dépôts. La zone subtidale peu profonde (<5 m) est caractérisée par un mince placage de sable sur la roche en place. Elle constitue une extension de la zone intertidale et elle est très affectée par l'action des glaces, d'où la faune marine réduite. La forte densité des espèces opportunistes et tolérantes à la pollution le long des transects de Turton Bay s'explique par les fuites du lagon de vidange et des dépotoirs situés à proximité.

Géographie physique et Quaternaire, 2006, vol. 60, n° 1, p. 63-80, 11 fig., 6 tabl.

SEDIMENTS AND BIOTA OF THE MARINE COASTAL ZONE OF IGLOOLIK ISLAND, NUNAVUT

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ABSTRACT Few studies in arctic Canada have combined research on both the physical marine environment and benthic invertebrates. This is the first detailed study of the oceanographic conditions and distribution of sediments and biota in the intertidal and subtidal zones of Igloolik Island, Nunavut. Oceanographic measurements (temperature, salinity, dissolved oxygen, turbidity), and sediment and biological sampling were undertaken over two summers (1999, 2002). Intertidal zones are underlain by bedrock with a thin veneer of gravel with a very poorly sorted fine matrix and devoid of benthic invertebrates, due to harsh environmental conditions. Ninety-six benthic invertebrates species were identified in the subtidal zone of Turton Bay, a shallow embayment of Igloolik Island that opens to the south into Hooper Inlet. Oceanographic conditions were similar throughout Turton Bay. The shallow depth of Turton Bay (<25 m) and open fetch to the south means that the bay water is well mixed throughout during the ice-free period. Variations in species, abundances and densities result from local conditions and substrate characteristics. Subtidal areas with unconsolidated substrates have abundant and diversified benthic fauna, whereas those with consolidated substrates have more limited species dominated by epifauna. The greatest abundances and densities occur at the deepest sites with the finest sediments and deposit-feeding species. The shallow subtidal zone (<5 m) is characterized by a thin sandy surface veneer overlying bedrock. It is an extension of the intertidal zone and is much affected by ice action during break-up with reduced numbers of marine fauna. High densities of opportunistic and pollution tolerant species along transects in Turton Bay are explained by the outflow and seepage from the sewage lagoon and dumpsites proximal to these transects.

RÉSUMÉ *Sédiments et invertébrés de la zone marine côtière de l'île d'Igloolik, Nunavut.* Peu d'études menées dans l'arctique canadien combinent les données sur l'environnement physique marin et les invertébrés. Ceci est la première étude détaillée portant sur les conditions océanographiques et la distribution des sédiments et des invertébrés dans les zones intertidales et subtidales de l'île d'Igloolik, Nunavut. Les mesures océanographiques (température, salinité, oxygène dissous, turbidité) et l'échantillonnage des sédiments et des invertébrés ont été menées durant les étés de 1999 et 2002. Les zones intertidales reposent sur de la roche en place avec un mince placage de graviers faiblement triés, exempts d'invertébrés à cause des conditions environnementales rigoureuses. Quatre-vingt-seize espèces d'invertébrés marins ont été identifiées dans la zone subtidale de Turton Bay, une baie peu profonde qui se déverse au sud dans Hooper Inlet. La faible profondeur de la baie (<25 m) et son ouverture vers le sud signifie que l'eau est bien mélangée sur toute sa profondeur, pendant la période sans glace. Les variations d'espèces, d'abondance et de densité sont le résultat des conditions locales et de la nature du substrat. Les zones subtidales avec un substrat non consolidé possèdent une faune abondante et diversifiée tandis que celles au substrat consolidé présentent une variété d'espèces plus limitée. L'abondance et la diversité maximales des espèces se trouvent aux sites les plus profonds composés de sédiments fins, dominés par des espèces se nourrissant de dépôts. La zone subtidale peu profonde (<5 m) est caractérisée par un mince placage de sable sur la roche en place. Elle constitue une extension de la zone intertidale et elle est très affectée par l'action des glaces, d'où la faune marine réduite. La forte densité des espèces opportunistes et tolérantes à la pollution le long des transects de Turton Bay s'explique par les fuites du lagon de vidange et des dépotoirs situés à proximité.

Manuscrit reçu le 5 juin 2006 ; manuscrit révisé accepté le 12 octobre 2006 (publié le 2e trimestre 2007)
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INTRODUCTION

Concerns over global climate change have galvanized the research community into increasing their understanding of ecosystems around the globe. This concern is shared for arctic locales and the possible impacts on marine arctic ecosystems. Our knowledge of these systems is still rudimentary, with relatively little work and few long-term studies in arctic Canada. The few marine research sites are far apart leaving large gaps in our current database (Dunbar, 1951; Ellis, 1955, 1960; Aitken and Gilbert, 1986; Dale *et al.*, 1989; Aitken and Gilbert, 1996; Dale *et al*. 2002). This is the first detailed study of the oceanographic conditions and distribution of sediments and biota in the intertidal and subtidal zones of Igloolik Island, Nunavut. Oceanographic measurements of the temperature, salinity, dissolved oxygen and turbidity of the marine environment, and sediment and biological sampling were undertaken over two summers (1999, 2002) of the southern and western intertidal and subtidal coastal zones of the island of Igloolik (Fig. 1).

There has been very little marine research in the Igloolik area. Ellis (1955, 1960) dredged for biological samples at 20 and 50 m water depths in Hooper Sound to the south of Igloolik Island. But no detailed biogeographical studies have been undertaken on the intertidal zone or a detailed analysis of the shallow subtidal zone of Igloolik Island itself. Oceanographic measurements of marine conditions in the area were taken during the “Calanus” expedition in Hooper Inlet from September 1955 to September 1956 but not on the island itself (Grainger, 1959; Bursa, 1961). Kristensen *et al.* (1991) measured temperature and salinity values in Turton Bay at a 4.5 m depth in late June but prior to ice break-up. His findings do not cover the range of depths nor spatial variability in Turton Bay nor conditions during the summer ice-free period.

Igloolik Island sits in a unique location at the southern limit of the Canadian High Arctic Zone in the northern part of Foxe Basin, a shallow inland sea (Kristensen *et al.*, 1991; Fig. 1). It receives water from the Arctic Ocean through Fury and Hecla Strait (Campbell and Ollin, 1956; Campbell, 1964). Arctic water from the northwest dominates the Igloolik marine environment from currents flowing from west to east through Hooper Sound and from the north flow along the west and east coasts of the island (Grainger, 1959). The flow of Arctic water through Fury and Hecla Strait has been identified as a possible route for species migrating from the Pacific Ocean. Cold water molluscs exchanged between the Pacific and Atlantic oceans through the Arctic (Durham and MacNeil, 1976; Dyke *et al.*, 1996). Marine invertebrates with Pacific origins have been identified in the Atlantic side of the Arctic including *Macoma calcarea* and *Serripes groenlandicus* collected in this study (Lubinsky, 1980; Dyke *et al.*, 1996). Identification of species with Pacific or High Arctic affinities at Igloolik helps to understand the migration and distribution of arctic marine invertebrates.

LOCATION

Igloolik Island is located in the northwest of Foxe Basin (81° 48’ W, 69° 22’ N) near the entrance to Fury and Hecla Strait (Fig. 1). The island is 103 km^2 in size and almost completely bisected by Turton Bay, a shallow embayment that opens to the south and contains the town of Igloolik. The island is 18 km long and consists of several buttes that join the lowland plains where bedrock is partially covered by old raised beaches. The highest buttes occur on the western portion of the island; the airport butte has an elevation of 56 m and the cemetery butte 51 m. A smaller butte on the eastern part of the island has an elevation of 33 m (Dredge, 1992). Turton Bay is 9 km long, 5.5 km at it widest, 20-25 m in depth, and 30 m at its deepest point at the mouth.

Igloolik Island is located in the eastern lowlands of Melville Peninsula, which consists of Precambrian rocks flanked by Paleozoic sediments (Schau, 1984; Schau *et al.*, 1994). Carbonate rocks of Paleozoic age underlie Foxe Basin, eastern

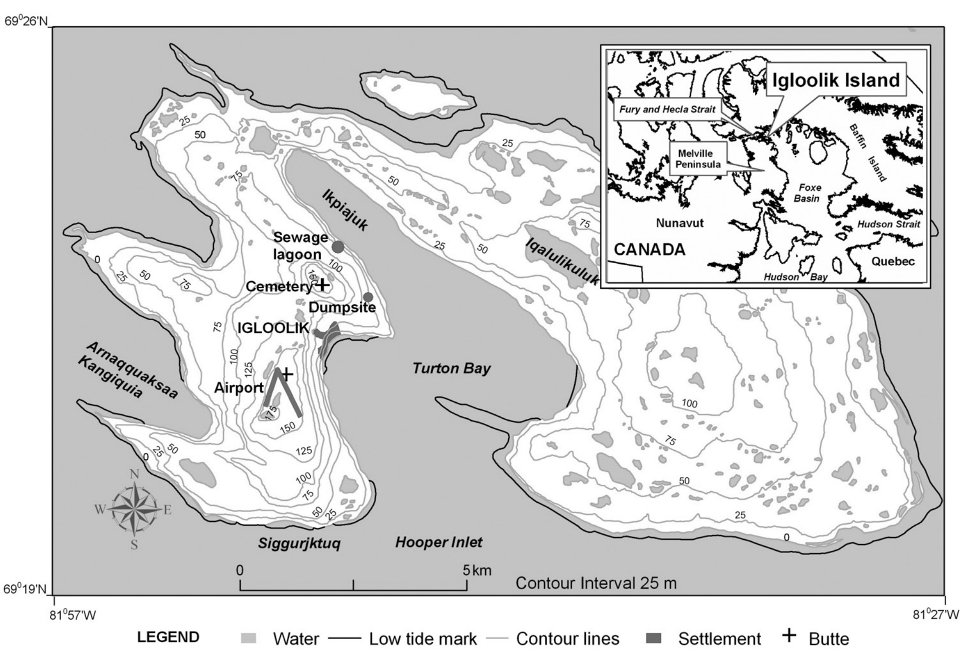

FIGURE 1. Location map of the study area.

Carte de localisation de la région d’étude.

Melville Peninsula and are exposed on Igloolik Island (Boulton *et al.*, 1977; Fig. 2). The lower Ship Point Formation is a sandstone and dolomite unit. Overlying this is a conglomerate and limestone unit called the Bad Cache Formation that makes up the upper parts of the buttes.

A thin layer of pebbly till overlies much of the bedrock in the lowland areas of the island. Much of the surface, and in particular, the cobble beaches are composed primarily of Paleozoic materials, limestone and dolomite. Granitic and quartzite erratics are present and thought to have originated on Melville Peninsula or Baffin Island and were transported to this location during numerous glacial advances during the Pleistocene (Dredge, 1992). The island appears to have been ice covered at 7000 BP and ice-free by 6000 BP (Dyke and Prest, 1987; Dredge, 1992; Dyke *et al.*, 1996). A thin layer of till was deposited on the surface, and exposed bedrock, felsenmeer and raised shingle beaches occur elsewhere (Fig. 3). The bedrock dominates the subtidal marine environment as well. Although there are pockets of thicker marine sediments in Turton Bay and bays along the west coast of Igloolik Island, for the most part, the marine substrate consists of bedrock with a thin layer of till and marine sediments.

Supratidal coastal areas are covered with raised shingle beaches composed of sub-rounded to well-rounded flattened pebbles and cobbles with narrow gravel intertidal zones of mixed angular material. Even the highest beaches are largely devoid of vegetation except for hardy xerophytic vegetation (Fig. 3). In most cases intertidal zones are steep gravel-covered bedrock or, as in the case of the south shore (Siggurjktuq on Fig. 1), steep, rock cliff faces that extend into the subtidal zone (Fig. 2). Flat low-lying intertidal zones are very restricted and typically underlain by bedrock with a thin veneer of fines and gravels (Figs. 4-5). Sampled intertidal sites were limited to locations within Turton Bay, particularly around the town site and a rocky spit area along the west coast where the corer could never penetrate more than 30 cm into the unconsolidated material (Figs. 4-5).

Turton Bay is a shallow embayment (<25 m depth) with a mouth that opens to the south into Hooper Inlet. The bay narrows towards the head to the north; this narrow region is named Ikpiajuk (MacDonald, pers. comm., 1999, 2002). From echo-sounding profiles, the subtidal zone of Ikpiajuk is characterized by steep rocky sidewalls and a flat featureless bottom. As Turton Bay opens towards the south, it retains its steep rocky sidewalls, with a wider flat bottom.

CLIMATE AND MARINE CONDITIONS

Igloolik Island is classified as High Arctic with a climate known as Polar Tundra (Koeppe and deLong, 1958; Forbes *et al.*, 1992). It has a mean annual temperature of -13.2 °C, with only three to four months of the year having mean daily temperatures above 0 °C (Fig. 6). During fieldwork in Igloolik

FIGURE 3. Raised shingle beaches of Igloolik overlying bedrock with several erratics.

Plages soulevées d'Igloolik recouvertes de quelques erratiques.

FIGURE 2. Cliffs of the rocky intertidal zone composed of Paleozoic bedrock along the south shore of Igloolik (Siggurjktuq) with anchor ice (ice foot).

Falaises de la zone intertidale rocheuse composée de roche en place datant du paléozoïque le long de la rive sud de Igloolik (Siggurjktuq), avec un pied de glace.

FIGURE 4. Sampling the gravel intertidal zone along the South Spit transect.

Échantillonnage de la zone intertidale graveleuse le long du transect South Spit.

FIGURE 5. Intertidal zone of the North Spit transect.
Zone intertidale du transect North Spit.

in 1999, the minimum temperature was 2 °C and maximum temperature 14.5 °C. Average daily temperatures during July and August are typically 7.0 °C and 4.9 °C, respectively. Mean annual precipitation is 285.9 mm. August is the wettest month, receiving on average 50 mm of precipitation. Prevailing winds are from the northwest although maximum wind speeds come on average from the southeast (Environment Canada, 2006). Thus, for much of the time Turton Bay is relatively protected from wind action, except when low pressure cells dominate the area and southeast winds blow directly into the bay from Foxe Basin, a condition that occurred for much of the 2002 sampling period.

Sea ice influences the island for approximately nine months of the year with an ice-free period lasting from mid-July to mid-October (MacDonald *et al.*, 1998). Most of the sea ice is first year ice, although some second year floes have been reported moving from the north through Fury and Hecla Strait (Prinsenberg, 1986). During the fieldwork in Igloolik in 1999, southeast winds rafted ice floes from Foxe Basin into Turton Bay on July 28th and these persisted into early August periodically filling up portions of the bay. In 2002, sea ice cleared around Igloolik Island in early July (MacDonald, pers. comm., 2002) and did not return during the field season. Differences in sea ice conditions between 1999 and 2002 field seasons likely account for some of the variability in oceanographic conditions.

Igloolik is near the southern limit of the Canadian High Arctic Zone for marine conditions. It receives Arctic water from the northwest that flows eastward through Hooper Inlet and southward along the east and west coasts of the island (Grainger, 1959). The tidal range is approximately 2.9 m (Department of Fisheries and Oceans Canada, 1999) and classified as mesotidal (Davies, 1964).

METHODS

To determine the distribution of sediment and biota in the intertidal and subtidal zones of Igloolik Island a series of transects were chosen that reflected the variability of the physical conditions on the island (Fig. 7). Accessibility, narrow intertidal zone and paucity of sites with unconsolidated sediments limited the locations of intertidal sampling in Turton Bay. Intertidal transects ran perpendicular to the shoreline from the highest high tide mark to the lowest low water mark. Surveying using a Sokkisha transit level from the lowest low tide position, fixed the tidal height of each sample site. Four replicate sediment samples were taken with a plastic corer for a total surface area of 125 cm^2, at each sampling plot along each transect. Due to the narrow tidal zone, a systematic distance between sampling plots was not used, and instead samples were taken at regular intervals along each line.

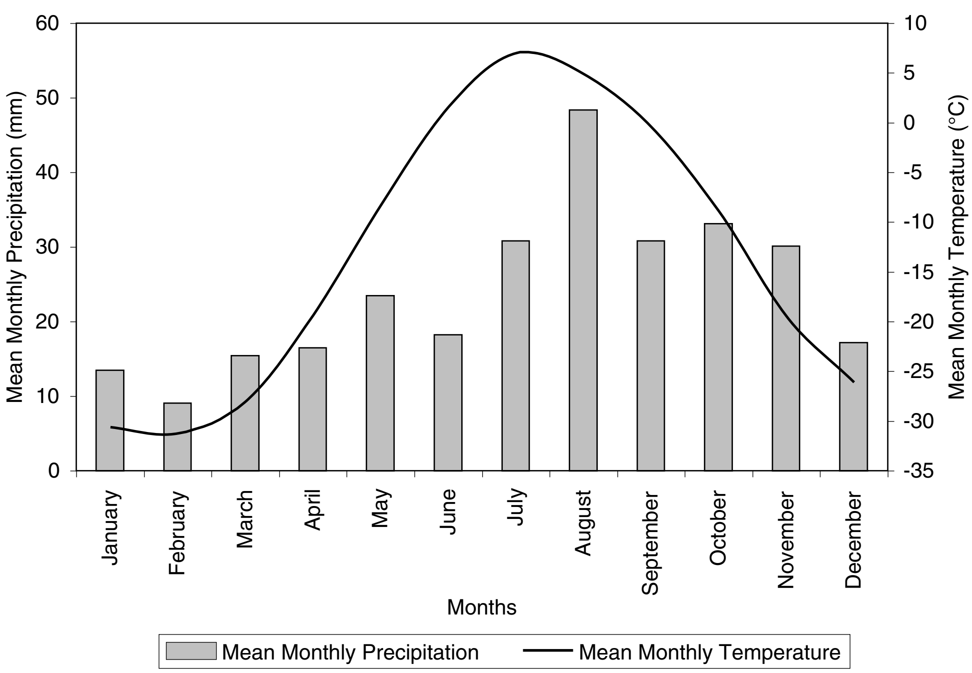

FIGURE 6. Climograph of Igloolik, Nunavut (Source: http://www.climate.weatheroffice.ec.gc.ca/climate_normals/).

Climatogramme de Igloolik, Nunavut (source: http://www.climate.weatheroffice.ec.gc.ca/climate_normals/).

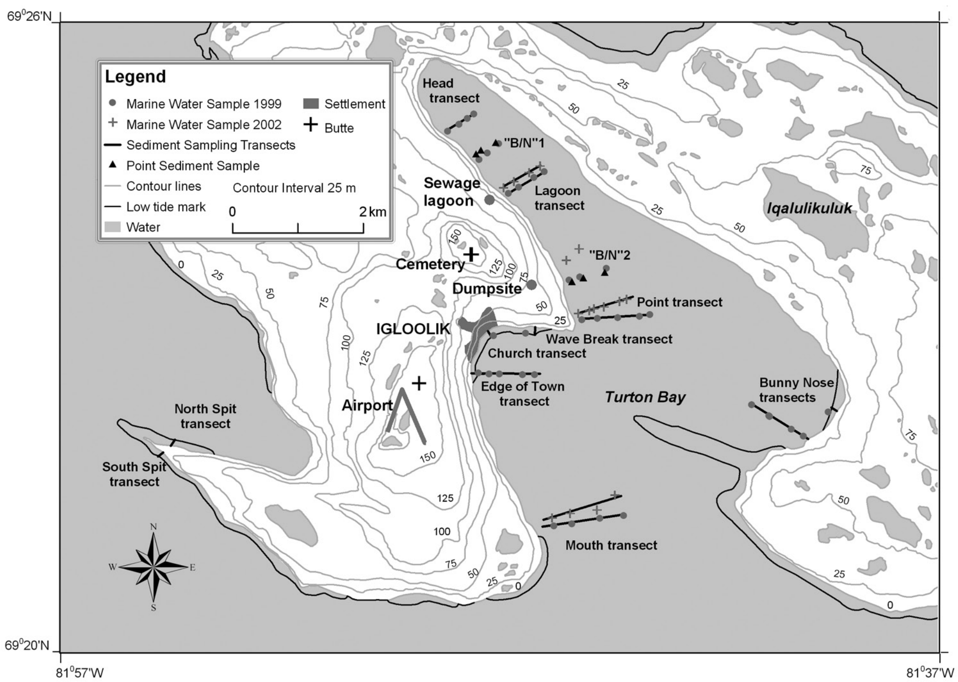

FIGURE 7. Location of water, sediment and biological samples in 1999 and 2002.

Localisation des échantillons d'eau, de sédiments et des prélèvements biologiques en 1999 et 2002.

Suitable subtidal sites for sampling were also difficult to find and only the detailed intertidal sampling in Turton Bay are presented here (Leontowich, 2003). All subtidal sampling was conducted from a 5 m freighter canoe. Transects ran perpendicular from shore from the shallowest to deepest depth. Two to three grab samples and one to two water samples were taken at 5 m depth intervals along each transect. Seventy-one grab samples from six subtidal transects and two point sample sites were collected in 1999. Eighteen additional grab samples were taken from three subtidal transects in 2002 to address the impacts of the sewage and dumpsite outflows on bottom fauna and to observe changes in biota since 1999. The locations of the sample sites were established using a Garmin Etrex GPS unit and water depths were measured using an Eagle Strata 128 echosounder. Subtidal grab samples for sediment and biota were taken using a heavy weight clamshell sampler (opening size: 17 by 14.5 cm) and dredged samples using a modified bucket dredge. Access to the dredge in 2002 permitted extensive dredging at the mouth in 2002 in areas with a rocky bottom. Water samples were collected using a horizontal Kemmerer bottle. Measurements of temperature, salinity, dissolved oxygen and pH were made as soon as the samples were retrieved using a variety of portable field meters (YSI Model 33 SCT, YSI Model 57 dissolved oxygen meter, Corning Scientific Model 5 pH meter and Fisher Scientific thermometer with probe). Turbidity measurements were made on-shore in the Igloolik laboratory within hours of sampling using an Orbeco-Hellige portable turbidity meter. There was no difference between turbidity measures made in the boat from those measured onshore. The fragility of the equipment and need for calm sea precluded its use in the boat.

Bulk substrate samples were split for sediment and biological analyses. Biota were hand picked from a 0.5 mm mesh sieve, fixed in 10% buffered formalin and transferred to 80% ethanol for preservation. Species identification was conducted using arctic taxonomic keys (Macpherson, 1971; Lubinsky, 1980; Pocklington, 1989) and the reference collection housed at the University of Regina that had been validated using the type specimens and collection housed at the Museum of Nature in Ottawa. Grain size analyses of the sediments were made using standard sieve and sedigraph techniques in the laboratory at the University of Regina (Folk, 1974; Buchanan, 1984; Syvitski and Hein, 1991; Boggs, 2001).

Faunal species richness (number of species), abundance (number of individuals) and density (total number of individuals per 100 cm^2) were determined at each site for the combined data including total fauna, polychaetes and mollusc data. In addition, they were calculated for the individual sample counts for polychaete, mollusc, echinoderm and crustacean values. Several diversity indices were chosen to characterize the faunal population (Magurran, 1988; Buhl-Mortensen and Hoisaeter, 1993). These included Margalef, Menhinick, Shannon-Weiner diversity and Evenness, and Simpson's indices using Jandel Sigmastat Statistical Software (1994). Regression analyses were conducted for each transect with the dependent variables of richness, abundance, density, Simpson index, Shannon-Weiner index and Evenness, and the independent variable of water depth (Hammond and McCullagh, 1978; Magurran 1988).

RESULTS

INTERTIDAL SEDIMENTARY ENVIRONMENT

Results of the grain size analyses for the intertidal sites are summarized in Table I. Gravels dominate the intertidal zone and the grain size analyses were conducted on the intervening finer matrix, which ranged from poorly to very poorly sorted

TABLE I

Characteristics and grain size statistics of the fine fraction of the intertidal transects on Igloolik Island

Transect	Transect length (m)	Maximum elevation of transect (m above lowest low tide)	Mean grain size ranges (m)	Wentworth size class	Range of inclusive graphic standard deviation (phi)	Verbal sorting description
Outside Turton Bay						
North Spit	78	2.3	37.09-18.36	Coarse silt to medium silt	4.08-3.75	Very to extremely poorly sorted
South Spit	46	3.3	130.56-80.72	Fine sand to very fine sand	3.95-3.68	Very poorly sorted
Inside Turton Bay						
Wave Break	74	3.3	147.20-61.04	Fine sand to very fine sand	3.74-3.59	Very poorly sorted
Church	38	3.9	202.41-119.60	Fine sand to very fine	3.85-3.44	Very poorly sorted
Edge of Town	31	3.3	241.05-13.50	Medium sand to fine sand	4.33-3.24	Very to extremely poorly sorted
Bunny Nose	78	2.8	64.67-3.86	Very fine sand to very fine silt	4.09-3.26	Very to extremely poorly sorted

medium sand to very fine silt. Overall mean grain size decreased slightly with increasing water depth and distance from shore. Only the South Spit transect showed a statistically significant relationship between increasing water depth with decreasing grain size. The combination of low tidal range, narrow intertidal zones and extensive ice action over underlying bedrock surfaces does not aid in sedimentation or sorting in the intertidal zone. Ice cover for the majority of the year also reduces wave and current action limiting transport and deposition of sediment. There are no extensive tidal flats on this island. Of the sites studied, only the more protected Bunny Nose transect would appear to have the flat expanse and location that could under the right conditions develop the sedimentary zonation more typical of tidal flat formation in the Arctic (Martini, 1991; Dale *et al.*, 2002). At present the thin deposits of very fine sand to very fine silt were too poorly sorted and fined only in a seaward direction to be considered a tidal flat.

INTERTIDAL BIOLOGICAL SAMPLING

Despite repeated sampling programs over two seasons no marine benthic fauna were collected from the intertidal sites. The shortened summer season, ice scouring, substrate temperature fluctuations, rocky terrain and presence of anchor ice account for the barren intertidal zone (Ellis and Wilce, 1961; Thomson, 1982; Aitken and Gilbert, 1996). The same processes that account for the poor sorting of the sediments are responsible for a high mixing and turnover of sediments, precluding settlement of spat or a return of previous colonizers. The short duration of the ice-free period of three months at best, restricts colonization of many fauna in the intertidal zone (Petersen, 1991), although arctic molluscs can exploit the short ice-free period and tolerate long periods of sub-zero temperatures (Thorson, 1936; Ellis, 1955; Williams, 1970; Hewitt and Dale, 1984; Dyke *et al.*, 1996). Only highly adaptable pelagic species such as amphipods were observed swimming in the harsh intertidal zone of Igloolik. Even macroalgae was rarely observed and only on rock surfaces at the lowest part of the intertidal zone. Researchers from McGill University also reported an absence of intertidal infauna in the intertidal zone at Igloolik (MacDonald, pers. comm., 1999, 2002).

SUBTIDAL OCEANOGRAPHIC CONDITIONS

There is little known about the oceanographic conditions of Turton Bay and Igloolik Island. The only oceanographic measurements for the Igloolik Island area were taken in September 1955 to September 1956 during the “Calanus” expedition and in Hooper Inlet to the south of Igloolik Island (Grainger, 1959; Bursa, 1961). Kristensen *et al.* (1991) measured temperature and salinity in Turton Bay at a 4.5 m depth (-0.5 °C, 26‰) and in Hooper Inlet at a depth of 52 m (-1.8 °C, 35‰). These samples were collected in late June prior to ice break-up and not comparable to the results in this study. Overall, the shallow nature of Turton Bay, in combination with the lack of terrestrial runoff sources during the brief summer field season, may be responsible for the relatively low variability of recorded oceanographic conditions.

Oceanographic sampling sites are shown in Figure 7 and the results summarized in Figures 8, 9, 10 and 11. Marine water samples were taken along all transects in 1999 and repeated at selected transects in 2002. Samples were taken at the water surface and just above the substrate surface (<1 m above bottom). Oceanographic conditions did not appear to be greatly influenced by increased depth along transects and are likely the result of the shallow depths (<25 m) encountered throughout the Turton Bay transects (deepest site is at 23.4 m). In addition, few strong trends were observed in the oceanographic measurements between transects at comparable depths from the head to the mouth. However there is some variability in temperature, dissolved oxygen, salinity and turbidity values along the transects.

Generally, bottom subtidal temperatures at all transects showed a decrease with increased depth, and surface water temperatures were always higher than the bottom water temperatures (Fig. 8). The highest surface water temperatures were measured at the Head transect in 1999 (5.4 to 7.7 °C), and resulted from summer heating and reduced influence from the deeper waters in Hooper Inlet at the mouth of Turton Bay. Temperatures below 0 °C were measured in 1999 along the Point transect at sites below 15 m water depth. Overall, cooler bottom water temperatures were measured in 1999 than in 2002.

All of the transects with the exception of the Bunny Nose transect exhibited an increase in salinity with increased water depth, and the surface water layer was always lower in salinity than that collected at the bottom (Fig. 9). While the differences in salinity were never great, the resultant weak water stratification with warm, less saline water overlying a colder more saline bottom layer is a common occurrence in arctic water in the summer (Grainger, 1959; Bursa, 1961). Turton Bay has very few sources of terrestrial water runoff in the sum-

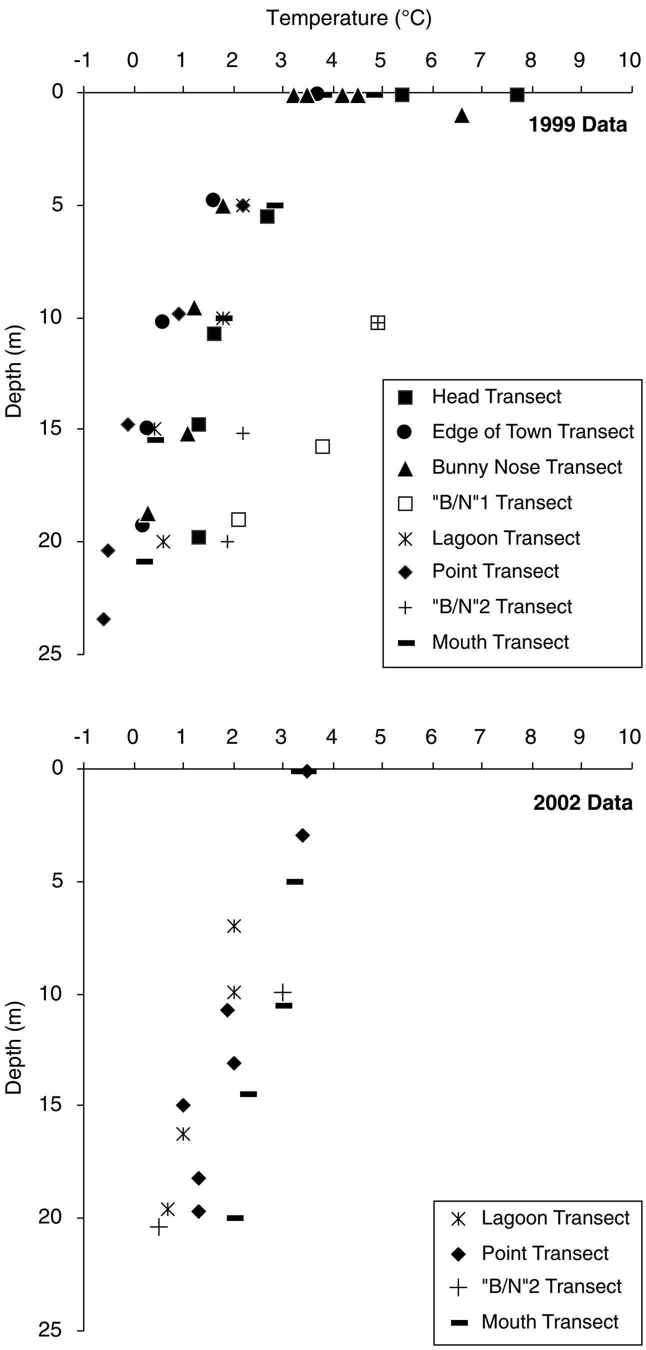

FIGURE 8. Water temperature values with depth along transects in Turton Bay in 1999 and 2002.

Valeurs de température de l'eau en fonction de la profondeur le long des transects de Turton Bay en 1999 et 2002.

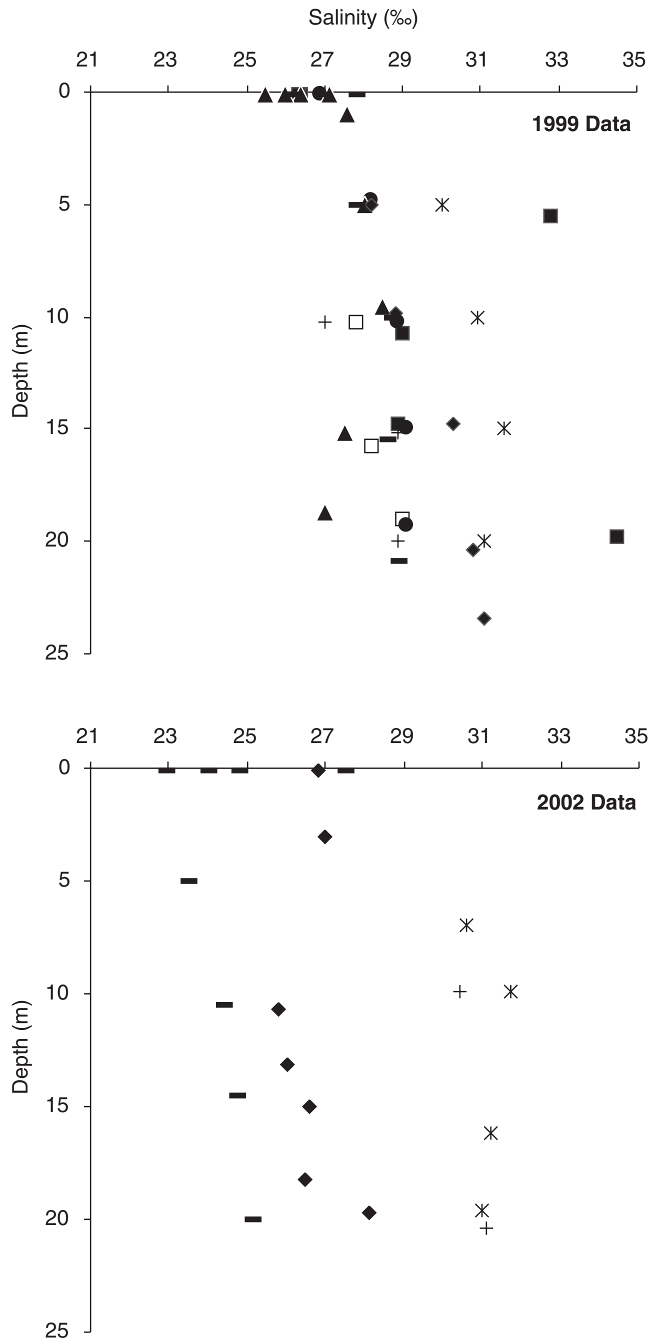

FIGURE 9. Water salinity values with depth along transects in Turton Bay in 1999 and 2002.

Valeurs de salinité de l'eau en fonction de la profondeur le long des transects de Turton Bay en 1999 et 2002.

mer after snowmelt is complete. Rain percolates quickly into the porous raised beaches and tundra areas. The only continuous streams noted in the sampling periods were a few small streams that entered Turton Bay from the dumpsite and sewage lagoon on the west side of the bay and at the settlement near the Church transect. Element analyses of these streams showed that they were enriched with respect to nitrate (maximum measurement: 87 mg/L) and phosphorus (maximum measurement: 4.7 mg/L) above acceptable levels for drinking water (Leontowich, 2003). Lower values for salinity were measured for the Mouth and Point transects in 2002.

Dissolved oxygen values remained high throughout the field seasons (Fig. 10), and well within the range of a well-oxygenated marine environment for the Canadian Arctic

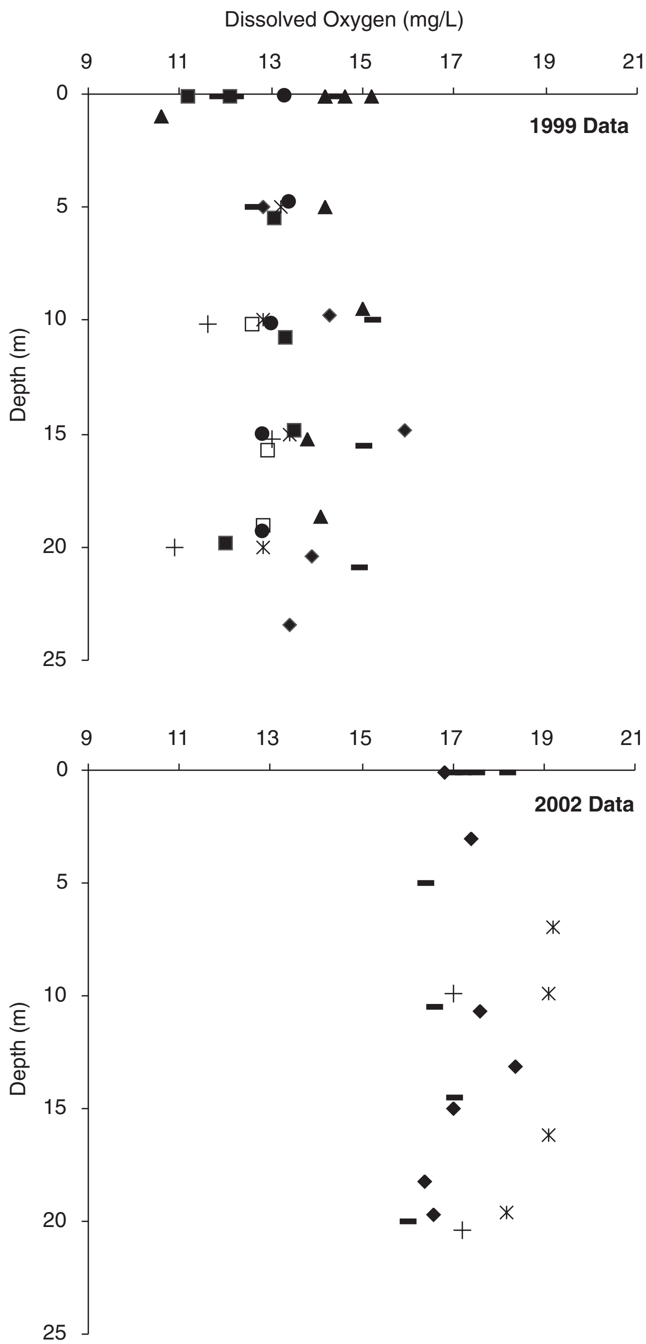

FIGURE 10. Dissolved oxygen values with depth along transects in Turton Bay in 1999 and 2002.

Valeurs d'oxygène dissous en fonction de la profondeur le long des transects de Turton Bay en 1999 et 2002.

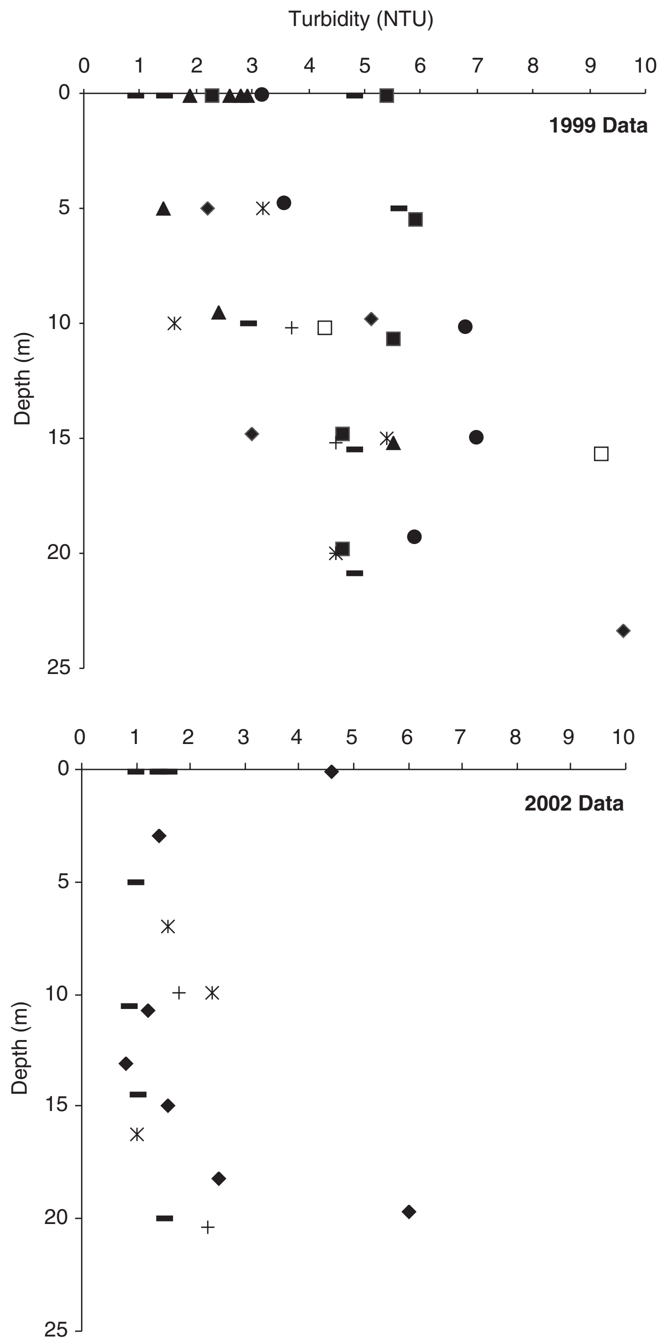

FIGURE 11. Water turbidity values with depth along transects in Turton Bay in 1999 and 2002.

Valeurs de turbidité de l'eau en fonction de la profondeur le long des transects de Turton Bay en 1999 et 2002.

(Aitken and Gilbert, 1996). Dissolved oxygen levels were elevated in 2002 due to a longer ice-free period and increased wind and wave action that summer from strong southeast winds. Overall no trends in dissolved oxygen appear with increasing depth.

Turbidity values were low for bottom and surface water samples, reflecting the small amount of suspended sediment in the water column (Fig. 11). Overall, the low turbidity can be attributed to the paucity of terrestrial runoff into Turton Bay. Even wave and current action along the shoreline failed to contribute much into the marine environment. Higher turbidity in 1999 may have been due to the presence of sediments dropped from the ice floes present during the fieldwork. In addition, the presence of the floes may have helped the fines remain in suspension for a longer period by reducing wave action and dispersal throughout the bay. Turbidity values generally tended to fluctuate with increased depth, suggesting that they were not strongly influenced by depth. The highest values for turbidity were measured in 1999 at the deepest sampling point at the "B/N"1 site and at depth for the Point Transect in 1999 and 2002.

SUBTIDAL SEDIMENTARY ENVIRONMENT

All transects exhibited very poor to extremely poor sorting and generally fined with increasing water depth (Fig. 7; Table II). Mean grain size ranged from coarse silt to coarse clay in Turton Bay. The finest sediments were found at the deepest sites on the Head, Lagoon and Point transects at the head of Turton Bay. Whereas those transects closer to the mouth of Turton Bay, Edge of Town and Mouth transects were coarser containing more sands at their deepest sites than those at the head. The Head and Lagoon transects also had thicker accumulations of fines with increased depth, reflecting lower current action and more reduced circulation that enhanced sedimentation. This was observed from the echo-sounding record and the full grab samples obtained at these sites. The bay head experienced reduced exposure to wind, wave and to ice rafting processes than the more open sites towards the mouth. The Mouth transect, in comparison, had thin rippled, sediment accumulation over a rocky substrate, which was observed from the boat during calm conditions. Echo-sounding results suggest that this flat low angled surface is an extension of the bedrock carbonate beds onshore. The rocky nature of the mouth of Turton Bay and higher amounts of sand-sized particles are likely related to more vigorous wave and current action from its exposed location adjacent to Hooper Inlet and Foxe Basin. Only a few complete samples were collected for sediment analyses at the Mouth transect. The unconsolidated substrate was dominated by gravel and a matrix with a mean grain size of medium silt that was very poorly sorted. The Bunny Nose transect was protected from the main fetch length from Hooper Inlet. It had a medium silt grain size similar to the Mouth transect at sites above 5 m and coarse clay sediments similar to the head of the Bay at depths below 10 m.

Underlying bedrock made sampling extremely difficult throughout Turton Bay. Sites above 5 m depths in the shallow subtidal zone were characterized by a thin sandy surface veneer overlying bedrock and appeared similar in character to the intertidal zone. This shallow zone was affected by ice action during break-up and when ice was blown into Turton Bay throughout the summer season in 1999. Erosion by ice moved onshore was observed in the intertidal zone and upper subtidal zone in 1999. Ice floes with gravel were observed rafting about the bay in 1999. Ice-rafted gravels and cobbles were found in the sediment samples throughout the bay at all depths. Features used to identify these ice-rafted deposits include materials that lay unconformably on the substrate surface, fresh surfaces with no epifauna or flora and a coarse grain size that exceeded that of the coarse silt and clay deposited on the bay floor by marine sedimentation processes.

Regression analyses did not disclose any significant relationships between mean grain size and depth for three of the

TABLE II

Characteristics and grain size statistics of the fine fraction of the subtidal transects in Turton Bay

Transect	Transect length (m)	Maximum depth below lowest low tide (m)	Mean grain size ranges (m)	Wentworth size class	Range of inclusive graphic standard deviation (phi)	Verbal sorting description
Head	500	19.2	27.62-1.88	Coarse silt to coarse clay	3.64-1.64	Poorly to very poorly sorted
Lagoon	500	20.0	47.62-2.32	Coarse silt to coarse clay	3.69-2.56	Very poorly sorted
Point	1150	23.4	4.07-1.46	Very fine silt to coarse clay	2.91-2.09	Very poorly sorted
Edge of Town	550	19.4	53.67-4.47	Coarse silt to fine silt	3.60-2.37	Very poorly sorted
Bunny Nose	950	18.2	21.52-2.60	Medium silt to coarse	3.58-2.02	Very poorly sorted
Mouth	1350	19.9	19.91	Medium silt	3.71	Very poorly sorted
Point sampling towards the head						
"B/N"2 samples	n/a	15.2	3.66-2.71	Coarse clay	3.53-3.01	Very poorly sorted
"B/N"1 samples	n/a	15.7	3.61-2.23	Coarse clay	2.78-2.20	Very poorly sorted

six transects, although fining with depth was generally observed. Ice-rafted materials throughout as well as shell debris and algal covered rocks in the upper subtidal zone likely contributed to a lack of significant relationships with depth. The Head ($n = 11$, $R = 0.817$, $p = 0.05$) and Edge of Town ($n = 12$, $R = 0.887$, $p = 0.05$) transects did exhibit a significant relationship of decreasing mean grain size with increasing depth.

SUBTIDAL INVERTEBRATES

Over 2800 organisms were identified for a total of 96 benthic marine invertebrate species. This total included: 51 species of polychaetes, 15 bivalves, 14 gastropods, 3 ophiuroids, 2 holothurians, 2 polyplacophores, 2 amphipods, and 1 each of brachiopod, asteroid, echinoid, isopod, copepod, ostracod, and decapod (Table III). Roughly a third of the species were found on at least four of the eight transects. There was a similar number of species identified along each line, and ranged from a minimum of 32 (Edge of Town) to a maximum of 37 at Bunny Nose transect (Table IV). Fewer species were collected at the "B/N"1 and "B/N"2 point sites. No trends in total species richness were noted when comparing transects from the head to those towards the mouth in Turton Bay. No obvious trends were seen with total abundances, although over 600 organisms were collected along the Bunny Nose transect and 142 at the Mouth transect (Table IV). Total abundances reflect the total number of samples taken and the relative ease of sampling at sites near the head of the bay and the Bunny Nose transect as opposed to those at the mouth. Polychaete diversity ranges from 16 species at the Mouth transect to 20 at the Head and Bunny Nose transects. Conversely, the number of bivalve species increases towards the bay mouth, whereas the gastropod species decreases towards the bay mouth. *Chaetozone setosa* was the most common polychaete and *Macoma calcarea* the most common bivalve. Average densities for the Turton Bay transects range from 10 to 15 individuals per 100 cm^2 (Table IV). The Bunny Nose transect has the highest average density (21 per 100 cm^2).

Twenty-nine polychaete species were identified from the Head, Lagoon and Point transects in the Ikpiajuk region of Turton Bay (Table III). Four species had higher abundances and densities along these transects than that found along transects towards the mouth. *Chaetozone setosa, Nephtys neotena*, and *Eteone longa* were found along all three transects at the head of the bay, and *Pectinaria hyperborea* along the Head and Lagoon transects. These four species are opportunistic and pollution tolerant, and diagnostic of organically enriched environments when found in high densities (Pearson and Rosenberg, 1978; Rygg, 1985; Pocklington, 1989; Weston, 1990). In this study, they are found in high densities on transects located close to streams entering Turton Bay that drain the dump and sewage lagoon sites onshore.

Other common invertebrate species in the Ikpiajuk region include *Pholoe minuta, Harmothoe imbricata* and *Nereimya aphroditoides.* These epifaunal, errant (freely moving) polychaetes were more abundant at the shallower depths where the coarser substrate of rock, shell debris and macroalgae provided a firm surface on which to move (Dale *et al.*, 1989). The remaining 21 polychaete species had substantially reduced distributions and densities, usually limited to less than five individuals per site in this region of the bay. The presence of coarser materials such as gravels and boulders (some from ice rafting) at 10 to 15 m depths also supported higher abundances of the gastropod *Margarites helicinus* and *Melagonia* spp., a macroalgae that provides food and cover for the gastropod. These two species were particularly abundant along transects near the sewage and dump outflow sites.

The Edge of Town transect exhibited notable differences in the most abundant species. The bivalve *Macoma calcarea* and the brittlestar *Ophiura albida* were especially abundant along this transect. Higher numbers of the brittlestar may have played a role in the reduced polychaete abundances, since it likely preyed on the polychaetes and competed with them for habitat and food. No macroalgae were collected along this transect, which explains the reduced number of scale worms, *Harmothoe* sp. *Pholoe minuta, Eteone longa*, and the gastropod *Margarites helicinus*. With increasing depth, *Chaetozone setosa* and *Nephtys neotena* were more abundant, but never to the levels found in the Ikpiajuk region of Turton Bay. The presence of these opportunistic species here suggests that organic enrichment from the sewage lagoon influences their abundance, but not their distribution.

The Bunny Nose transect showed similar trends to those in the Ikpiajuk region of Turton Bay in terms of the number of polychaete species and abundances. In total, 20 species of polychaetes were identified, with *Chaetozone setosa, Nephtys neotena, Pholoe minuta* and *Eteone longa* being the most prevalent. The remaining 16 polychaete species were collected sporadically along the transect at low densities, generally with less than five individuals per site.

The Mouth transect revealed several invertebrates not sampled elsewhere in Turton Bay including six polychaete species, the bivalves *Macoma calcarea*, and *Thyasira gouldii*, the gastropod *Oenopota harpularia*, the brachiopod *Hemithiris psittacea* and the echinoid *Strongylocentrotus droebachiensis* (Table III). *Oenopota harpularia, Hemithiris psittacea* and *Strongylocentrotus droebachiensis* are more commonly associated with firmer substrates (Dale *et al.*, 1989), such as that found on this transect. This transect has a highly patchy distribution of medium silt sediment of variable thickness (usually <10 cm when present) that overlays a rocky surface.

With respect to temporal changes in the subtidal biota over time, there appeared to be relatively few changes in the number of polychaete and mollusc species from 1999 to 2002. Polychaete abundances and densities were elevated in 2002. Since many of the polychaetes species survive only for a single season (Pettibone, 1963; Curtis, 1977; Fauchald and Jumars, 1979). Opportunistic species have been reported to appear literally overnight in sediments after the sea ice has disappeared (Dale *et al.*, 2002). The earlier disappearance of the sea ice, and sampling a few weeks later in the summer season may account for the apparent increase in number.

INVERTEBRATE FEEDING GUILDS

Most arctic benthic invertebrates are deposit-feeders (Lalli *et al.*, 1973) and tend to be common in fine sediments where

TABLE III

Subtidal faunal species list for the Turton Bay transects

Date	Head	Lagoon	Point	"B/N"1	"B/N"2	Edge of Town	Bunny Nose	Mouth	Number of transects encountered
Polychaeta									
Ampharete cf. *acutiformis* (Grube)								X	1
Ampharete sp.							X		1
Aricidea cf. *nolani* (Webster and Benedict)		X	X			X	X		4
Brada inhabilis (Rathke)								X	1
Brada villosa (Rathke)								X	1
Capitella cf. *capitata* (Fabricius)		X					X		2
Capitella sp.							X		1
Chaetozone setosa (Malmgren)	X	X	X	X	X	X	X	X	8
Chone infundibuliformis (Kroyer)			X	X			X	X	4
Chone sp.			X					X	2
Cirratulus cirratus (Muller)							X		1
Enipo torelli (Malmgren)						X			1
Eteone longa (Fabricius)	X	X	X	X	X	X	X	X	8
Euchone analis (Kroyer)	X			X	X	X			4
Flabelligera affinis (Sars)		X		X			X		3
Gattyana amondseni (Malmgren)	X		X			X			3
Harmothoe imbricata (Linnaeus)	X	X	X	X			X		5
Harmothoe oerstedi (Malmgren)	X	X	X					X	4
Heteromastus filiformis (Claparede)	X		X			X	X		4
Lanassa nordenskioldi (Malmgren)	X	X			X	X	X		5
Leaena cf. abranchiata (Malmgren)	X								1
cf. *Microspio* sp.								X	1
Nephtys caeca (Fabricius)						X			1
Nephtys ciliata (Muller)	X	X							2
Nephtys incisa (Malmgren)	X	X	X		X	X			5
Nephtys longosetosa (Oersted)		X				X			2
Nephtys neotena (Noyes)	X	X	X		X	X	X	X	7
Nereimyra aphroditoides (Fabricius)	X	X	X	X			X		5
Nicomache lumbricalis (Fabricius)								X	1
Nicomache sp. "A" (Ushakov)		X							1
Pectinaria hyperborea (Malmgren)	X	X	X	X	X	X	X	X	8
Petaloproctus tenuis (Thiel)								X	1
Pholoe minuta (Fabricius)	X	X	X	X	X	X	X	X	8
Polydora concharum (Verrill)							X		1
Polydora quadrilobata (Jocobi)	X		X	X	X		X	X	6
Polydora sp.		X		X					2
Praxillella cf. *affinis* (Sars)									1
Praxillella cf. *gracilis* (Sars)			X						1
Praxillella praetermissa (Malmgren)	X	X	X		X	X	X	X	7
Prionospio malmgreni (Claparede)							X		1
Proclea cf. *graffi* (Langerhans)	X								1
Sabellidae sp.			X						1
Scoloplos armiger (Muller)	X			X					2
Spio filiformis (Muller)						X			1
Spio cf. *goniocephala* (Thules)			X						1
Spionidae sp.			X			X	X	X	4
Spirobis sp.	X	X			X		X	X	5
Syllidae sp.			X						1
Terebellides cf. *stroemi* (Sars)		X	X		X				3
Terebellidae sp.	X		X			X		X	4
Thelepus cf. *cincinnatus* (Fabricus)				X					1
Nemertean spp.	X						X	X	3
Bivalvia									
Astarte borealis (Schumacher)		X	X						2
*Axinopsida orbiculat*a (Sars)	X					X	X	X	4
Hiatella arctica (Linne)			X					X	2

TABLE III (continued)

Subtidal faunal species list for the Turton Bay transects

Date	Head	Lagoon	Point	"B/N"1	"B/N"2	Edge of Town	Bunny Nose	Mouth	Number of transects encountered
Macoma calcarea (Gmelin)	X	X	X			X	X	X	6
Macoma loveni (Jensen)								X	1
Musculus discors (Linne)		X							1
Musculus niger (Gray)							X	X	2
Mya truncata (Linnaeus)	X	X		X		X	X		5
Nucula belloti (Adams)	X	X	X			X	X	X	6
Nuculana minuta (Fabricius)						X			1
Nuculana pernula (Muller)						X		X	2
Portlandia arctica (Gray)	X	X	X			X	X		5
Serripes groenlandicus (Bruguliere)	X	X	X			X	X	X	6
Thyasira gouldii (Philippi)								X	1
Yoldia hyperborea (Torell)			X			X	X		3
Bivalvia sp.								X	1
Gastropoda									
Buccinum totteni (Stimpson)								X	1
Cingula moerchi (Collin)	X								1
Colus sp.	X								1
Cylichna alba (Brown)			X						1
Margarites helicinus (Phipps)	X	X	X		X				4
Margarites sp.	X	X							2
Oenopota arctica (Adams)		X	X						2
Oenopota harpularia (Couthouy)								X	1
Oenopota incisula (Verrill)			X						1
Oenopota novajasemliensis (Leche)	X								1
Retusa Obtusa (Montagu)		X	X			X			3
Trichotropis bicarinata (Sowerby)			X						1
Trichotropis borealis (Broderip and Sowerby)	X		X				X		3
Gastropoda sp.	X					X			2
Polyplacophora									
Tonicella rubra (Linnaeus)								X	1
Brachiopoda									
Hemithiris psittacea (Gmelin)								X	1
Holothuroidea									
Cucumaria frondosa (Gunnner)	X	X	X			X	X		5
Myriotrochus rinkii sp.							X	X	2
Ophiuroidea									
Ophiura albida (Forbes)		X	X		X	X	X	X	6
Ophiopholis aculeata (Muller)							X		1
Ophiolimna sp.								X	1
Asteroidea									
Leptasterias sp.	X		X						2
Echinoidea									
Strongylocentrotus droebachiensis (Muller)								X	1
Crustacea								X	1
Isopoda									
Mesidotea sibrica		X			X	X	X		4
Amphipoda spp.	X	X	X	X	X	X	X	X	8
Copepoda		X	X			X	X	X	5
Ostracoda			X				X	X	3
Decapoda spp.		X					X		2

TABLE IV

Number of species, average density, faunal abundances and species diversity indices for transects in Turton Bay

Transect	Depth (m)	Number of species per site	Number of individuals	Density (ind/ 100 cm²)	Total number of species per transect	Average density (ind/ 100 cm²)	Total faunal abundance	Simpson's index (I/D)	Shannon-Weiner index (H')	Evenness (E)
Head	5	17	70	9.47	35	10.54	312	4.773	2.302	0.812
	10	16	51	6.90				6.255	2.356	0.806
	15	9	37	5.00				3.988	1.613	0.734
Lagoon	19	14	154	20.82				4.247	1.714	0.649
	5	9	15	3.04	34	9.99	289	18.200	2.119	0.964
	10	20	64	8.52				28.800	2.494	0.833
	15	14	77	10.41				4.148	1.723	0.655
Point	20	14	133	17.99				4.394	1.841	0.697
	10	12	60	8.11	35	13.69	405	4.097	1.718	0.692
	15	6	18	2.43				2.679	1.242	0.693
Edge of Town	20	17	115	15.55				5.097	1.876	0.662
	23	27	212	28.67				4.097	2.140	0.649
	5	14	43	5.81	32	10.58	313	8.039	2.261	0.856
Bunny Nose	10	14	70	9.47				16.541	1.832	0.694
	15	16	88	11.90				10.208	1.875	0.676
	19	23	112	15.15				5.718	1.959	0.625
Mouth	5	13	51	6.90	37	20.83	616	4.861	1.958	0.764
	10	14	58	7.80				7.156	2.144	0.812
	15	17	245	33.13				3.640	1.687	0.595
	18	26	262	35.43				2.707	1.721	0.528
	15	29	89	12.04	35	11.40	142	2.799	0.831	
	20	19	53	10.75				2.688	0.913	

organic content is high (Walker and Bambach, 1974; C. Petersen, 1991). Deposit-feeders dominate both the polychaetes and molluscs in species richness and abundance (Tables V-VI). *Chaetozone setosa* was the most abundant deposit-feeder in Turton Bay. Suspension-feeders exhibit low species richness and abundance values on each transect. *Chone infundibuliformis, Enchone analis* and *Spirorbis* sp. were the most common of the suspension-feeders. *Spirorbis* sp. favour firm substrates with low turbidity and the Sabellid family of which *Chone infundibuliformis* and *Enchone analis* are members can switch to selective deposit-feeding when the suspended food source is low (Fauchald and Jumars, 1979). The low turbidity values measured in this study is sufficient to support these organisms although it could limit the diversity and density of some suspension-feeders resulting in the dominance by the deposit-feeders (Lalli *et al.*, 1973).

Carnivorous polychaetes were more abundant and showed greater species diversity than the suspension-feeders. *Nephtys neotena* was the most common carnivore at deeper sites whereas the scale worms *Pholoe minuta*, *Harmothoe imbricate* and *Harmothoe oerstedi* were more abundant at shallower depths among the algae, rocks, and shell debris that provided the necessary habitat. *Nephtys neotena* increased in abundance and were associated with the deposit-feeder, *Chaetozone setosa*. Both of these opportunistic polychaetes have an affinity to sites of organic enrichment that occurred in Turton Bay particularly at sites in the Ikpiajuk region below 15 m depth, where fining of sediments with depth likely contributed to the increase in numbers. According to Ellis (1960) and Schmid and Piepenburg (1993), the low amount of predation in the arctic can be attributed to low infaunal production in arctic waters. Thorson (1957) found that low predator abundance results in low predatorial pressure in arctic waters.

The smaller mollusc population was dominated by deposit-feeders and included only four species of suspension-feeders. Gastropod populations were very low in comparison to

TABLE V

Polychaete feeding guilds for Turton Bay transects

Transect	Deposit-feeders		Suspension-feeders		Carnivores	
	Number of species	Number of individuals	Number of species	Number of individuals	Number of species	Number of individuals
Head	12	115	2	12	7	88
Lagoon	12	150	1	1	7	49
Point	14	230	2	4	7	64
Edge	11	91	1	10	7	24
Bunny Nose	17	346	2	6	3	99
Mouth	11	38	3	4	4	15

TABLE VI

Mollusc feeding guilds for Turton Bay transects

Transect	Deposit-feeders		Suspension-feeders		Carnivores	
	Number of species	Number of individuals	Number of species	Number of individuals	Number of species	Number of individuals
Head	4	7	2	3	5	7
Lagoon	4	9	3	6	3	16
Point	4	36	1	4	4	5
Edge	5	52	4	13	1	1
Bunny Nose	5	17	3	8	0	0
Mouth	5	18	5	7	1	1

the bivalves, except in those areas of increased algal cover (*Melagonia* spp.). This occurred along transects in the Ikpiajuk region of Turton Bay that have increased numbers of the gastropod *Margarites helicinus,* found on the surfaces of the algae. Low species richness and diversity of gastropods is common in the Arctic (Macpherson, 1971).

FAUNAL ANALYSES

A series of regression analyses were run on the faunal data to test for relationships between fauna and depth. At each site six different regression tests were run using total faunal richness, faunal abundance, combined faunal density, Simpson's diversity index, Shannon-Weiner diversity index and the Evenness index (Table IV). The same tests were also run on the polychaete and on the mollusc data alone since they were the most abundant and dominant of the organisms. No significant statistical relationships were found for the molluscs.

Statistical analyses of the data only revealed a few significant relationships. Statistically significant relationships were identified for the Lagoon and Edge of Town transects where the abundance and density of the total fauna did increase with depth. Values for the regression analyses for the Lagoon transect for the total invertebrate abundance was R = 0.977 (n = 10, p = 0.05) and density R = 0.976 (n = 10, p = 0.05). The Lagoon transect showed significance for an increase in polychaete abundance with depth (R = 0.970, n = 10, p = 0.05). Regression values for the Edge of Town were R = 0.992 (n = 12, p = 0.05) for increasing total abundance and R = 0.996 (n = 12, p = 0.05) for density. Both the Lagoon and Edge of Town transects had large populations of opportunistic deposit-feeding species at deeper sites. The Lagoon site was proximal to the sewage lagoon and dumpsite outflows noted earlier.

Of the diversity indices the only site to show any statistical significance was the Head transect for the polychaetes. The combined polychaete data revealed a decrease in the Shannon-Weiner diversity index (R = 0.976, n = 11, p = 0.05) and Evenness with depth for the Head transect (R = 0.917, n = 11, p = 0.05). This is likely due to the large increase in the number of polychaetes and accompanying rise in density at the deepest site (21 individuals per 100 cm^2) compared to between 5 to 10 individuals per 100 cm^2 at the shallower sites.

Although not statistically significant there are a number of other trends in the biological data worth noting (Table IV). Combined faunal total Evenness values decreased with depth at all transects. Evenness is a measure of relative abundance, and values range from 0 to 1 where 1 represents complete evenness among species and 0 complete unevenness (Magurran 1988). Abundance of organisms increased with depth along all transects, although the number of species increased for the Point, Edge of Town and Bunny Nose transects, it did not for the others. The Simpson diversity index applies more towards organism abundance and is less sensitive to species richness whereas the Shannon-Weiner diversity index applies more to species richness (Pielou, 1975, Magurran, 1988). The reciprocal (I/D) of the Simpson index used here ensures that the index represents an increase in diversity (James and Shugart, 1970). Results of the Simpson's Index were variable and showed no trend with depth. The Shannon-Weiner index decreased with increasing water depth for the Head, Lagoon Point and Edge of Town transects, reflecting the fact that the number of species and total abundance of organisms increased with increasing depth.

DISCUSSION

Steep, narrow intertidal zones, and mesotidal range precluded development of an extensive intertidal zone. The intertidal zone was barren with no invertebrate benthic organisms and rare macroalgae on exposed rock surfaces. The shortened summer season, ice scouring, substrate temperature fluctuations, rocky terrain and presence of anchor ice, account for the barren intertidal zone in Igloolik. Only highly adaptable pelagic amphipods were observed swimming in the intertidal zone. Other studies have found that brackish water conditions from ice melt and terrestrial runoff also restrict benthic fauna in intertidal zones (Ellis, 1960; Ellis and Wilce, 1961; Dale *et al.*, 1989). The same processes that account for the poor sorting of the sediments also produce a high mixing and turnover of sediments, which precluded the formation of intertidal communities.

In general, oceanographic conditions throughout Turton Bay were not sufficiently variable to produce significant differences in potential habitats for benthic communities. Oceanographic measurements made in 1999 and 2002 fit within the range of those measured by earlier workers (Grainger, 1959; Bursa, 1961; Kristensen, 1991). Likely due to the shallow nature of the bay (<25 m) and wave action from an open fetch to the south, the water in this embayment mixes to the bottom creating only short-term and minimal differences in temperature, salinity, dissolved oxygen and turbidity with depth (Figs. 8-11). The most obvious oceanographic trend showed that water temperatures decreased with increased depth, this is likely due to daily heating of the water surface (Fig. 8). Even water temperatures below 0 °C such as those measured at the Point transect in 1999 would not limit arctic marine benthos. The colder temperatures in 1999 at depth are likely due to the later ice break-up and earlier sampling period and summer warming at the surface had not yet had to time to influence bottom temperatures.

Salinity fell within the range for arctic waters and showed a weak trend of decreasing salinity with depth (Fig. 9). The lower values measured in 2002 at the Mouth and Point transects reflect mixing of water from Hooper Inlet and Foxe Basin from the prevalent southeast winds experienced that summer. Strong southeast winds and considerable wave action in 2002 likely also accounts for the higher dissolved oxygen values measured in Turton Bay (Fig. 10). In both 1999 and 2002 dissolved oxygen values were high and never limiting to bottom organisms.

Turbidity values were highly variable throughout the two field seasons (Fig. 11). The higher values in 1999 were probably due to the later sea ice break-up that reduced the dispersal time for suspended sediments. The presence of sea ice helped to reduce wave action in the bay. In addition, deposition of materials from the ice floes was observed during the sampling period in 1999. The highest turbidity values occurred at depth and at sites proximal to the sewage and dumpsite outflows at the Point and "B/N"1 transects. Turbidity values were never at levels that would be limiting to marine organisms. While dissolved oxygen was higher in 2002 and turbidity values lower in 2002 they did not appear to affect the composition and abundance of marine biota.

Analyses of the sediment in intertidal and subtidal sites reveal a number of differences (Tables I-II). Grain size analyses were undertaken on the fine-grained matrix of the coarse gravely intertidal zone. These fines were all very to extremely poorly sorted and ranged from medium sand to coarse silt in mean grain size. These fines along with the coarse angular gravel of this zone were subject to wave and ice action. The intertidal surface at the North and South Spit sites appear to be armoured by the gravels with the fines underneath. Plumes of fine sediment observed during wave action indicated removal of the fine fraction leaving the coarser materials behind. In addition, intertidal sediment was observed frozen into the ice foot and fast ice floes. Wind and wave action frequently pushed the fast ice onshore scraping and gouging the intertidal zone.

The subtidal sediments are composed of poorly to very poorly sorted, coarse silt to coarse clay with varying amounts of gravels of pebble to cobble-sized rocks (Table II). Some of these materials were identified as ice-rafted deposits. Greater exposures of rocky substrate were apparent along the bay sidewalls in the upper subtidal zone and along the Mouth transect. Echo-sounding, grab samples and direct observations from the boat, showed that gravel with cobbles and boulder-sized materials and exposed bedrock were more common at these sites, whereas the deepest parts of the bay were dominated by the fine fraction.

Overall the oceanographic conditions do not limit the distribution of species collected in Turton Bay. The differences in biota are more likely the result of substrate characteristics and local marine conditions. Subtidal zones with unconsolidated substrates are host to a wide range of benthic fauna, whereas those with rocky substrates such as the coarser sediment in the upper subtidal zones exhibit more limited species with greater numbers of epifauna. Epifauna such as the gastropod *Margarites helicinus* and the errant polychaetes *Pholoe minuta, Harmothoe imbricata* and *Nereimyra aphroditoides* are more common than sedentary and errant infauna. These epifaunal species are collected in larger numbers when associated with the macroalgae (*Melagonia* spp.) that grow on rock surfaces, particularly at depths between 5 and 15 m in the Ikpiajuk region. The lowest number of species and densities on the Head, Lagoon and Point transects always occurred at the 15 m depth (Table IV). Echo-sounding showed that this depth was near the bottom of the steep side slope, with a coarse substrate with cobbles and boulders. This resulted in lower numbers of infaunal deposit-feeding polychaetes. In addition, at the 15 m depth at the Point transect a thick black anoxic layer of sediment covered the substrate surface over a wide area in 1999, only two polychaete species were collected (*Pholoe minuta*, *Polydora quadrilobata*) that year from the sediment at this site. This anoxic layer was linked to a sewage lagoon breach and subsequent flow of sewage over this transect that occurred in 1998 (MacDonald, pers. comm., 1999, 2002). By 2002, the black surface layer had disappeared, although species richness and abundances remained low.

The abundance of organisms and number of species among transects are similar throughout the bay, although differences in species composition are evident (Table IV). The total number of species range from 32 at the Edge of Town transect to a high of 37 at the Bunny Nose transect. The Bunny Nose transect has the greatest faunal abundance (616 organisms) and highest densities (21 individual per 100 cm^2) of any line in Turton Bay. This site has fewer gravels and thicker deposits of fine sediments judging by the full grabs that were easily collected along this transect. The fauna are dominated by polychaetes with 17 species of deposit-feeders (346 individuals) (Table V). There are also abundant carnivorous polychaetes (99 individuals) represented by three species. This transect has only one gastropod species (*Trichotropis borealis*) and five deposit-feeding and three suspension-feeding bivalves (Table VI). The protected location of this transect out of the main fetch from Hooper Inlet favours quieter water and increased fine sedimentation that supports a rich population of deposit-feeders.

Differences occur at the mouth where the rocky bottom favours lower faunal abundances and more epifaunal organism such as the Ophiuroids and Echinoids not common elsewhere (Table III). In addition, the proximity to the larger marine populations of Hooper Inlet has lead to the appearance of 11 species not seen elsewhere in Turton Bay (Table III). The thin and patchy nature of unconsolidated sediments along the Mouth transect has resulted in low numbers of deposit-feeding polychaetes and molluscs and more carnivorous errant polychaetes.

Transects in the Ikpiajuk region of the bay have sites proximal to the sewage lagoon and dumpsite outflows. Leontowich (2003) found surface waters flowing into the bay in this area to be enriched in nitrate and phosphorus. The organic enrichment from this water favours the presence of opportunistic and pollution tolerant polychaetes. *Chaetozone setosa, Nephtys neotena,* and *Eteone longa* are found in high densities along all three transects at the head of the bay, along with *Pectinaria hyperborea* (Pearson and Rosenberg, 1978; Rygg, 1985; Pocklington, 1989) at the Head and Lagoon transects (Tables III, V, VI).

Most arctic benthic invertebrates in fine sediments are deposit-feeders (Lalli *et al*., 1973). The fining of sediments with increased depth favours the appearance of deposit-feeders at the deeper sites where finer sediments predominated. In Turton Bay, *Chaetozone setosa* are the most common polychaete and *Macoma calcarea* the most abundant bivalve, both deposit-feeders. Suspension-feeding species are present throughout the bay, molluscs more common than polychaetes, but never in large numbers. Turbidity values likely play little role in their distribution throughout the bay.

CONCLUSIONS

This is the first detailed study of the distribution of sediments and biota in the intertidal and subtidal zones of Igloolik Island. The narrow intertidal zone is characterized by gravels with a matrix of extremely poorly sorted medium sands to coarse silts. No benthic epifauna or infauna were collected in the intertidal zone likely due to the harsh conditions, subject to anchor ice, ice scouring, the rocky terrain and the shortened summer season. The subtidal zone of Turton Bay supports 96 species of benthic invertebrates of which polychaetes (51 species) and molluscs (29) are the most abundant. Seven bivalves and 28 gastropod species are identified in these waters for the first time. Previous studies (Ellis, 1955, 1960) had only reported polychaete families and so the 51 species recognized in this study supply additional information on this phyla. Other fauna identified are similar to those collected earlier by Ellis (1955, 1960). Overall the benthic invertebrate species identified in this study are consistent with those found in arctic and high arctic waters (Macpherson, 1971; Lubinsky, 1980; Pocklington, 1989; Dyke *et al*., 1996).

The greatest abundances and densities occur at the deepest sites with the finest sediments and least amount of gravels. No obvious trends are found when comparing transects from the head to the mouth of Turton Bay. Oceanographic conditions are similar throughout Turton Bay. The most obvious trend in marine conditions was observed for water temperatures that decreased with depth. Dissolved oxygen, salinity and turbidity values were highly variable with depth and spatial distribution. These values were never consistent enough to show any trends nor were they considered to be limiting to marine organisms. Thus marine oceanographic conditions likely do not play an important role in the distribution of benthic invertebrates in Turton Bay. The few statistical trends that exist support the notion that for the most part, benthic invertebrates are similar throughout Turton Bay.

Differences in the presence and abundance of species that were observed can be related to substrate characteristics and local environmental conditions. One condition relates to the impact of sewage and dump outflow in the Ikpiajuk area of the bay. High densities of opportunistic and pollution tolerant species occur in these zones proximal to small streams draining the dump and sewage lagoon. A sewage spill in 1998 across the Point transect was still recognizable in 1999, and although the thick anoxic sediment layer at a 15 m depth apparent in 1999 was gone in 2002, the site was still largely devoid of infauna.

Substrate conditions also affect the distribution of organisms. The steep rocky sidewalls of the upper subtidal zone support a coarser substrate and a large number of macroalgae on rock surfaces. This in turn supports increased numbers of epifauna such as the gastropod, *Margarites helicinus* and errant polychaetes such as *Pholoe minuta, Harmothoe imbricata* and *Nereimyra aphroditoides*. The Mouth transect has a thin layer of unconsolidated material overlying a bedrock surface. Fewer infaunal polychaetes and molluscs were collected along this line. Instead large numbers of epifauna were collected including 11 species not seen elsewhere in the bay, likely having moved in from Hooper Inlet.

ACKNOWLEDGMENTS

The authors wish to thank John J. MacDonald and Maurice Ulajuruluk from the Igloolik Research Laboratory for their assistance in expediting the fieldwork required for this project. We thank Michelle Hanson for her help in the field as a research assistant, Deliang Han for drafting the figures and Van Tran for creating the tables. We acknowledge the financial support from the Faculty of Science at the University of Regina and a NRSEC Operating Grant held by J. Dale that made this study possible. This paper benefited from the constructive comments of Mary-Louise Byrne and two anonymous reviewers.

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