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Identification of Mega- and Macrobenthic Ecologically and Biologically Significant Areas (EBSAs) in the Hudson Bay Complex, the Western and Eastern Canadian Arctic

Identification de zones d'importance écologique ou biologique (ZIEB) mégabenthiques et macrobenthiques dans le complexe de la baie d'Hudson ainsi que dans l'est et l'ouest de l'Arctique canadien

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ABSTRACT

Benthic communities and their activity are important to ecosystem processes in the polar marine environment. Benthic diversity and production feeds into higher levels of the food chain, benthic remineralization returns nutrients into the water column usable for primary production, and sponge and deep sea coral beds provide structural complexity to habitats and host many associated species. Given the limited spatial coverage of benthic sampling, proxies such as sediment pigment concentration, strong topographic features and polynyas can be used as indicators for benthic production. We used the density of coral and sponge beds, benthic diversity and biomass, benthic remineralization and sediment pigment concentration to identify benthic ecologically and biologically significant areas (EBSA)s in the Canadian Arctic for the Hudson Bay Complex, Eastern Arctic and Western Arctic biogeographic regions. Areas of Hudson Strait have relatively high concentrations of soft corals and sponges compared to other areas within the Hudson Bay Complex, while Baffin Bay-Davis Strait areas in the Eastern Arctic are characterized by large aggregations of sea pens, large gorgonian corals and sponges. In Baffin Bay, particularly important populations of Pennatulacean sea pens are found at the outflow of Lancaster Sound and along the continental slope off Baffin Island. In Davis Strait particularly abundant beds of large gorgonian coral and sponges are found in the Hatton Basin (outflow of Hudson Strait). The Narwhal over-wintering site in Davis Strait has large aggregations of gorgonian corals as well as the rarer black corals. Lancaster Sound and the North Water Polynya areas support high benthic diversity, benthic biomass and high benthic boundary fluxes, as well as still undescribed species such as rare species of enteropneusts. Both polynyas and strong current zones are indicative of high benthic diversity and activity in the Western Arctic, more specifically in Victoria Strait and Franklin Strait. In the Beaufort Sea LOMA, additional benthic EBSAs are suggested in Franklin Bay and the Prince of Wales Strait. There is a large deficiency of data in the Arctic Basin and Canadian Arctic Archipelago, but presence of polynyas in those regions may serve as a proxy of high benthic biodiversity and productivity.

RÉSUMÉ

Les communautés benthiques et leur activité sont importantes pour les processus écosystémiques dans l'environnement marin polaire. La diversité et la production benthiques s'intègrent à des niveaux plus élevés de la chaîne alimentaire, la reminéralisation benthique rediffuse dans la colonne d'eau des nutriments utilisables pour la production primaire, alors que les lits d'éponges et de coraux de grande profondeur fournissent une complexité structurelle aux habitats et abritent de nombreuses espèces apparentées. Étant donné la couverture spatiale limitée de l'échantillonnage benthique, des indicateurs comme la concentration pigmentaire du sédiment, des caractéristiques topographiques importantes et des polynies peuvent être utilisés en guise d'indicateurs de la production benthique. Nous avons utilisé la densité des lits de coraux et d'éponges, la diversité et la biomasse benthiques, la reminéralisation benthique et la concentration pigmentaire du sédiment pour identifier les zones d'importance écologique ou biologique (ZIEB) benthiques dans l'Arctique canadien pour les régions biogéographiques du complexe de la baie d'Hudson ainsi que de l'est et de l'ouest de l'Arctique. Les zones du détroit d'Hudson présentent des concentrations relativement élevées de coraux mous et d'éponges comparativement à d'autres zones du complexe de la baie d'Hudson, alors que les zones de la baie de Baffin et du détroit de Davis dans l'est de l'Arctique se caractérisent par d'importants bancs de plumes de mer, de grandes gorgones et d'éponges. Dans la baie de Baffin, des populations particulièrement importantes de plumes de mer Pennatulacés sont présentes dans le courant de débordement du détroit de Lancaster et le long de la pente continentale de l'île de Baffin. On trouve des lits particulièrement abondants de grandes gorgones et d'éponges dans le détroit de Davis au niveau du bassin Hatton (courant de débordement du détroit d'Hudson).Le site d'hivernage du narval dans le détroit de Davis abrite d'importants bancs de grandes gorgones et de coraux noirs, qui sont plus rares. Les régions du détroit de Lancaster et de la polynie des eaux du Nord (NOW) présentent une grande diversité benthique, une forte biomasse benthique et des flux de reminéralisation benthique importants, de même que des espèces non encore décrites, notamment de rares espèces d'entéropneustes. Tant les polynies que les zones de courant fort sont des signes de diversité et d'activité benthiques importantes dans l'ouest de l'Arctique, plus précisément dans le détroit de Victoria et le détroit de Franklin. D'autres zones d'importance écologique ou biologique pourraient exister dans la zone étendue de gestion des océans (ZEGO) de la mer de Beaufort, c'est-à-dire dans la baie de Franklin et le détroit du Prince-de-Galles. Il manque énormément de données sur le bassin arctique et l'archipel arctique canadien, mais la présence de polynies dans ces régions pourrait indiquer une biodiversité et une productivité benthiques importantes.

INTRODUCTION

Participants at a recent IUCN workshop (2010) have identified thirteen “super” ecologically and biologically significant areas (EBSAs) in the Arctic, three of which fall in Canadian territorial waters (Beaufort Sea Coast/Cape Bathurst, Polar Pack, North Water Polynya/Lancaster Sound; Figure 1). Super EBSAs meet most or all of the seven Convention on Biological Diversity (CBD) criteria, or meet one or more at a global level of significance. The CBD criteria, established in 2008 (Decision IX/20) for identifying EBSAs in need of protection (Annex I) are: Uniqueness or rarity; Special importance for life history of species; Importance for threatened, endangered or declining species and/or habitats; Vulnerability, fragility, sensitivity, and slow recovery; Biological productivity; Biological diversity; and Naturalness. The IUCN workshop participants further identified regional EBSAs with 24 in, or partially in, Canadian waters (IUCN 2010). These regional EBSAs are illustrated in Figures 2 and 3. Details for the selection of the regional EBSAs were only tabulated in an Annex against the CBD criteria, but the document notes that benthic data were lacking for much of the Arctic and it appears not to have been a factor in the selection of any of the IUCN super EBSAs which are more fully described. The workshop participants considered the identification of CBD EBSAs to be a work in progress, requiring further consultation.

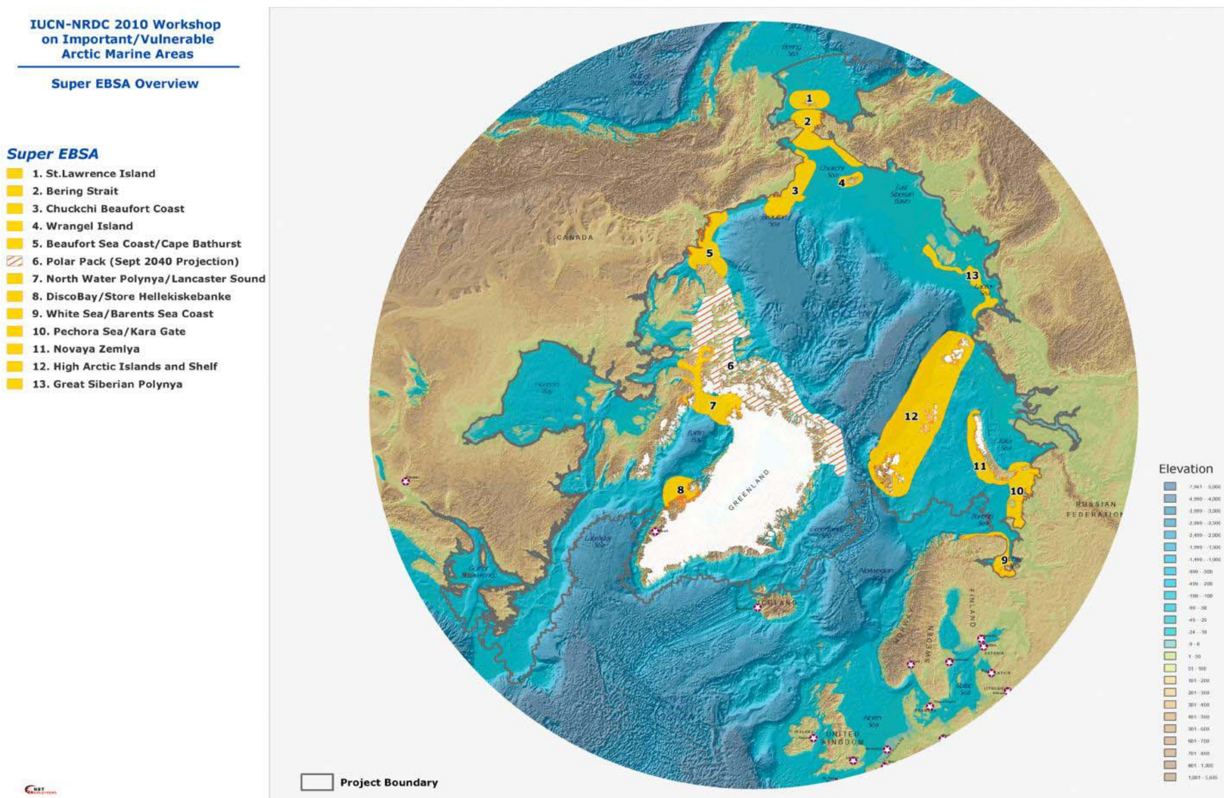

Figure 1. Location of super EBSAs in the Arctic identified by an IUCN expert workshop (from IUCN 2010).

Canadian guidelines for the identification of EBSAs in Canadian waters were established prior to the CBD deliberations, but differ only slightly from the CBD EBSA criteria (DFO 2004). Identification of EBSAs in Canada is made using three criteria: Uniqueness/Rarity; Aggregation; and Fitness Consequences; while Naturalness and Resilience qualities are used to prioritize amongst sites. EBSAs have been identified in some of the Canadian large ocean management areas (LOMAs) and "lessons learned" from their application were recently reviewed (DFO 2011a). Here we present a summary of benthic data for the Canadian Arctic and identify possible EBSAs based on benthic attributes following the Canadian identification criteria.

There have been a number of multidisciplinary research programs in the Arctic seas since the late 1980s, primarily in the Eurasian–Arctic (Greenland, Barents, Kara, and Laptev Seas) and the American–Arctic seas (Bering, Chuckchi and Beaufort Seas, Baffin Bay). These have enriched our knowledge and understanding of Arctic benthic fauna and allowed for some degree of synthesis about the structure and functioning of high latitude benthic systems to be drawn (Klages et al. 2004, Piepenburg 2005). In contrast, the benthic fauna of the Canadian Arctic and its functioning is generally poorly sampled with limited geographic coverage. This is also true compared to less remote areas of Canada (Klages et al. 2004, Archambault et al. 2010, Piepenburg et al. 2011). Recent benthic studies undertaken by the Canadian Healthy Oceans Network (CHONe) and ArcticNet (e.g., Link et al. 2011, Link et al. in prep.), as well as analyses of Canadian Department of Fisheries and Oceans (DFO) research vessel bottom trawl bycatch in the Eastern Arctic (Davis Strait, Hudson Strait, lower Baffin Bay) (Kenchington et al. 2010, Wareham et al. 2010) are exceptions and add important new knowledge to earlier syntheses.

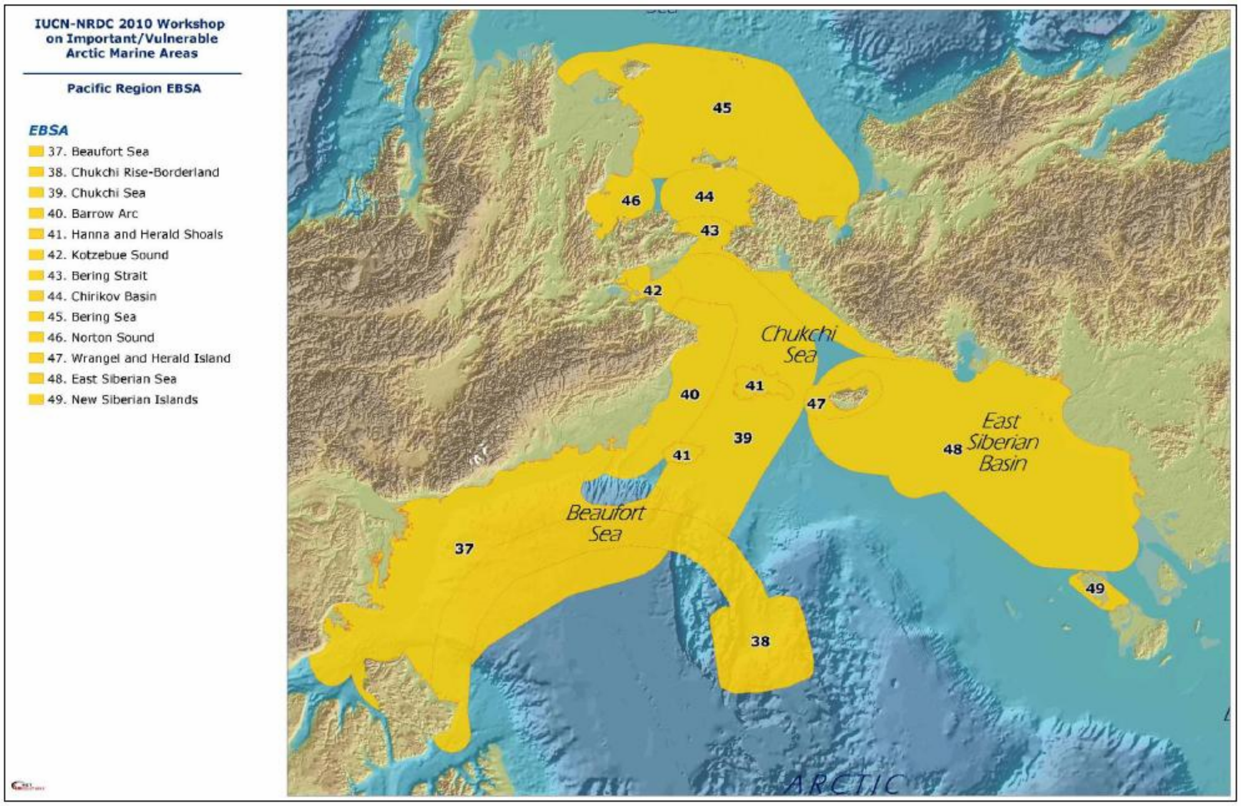

Figure 2. Location of regional EBSAs in the Arctic identified by an IUCN expert workshop (from IUCN 2010).

Kenchington et al. (2010) identified significant concentrations of corals and sponges[1] in the biogeographic zones along the east coast of Canada, including the Eastern Arctic and Hudson Bay Complex. Corals and sponges can have important ecological roles in structuring benthic communities (Boutillier et al. 2010 and references therein). Some of these areas may also be critical life history areas for other animals, such as the narwhal (e.g., Narwhal Over-wintering site; see Figure 7) and areas of enhanced productivity.

[1] These taxa meet the FAO Guidelines (FAO 2009) for vulnerable marine ecosystem (VME) components. Characteristics described by these guidelines have points in common with the DFO EBSA identification criteria and with the criteria adopted by the CBD.

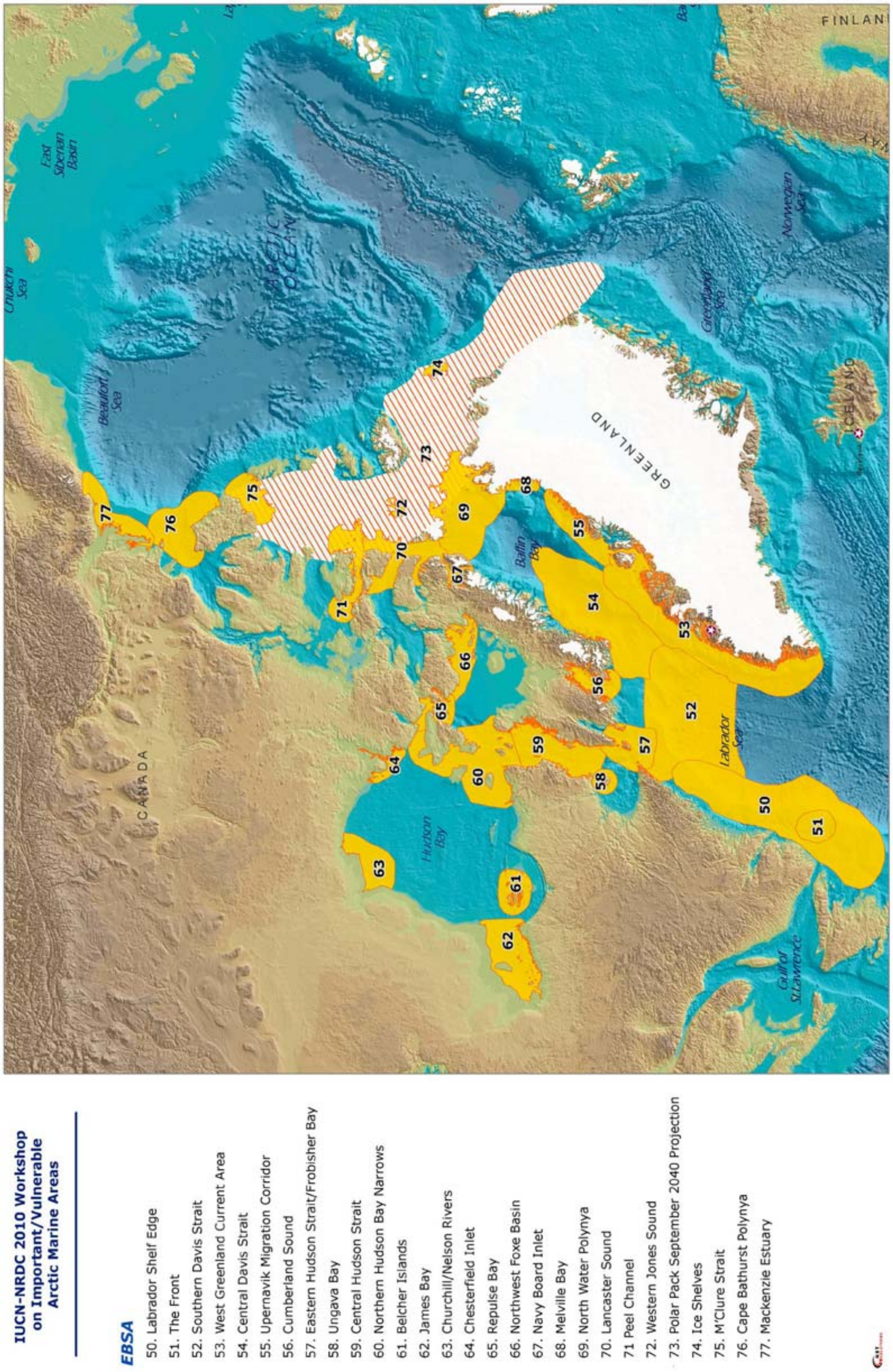

Figure 3. Location of regional EBSAs in the Arctic identified by an IUCN expert workshop (from IUCN 2010).

The current description of benthic macrofauna shows that it is more diverse in the Eastern Arctic than in the western and central regions (Cusson et al. 2007) and the fauna is composed of widespread boreal-arctic species (Piepenburg 2005). Regional hot spots of benthic diversity have been defined (see below), but our knowledge is still limited (Archambault et al. 2010, Piepenburg et al. 2011).

Most scientists have also recognized the influence of mesoscale variability in physical and biotic parameters on the functional composition of benthic assemblages (Thomson 1982, Lalande 2003, Conlan et al. 2008, Lalande et al. 2009, Schmid et al. 2009) and the partitioning of organic matter remineralization by different community members (Piepenburg 2005, Renaud et al. 2007b). However, benthic remineralization (Figure 4) of other nutrients (silicic acid, phosphate, nitrate) that are essential for pelagic processes has not been reported from the Canadian Arctic. Moreover, the link between diversity and processes has been rare in polar benthic research (Sun et al. 2009, Wassmann 2011), and the identification of key benthic species for these processes has not been attempted to our knowledge. So far only large charismatic species have been evaluated (e.g., marine mammals, fishes) (Wassmann 2011). Considering the numerous evidences for the variability of the biodiversity - ecosystem function relationship it seems important to include measures of benthic functioning and their vulnerability to diversity changes in the description of EBSAs.

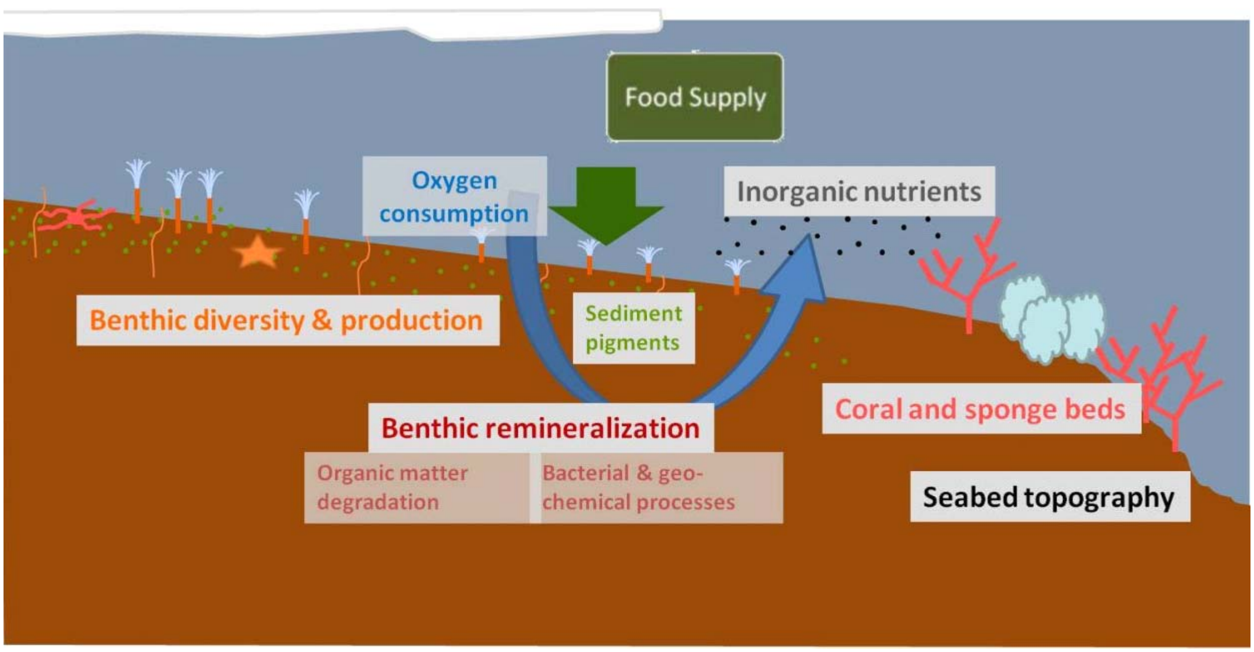

Figure 4. Schematic illustration of benthic ecosystem functioning in Arctic soft-bottom habitats including the parameters used in Table 1.

The activity of benthic communities has also been related to the amount and quality of food supply reaching the seabed (Figure 4, Grebmeier et al. 2006, Sun et al. 2007, Renaud et al. 2007b, Morata et al. 2008). The concentration of chlorophyll *a* (Chl *a*) in surface sediments – an indicator of detritus freshness, and therefore of tight pelagic-benthic coupling – has repeatedly been correlated with benthic carbon remineralization (Renaud et al. 2007a,b, Carroll et al. 2008, Morata et al. 2008), and seems to be a better predictor than substrate heterogeneity (Piepenburg 2005). Therefore, when direct remineralization data is not available, it can be estimated from Chl *a* content in the sediments. In their role as food supply proxies, these sediment parameters could also serve as indicators for benthic abundance and biomass (Ambrose and Renaud 1995, Piepenburg et al. 1997, Carroll et al. 2008, Ambrose et al. 2009, Cochrane et al. 2009). However, benthic diversity and richness in the Arctic are often better explained by the heterogeneity of the habitat (e.g., sediment grain size) (Grebmeier and Barry 1991, Lalande 2003, Carroll et al. 2008, Ambrose et al. 2009) because heterogeneity favours benthic diversity and richness through niche partitioning (Kostylev et al. 2005). Seabed topographic heterogeneity has been used as a surrogate to predict diversity in remote and under-surveyed areas (Dunn and Halpin 2009, McArthur et al. 2010), but this approach has not been applied to the Canadian Arctic. Owing to its stable character and accessibility, seabed topographic heterogeneity could be a valuable surrogate for benthic diversity in the Canadian Arctic where other data are scarce or nonexistent. In even less surveyed regions, it may be possible to infer important benthic processes in areas of known polynyas (Figure 5). Polynyas are recurring areas of seasonally open water surrounded by ice. Energy and material transfer between the atmosphere, surface waters, and the deep-sea in polynyas create high productivity and intense biogeochemical recycling. Studies have shown enhanced abundance of benthic organisms and their activity at the seafloor beneath such physical oceanographic phenomena (Grebmeier and Barry 2007).

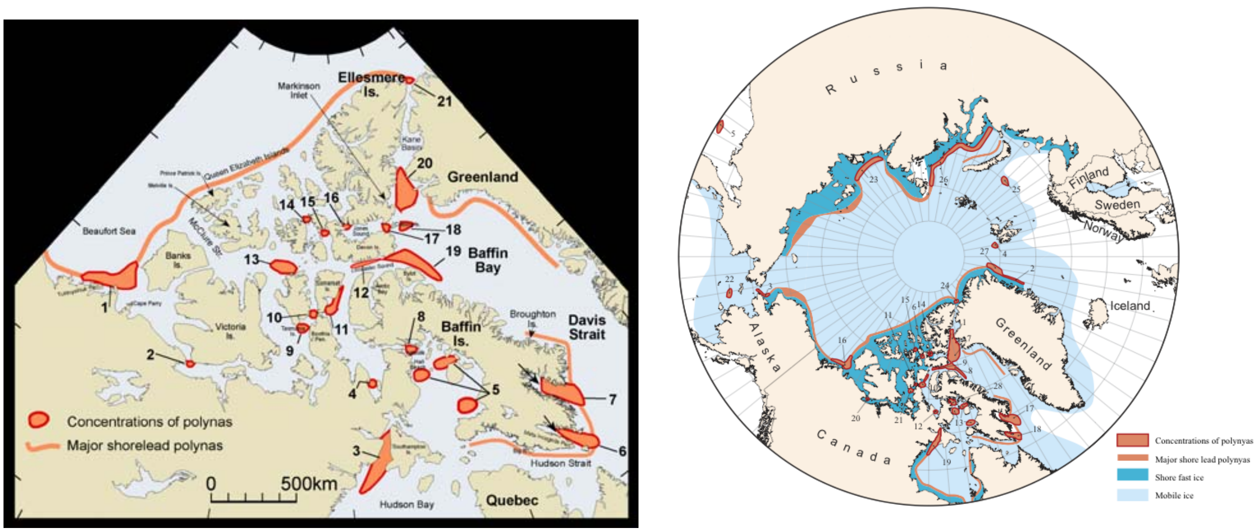

Figure 5. Polynyas (left) and ice cover (right) in the Arctic from Barber and Massom (2007).

Identification of benthic EBSAs in the Canadian Arctic can be based on the presence of corals and sponge beds, high benthic diversity and biomass and/or important areas for benthic remineralization with high confidence. Where such data are not available, benthic EBSAs can be inferred from data on sediment Chl *a* and carbon content or the presence of polynyas known from the literature referred to above. Here, we first give a general overview of data available from the literature and new unpublished results. Subsequently, we identify EBSAs for benthic systems in the Canadian Arctic by ecoregion (DFO 2004) with the proviso that additional areas may emerge as recent (ArcticNet, CHONe) and anticipated (DFO) benthic surveys are completed and analysed.

CORALS AND SPONGES

DFO trawl survey data on the location of coral in the eastern Arctic has been available since the late 1990s and was summarized in 2007 (Wareham and Edinger 2007). Since then, with increasing international profile, further data collection and analyses have been undertaken to identify species and important aggregations (Kenchington et al. 2010, Wareham et al. 2010). DFO, following international leads, has recognized corals and sponges as important benthic attributes (DFO 2010).

INFORMATION SOURCES AND LIMITATIONS

The southern portion of the Eastern Arctic Biogeographic Zone (DFO 2009) is well sampled but there are areas in the northern portion of the Northwest Atlantic Fisheries Organization (NAFO) Division 0A and in the deeper water below 1500 m throughout that are not surveyed (Kenchington et al. 2010). The surveys also do not sample close to the coastline including the fjords and bays such as Frobisher Bay and Cumberland Sound. These latter are areas of known polynyas (Figure 5; Barber and Massom 2007; and see Section Benthic Productivity as Indicated by Physical Oceanographic Features (Polynyas, Ice Edges) below) and so may harbour coral and sponges aggregations. However for most of the coastline which is scoured by ice, the upright and sessile nature of many of these species makes it unlikely that they would persist in large aggregations. A study in a coastal area in the southwest of Greenland found predominantly polychaetes (Sejr et al. 2010).

Data from the Eastern Arctic Biogeographic Zone (DFO 2009) comes from several sources (see Kenchington et al. 2010): DFO conducted eight depth stratified random surveys from 1999 through to 2009 (Treble et al. 2000, Treble 2002, Treble 2009), using a stern trawler (MV *Paamiut*) fitted with an Alfredo III bottom otter trawl equipped with rock hopper ground gear. These deep water multispecies surveys covered depths of 400 m to 1500 m and initially targeted Greenland Halibut (*Reinhardtius hippoglossoides*) with sampling of shrimp species added in 2006. In 2006 and 2008 two surveys were conducted in southern Division 0A (Baffin Bay south of 73.5°N) using two different trawl gears: a Cosmos shrimp trawl for the shallow water between 100 m and 800 m, and the Alfredo III trawl between 400 m and 1500 m (Treble 2009). In 2008 the vessel *Paamiut* carried both trawl gears and the surveys were done on the same cruise (PA2008-7). In 2009 the Alfredo III otter trawl was modified with a tagging box instead of the normal cod-end for use during a Greenland Halibut tagging exercise in which 19 tows were made in NAFO Division 0B. Since the analyses of Kenchington et al. (2010) the 2010 *Paamiut* survey data have been made available. This survey (PA2010-9) used the Alfredo III otter trawl for 163 sets and the Cosmos shrimp trawl for 29 sets (shallower water as above) and extended further northward in Baffin Bay to latitude (75.5°N) east of Lancaster Sound. Tow length with the Alfredo III trawl is 30 minutes at 3 knots, producing tows of approximately 0.93 km. Tow length with the Cosmos gear is about half that distance because of the slower tow speed, 2.6 knots, and shorter 15 minute tow duration.

Data for the Eastern Arctic Biogeographic Zone were also available from the Northern Shrimp Research Foundation (NSRF) and DFO joint industry/government shrimp surveys in NAFO Divisions 2G and 0B (NSRF-DFO). Those surveys were conducted on an industry vessel with DFO providing the scientific advice on sample design and analysis of the data collected. The first of an on-going annual survey was conducted in the summer of 2005 (BAL2005100) and data were available for the spatial analysis through to 2008 (Kenchington et al. 2010). Data from the 2009 and 2010 surveys have been considered here (BAL2009104, BAL2010105). The NSRF/DFO surveys are conducted at depths 100 m to 750 m in the Resolution Island area (from 63°W to 66°W and 60°30'N to 63°N) and in NAFO Division 0B (DFO 2007, 2008). The former extends into the Hudson Bay Complex Biogeographic Zone (DFO 2009). It should be noted that in 2008 the Shrimp Fishing Area 2EX study area (the majority of NAFO Division 0B) was sampled with a modified Campelen trawl. In 2007 a few sets from the DFO-conducted shrimp survey using Cosmos trawl gear in Canadian Shrimp Fishing Area 3 (SFA 3) occurred in the Eastern Arctic Biogeographic Zone and these were considered here (see DFO 2008). Also, a large data gap currently exists in the Hatton Basin area due to the exclusion from the sampling design for the NSRF-DFO survey of rough bottom areas that contained hard coral and sponge (as identified by shrimp fishermen) and the recent expansion of this area with the creation of the Voluntary Coral Protection Zone in 2008.

Collectively these surveys provided 778 records of coral and 803 null records (no coral) from depths between 100 m and 1482.5 m and 850 records of sponge and 761 null records (no sponge) from depths between 105 m and 1484 m.

Research vessel data of coral bycatch from the Hudson Bay Complex Biogeographic Zone is restricted to Hudson Strait and Ungava Bay in the eastern portion of the Zone. In 2007 and 2009 DFO conducted shrimp surveys using a Cosmos shrimp trawl in SFA 3 (see DFO 2008). The surveys were stratified-random as for the Eastern Arctic. Tow duration was 15 minutes at 2.6 knots. Two species of shrimp, northern shrimp (*Pandalus borealis*) and striped shrimp (*P. montagui*), occur in SFA3, although striped shrimp is the dominant species (DFO 2008). Three other records for this biogeographic zone were collected with Campelen trawl gear in 2006 during the NSRF-DFO survey of the Resolution Island Study Area (RISA) (see details in the Eastern Arctic Biogeographic Zone data source described above).

Wareham et al. (2010) used similar data: NSRF-DFO Survey (2005-2008), DFO Groundfish Stock Assessment Surveys (1996-1999), and Commercial Logbook Data (1998- 2009), but focused on Hatton Basin, including the Labrador Shelf as an area of interest. They also included soft corals in their analysis, which were recorded but not analyzed in Kenchington et al. (2010).

There were 132 records with coral bycatch and 96 null coral records for coral for this area (Hudson Strait and Ungava Bay) of the Hudson Bay Complex. Sponges were present in 178 sets and 27 sets were null for sponges.

Sponges on all surveys have not been identified routinely to species although in 2010 samples were identified on board the ship using a recently developed sponge at-sea identification guide (Best et al. 2010) and are being verified.

SPECIES COMPOSITION AND DISTRIBUTION

The species composition of coral in the Eastern Arctic and Hudson Strait is similar to that of the North Atlantic. Twenty-one taxa are recorded (see Kenchington et al. 2010 for full species list) with soft corals (Alcyonacea, Nephtheidae) being the most frequently reported, followed by sea pens and gorgonians (Figure 6). The black corals, *Stauropathes arctica* and *Bathypathes* sp. have also been identified (Kenchington et al. 2010). Although black corals are widespread in their distribution, their occurrence is relatively rare.

Of the species described for this area, NAFO considers large and small gorgonian corals, sea pens and sponge grounds to be vulnerable marine ecosystem components (Fuller et al. 2008). Significant catches were found in the vicinity of Hatton Basin at the outflow of Hudson Strait. Large gorgonians and sea pens occurred mostly in slope environments (Kenchington et al. 2010), including around Hatton Basin and along the Labrador Shelf edge (Wareham et al. 2010). New data obtained since Kenchington et al. (2010) led to the identification of significant concentrations of sea pens (*Ombellula* sp.) at the outflow of Lancaster Sound in Baffin Bay (Figure 7). Significant concentrations of sea pens were also identified north of the Narwhal Over-wintering Site and Deep-Sea Coral Conservation Area and at the outflow of Lancaster Sound (Figure 7). Gorgonians, sea pens and sponges are considered to be ecosystem engineers for the role they play in benthic ecosystems (Boutillier et al. 2010).

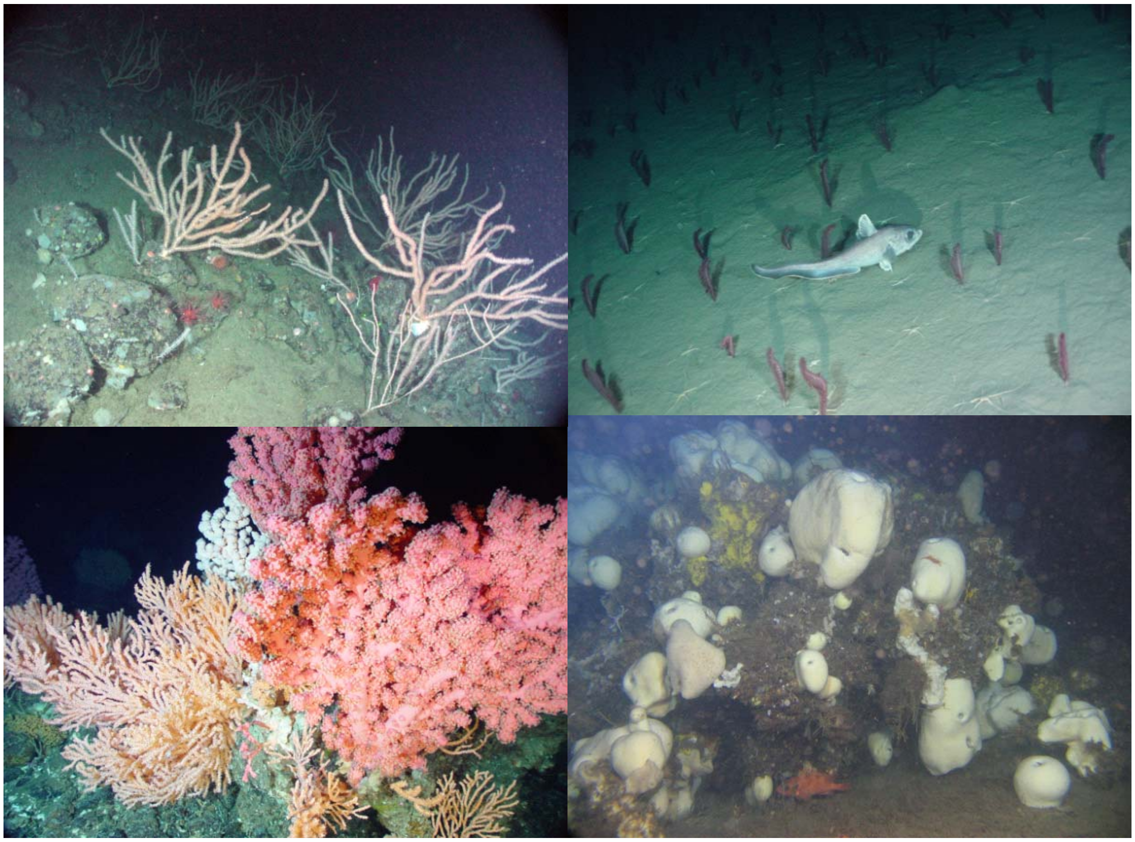

Figure 6. Coral and sponge taxa occurring in the Eastern Arctic (Davis Strait and Baffin Bay). Upper left: the bamboo coral Keratoisis *sp. Upper right: sea pen fields. Lower left:* Paragorgia arborea *and* Primnoa resedaeformis*. Lower right:* Geodia *spp. sponges.*

In Hudson Strait, the dominant taxon is the soft coral Nephtheidae spp., which is distributed throughout the surveyed area over the entire depth range sampled (99 to 966 m) (Figure 8). Soft corals also occurred throughout the sampled area in Davis Strait, primarily on the shelf. Although soft corals were not recognized as a NAFO conservation unit, significant concentrations, such as those found on Saglek Bank (Figure 9), may be indicative of important habitats (Wareham et al. 2010). Coral species richness was greatest in the Hatton Basin area (Figure 9).

The sponges are distributed throughout the sampled area but form significant concentrations in the southern Davis Strait, especially along the slopes, and are absent in shallower areas on the shelves (Figures 7). The vast majority of catches, and especially the large catches, collected the large ball sponge *Geodia* spp. (Figure 6).

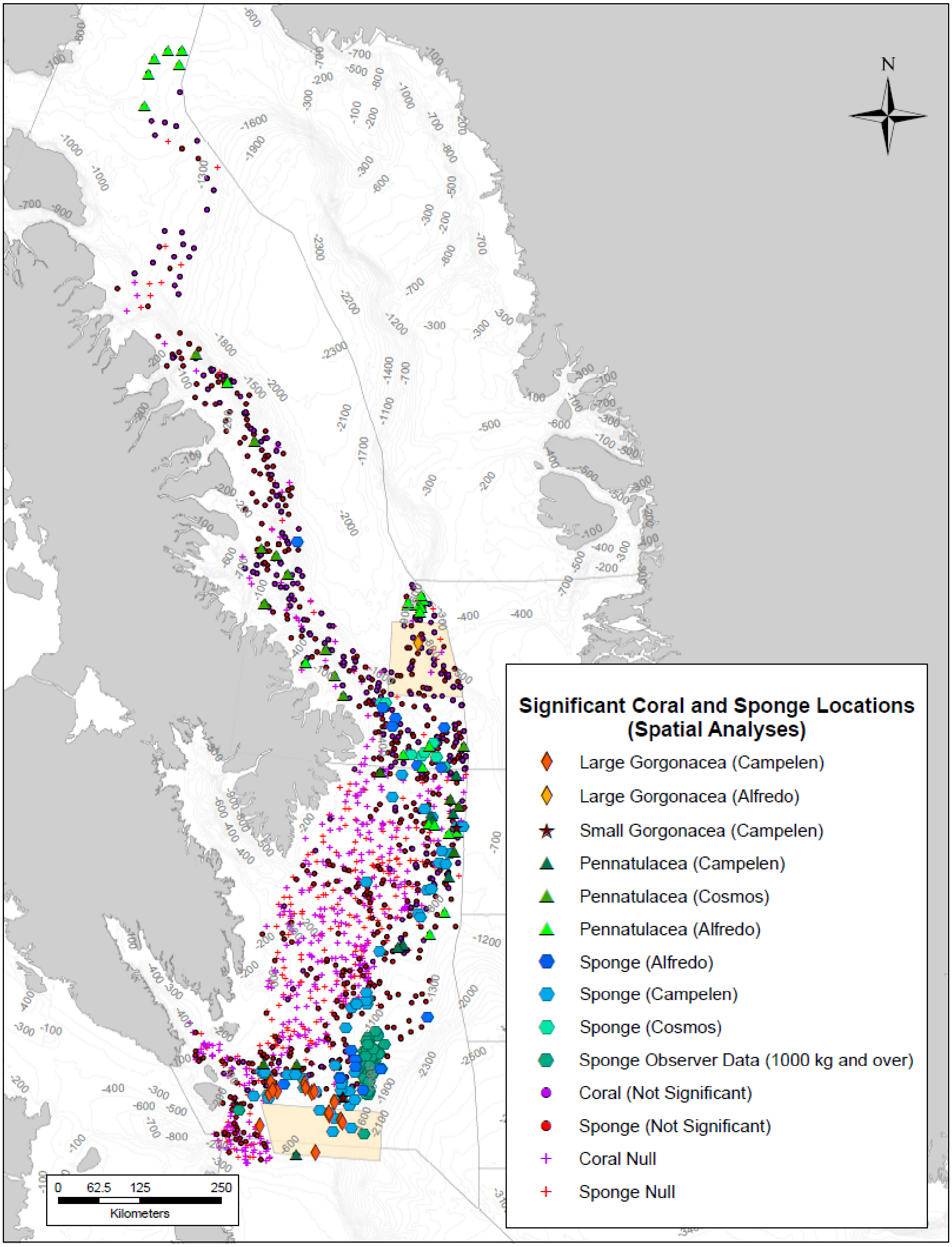

Figure 7. Location of significant concentrations of gorgonian corals, sea pens and sponges in south and central Baffin Bay and Davis Strait. Smaller concentrations of coral and sponge and null records (no coral or no sponge) are also indicated. The location of the Hatton Basin voluntary closure area put in place by the fishing industry is identified to the east of Hudson Strait. The Narwhal Over-wintering Site and Deep-Sea Coral Conservation Area is indicated further north.

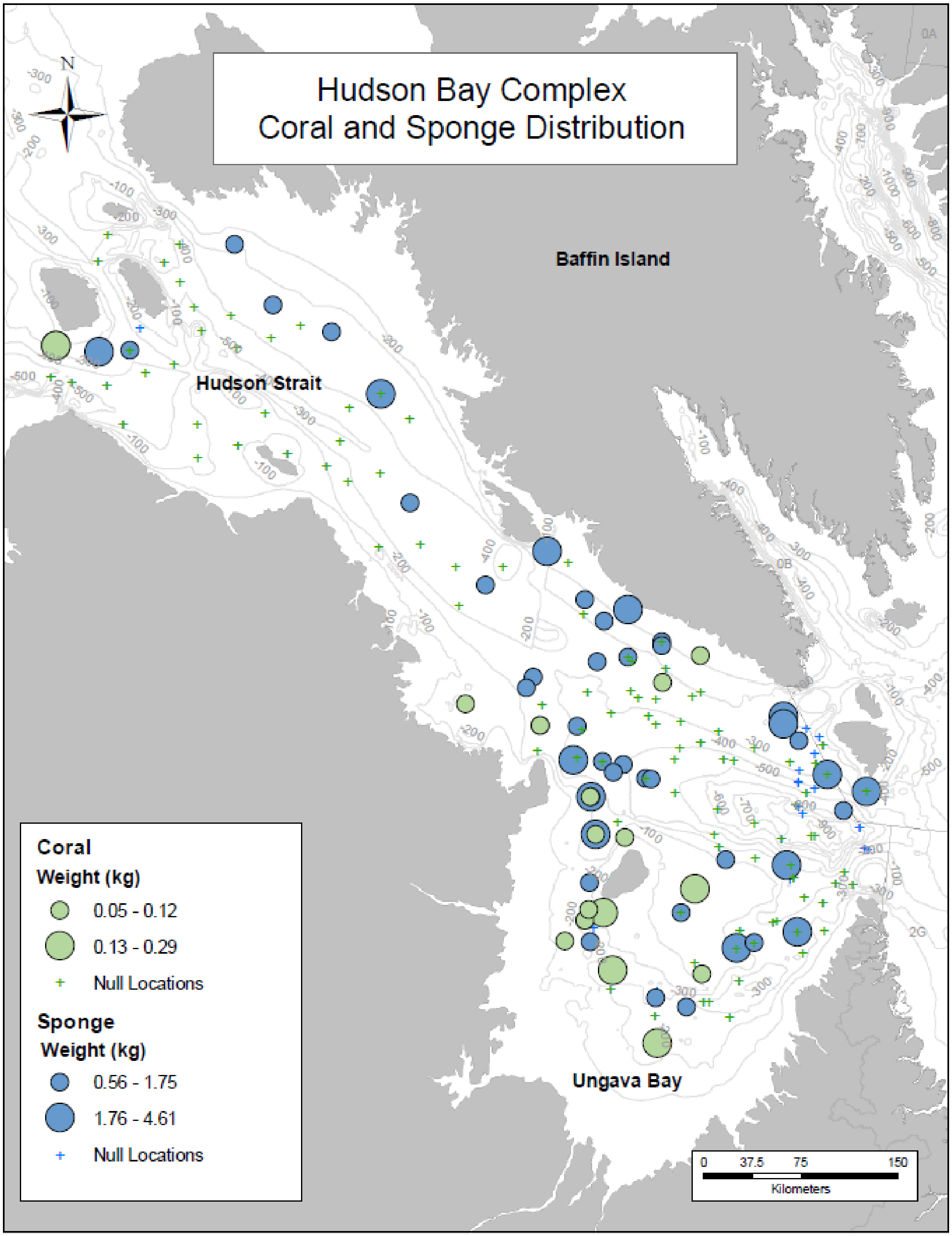

Figure 8. Location of significant concentrations of Nephtheid soft corals and sponges in Hudson Strait collected from research vessel surveys. Smaller concentrations of coral and sponge and null records (no coral or no sponge) are also indicated.

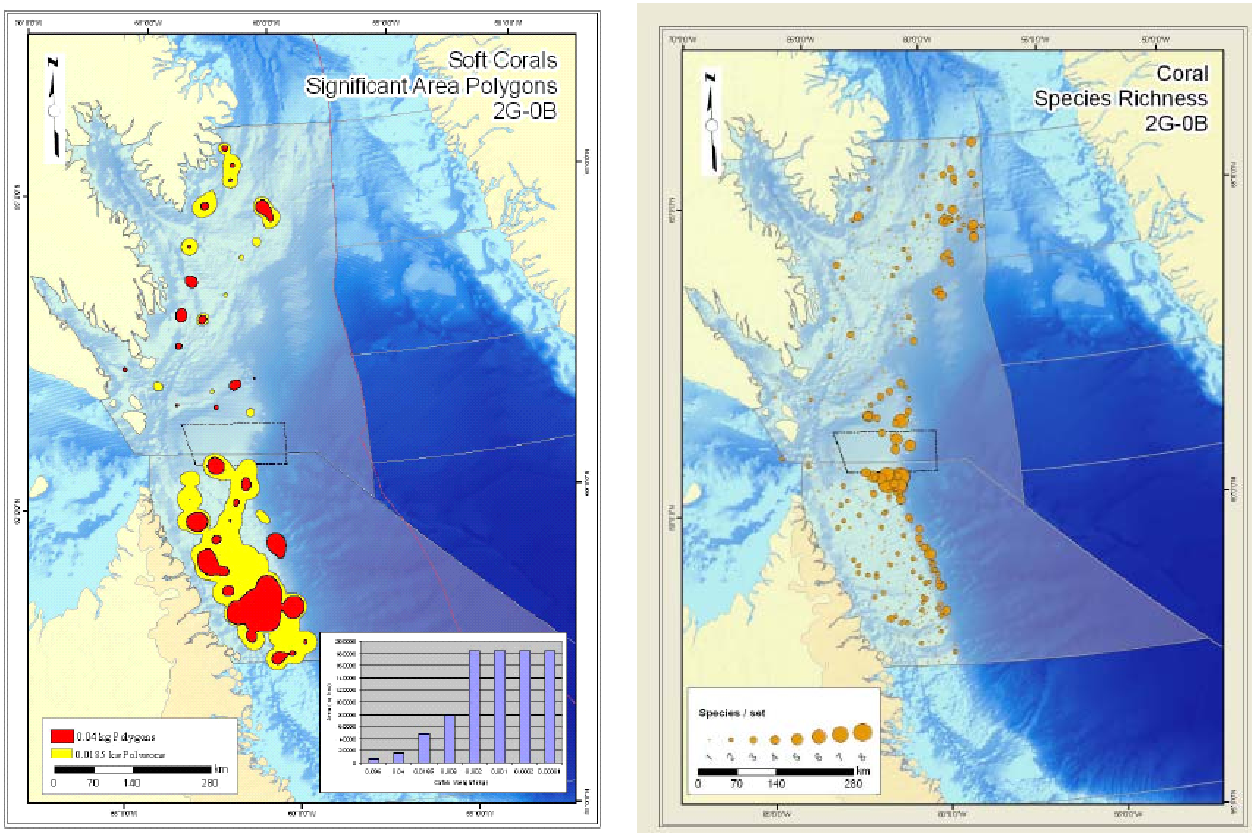

Figure 9. Left: Location of significant concentrations of soft corals (Nephtheidae) from the Labrador Shelves and Davis Strait areas (from Wareham et al. 2010). Right: Coral species richness from the Northern Shrimp Survey bycatch (from Wareham et al. 2010). The location of the voluntary Coral Conservation Closure is indicated by a box at the outflow of Hudson Strait.

MEGA- AND MACROBENTHIC DIVERSITY

Here, mega- and macrobenthic diversity refers to seabed invertebrate fauna > 0.5 mm; benthic fishes are not considered. Macrobenthos include mostly infaunal organisms caught by grab or box corer, while megabenthos represent mostly large epifaunal organisms visible in seabed images and/or caught by towed gear.

INFORMATION SOURCES AND LIMITATIONS

The data used compiles historical data (1955 to 2007) (Wacasey et al. 1976, Wacasey et al. 1977, Wacasey et al. 1979, Wacasey et al. 1980, Atkinson and Wacasey 1989a, b, Cusson et al. 2007, Archambault et al. 2010) and data from recent Arctic programs: ArcticNet, Circumpolar Flaw Lead study (CFL), and CHONe. The gears used were grabs, box corers and Agassiz trawls.

Macrobenthic diversity data in the Canadian Arctic have been available since the 1950s through DFO data reports and various petroleum industry studies. Recent synthesis papers have compiled them in order to compare macrobenthic diversity among Canadian Arctic regions (Stewart et al. 2001, Cusson et al. 2007, Chapman and Kostylev 2008, Archambault et al. 2010) or within the whole Arctic Ocean (Piepenburg et al. 2011). Most of these historical data were collected as general baseline information or specifically to study the impacts of anthropogenic activities, in particular in relation to hydrocarbon exploration. More recent data on macrobenthic diversity in the Canadian Arctic has been published from Lancaster Sound (Thomson 1982) and from the Canadian Arctic Shelf Exchange Study (CASES 2003-2004; Conlan et al. 2008) on the Beaufort Shelf, and reported from the North Water Polynya study (NOW) (1997-1998; Lalande 2003) in northern Baffin Bay.

Further data on macrobenthic diversity has been gained from the Hudson Bay, Mackenzie Shelf, the Amundsen Gulf, Prince of Wales Strait, Viscount-Melville Sound, Franklin Strait, Victoria Strait, Barrow Strait, Lancaster Sound, the NOW and central Baffin Bay since 2007 through the ArcticNet-CHONe campaigns. To our knowledge, there is no data available for other regions of the Canadian Arctic.

Megabenthic diversity on the whole, including corals and sponges, has been only recently studied in the Canadian Arctic. To our knowledge, no published papers and/or Canadian governmental reports exist on megabenthic diversity other than sponge and coral diversity in the Canadian Arctic.

Archambault et al. (2010) and Piepenburg et al. (2011) identified areas of the Canadian Arctic that are under-represented in sampling effort such as the High Arctic Archipelago. Furthermore, many studies show clear changes in Arctic marine ecosystems (mostly marine mammals, polar bears and fishes), but there are few well-documented examples for changes in benthic diversity (Wassmann et al. 2011), and the Canadian Arctic with its size is probably the least sampled area after the deep Central Arctic basin. Finally, if the deepest part is under-sampled, the intertidal zone (including rocky shores) is even more under-sampled and was not included in any historic data or compilation to date. There is a clear lack of information for the shallow coastal zone.

PATTERNS AND DISTRIBUTION

The general diversity pattern of Arctic macrobenthos is considered to be intermediate in global comparison (Piepenburg 2005). There are more than 4800 macrobenthic species described to date. The distribution of these communities in the Arctic Ocean differs significantly among the regions, e.g., supporting less diverse benthic communities in oligotrophic primary production regimes such as the Arctic Basin, and highly diverse assemblages in productive areas such as the Chuckchi shelf (Piepenburg et al. 1997, Klages et al. 2004, Grebmeier et al. 2006, Witman et al. 2008, MacDonald et al. 2010).

In their review, Cusson et al. (2007) demonstrate that benthic assemblages differed among the seven regions on the Canadian Arctic Shelf. A total number of 947 macrobenthic (infaunal) species and taxonomic groups were recorded, and taxonomic diversity was higher in eastern regions than in the central and western Canadian Archipelago. A more recent review (Archambault et al. 2010) which assessed the macrobenthic (infaunal) diversity for the three Canadian oceans showed that the Canadian Arctic has 992 taxa. This number is not much lower than for the Atlantic (1044 taxa) and higher than for the Pacific (814 taxa). However, the Arctic and the Pacific oceans are under-sampled compared to the Atlantic and these relations (or ratios) could change with further study.

When comparing studies on macrobenthic diversity on the Canadian Arctic Shelf, the following regional biodiversity hotspots have been defined (and see the Section on Identification of EBSAs in the Canadian Arctic by Region, below):

Lancaster Sound (Thomson 1982): Macrofaunal abundance, biomass and taxonomic richness were highest when compared to regions west of Barrow Strait and east of Lancaster Sound.

The mega- and macrofauna of Lancaster Sound have been studied in detail during recent ArcticNet-CHONe cruises. Even at great depths (ca 600-800 m), their diversity, biomass and abundance remain high when compared to those near the sill of Barrow Strait (ca 150 m). Those results are reported below under the Lancaster Sound EBSA description as they are regional in focus (see the Section on Identification of EBSAs in the Canadian Arctic by Region).

North Water Polynya (Lalande 2003): Individual abundance and species diversity was very high in the center of the North Water Polynya, even though it did not directly reflect sedimentation patterns.

Cape Bathurst and Mackenzie Canyon (Conlan et al. 2008): Abundance was highest with comparable diversity within the southwestern Beaufort Shelf region.

BENTHIC FUNCTIONING AS INDICATED BY BENTHIC REMINERALIZATION

Benthic ecosystem functioning can be measured in several ways (Danovaro et al. 2010). Remineralization of carbon and nutrients by benthic communities is a function related to many processes in the water column. Here, we use results on benthic boundary fluxes to define areas of important benthic functioning in the Canadian Arctic.

INFORMATION SOURCES AND LIMITATIONS

Data on benthic carbon remineralization in the Canadian Arctic has been published from the Canadian Arctic Shelf Exchange Study (CASES, 2003-2004) on the Beaufort Shelf (Renaud et al. 2007a, Renaud et al. 2007b), the Circumpolar Flaw Lead study (CFL, 2007-2008) in the Amundsen Gulf (Link et al. 2011, Forest et al. 2011) and the North Water Polynya study (NOW, 1997-1998, Grant et al. 2002) in northern Baffin Bay, but the region is still under-studied in the Arctic (Klages et al. 2004).

Further data on benthic remineralization has been gained from the Mackenzie Shelf, the Amundsen Gulf and Viscount-Melville Sound in 2009, and from Barrow Strait, Lancaster Sound, the NOW and central Baffin Bay in 2008 and 2009 during the Malina and ArcticNet-CHONe campaigns. To our knowledge, there is no data available for other regions of the Canadian Arctic.

To determine benthic remineralization, an USNEL box corer was deployed for collecting seafloor sediments at each sampling site. From each box core, three to five sub-cores of 10 cm diameter and 20 cm sediment depth were taken for assessing benthic boundary fluxes in microcosm incubations. The sub-cores were incubated onboard to measure sediment oxygen demand (SOD) in a dark and temperature controlled room (2-4°C), applying the protocol described in Renaud et al. (2007 b) and Link et al. (2011). Benthic carbon remineralization can be calculated from the SOD via fixed ratios. Moreover, water samples were taken from the incubation chambers at three stages to determine remineralization of silicic acid, phosphate (Link et al. in prep.). We chose a multivariate approach including the three benthic fluxes to identify differences between regions using PERMANOVA (Anderson 2001a, b).

PATTERNS AND DISTRIBUTION OF BENTHIC REMINERALIZATION

According to earlier published studies, community oxygen demand was much higher in the Beaufort region than in the NOW (1.8 – 21.0 vs 1.7 – 4.1 mM O_2 m^{-2} d^{-1}) (Renaud et al. 2007a, Grant et al. 2002). More recent results from 2008-2009 show the following pattern (Link et al. in prep., Figure 10): Highest carbon remineralization was recorded from the Mackenzie Delta and Barrow Strait/Lancaster Sound. Slightly lower carbon fluxes were measured in the NOW and Cape Bathurst Polynya area, and lowest carbon cycling in the central Amundsen Gulf, Viscount-Melville Sound and central Baffin Bay (Figure 10). Remineralization of sicilic acid was higher in Barrow Strait/Lancaster Sound and the NOW than in the western Canadian Arctic (Figure 10). Phosphate fluxes are more heterogeneous and did not show general patterns (Figure 10). In general, benthic boundary fluxes were lower in 2009 than in 2008.

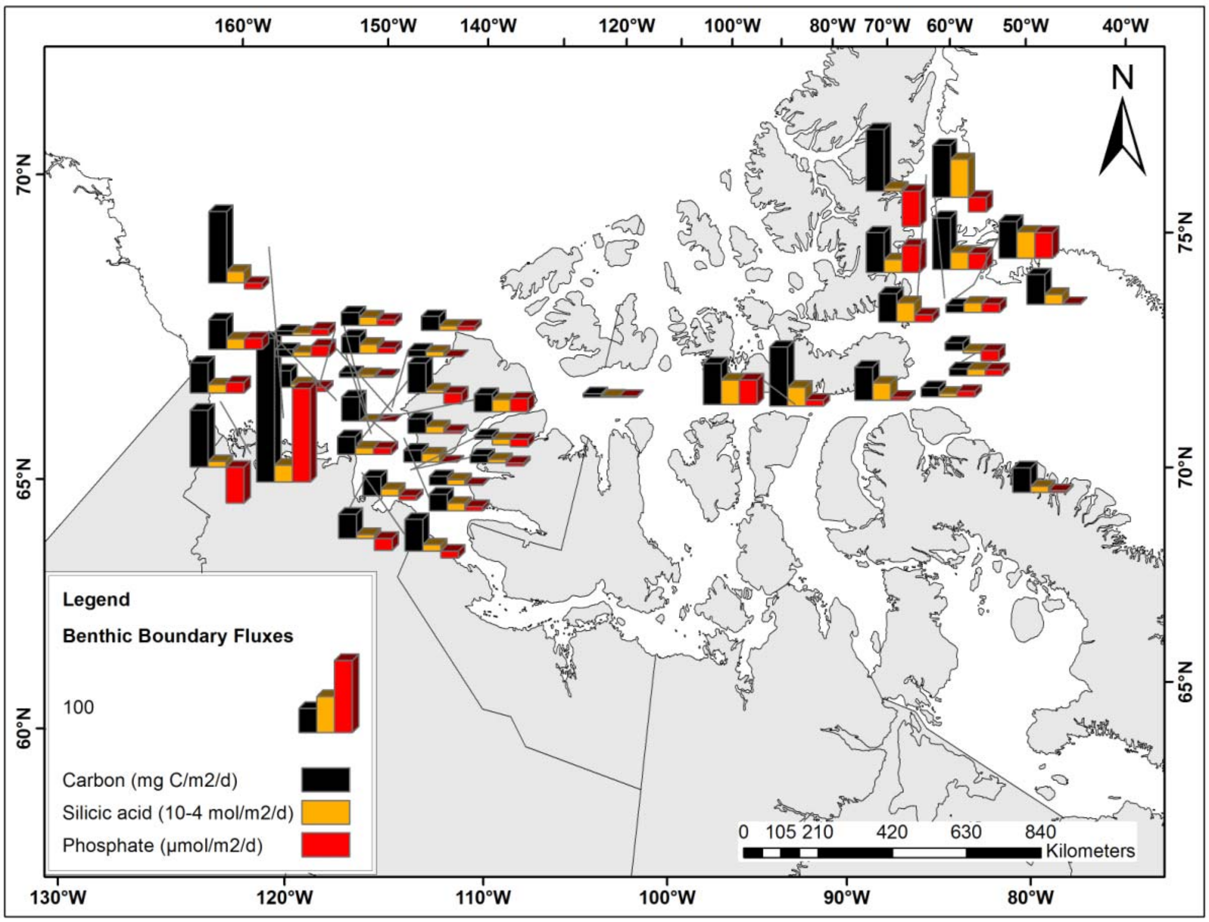

Figure 10. Mean benthic remineralization measured from microcosm incubation cores in the Canadian Arctic in 2008 and 2009. black: carbon remineralization, yellow: silicic acid remineralization, red: phosphate flux.

Results from the multivariate analysis show that benthic remineralization: (a) on the Mackenzie Shelf is significantly different from the Amundsen Gulf, central Baffin Bay and NOW; (b) in the NOW is significantly different from the Amundsen Gulf, central Baffin Bay and Mackenzie Shelf; and (c) in Barrow Strait is significantly different from the Amundsen Gulf, central Baffin Bay, eastern Lancaster Sound and the Mackenzie Basin (Figure 11).

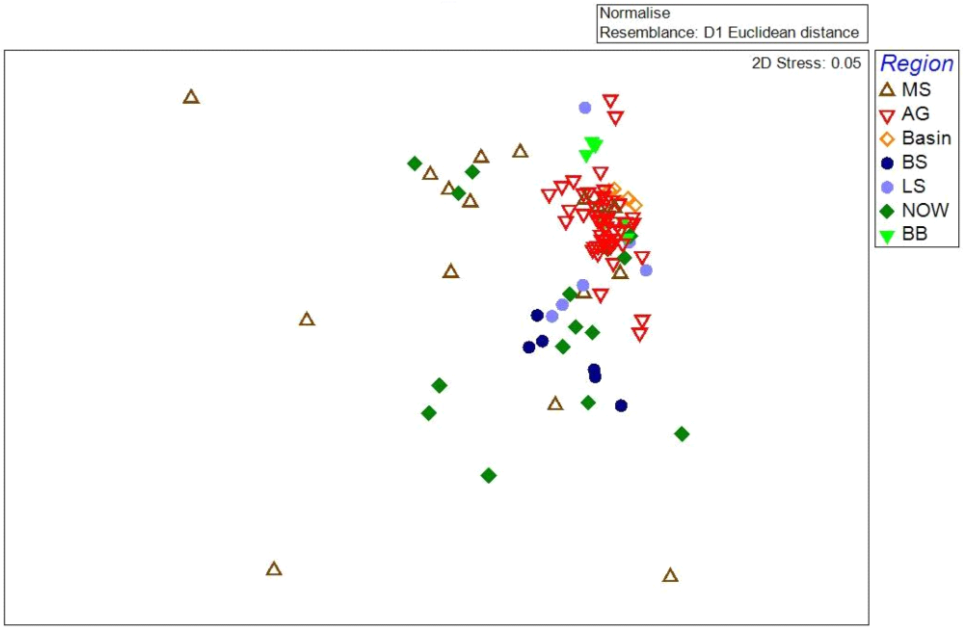

Figure 11. Multidimensional Scaling Plot showing the distance of replicates based on the three benthic fluxes presented in Figure 10. MS= Mackenzie Shelf, AG= Amundsen Gulf, Basin= Mackenzie Basin (or Beaufort Sea), BS= Barrow Strait, LS= Lancaster Sound, NOW= North Water Polynya, BB= Baffin Bay.

SEDIMENT PIGMENT AND CARBON CONTENT AS INDICATORS FOR BENTHIC DIVERSITY AND FUNCTIONING

Sampling and analysis of bulk sediment pigment or carbon content is relatively fast and easy compared to taxonomic analyses. Their quality and quantity at the seafloor have often been related to abundance, biomass, diversity and/or functioning (Grebmeier et al. 2006, Carroll et al. 2008). Sediment pigment or carbon content may be used to infer benthic diversity and functioning in areas where more explicit data is lacking.

INFORMATION SOURCES AND LIMITATIONS

Data on sediment pigment and carbon content in the Canadian Arctic has been published from the Canadian Arctic Shelf Exchange Study (CASES, 2003-2004) on the Beaufort Shelf (Renaud et al. 2007b, Conlan et al. 2008, Morata et al. 2008), the Circumpolar Flaw Lead study (CFL, 2007-2008) in the Amundsen Gulf (Forest et al. 2011, Link et al. 2011) and the North Water Polynya study (NOW 1997-1998) in northern Baffin Bay (Grant et al. 2002). Other sedimentary organic carbon content data are available for the Hudson Bay Complex (Kuzyk 2009).Further data has been collected from the Mackenzie Shelf, the Amundsen Gulf and Viscount-Melville Sound in 2009 and 2010, and from Barrow Strait, Lancaster Sound, the NOW and central Baffin Bay in 2008 to 2010 during the Malina and ArcticNet-CHONe campaigns. For the first time, samples were collected in Franklin Strait, Victoria Strait and Prince of Wales Strait in 2010. To our knowledge, there is no data available for other regions of the Canadian Arctic.

PATTERNS AND DISTRIBUTION

Figures 12 and 13 provide maps of total pigments (Chl *a* + phaeopigments), and organic carbon content in sediments collected during ArcticNet-CHONe cruises from 2008 to 2010.

The overall pattern of total pigment shows higher concentrations on the Mackenzie Shelf, in Lancaster Sound and in the NOW and lower concentrations in the center of Hudson Bay and in Viscount-Melville Sound. Data on sedimentary pigments is also available for the NOW (Grant et al. 2002) and for the southeastern Beaufort Sea (Renaud et al. 2007a, b, Morata et al. 2008) but could not be integrated into Figures 12 and 13.

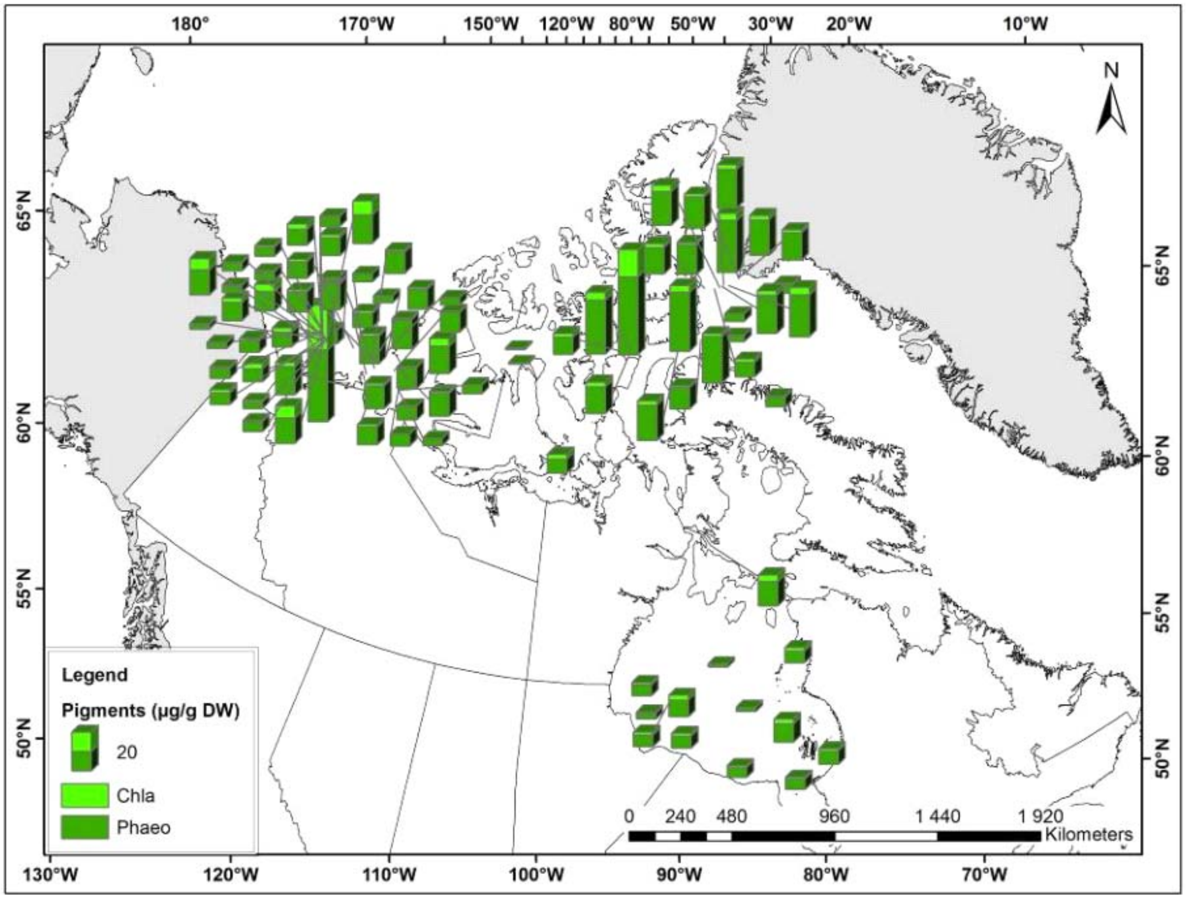

Figure 12. Concentration of total pigments (Chl a and phaeopigments) in sediments collected during 2008-2010 ArcticNet-CHONe cruises.

Sedimentary organic carbon content is generally higher in Eastern and Western Arctic regions than in the central Archipelago and in the Hudson Bay Complex, but differences are smaller than for pigment patterns described above. Published sedimentary organic carbon content data for the Hudson Bay Complex (Kuzyk 2009) and for the Beaufort Sea (Forest et al. 2011, Link et al. 2011) corroborate with the ArcticNet-CHONe data presented here.

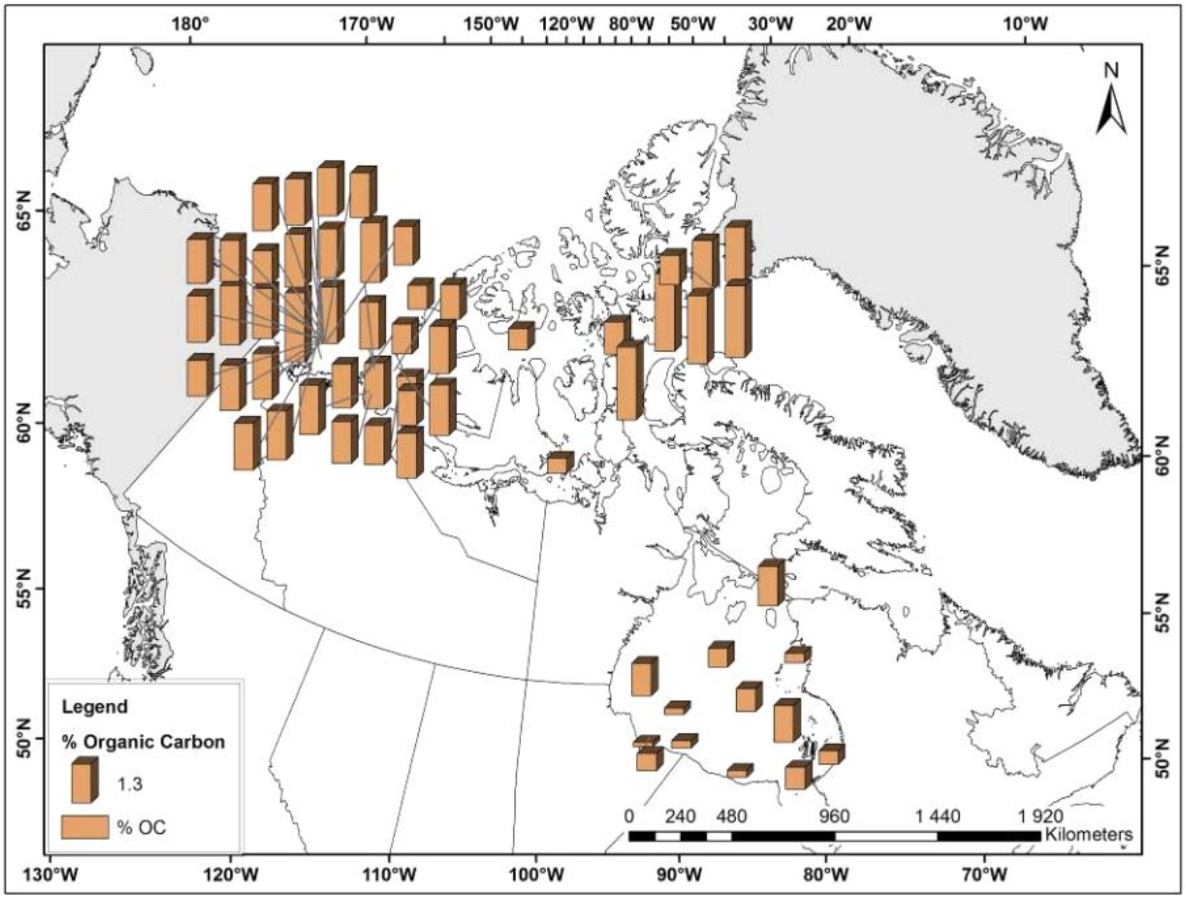

Figure 13. Concentration of organic carbon in sediments collected during 2008-2010 ArcticNet-CHONe cruises.

SEABED TOPOGRAPHY AS INDICATOR FOR BENTHIC DIVERSITY

Seabed topography characterization at large scales in offshore regions is done primarily by multibeam echo sounders providing a high density of detailed bathymetric data from which terrain parameters, such as the slope and variability (rugosity), can be derived (Wilson et al. 2007). There is a growing demand for this kind of abiotic surrogate where opportunities to directly survey the benthic fauna remain limited (Wilson et al. 2007, Dunn and Halpin 2009, MacArthur et al. 2010).

INFORMATION SOURCES AND LIMITATIONS

The explicative power of seabed topography has not yet been tested for Arctic ecosystems. However, it will be tested in the Lancaster Sound and Beaufort Sea regions (data owned by Laboratoire d'écologie benthique, ISMER, UQAR, V. Roy PHD project) in the near future. If seabed topography proves to be a good predictor of benthic diversity, then we should be able to estimate where we expect to find diverse benthic communities in areas of the Canadian Arctic from bathymetric data (through high-density multibeam data).

BENTHIC PRODUCTIVITY AS INDICATED BY PHYSICAL OCEANOGRAPHIC FEATURES (POLYNYAS, ICE EDGES)

In the Arctic, tidal mixing fronts and polynyas are regions of enhanced biological productivity relative to the surrounding ocean (Hannah et al. 2009) and may thus represent areas of enhanced benthic functioning and/or diversity.

INFORMATION SOURCES AND LIMITATIONS

Barber and Massom (2007) have mapped the location of polynyas and ice cover in the Canadian Arctic (Figure 5).

IDENTIFICATION OF EBSAS IN THE CANADIAN ARCTIC BY REGION

GENERALITIES

We used the Criteria and Dimensions developed by DFO (2004) to identify benthic EBSAs from our data. For this, each of the benthic parameters considered in this study was assigned one function or structural feature (Table 1). We adapted the dimension description from DFO (2004) for our parameters. Table 1 gives examples of the value application (high vs. low) for each parameter and dimension. In the summary table of EBSA identification (Table 2) we refer to ‘high’, ‘medium’ or ‘low’ for each dimension based on the description given in Table 1 for the extremes (high and low), and based on the results reported hereafter. EBSA numbers refer to those used by DFO (2011b) and are presented as maps in Appendix 1. These values rank the value of the parameter. For most parameters High (H) values for a dimension indicate a high priority for EBSA designation. The exception is the Resilience dimension. Low resilience equates to a higher importance for EBSA classification.

Species endemism is not a common feature due to the relatively recent migration of many species during the Pliocene migration of North Pacific marine fauna to the North Atlantic via the Arctic Ocean (e.g., Marincovich 2000). This is in contrast to the Antarctic fauna which has an extremely high degree of endemism. For example, Antarctic endemism reaches 90% in Pycnogonida (Fry 1964) and 95% in Amphiphoda (Jazdzewski et al. 1991). Consequently, the **Uniqueness/Rarity** criterion is expected to be applied with less certainty in Canadian Arctic biogeographic regions (DFO 2009) due to the low degree of endemism and the gaps in sampling effort.

Kernel density analyses were applied to the coral and sponge data for each of the large and small gorgonian corals, sea pens and sponges in the Eastern Arctic excluding Hudson Strait (Kenchington et al. 2010, Wareham et al. 2010). For the data obtained since Kenchington et al. (2010) did their analyses, we applied the same thresholds (by taxonomic group and gear type) to determine significant concentrations. This method identifies biomass aggregations of these taxa and is sometimes referred to as “hotspot” analysis. Areas with significant concentrations of these taxa would directly meet the Canadian EBSA criterion for **Aggregation** (DFO 2004, 2011). Other measures to apply this criterion for benthic fauna used hereafter are biomass and individual abundance.

Being one of the last pristine areas on our planet, the **Naturalness** dimension will most often be considered as high. The slow growth of many polar organisms leads to the assumption of low **Resilience,** thus tagging many functions as ‘low’ for this dimension.

Table 1. Criteria and dimensions developed by DFO (2004) and applied to each of the benthic parameters considered in this study. Each parameter was assigned one function (F) or structural (S) feature and examples of the extremes of the value application (High vs. Low) for each parameter and dimension are provided.

Benthic Parameter in this Document	DFO Function (F) or Structural Feature (S)		Uniqueness	Aggregation	Fitness Consequences	Resilience	Naturalness
Corals and Sponges	Structural Habitat Feature (S)	High	Geographic scale and species composition of the assemblage is regionally or globally unique	High density and size of reef or bed structure, high number of species	Older/larger individuals provide greater population fecundity and community structure; habitat for numerous associated species	Long-lived, fast growing species with medium recovery time after physical disturbance	Relatively undisturbed and extremely old pristine habitat
		Low	Geographic scale and species composition of the assemblage is found repeatedly	Low density and size of reef or bed structure, low number of species	Individual size and age has little influence on population fecundity and community structure; few associated species	Long-lived, slow growing species with long recovery time after physical disturbance	Habitat altered by structural (landslide) or anthropogenic disturbance (e.g. trawling)
Macrobenthic Diversity	Biodiversity (S)	High	Species or communities cannot be found elsewhere	Exceptional high diversity and/or biomass	Area is important for the survival of many species or the community	Community with mostly equally important species of high functional redundancy	Community is composed of autochthonous species
		Low	Species or communities are common elsewhere	Average diversity and biomass	Survival of the species or community is guaranteed in other areas	Long-lived community with few key species	Community has been altered by climate induced species shifts or invasive species
Benthic Remineralization	Feeding (F)	High	Remineralization of rare nutrients	High remineralization of nutrients (sediment-to-water flux)	Remineralized nutrients are a major contribution to ecosystem's sustainability (e.g. Primary production)	Physical-pelagic or species alterations invoke short-term changes on remineralization	Climate, invasive species and/or anthropogenic influence have little effect on remineralization
		Low	No particular nutrient remineralization	Low remineralization of nutrients (sediment-to-water flux)	Remineralized nutrients are a common contribution to ecosystem's sustainability (e.g. Primary production)	Physical-pelagic or species alterations invoke long-term changes on remineralization	Climate, invasive species and/or anthropogenic influence have strongly altered remineralization

Sediment Pigment and Carbon Content (Proxy of Food Supply)	Feeding (F)	High	Food supply is composed of rare pigment sources (e.g. Types of ice-algae)	High concentration of pigments or carbon; usually associated with high benthic biomass	Food supply is a major contribution to consumers' growth or reproduction and population sustainability	Concentration of food supply less dependent from physical disturbance	Climate, invasive species and/or anthropogenic influence have little effect on composition of food supply
		Low	No particular pigment source detectable	Low concentration of pigments or carbon	Occasional use of food supply	Concentration of food supply strongly depends on physical-pelagic processes	Climate, invasive species and/or anthropogenic influence have strongly altered composition of food supply
Seabed Topography	Physical Oceanographic Feature (S)	High	Unique structure (e.g. seamount, canyon along the continental shelf, pitted area)	Topography invokes high density of benthic organisms	Habitat structure important for the life cycle a species	Dynamic soft bottom structure (e.g. Mud-volcano) or high-density hard bottom	Habitat unaltered by mechanical disturbance
		Low	Homogeneous topography	No indication that topography invokes high density of benthic organism	No known association of particular habitat with species	Old soft bottom or reef structure, easily disturbed	Habitat altered by structural (landslide) or anthropogenic disturbance (e.g. trawling)
Polynyas and Ice Edges	Physical Oceanographic Feature (S)	High	Unique physical conditions lead to enhanced biological processes	Enhanced biological processes lead to high density of benthic organisms	Oasis of primary production in otherwise ice-covered areas provides greater benthic species survival	Recurring polynyas varying only in its extent	No anthropogenic disturbance on physical oceanographic conditions (e.g. heat exchange)
		Low	Enhanced physical conditions lead to not strongly enhanced biological processes	No indication that physical conditions lead to enhanced biological processes	Enhanced primary production does not increase benthic species' growth and fecundity	Location and extent of polynya varies; underlying factors unknown	Polynya induced by anthropogenic activity (e.g. hot water from a power plant)

1.0 HUDSON BAY COMPLEX

Data Sources and Gaps

Historical macrofaunal data for this region was compiled by Cusson et al. (2007) drawing on the work of Wacasey et al. (1976) and Atkinson and Wacasey (1989a, b) (Figure 14). Recent cruises (MERICA (short for "études des MERs Intérieures du CAnada," studies of Canada's inland seas) 2003 and ArcticNet-CHONe 2010) have collected a large amount of data but identification of taxa is not yet completed (Figure 14). Benthic data are available for EBSAs #1.5-1.10 and prediction could be made for EBSA #1.7 and 1.9 based on sediment predictors (pigments and organic content) and for EBSA # 1.5 based on the presence of a polynya (Table 2).

Research vessel trawl survey bycatch is the primary data source for the Hudson Strait area. Data on coral and sponge bycatch is presented in Figure 8. Details of data sources and gaps for these taxa can be found in the Coral and Sponge section of this report above.

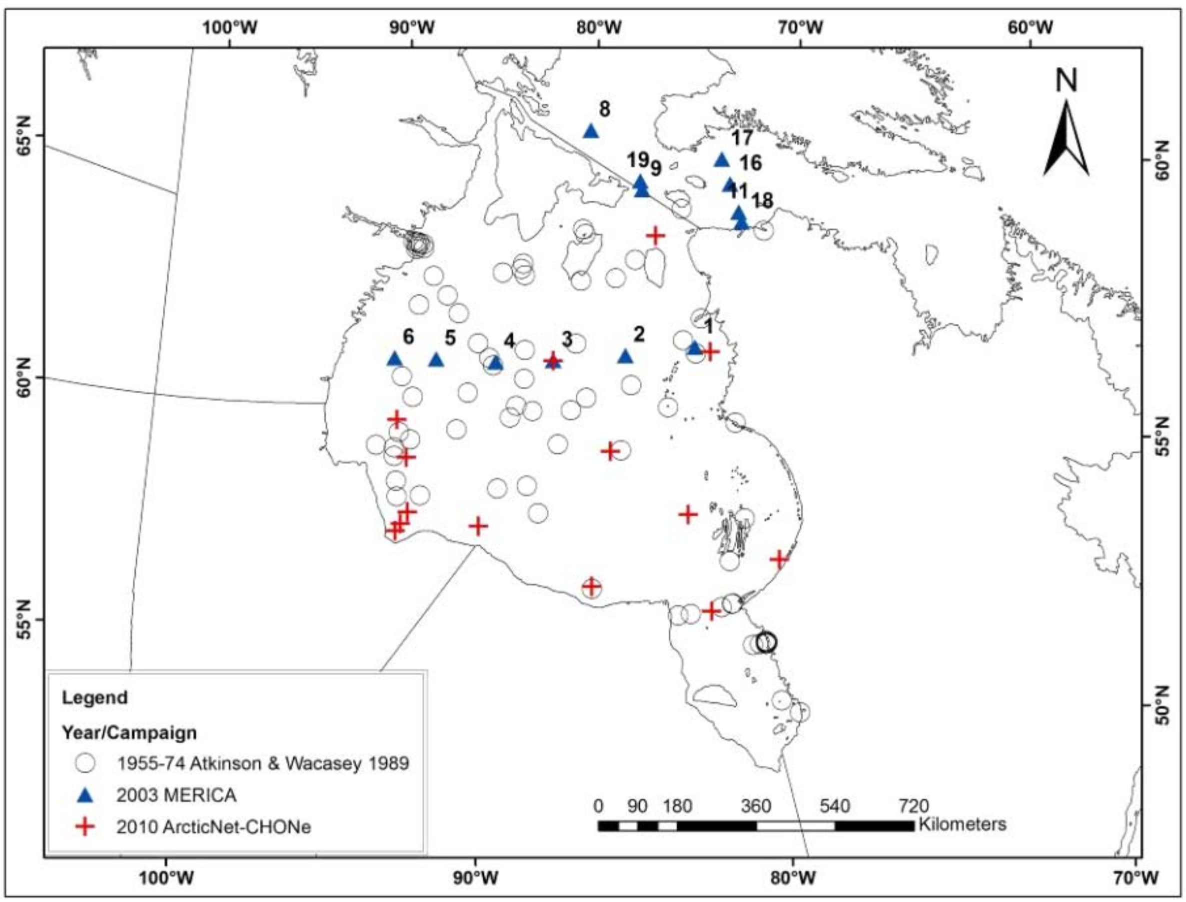

Figure 14. Location of historical stations of Atkinson and Wacasey (1989) and recently sampled during the 2003 MERICA (Archambault, unpublished data) and 2010 ArcticNet-CHONe cruises.

Regional Characteristics of EBSAs

EBSAs #1.5-1.10: Hudson Bay

The study of Cusson et al. (2007) based on historical data demonstrates that Hudson Bay has low values of taxonomic distinctness (Δ+), but high values of turnover (β) diversity compared to Western and Eastern Arctic regions. There are also strong differences among infaunal communities in various regions of the Hudson Bay complex; preliminary analyses of recent 2003 MERICA data (Archambault, unpublished data) show distinct benthic communities in Hudson Bay, Hudson Strait and Foxe Basin (Figure 15).

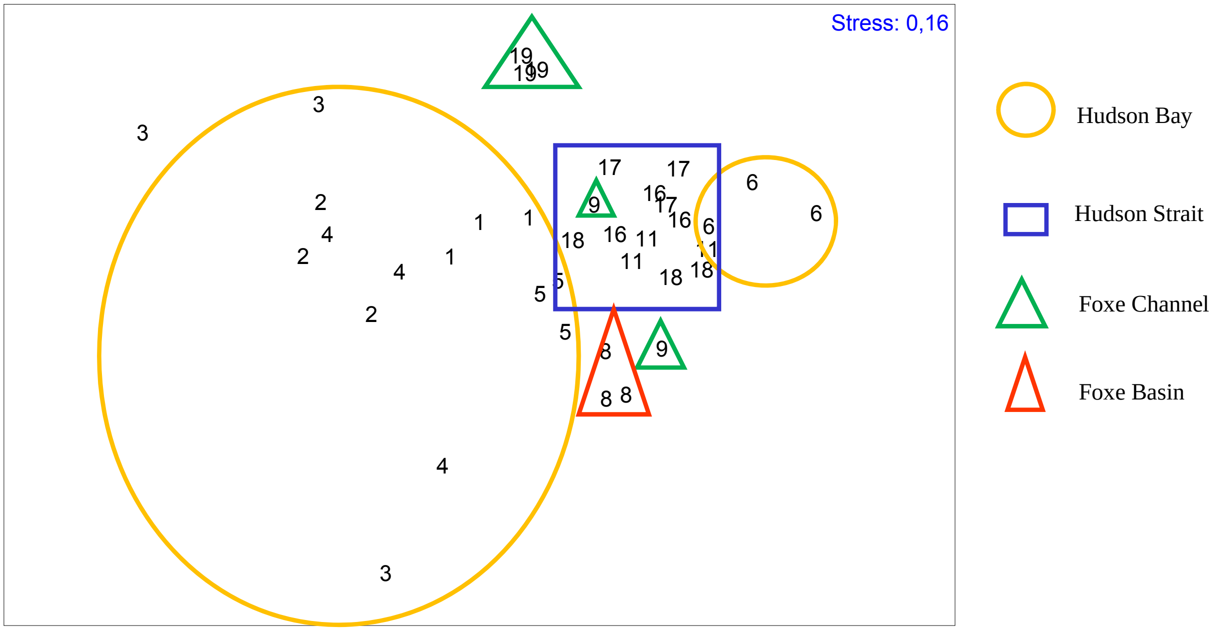

Figure 15. Non-metric multidimensional scaling of benthic communities based on a Bray-Curtis similarity matrix of untransformed abundance. Numbers correspond to sampled stations (Figure 14).

Furthermore, Archambault (unpublished data) observed more abundant and diverse infaunal communities in Hudson Strait than in Hudson Bay, and within Hudson Bay, infaunal communities were more abundant although less diverse in the West compared to the East (Figure 16). Surface sediment pigment data are higher around the margin of the Bay than in the center and might reflect higher primary production in surrounding surface waters (Figure 17). Sedimentary organic carbon content shows a different pattern with slightly higher concentrations in the center of the Bay than in nearshore areas (Figure 18), possibly attributable to a transition from sandy to muddy sediments in the deeper part of the Bay due to lower current velocity.

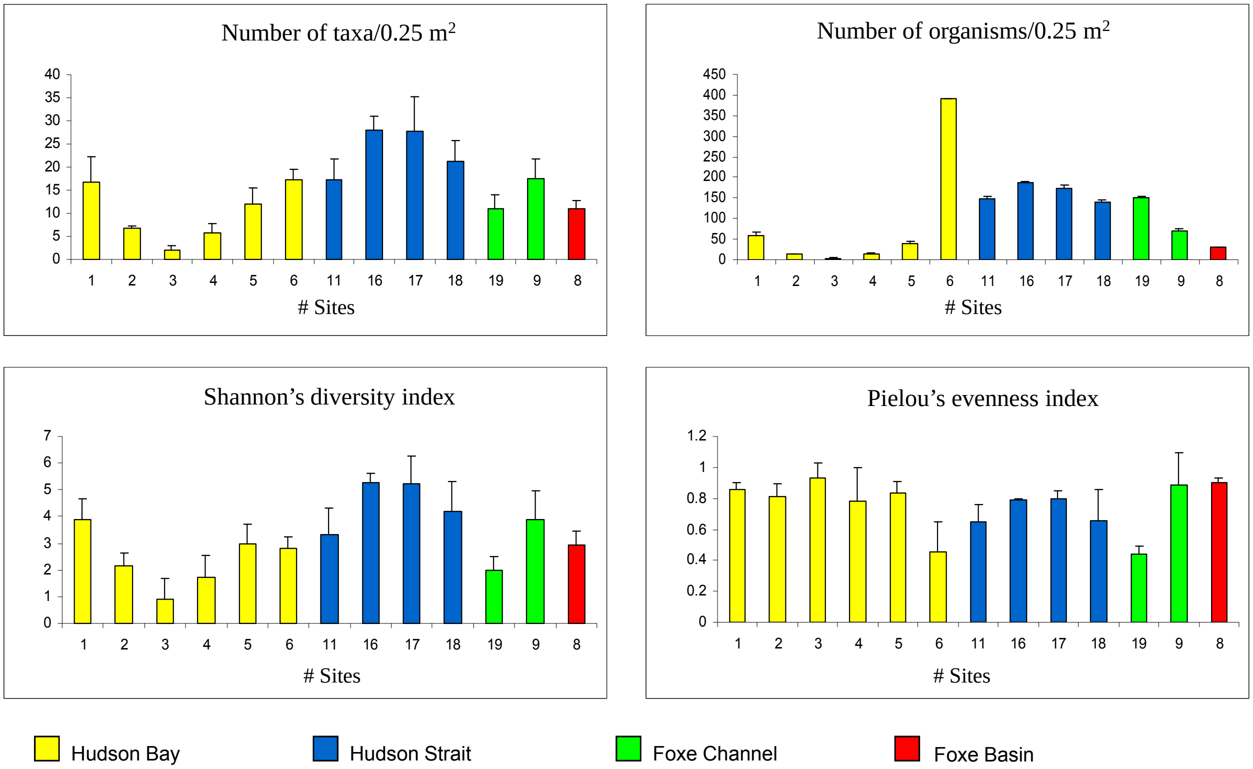

Figure 16. Diversity of benthic communities derived from the 2003 MERICA cruise in Hudson Bay, Hudson Strait, Foxe Channel and Foxe Basin. Numbers correspond to sampled stations (Figure 15).

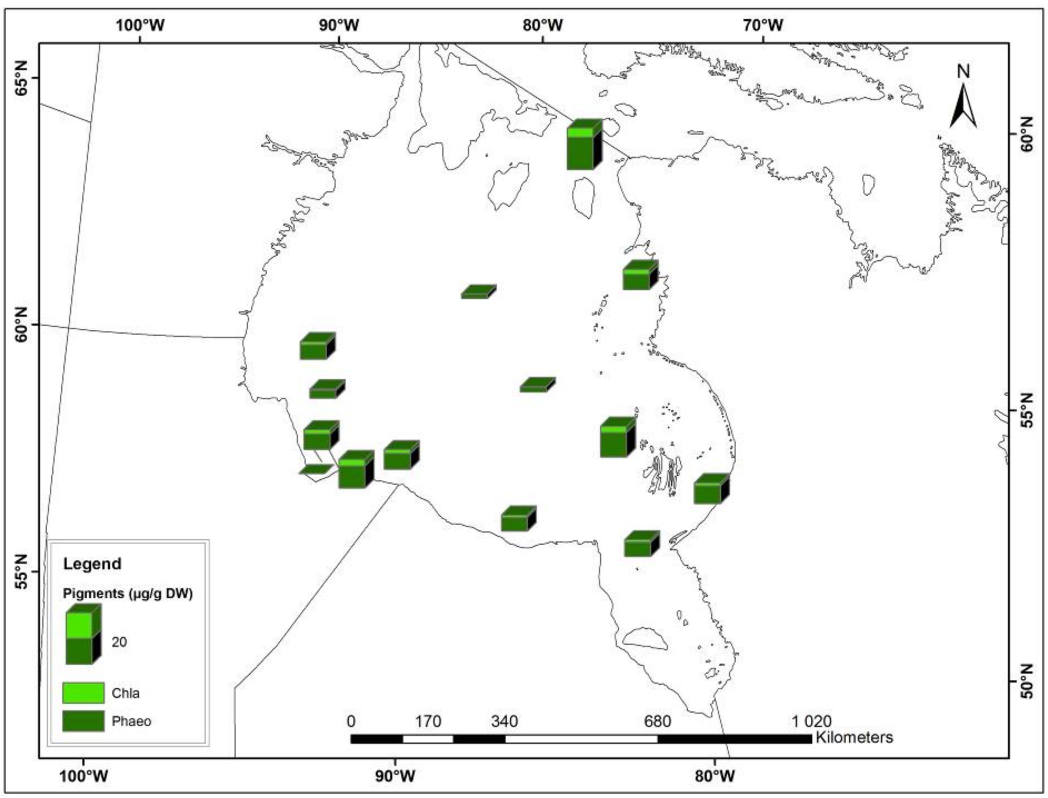

Figure 17. Concentration of total pigments (Chl a and phaeopigments) in Hudson Bay sediments collected during the 2010 ArcticNet-CHONe cruise.

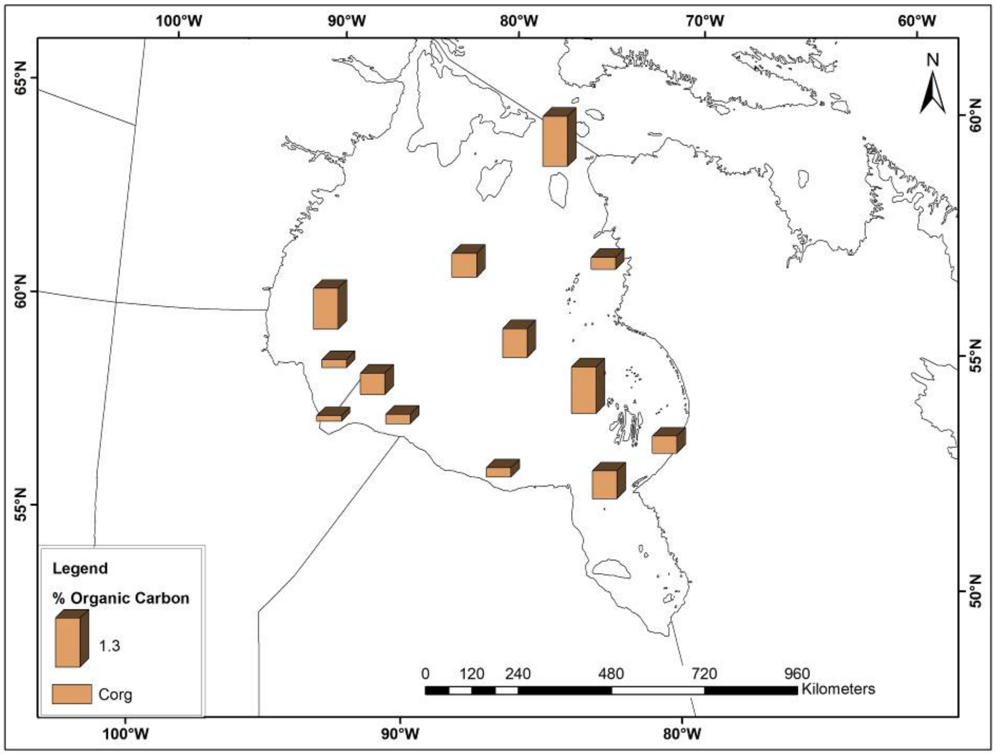

Figure 18. Concentration of organic carbon in Hudson Bay sediments collected during the 2010 ArcticNet-CHONe cruise.

<u>EBSA #1.5: Southampton Island Polynya</u>

Barber and Massom (2007) have identified a polynya in the northeast portion of Hudson Bay, west and southwest of Southampton Island. In winter there is shorefast ice through much of the coastal waters with mobile ice in the interior. The polynya west of Southampton Island (Barber and Massom 2007; Figure 5) may indicate higher benthic productivity in that area. This area has been identified by the IUCN workshop (IUCN 2010, Regional EBSAs 60; Figure 3).

<u>EBSA #1.7: Southwestern Hudson Bay Estuaries</u>

Sedimentary pigment and organic carbon contents are high in this region (Figure 17, 18) and may thus support highly productive and rich benthic communities. Faunal samples were also taken in this area in 2010 but identification is not completed yet.

<u>EBSA #1.9: Belcher Islands</u>

High pigment and organic carbon contents in surface sediments northwest of Belcher Islands (Figure 17, 18) are potential indicators of high benthic productivity and richness (Figure 17, 18). Faunal samples were also taken in this area in 2010 but identification is not completed yet.

<u>EBSAs #1.11-1.13: Hudson Strait</u>

Barber and Massom (2007) report a major shorelead polynya extending along the northern coast of Hudson Strait (Figure 5). The rest of the Strait has mobile ice in winter (Figure 5).

EBSA #1.11: Hudson Strait-West

High pigment and organic carbon contents in surface sediments north of Mansel Island (Figure 17, 18) are potential indicators of high benthic productivity and richness. Faunal samples were also taken in this area in 2010 but identification is not completed yet.

A large catch (relative to this biogeographic zone) of habit-forming Nephtheid soft corals was made south of Nottingham Island (Figure 8). Benthic diversity is also high in this area in compared to other areas of Hudson Bay (Figure 16). A portion of this area has been identified by the IUCN workshop (IUCN 2010, Regional EBSAs 60; Figure 3).

EBSA #1.12: Hudson Strait - East

The shorelead polynya west of Resolution Island coincides with relatively large catches of sponges (Figure 7). A portion of this area has been identified by the IUCN workshop (IUCN 2010, Regional EBSAs 57; Figure 3).

EBSA #1.13: Ungava Bay

Nephtheid soft corals are found throughout Hudson Strait with the highest concentrations in Ungava Bay (Figure 8). A portion of this area has been identified by the IUCN workshop (IUCN 2010, Regional EBSAs 58; Figure 3).

2.0 EASTERN ARCTIC

Peel Sound, Prince Regent Inlet and Franklin Strait

Data Sources and Gaps

The only data for the west and east coasts of Somerset Island (Peel Sound and Prince Regent Inlent) come from Barber and Massom (2007) who report the location of polynyas and ice cover (Figure 5). To our knowledge, benthic communities of Franklin Strait were sampled for the first time during the 2010 ArcticNet-CHONe campaign. Identification of taxa is not completed yet.

Regional Characteristics of EBSAs

EBSA #2.3: Prince Regent Inlet

The polynyas in Prince Regent Inlet are the only data source at present (Figure 5). A portion of this area has been identified by the IUCN workshop (IUCN 2010, Regional EBSAs 57; Figure 3).

EBSA #2.5: Peel Sound and Franklin Strait

The polynyas in Peel Sound are the only data source at present (Figure 5). Franklin Strait has high epifaunal diversity (V. Roy, pers. obs.). Strong tidal currents in this area (Hannah et al. 2009) suggest that hydrodynamic processes might favour highly productive and diverse benthic communities. There is also a concentration of polynyas in Franklin Strait (Figure 5). A portion of this area has been identified by the IUCN workshop (IUCN 2010, Regional EBSAs 57; Figure 3).

Lancaster Sound and Barrow Strait

Data Sources and Gaps

Few benthic scientific studies have been carried out in this region of the Eastern Arctic. The most exhaustive studies are from Thomson (1982) and Thomson et al. (1986). The study of Thomson (1982) was carried out as part of the Eastern Arctic Marine Studies Program (EAMES) and included data from 1978-79. Thomson et al. (1986) contains a summary of previously unpublished benthic data arising from environmental baseline projects in the Lancaster Sound region of the Canadian Eastern Arctic in the late 1970s-early 1980s. Projects were carried out under the Northern Oil and Gas Action Program (NOGAP) of the Canadian government. Benthic data from near Devon Island (Philpots Island, Phoenix Head glacier) and Baffin Island (Cape Fanshawe, Possession Bay, Eclipse Sound, Cape Hatt and Scott Inlet) was collected in 1978-79 and 1981. These studies, however, focus on nearshore infauna communities and few sites are located offshore in Lancaster Sound (3 stations, including 89 taxa, Thomson 1982). Additionally, data on offshore epifauna communities' diversity and the environmental factors structuring it has not been collected or published in these studies to our knowledge. Recent synthesis papers on the Arctic benthic diversity highlight the need of benthic data in this region (Michel et al. 2006, Piepenburg et al. 2011).

To better document this region, data collected during 2008-2011 ArcticNet-CHONe cruises is used to determine the composition and structure of the macro-infaunal and epifaunal communities of offshore stations along the depth gradient between the shallow Barrow Strait (150 m) and the deep entrance of Lancaster Sound facing Baffin Bay to the east (800 m) (data owned by Laboratoire d'écologie benthique, ISMER, UQAR). Data on benthic remineralization were collected for the same region during the ArcticNet-CHONe cruises 2008-2009 (Link et al. in prep.) and 2011. However the area is still under-sampled.

Regional Characteristics of EBSAs

EBSA #2.6: Lancaster Sound and Barrow Strait

Based on historical and recent data, it is obvious that this region supports a high macro- and megafaunal abundance, biomass and diversity (both infauna and epifauna) (Figures 19-22, Thomson 1982).

Recent results on benthic remineralization show higher recycling of exported organic matter here than in all other regions of comparable depth in the Canadian Arctic, except the NOW (Figures 10, 23). Lancaster Sound is an important source for nutrient enrichment in deep waters (Link et al. in prep.).

This area also has relatively high levels of organic enrichment (pigments, organic carbon) suggesting enhanced benthic production generally (Figures 24, 25). These results highlight the importance of the eutrophic regime in surface waters and the tight pelagic-benthic coupling, even at deep sites.

Two polynyas are located in this area (Figure 5). One is along the northern coast of Lancaster Sound and the other at the eastern outflow (Barber and Massom 2007). The IUCN has also identified the North Water Polynya/Lancaster Sound as a super EBSA following the CBD criteria (Figure 1).

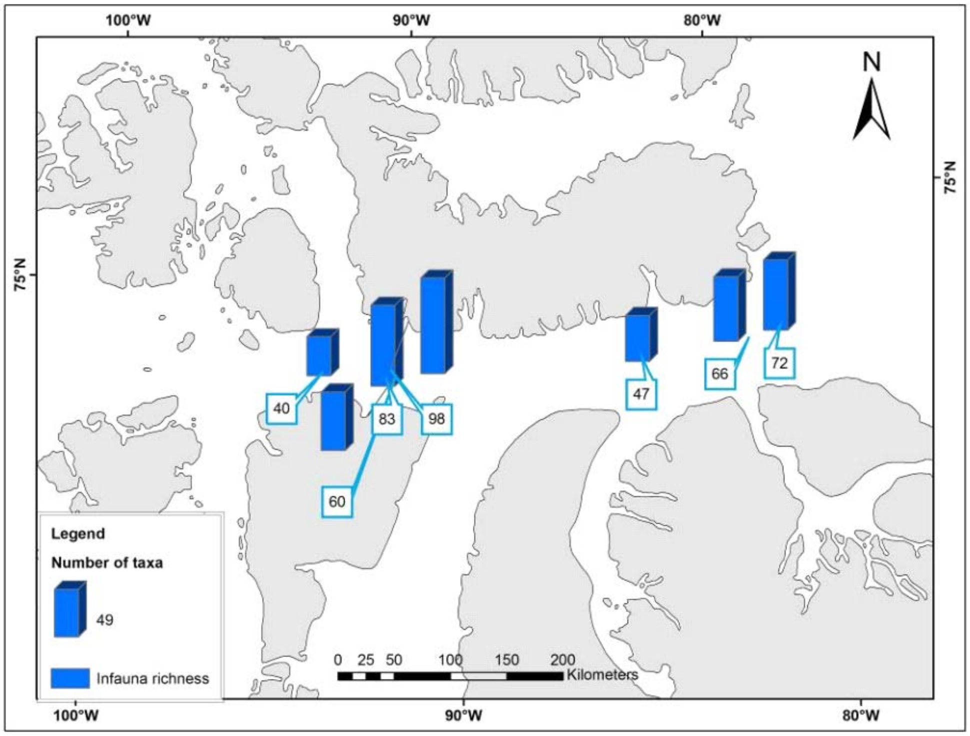

Figure 19. Infauna species richness in Lancaster Sound and Barrow Strait from preliminary analyses of ArcticNet-CHONe data.

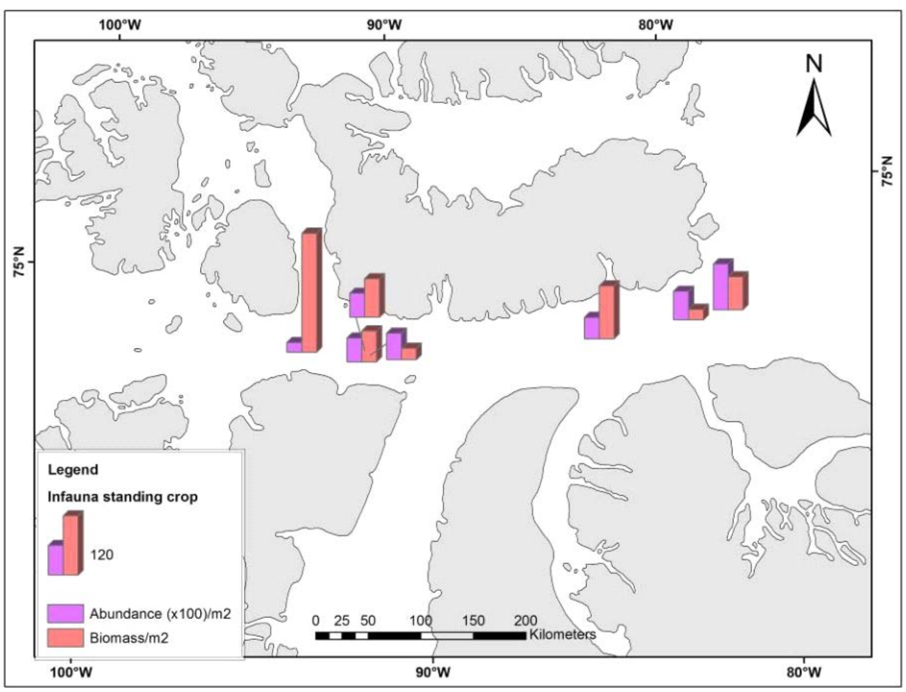

Figure 20. Infauna abundance and biomass per m^2 in Lancaster Sound and Barrow Strait from preliminary analyses of ArcticNet-CHONe data.

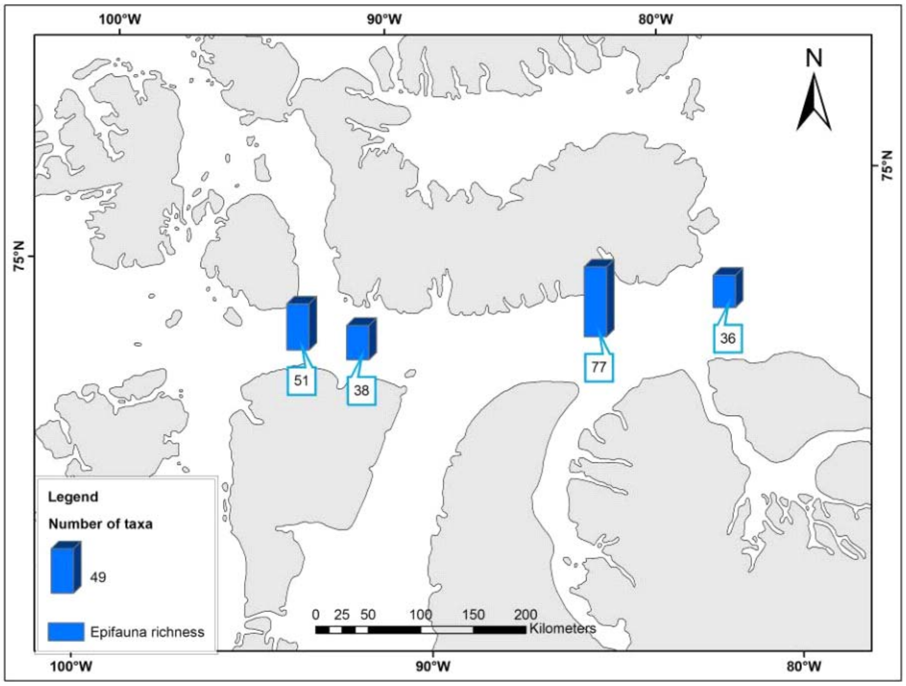

Figure 21. Epifauna species richness in Lancaster Sound and Barrow Strait from preliminary analyses of ArcticNet-CHONe data.

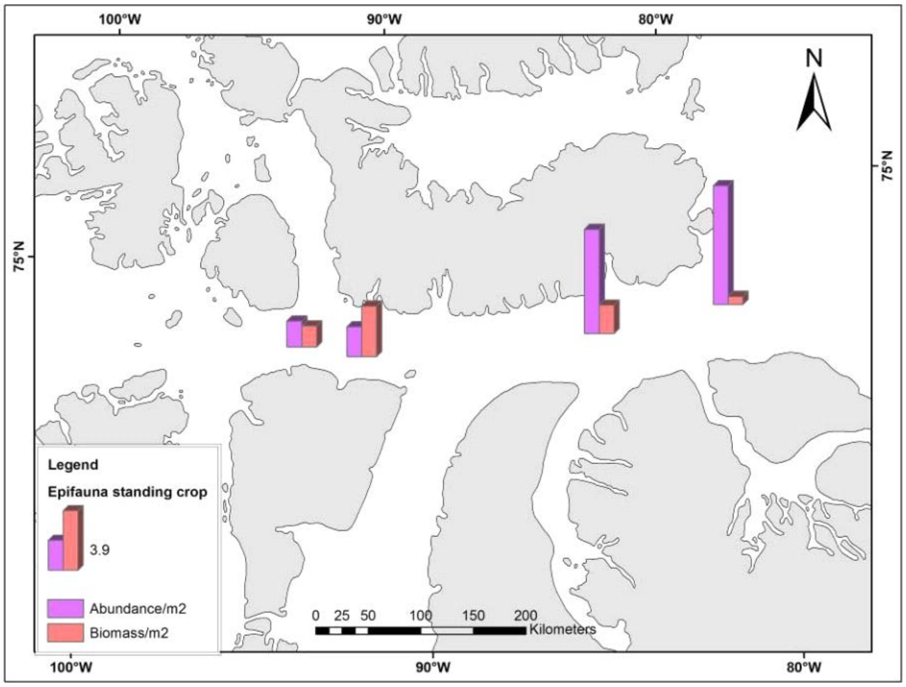

Figure 22. Epifauna abundance and biomass per m^2 in Lancaster Sound and Barrow Strait from preliminary analyses of ArcticNet-CHONe data.

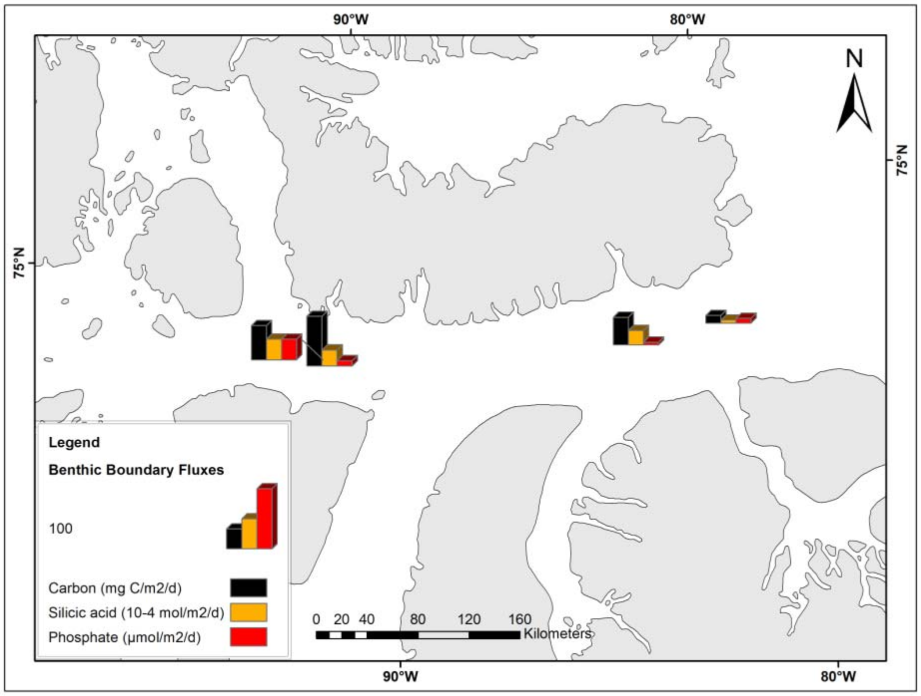

Figure 23. Lancaster Sound and Barrow Strait benthic remineralization fluxes during 2008-2009.

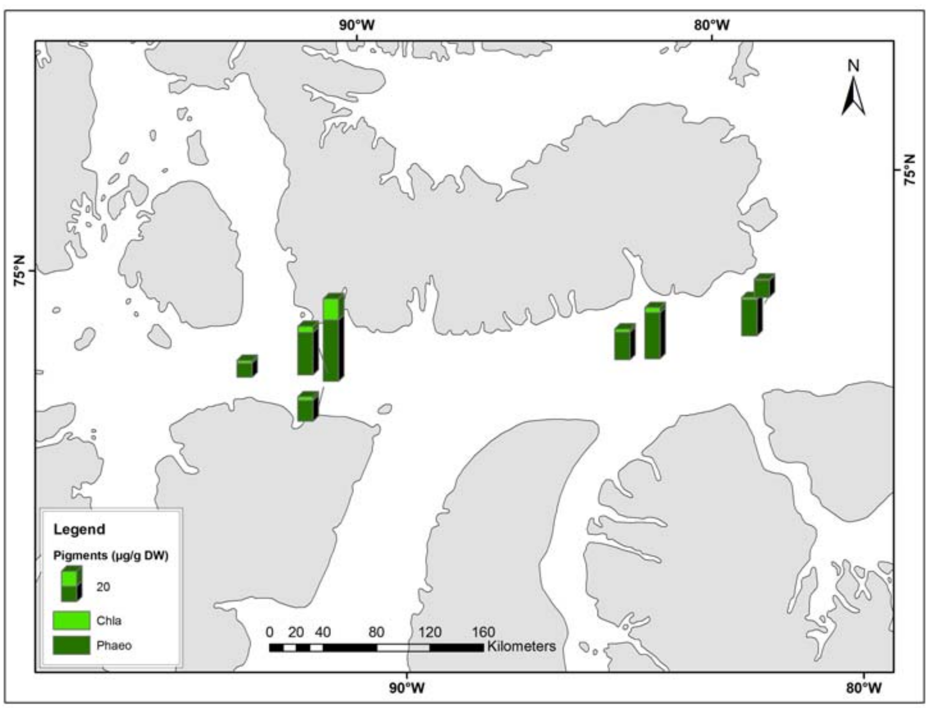

Figure 24. Concentration of total pigments (Chl a and phaeopigments) in Lancaster Sound and Barrow Strait sediments collected during the 2008-2010 ArcticNet-CHONe cruises.

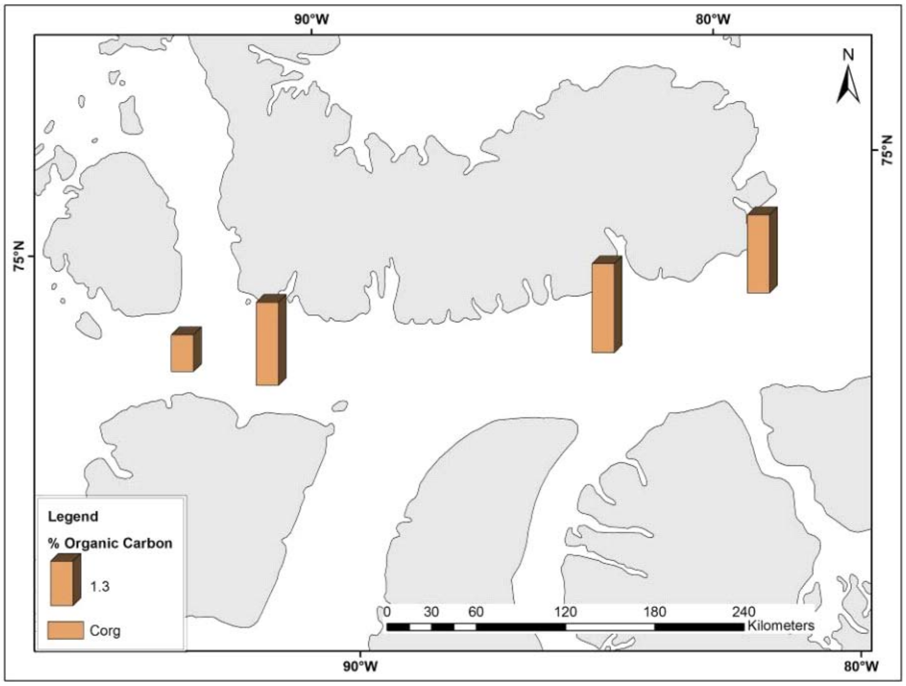

Figure 25. Concentration of organic carbon in Lancaster Sound and Barrow Strait sediments collected during the 2010 ArcticNet-CHONe cruises.

Baffin Bay and Davis Strait

Data Sources and Gaps

Research vessel trawl survey bycatch is the primary data source for the area south of the NOW. Data on the NOW was gathered during recent ArcticNet-CHONe cruises. Data on coral and sponge bycatch is presented in Figure 7. Details of data sources and gaps for these taxa can be found in the Coral and Sponge section of this report above.

Regional Characteristics of EBSAs

The NOW is the largest polynya in the Arctic and is considered to be the most productive region in the Arctic (Michel et al. 2006). Barber and Massom (2007) report a major shorelead polynya extending along the northeast coast of Baffin Bay and along the west coast of Davis Strait (extending into Hudson Strait) (Figure 5). The rest of the Strait has mobile ice in winter. Polynyas are also located at the mouth of Lancaster Sound, Jones Sound and Kane Basin in Baffin Bay, and in Frobisher Bay and Cumberland Sound in Davis Strait. The rest of the area is covered with mobile ice in winter.

EBSA #2.8: Davis Strait and Hatton Basin

Hatton Basin is a very important area for dense aggregations of coral and sponge (Kenchington et al. 2010, Wareham et al. 2010) and is the site of a voluntary closure by members of the fishing industry. Wareham et al. (2010) show this area to also have a high diversity of coral species. The EBSA extends north and south along the continental margin. This area has been identified by the IUCN workshop (IUCN 2010, Regional EBSAs 50 and 52; Figure 3).

The Canadian continental slope from Hatton Basin to Cape Dyer below 400 m holds significant aggregations of sea pens, sponges and gorgonian corals.

EBSA #2.10-2.11: Continental Slope-Central Baffin Island

The Canadian continental slope from Cape Dyer to Lancaster Sound below 400 m holds several significant catches of sea pens and one significant catch of sponge. A portion of this area has been identified by the IUCN workshop (IUCN 2010, Regional EBSAs 54; Figure 3) however data on the distribution of coral and sponges in this area suggests an extension northward along the slope of the IUCN designation.

EBSA #2.12: Narwhal Over-wintering Site and Deep-sea Coral Conservation Area

The location of the narwhal over-wintering site coincides with deep-sea coral aggregations. One of the largest catches of the large gorgonian coral *Keratoisis* sp. was recorded in this area. Large aggregations of sea pens (Figure 7) occur north of the current boundaries of the conservation area and should be included in the EBSA. A portion of this area (boundaries not clear) has been identified by the IUCN workshop (IUCN 2010, Regional EBSAs 54; Figure 3).

EBSA #2.13: Baffin Bay-North

Recent surveys of this area (2010) identified significant concentrations of the sea pen *Ombellula* sp. east of Lancaster Sound. These sea pens not only form significant concentrations but they are exceptionally large. One specimen was approximately 270 cm in length, or almost 10 times the height of specimens measured elsewhere in the region. The diameter of the polyp was twice as large as recorded elsewhere. This area appears to be included in the IUCN area identified by the IUCN workshop (IUCN 2010, Regional EBSAs 69; Figure 3), but GIS overlays should be used to verify this.

EBSA #2.14: North Water Polynya (NOW)

Macrobenthic data from four sites sampled during the NOW study are discussed in Lalande (2003). Macrofaunal abundance was highest in the central region of the polynya and lowest on the east side where the highest sediment organic carbon and nitrogen concentrations were found. Sediment grain size and hydrodynamic processes were important determinants of benthic community structure in the NOW, whereas particulate food input had no detectable influence. Benthic remineralization showed a similar pattern as macrofauna reported by Lalande (2003) (Figure 26), but annual variation may be a confounding factor in these spatial patterns (Link et al. in prep.). Nevertheless, benthic fluxes measured in the NOW are the highest so far reported from the Canadian Arctic.

Additional data collected during 2008-2010 ArcticNet-CHONe cruises show that, on the whole, sediment pigment and organic carbon contents are reasonably high throughout the polynya and may actually support highly productive and rich benthic communities (Figures 27, 28). Further taxonomic analyses on macro- and megafauna gathered during those cruises will complement this information.

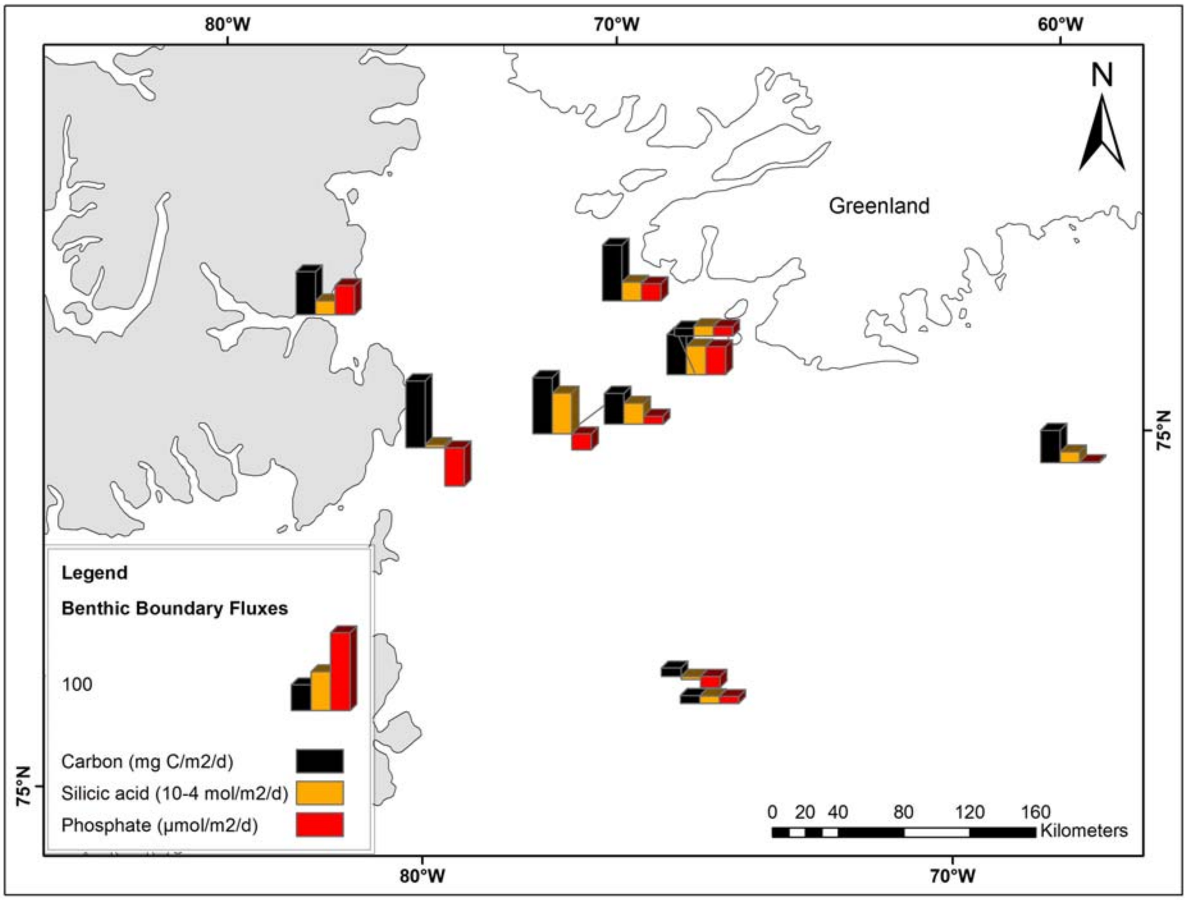

Figure 26. Benthic remineralization in the NOW during 2008 - 2009.

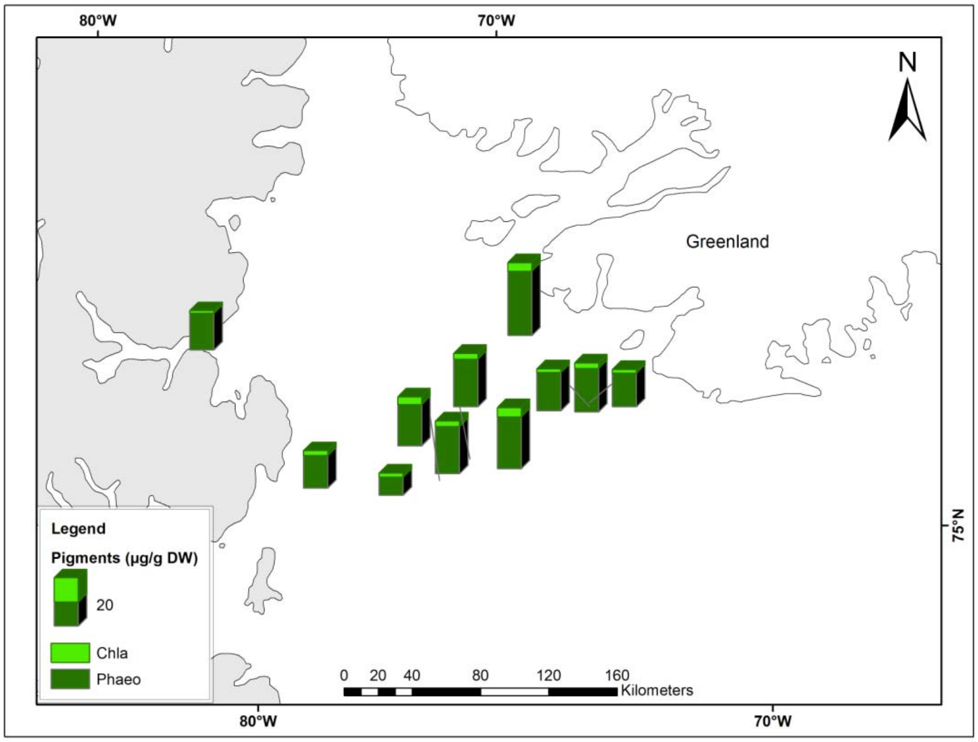

Figure 27. Concentration of total pigments (Chl a and phaeopigments) in the NOW polynya sediments collected during the 2008-2010 ArcticNet-CHONe cruises.

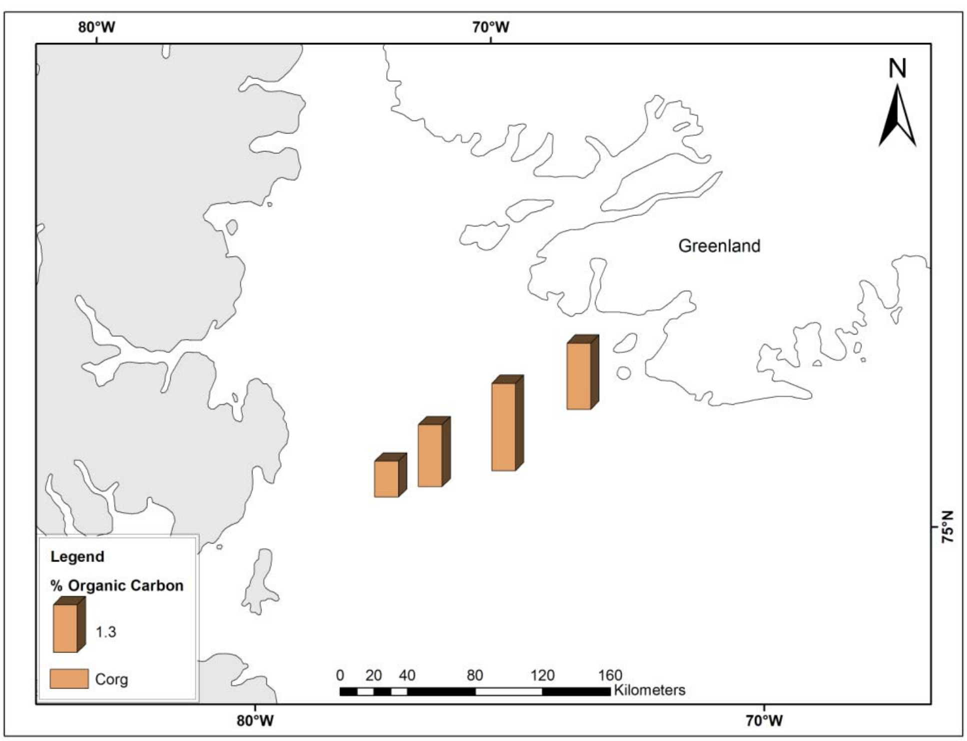

Figure 28. Concentration of organic carbon in the NOW polynya sediments collected during the 2010 ArcticNet-CHONe cruises.

3.0 WESTERN ARCTIC (EXCEPTING THE LOMA REGION)

Data Sources and Gaps

Few historical and recent data exist for the whole Western Arctic region. In the vicinity of Queen Maud Gulf, Atkinson and Wacasey (1989b) report data on 10 stations along Victoria Island. In Viscount-Melville Sound, Thomson et al. (1986) report data on nearshore stations between Melville Island and Somerset Island.

Recent faunal data have been collected from ArcticNet-CHONe cruises between 2008 and 2010, but identification is not yet completed.

Regional Characteristics of EBSAs

EBSA #3.2: Bathurst Inlet

Locations of polynyas are reasonable surrogates for benthic productivity (Figure 5).

EBSA #3.5: West King William Island

This area has high food supply proxies (Figures 29, 30) and high macro-epifaunal diversity (V. Roy, pers. obs). Strong tidal currents in this area (Hannah et al. 2009) suggest that hydrodynamics processes might favour highly productive and diverse benthic communities.

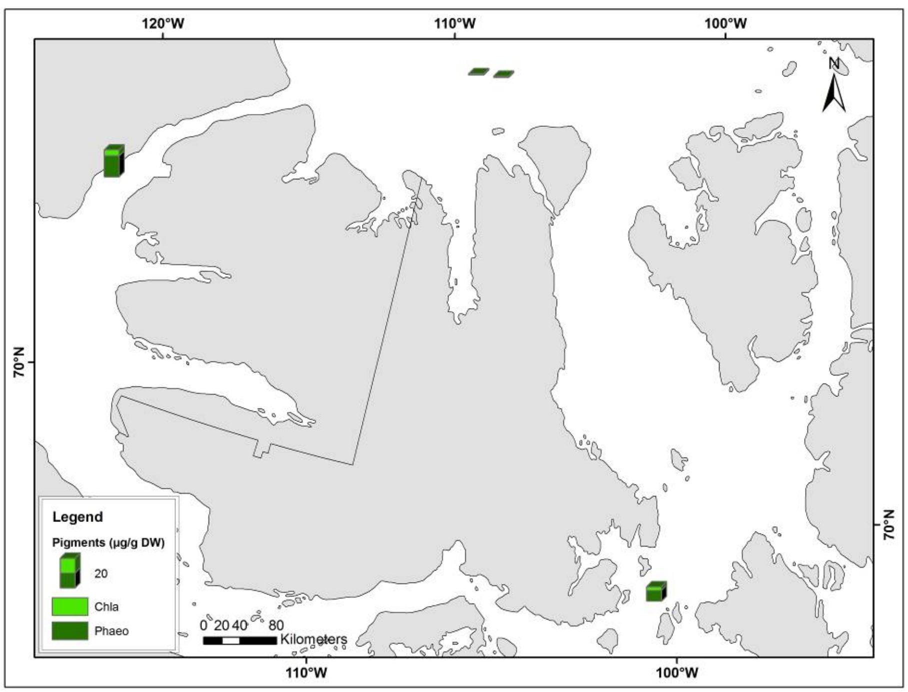

Figure 29. Concentration of total pigments (Chl a and phaeopigments) in the Western Arctic sediments collected during the 2009-2010 ArcticNet-CHONe cruises.

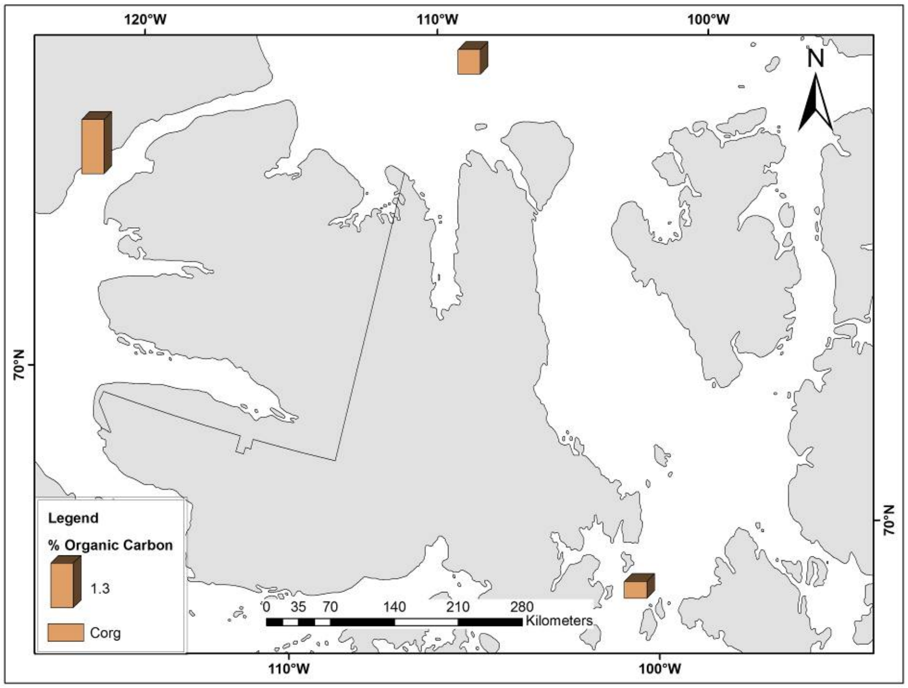

Figure 30. Concentration of organic carbon in the Western Arctic sediments collected during the 2010 ArcticNet-CHONe cruises.

4.0 ARCTIC BASIN

Data Sources and Gaps

To our knowledge, no published or unpublished benthic data exist for this region (Archambault et al. 2010, Piepenburg et al. 2011, Bluhm et al. 2011).

Regional Characteristics of EBSAs

EBSA #4.1: Beaufort Gyre

The location of a major shorelead polynya is a reasonable surrogate for benthic productivity in this area (Figure 5).

5.0 HIGH CANADIAN ARCTIC ARCHIPELAGO

Data Sources and Gaps

To our knowledge, no published or unpublished benthic data exist for this region (Archambault et al. 2010, Piepenburg et al. 2011).

Regional Characteristics of EBSAs

EBSA Not Identified Previously

The location of the major shorelead polynya is a reasonable surrogate for benthic productivity (Figure 5). This lies outside of the EBSA areas 5.1, 5.2, 5.3, 5.4 and 5.5 (DFO 2011b).

6.0 ADDITIONAL INFORMATION ON BEAUFORT LOMA EBSAS

Beaufort Sea

Data Sources and Gaps

Conlan et al. (2008) report on the macrobenthos of the Canadian Beaufort Shelf. Data on sediment pigment and carbon content in this area has been published from the Canadian Arctic Shelf Exchange Study (CASES, 2003-2004) on the Beaufort Shelf (Renaud et al. 2007b, Conlan et al. 2008, Morata et al. 2008), and additionally in the Amundsen Gulf from the Circumpolar Flaw Lead study (CFL, 2007-2008) (Link et al. 2011, Forest et al. 2011). Total pigments (chlorophyll *a* + phaeopigments) and organic carbon content in sediments were also collected during ArcticNet-CHONe cruises from 2008 to 2010. During the same cruises, data on benthic remineralization were also collected (Figure 31).

Regional Characteristics of EBSAs

EBSA #3.24: Viscount Melville Sound

The area has very low benthic remineralization (Figure 31), low macrobenthic diversity and standing crops (H. Link, V. Roy, pers. obs.) and low sediment pigment concentration (Figure 29). Benthic data do not support an EBSA in this area at present.

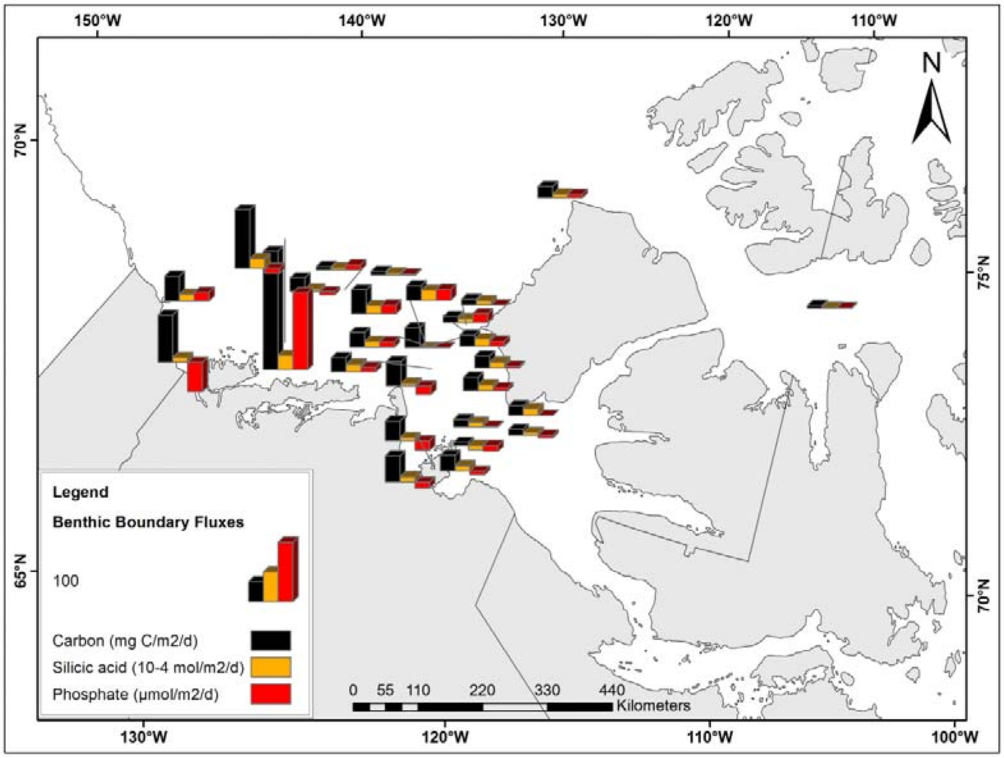

Figure 31. Benthic remineralization in the Beaufort Sea during 2008 - 2009.

<u>EBSAs #3.14: Cape Bathurst-Amundsen Gulf and #3.8, 3.9 and 3.13: Mackenzie Shelf</u>

Abundance of macrobenthos was highest with comparable diversity within the south-western Beaufort Shelf region (Conlan et al. 2008). This area also has relatively high values of sediment pigment (Figure 32) and carbon content (Figure 33) indicative of high benthic productivity. The IUCN has also identified the Beaufort Sea Coast/Cape Bathurst as a super EBSA following the CBD criteria (Figure 1). Results of benthic remineralization indicate high biological activity particularly in the western Amundsen Gulf and close to the Mackenzie Delta (Figure 31, Renauld et al. 2007b, Link et al. 2011, in prep.) and support the previously described EBSAs.

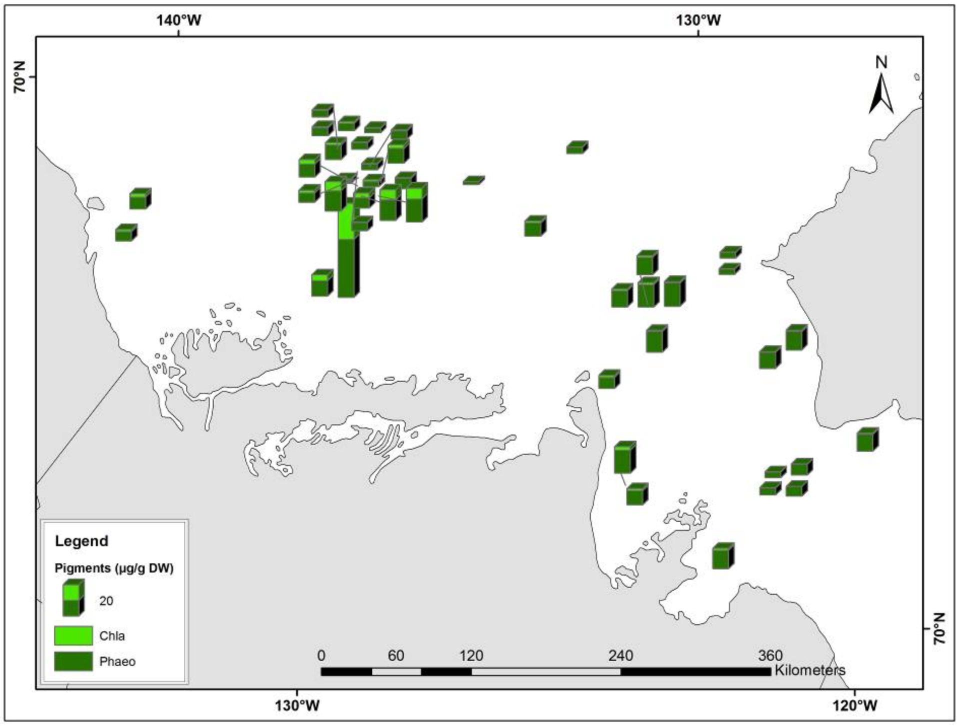

Figure 32. Concentration of total pigments (Chl a and phaeopigments) in the Beaufort Sea sediments collected during 2008-2010 ArcticNet-CHONe cruises.

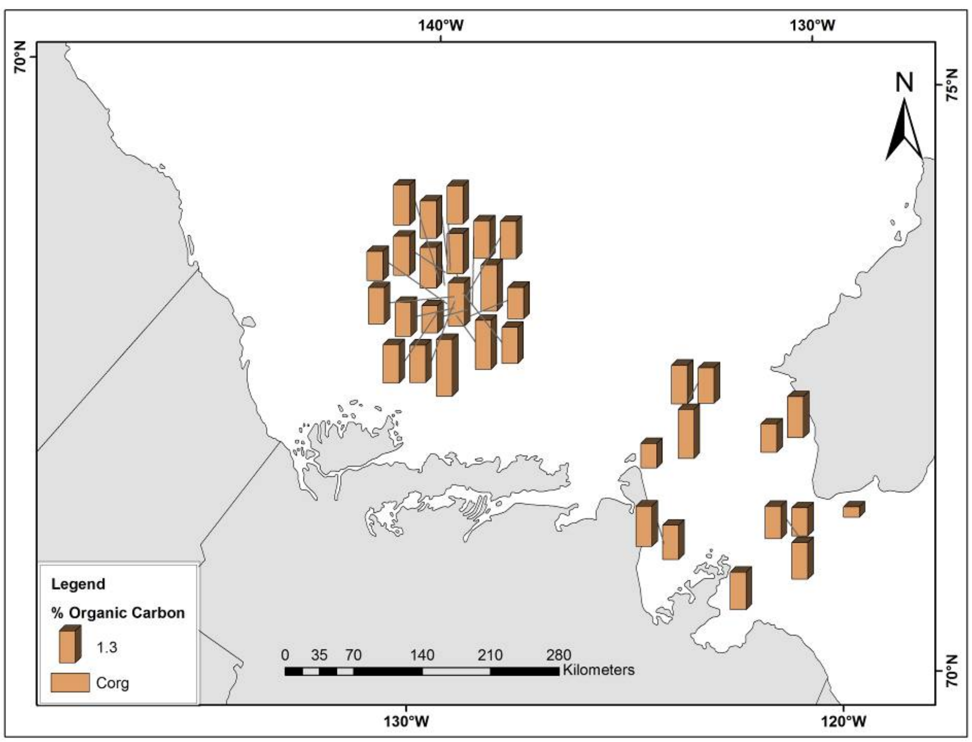

Figure 33. Concentration of organic carbon in the Beaufort Sea sediments collected during 2008-2010 ArcticNet-CHONe cruises.

EBSA Not Identified Previously: Prince of Wales Strait

This area has high food supply proxy (Figures 29, 30) and high macro-epifaunal diversity (V. Roy, pers. obs.). Strong tidal currents in this area (Hannah et al. 2009) suggest that hydrodynamics processes might favour highly productive and diverse benthic communities.

EBSA Not Identified Previously: Franklin Bay

Franklin Bay has been intensively studied during CASES (Renaud et al. 2007a) and revisited during CFL (Link et al. 2011). Both studies report benthic carbon remineralization higher than in the surrounding Amundsen Gulf.

SUMMARY

This report presents an updated and integrated description of benthic macro- and megafauna, benthic remineralization and forcing environmental parameters known to date in the Canadian Arctic. The benthic EBSAs described have been integrated into the report on EBSAs in the Canadian Arctic (DFO 2011b). Most benthic EBSAs presented here have been identified by the IUCN (2010) to very similar extents, but newly considered benthic data here has added a few EBSAs and redefined borders and areas.

Data on benthic ecosystems in the Canadian Arctic is particularly incomplete compared to other disciplines or regions. We therefore stress the importance of continuing sampling efforts in order to gain a better understanding of benthic ecosystems and their changes with projected ice retreat in the near future.

*Table 2. An assessment of available benthic data parameters against the DFO (2004) EBSA criteria (see Table 1) by Ecoregion, Subregion and EBSA (DFO 2011b, Appendix 1). – Indicates insufficient data to rank; * Refers to EBSAs that were not identified by the IUCN*

Ecoregion	Subregion	EBSA (DFO 2011b)	IUCN Regional EBSA / IUCN Super EBSA	Benthic Parameter	Function (F) or Structural (S) Feature	Uniqueness	Aggregation	Fitness Consequences	Resilience	Naturalness
Hudson Bay Complex		1.1 - 1.4, 1.6, 1.8, 1.10	62, 64, 65, 66			No Data to Assess				
	Southampton Island Polynya	1.5	60	Polynyas and Ice-edges	Physical Oceanographic (S)	M	H	M	-	H
	Southwestern Hudson Bay Estuaries	1.7	63	Macrobenthic Diversity	Biodiversity (S)	-	H	-	M	H
				Sediment pigment	Feeding (F)	-	H	H	-	-
	Belcher Islands	1.9	61	Macrobenthic Diversity	Biodiversity (S)	-	H	-	M	H
				Sediment pigment	Feeding (F)	-	H	H	-	-
	Hudson Strait - West	1.11	59,60	Corals and Sponges	Deep water corals (S)	M	L-M	H	H	H
				Corals and Sponges	Sponge reefs (S)	M	M	H	L	H
				Macrobenthic Diversity	Biodiversity (S)	-	H	-	M	H
				Sediment pigment	Feeding (F)	-	H	H	-	-
	Hudson Strait - East	1.12	57	Corals and Sponges	Sponge reefs (S)	M	H	H	L	H
	Ungava Bay	1.13	58	Corals and Sponges	Deep water corals (S)	M	H	H	H	H
				Corals and Sponges	Sponge reefs (S)	M	H	H	L	H
Eastern Arctic		2.1, 2.2, 2.4, 2.7	*, 67, 70, **7**			No Data to Assess				
		2.9, 2.15-2.16	69, 72, 73, **6**			No Data to Assess				
	Prince Regent Inlet	2.3	70, **7**	Polynyas and Ice-edges	Physical Oceanographic (S)	M	H	M	-	H

Peel Sound and Franklin Strait	2.5	71	Polynyas and Ice-edges	Physical Oceanographic (S)	M	H	M	-	H
			Macrobenthic Diversity	Biodiversity (S)	M	H	M	M	H
Lancaster Sound and Barrow Strait	2.6	69, 70, **7**	Macrobenthic Diversity	Biodiversity (S)	H	H	H	M	H
			Macrobenthic Diversity	Rare species (S)	H	L	-	-	H
			Benthic Remineralization	Feeding (F)	M	H	H	M	H
			Sediment pigment	Feeding (F)	H	H	H	L	H
			Polynyas and Ice-edges	Physical Oceanographic (S)	M	H	M	-	H
			Seabed Topography	Physical Oceanographic (S)	-	H	M	-	H
Davis Strait and Hatton Basin	2.8	52, 57	Corals and Sponges	Deep water corals (S)	H	H	H	L	H
			Corals and Sponges	Sponge reefs (S)	H	H	H	L	H
			Corals and Sponges	Biodiversity (S)	M	H	H	L	H
Continental Slope-Central Baffin Island	2.10, 2.11	54	Corals and Sponges	Deep water corals (S)	M	M	M	L	H
			Corals and Sponges	Sponge reefs (S)	L	L	M	L	H
			Seabed Topography	Physical Oceanographic (S)	-	H	M	-	H
Narwhal Site and Coral Area	2.12	54	Corals and Sponges	Deep water corals (S)	H	H	H	L	H
			Corals and Sponges	Sponge reefs (S)	M	L	M	L	H
Baffin Bay - North	2.13	69, **7**	Corals and Sponges	Deep water corals (S)	H	H	H	L	H
North Water Polynya (NOW)	2.14	69, **7**	Macrobenthic Diversity	Biodiversity (S)	H	H	H	M	H
			Macrobenthic Diversity	Rare species (S)	H	L	-	-	H
			Benthic Remineralization	Feeding (F)	M	H	H	M	H
			Sediment pigment	Feeding (F)	M	H	H	L	H

				Polynyas and Ice-edges	Physical Oceanographic (S)	M	H	M	-	H
Western Arctic		3.1, 3.3, 3.4, 3.6				No Data to Assess				
	Bathurst Inlet	3.2	*	Polynyas and Ice-edges	Physical Oceanographic (S)	M	H	M	-	H
	West King William Island	3.5	*	Macrobenthic Diversity	Biodiversity (S)	-	H	H	-	H
				Sediment pigment	Feeding (F)	-	H	H	-	H
				Seabed Topography	Physical Oceanographic (S)	-	H	M	-	H
	Beaufort LOMA-Mackenzie Shelf	3.8, 3.9, 3.13	37, 77, **5**	Macrobenthic Diversity	Biodiversity (S)	H	H	H	M	H
	Beaufort LOMA-Cape Bathurst-Amundsen Gulf	3.14	37, 76, **5**	Benthic Remineralization	Feeding (F)	M	H	H	M	H
				Sediment pigment	Feeding (F)	L	M	H	L	H
	Beaufort LOMA-Franklin Bay		37	Macrobenthic Diversity	Biodiversity (S)	H	H	H	M	H
				Benthic Remineralization	Feeding (F)	M	H	H	M	H
				Sediment pigment	Feeding (F)	L	H	H	L	H
				Polynyas and Ice-edges	Physical Oceanographic (S)	M	H	M	-	H
	Beaufort LOMA-Prince of Wales Strait		*	Macrobenthic Diversity	Biodiversity (S)	-	H	H	-	H
				Sediment pigment	Feeding (F)	-	H	H	-	H
	Beaufort LOMA-Viscount Melville Sound	3.24	72, **6**	Macrobenthic Diversity	Biodiversity (S)	L	L	-	L	H
				Benthic Remineralization	Feeding (F)	L	L	L	M	H
				Sediment pigment	Feeding (F)	L	L	L	-	H
Arctic Basin	Beaufort Gyre	4.1	*	Polynyas and Ice-edges	Physical Oceanographic (S)	M	H	M	-	H
High Canadian		5.1, 5.2, 5.3, 5.4, 5.5				No Data to Assess				

Arctic Archipelago									
	72, **<u>6</u>**	Polynyas and Ice-edges	Physical Oceanographic (S)	M	H	M	-	H

APPENDIX 1
LOCATIONS OF EBSAS IDENTIFIED IN DFO (2011b)

HUDSON BAY COMPLEX

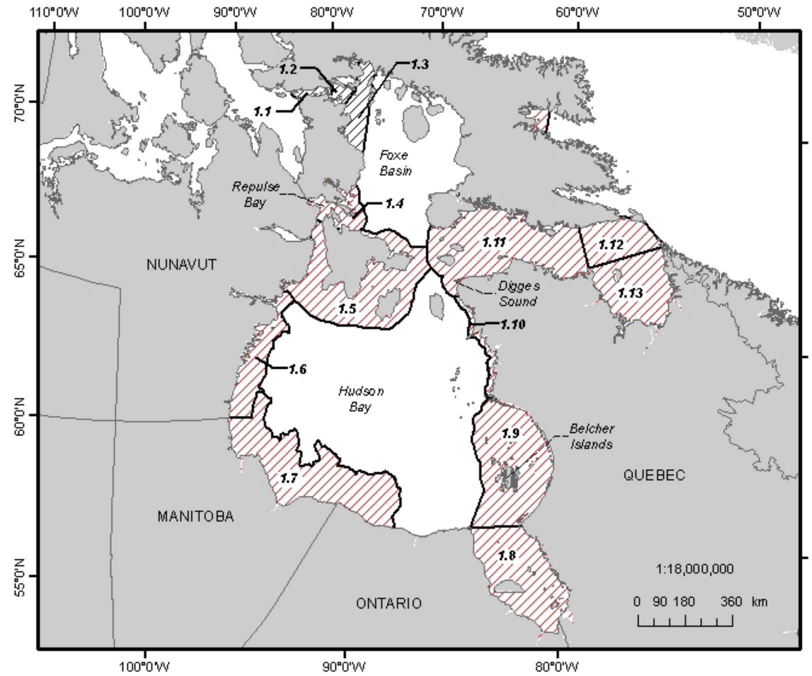

Figure 34. EBSAs identified within the Hudson Bay Complex biogeographic region from DFO (2011b).

EASTERN ARCTIC

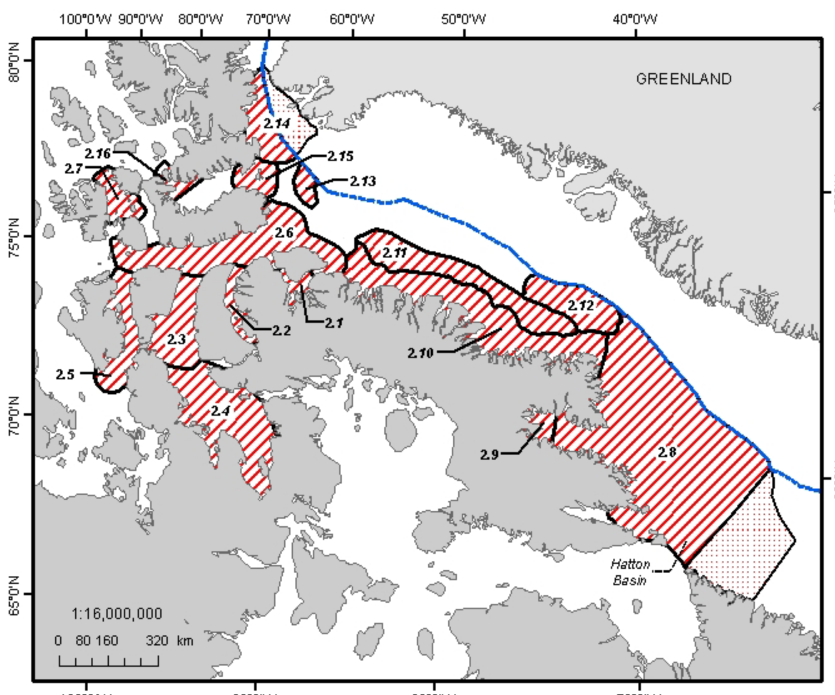

Figure 35. EBSAs identified within the Eastern Arctic biogeographic region from DFO (2011b).

WESTERN ARCTIC

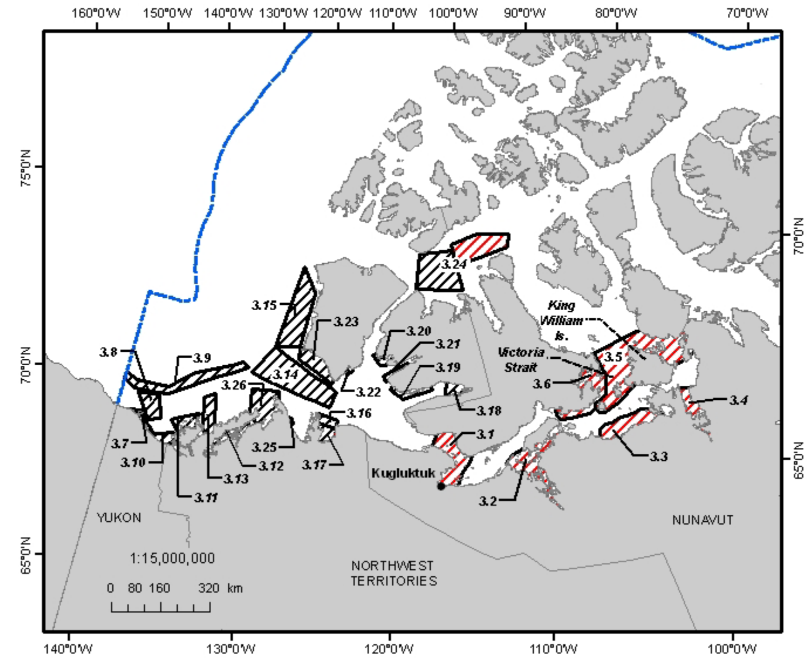

Figure 36. EBSAs identified within the Western Arctic biogeographic region from DFO (2011b).

ARCTIC BASIN

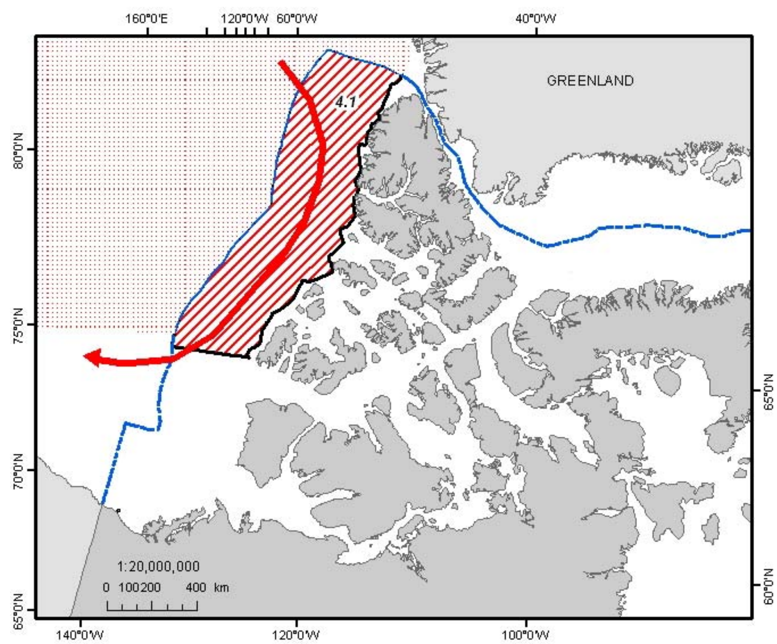

Figure 37. EBSAs identified within the Arctic Basin biogeographic region from DFO (2011b). The Beaufort Gyre (red arrow) and the Arctic Basin multi-year ice is defined by Canada's international boundary (blue dashed line). The ecological and biological features of this EBSA extend beyond Canadian waters and are identified (approximately) by the red stippled area adjacent (DFO 2011b).

ARCTIC ARCHIPELAGO

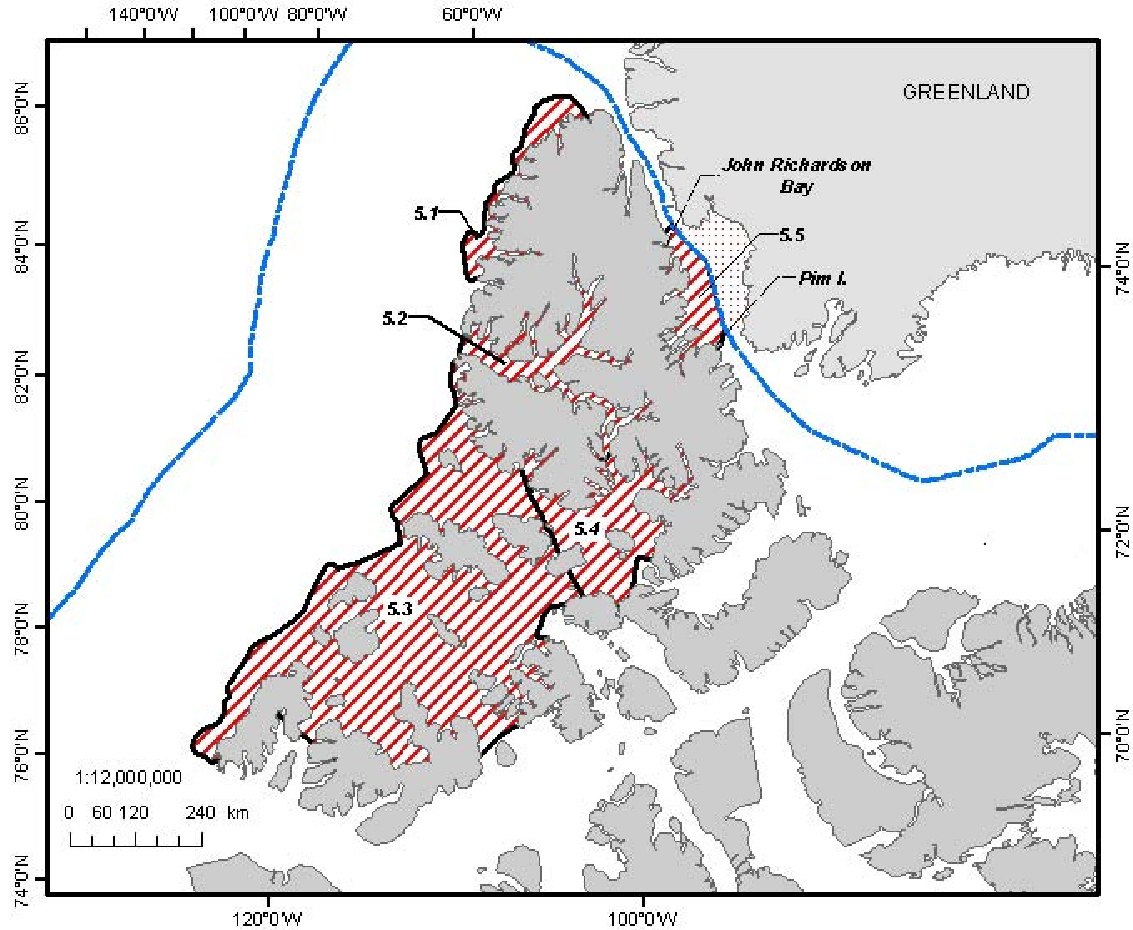

Figure 37. EBSAs identified for the Arctic Archipelago biogeographic region (DFO 2011b).

REFERENCES

Ambrose, W.G., Renaud, P.E., Cochrane, S.K.J., Denisenko, S.G., Skardhamar, J., 2009. Polychaete diversity patterns on two Arctic shelves: impacts of ice and primary production? In: Proceedings of the 9th International Polychaete Conference. Maciolek, N.J. and Blake, J.A. pp. 457-485.

Anderson, M.J. (2001a) A new method for non-parametric multivariate analysis of variance. Aust Ecol 26:32-46.

Anderson, M.J. (2001b) Permutation tests for univariate or multivariate analysis of variance and regression. Can J Fish Aquat Sci 58:626-639

Archambault, A., Snelgrove, P.V.R., Fisher, J.A.D., Gagnon, J.M., Garbary, D.J., Harvey, M., Kenchington, E.L., Lesage, V., Lévesque, M., Lovejoy, C., Mackas, D.L., McKindsey, C.W., Nelson, J.R., Pepin, P., Piché, L., Poulin, M., 2010. From Sea to Sea: Canada's Three Oceans of Biodiversity, *PLoS ONE, v.5, no.8*, e12182, 26 pp. doi:10.1371/journal.pone.0012182.

Atkinson, E.G., Wacasey, J.W., 1989a. Benthic invertebrates collected from Hudson Bay, Canada, 1953 to 1965. Can. Data Rep. Fish. Aquat. Sci. No. 744. iv + 121 p.

Atkinson, E.G., Wacasey, J.W., 1989b. Benthic invertebrates collected from the western Canadian Arctic, 1951 to 1985. Can. Data Rep. Fish. Aquat. Sci. No. 745. iv + 132 p.

Barber, D. G., Massom, R.A., 2007. A Bi-polar Assessment of Modes of Polynya Formation. In W. O. Smith and D. G. Barber (Editors), Polynyas: Windows to the World's Oceans, pp. 1-54, Elsevier, Amsterdam.

Best, M., Kenchington, E., MacIsaac, K., Wareham, V., Fuller, S.D., Thompson, A.B., 2010. Sponge Identification Guide NAFO Area. NAFO Scientific Council Studies, 43: 1-49. doi:10.2960/S.v43.m1.

Boutillier, J., Kenchington, E., Rice, J., 2010. A Review of the Biological Characteristics and Ecological Functions Served by Corals, Sponges and Hydrothermal Vents, in the Context of Applying an Ecosystem Approach to Fisheries. DFO Canadian Scientific Advisory Secretariat Research Document 2010/048, 36 pp.

Bluhm, B.A., Ambrose, W.G.J., Bergmann, M., Clough, L.M., Gebruk, A.V., Hasemann, C., Iken, K., Klages, M., MacDonald, I.R., Renaud, P.E., Schewe, I., Soltwedel, T., Włodarska-Kowalczuk, M. (2011) Diversity of the arctic deep-sea benthos. Mar Biodiv 41:87-107

Carroll, M.L., Denisenko, S.G., Renaud, P.E., Ambrose, W.G., 2008. Benthic infauna of the seasonally ice-covered western Barents Sea: Patterns and relationships to environmental forcing. Deep-Sea Research Part II-Topical Studies in Oceanography. 55 (20-21): 2340-2351.

Chapman, A.S., Kostylev, V.E., 2008. Distribution, abundance and diversity of benthic species from the Beaufort Sea and western Amundsen Gulf - a summary of data collected between 1951 and 2000. Natural Ressources Canada, Geological Survey of Canada (Atlantic), Open File 5685, 47 pp.

Conlan, K., Aitken, A., Hendrycks, E., McClelland, C., Melling, H., 2008. Distribution patterns of Canadian Beaufort Shelf macrobenthos. Journal of Marine Systems 74:864-886.

Cusson, M., Archambault, P., Aitken, A., 2007. Biodiversity of benthic assemblages on the Arctic continental shelf: historical data from Canada. Mar Ecol Prog Ser 331: 291–304.

Danovaro, R. (Editor), 2010. Methods for the Study of Deep-Sea Sediments, Their Functioning and Biodiversity. CRC Press, 458 pp.

DFO, 2004. Identification of Ecologically and Biologically Significant Areas. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2004/051.

DFO, 2007. Assessment Framework for Northern Shrimp (*Pandalus borealis*) off Labrador and the northeastern coast of Newfoundland; 28-30 May 2007. DFO Can. Sci. Advis. Sec. Proceed. Ser. 2007/034, 69 pp.

DFO, 2008. Assessment of northern shrimp (*Pandalus borealis*) and striped shrimp (*Pandalus montagui*) in shrimp fishing areas 0, 2 and 3. DFO Can. Sci. Advis. Sec. Advis. Rep. 2008/018, 19 pp.

DFO, 2009. Development of a Framework and Principles for the Biogeographic Classification of Canadian Marine Areas. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2009/056, 17pp.

DFO, 2010. Occurrence, susceptibility to fishing, and ecological function of corals, sponges, and hydrothermal vents in Canadian waters. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2010/041, 54 pp.

DFO, 2011a. Ecologically and Biologically Significant Areas – Lessons Learned. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2011/049.

DFO, 2011b. Identification of Ecologically and Biologically Significant Areas (EBSA) in the Canadian Arctic. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2011/055.

Dunn, D.C. and Halpin, P.N., 2009. Rugosity-based regional modeling of hard-bottom habitat. Marine Ecology-Progress Series. 377: 1-11.

FAO, 2009. Report of the Technical Consultation on International Guidelines for the Management of Deep-sea Fisheries in the High Seas. Rome, 4–8 February and 25–29 August 2008. ftp://ftp.fao.org/docrep/fao/011/i0605t/i0605t00.pdf

Forest, A., Tremblay, J-É, Gratton, Y., Martin, J., Gagnon, J., Darnis, G., Sampei, M., Fortier, L., Ardyna, M., Gosselin, M., Hattori, H., Nguyen, D., Maranger, R., Vaqué, D., Marrasé, C., Pedrós-Alió, C., Sallon, A., Michel, C., Kellogg, C., Deming, J., Shadwick, E., Thomas, H., Link, H., Archambault, P., Piepenburg, D. , 2011. Biogenic carbon flows through the planktonic food web of the Amundsen Gulf (Arctic Ocean): A synthesis of field measurements and inverse modeling analyses. Progress In Oceanography.

Fry, W.G., 1964. The pycnogonid fauna of the Antarctic continental shelf. Biologie Antarctique. Actual Sci. Ind. 1312: 263-269.

Fuller, S.D., Murillo Perez, F.J., Wareham, V., Kenchington, E., 2008. Vulnerable Marine Ecosystems Dominated by Deep-Water Corals and Sponges in the NAFO Convention Area. Serial No. N5524. NAFO Scientific Council Resaerch Document 08/22, 24pp.

Fry, W.G., 1964. The pycnogonid fauna of the Antarctic continental shelf. In: Carrick R, Holgate MW, Prevost J (eds) Biologie Antarctique. Hermann, Paris, pp 263–269.

Grant, J., Hargrave, B. and MacPherson, P., 2002. Sediment properties and benthic-pelagic coupling in the North Water. Deep-Sea Research Part Ii-Topical Studies in Oceanography, 49(22-23): 5259-5275.

Grebmeier, J.M. and Barry, J.P., 1991. The influence of oceanographic processes on pelagic-benthic coupling in polar regions: A benthic perspective. Journal of Marine Systems. 2: 495-518.

Grebmeier, J.M. and Barry, J.P., 2007. Benthic Processes in Polynyas. In: W.O. Smith and D.G. Barber (Editors), Polynyas: Windows to the World. Elsevier Oceanography Series. Elsevier, pp. 363-390.

Grebmeier, J.M., Cooper, L.W., Feder, H.M., Sirenko, B.I., 2006. Ecosystem dynamics of the Pacific-influenced Northern Bering and Chukchi Seas in the Amerasian Arctic. Progress in Oceanography. 71 (2-4): 331-361.

Hannah, C.G., Dupont, F., Dunphy, M., 2009. Polynyas and tidal currents in the Canadian Arctic Archipelago. Arctic 62:83-95.

IUCN, 2010. IUCN/NRDC Workshop to Identify Areas of Ecological and Biological Significance or Vulnerability in the Arctic Marine Environment. 20. November 2-4, 2010. http://data.iucn.org/dbtw-wpd/edocs/Rep-2011-001.pdf

Jazdzewski, K., Teodorczyk W., Sicinski, J., Kontek, B., 1991. Amphipod crustaceans as an important component of zoobenthos of the shallow Antarctic sublittoral. Hydrobiologia 223:105–117.

Kenchington, E., Lirette, C., Cogswell, A., Archambault, D., Archambault, P., Benoit, H., Bernier, D., Brodie, B., Fuller, S., Gilkinson, K., Levesque, M., Power, D., Siferd, T., Treble, M., Wareham, V., 2010. Delineating Coral and Sponge Concentrations in the Biogeographic Regions of the East Coast of Canada Using Spatial Analyses. DFO Can. Sci. Advis. Sec. Res. Doc. 2010/041. iv + 207 pp.

Klages, M., Boetius, A., Christensen, J.P., Deubel, H., Piepenburg, D., Shewe, I., Soltwedel, T., 2004. The benthos of Arctic seas and its role for the organic carbon cycle at the seafloor. In: The organic carbon cycle in the Arctic Ocean. Stein, R. and R.W. Macdonald. Springer, Berlin. pp. 139-167.

Kostylev, V.E., Erlandsson, J., Ming, M.Y., Williams, G.A., 2005. The relative importance of habitat complexity and surface area in assessing biodiversity: Fractal application on rocky shores. Ecological Complexity 2 (3): 272-286.

Lalande, C., 2003. Composition et structure de la communauté benthique et quantification de la bioturbation dans la polynie des Eaux du Nord. Mémoire de maîtrise, Institut des sciences de la mer de Rimouski, Université du Québec à Rimouski, Rimouski. 59 pp.

Lalande, C., Forest, A., Barber, D.G., Gratton, Y., Fortier, L., 2009. Variability in the annual cycle of vertical particulate organic carbon export on Arctic shelves: Contrasting the Laptev Sea, Northern Baffin Bay and the Beaufort Sea. Continental Shelf Research 29:2157-2165.

Lapoussiere, A., Michel, C., Gosselin, M., Poulin, M., 2009. Spatial variability in organic material sinking export in the Hudson Bay system, Canada, during fall. Continental Shelf Research 29(9):1276-1288.

Link, H., Archambault, P., Tamelander, T., Renaud, P.E., Piepenburg, D., 2011. Spring-to-summer changes and regional variability of benthic processes in the western Canadian Arctic. Polar Biology.

MacDonald, I.R., Bluhm, B.A., Iken, K., Gagaev, S., Strong, S., 2010. Benthic macrofauna and megafauna assemblages in the Arctic deep-sea Canada Basin. Deep-Sea Research Part Ii-Topical Studies in Oceanography. 57 (1-2): 136-152.

Marincovich Jr, L., 2000. Central American paleogeography controlled Pliocene Arctic Ocean molluscan migrations. Geology 28, 551–554.

McArthur, M.A., Brooke, B.P., Przeslawski, R., Ryan, D.A., Lucieer, V.L., Nichol, S., McCallum, A.W., Mellin, C., Cresswell, I.D., Radke, L.C., 2010. On the use of abiotic surrogates to describe marine benthic biodiversity. Estuarine Coastal and Shelf Science. 88 (1): 21-32.

Michel, C., Ingram, R.G., Harris, L.R., 2006. Variability in oceanographic and ecological processes in the Canadian Arctic Archipelago. Progress in Oceanography 71 (2-4): 379-401.

Morata, N., Renaud, P.E., Brugel,S., Hobson, K.A., Johnson, B.J., 2008. Spatial and seasonal variations in the pelagic-benthic coupling of the southeastern Beaufort Sea revealed by sedimentary biomarkers. Marine Ecology-Progress Series 371:47-63.

Piepenburg, D., 2005. Recent research on Arctic benthos: common notions need to be revised, Polar Biology 28:733-755.

Piepenburg, D., Archambault, P., Ambrose, W.G., Blanchard, A., Bluhm, B.A., Carroll, M.L., Conlan, K.E., Cusson, M., Feder, H.M., Grebmeier, J.M., Jewett, S.C., Lévesque, M., Petryashev, V.V., Sejr, M.K., Sirenko, B.I., Włodarska-Kowalczuk, M., 2011. Biodiversity of the benthic macro- and megafauna of Arctic shelf seas - a pan-Arctic synopsis. Marine Biodiversity 41:51–70, DOI 10.1007/s12526-010-0059-7.

Piepenburg, D., Ambrose, W.G., Brandt, A., Renaud, P.E., Ahrens M.J., Jensen, P., 1997. Benthic community patterns reflect water column processes in the Northeast Water polynya (Greenland). Journal of Marine Systems. 10 (1-4): 467-482.

Renaud, P.E., Riedel, A., Michel, C., Morata, N., Gosselin, M., Juul-Pedersen, T., Chiuchiolo, A. , 2007a. Seasonal variation in benthic community oxygen demand: A response to an ice algal bloom in the Beaufort Sea, Canadian Arctic? Journal of Marine Systems 67:1-12.

Renaud, P.E., Morata, N., Ambrose, W.G., Bowie, J.J., Chiuchiolo, A. , 2007b. Carbon cycling by seafloor communities on the eastern Beaufort Sea shelf. Journal of Experimental Marine Biology and Ecology 349:248-260.

Schmid, B., Balvanera, P., Cardinale, B., Godbold, J., Pfisterer, A.B., Raffaelli, D., Solan, M., Srivastava, D. , 2009. Consequences of species loss for the ecosystem functioning: meta-analyses of data from biodiversity experiments. In: Naeem S, Bunker DE, Hector A, Loreau M, Perrings C (eds) Biodiversity, Ecosystem Functioning, and Human Wellbeing: An Ecological and Economic Perspective. Oxford University Press, Oxford, United Kingdom, p 14-29.

Sejr, M.K., Wiodarska-Kowalczuk, M., Legezynska, J., Blicher, M.E., 2010. Macrobenthic species composition and diversity in the Godthaabsfjord system, SW Greenland. Polar Biology 33: 421-431.

Stewart, P.L., Levy, H.A., Hargrave, B.T., 2001. Database of Benthic Macrofaunal Biomass and Productivity Measurements for the Eastern Canadian Continental Shelf, Slope and Adjacent Area. Can. Tech. Rep. Fish. Aquat. Sci. 2336. vi + 31p. + AI-6.

Sun, M.Y., Clough, L.M., Carroll, M.L., Dai, J.H., Ambrose, W.G., Lopez, G.R. , 2009. Different responses of two common Arctic macrobenthic species (*Macoma balthica* and *Monoporeia affinis*) to phytoplankton and ice algae: Will climate change impacts be species specific? Journal of Experimental Marine Biology and Ecology 376:110-121.

Thomson, D.H., 1982. Marine benthos in the eastern Canadian high arctic: Multivariate analyses of standing crop and community structure. Arctic 35(1):61-74.

Thomson, O.H., Martin, C.M., Cross, W.E., 1986. Identification and characterization of Arctic nearshore benthic habitats. Can. Tech. Rep. Fish. Aquat. Sci. 1434. vii + 70.

Treble, M.A., 2002. Analysis of Data from the 2001 Trawl Survey in NAFO Subarea 0. NAFO Scientific Council Research Document 02/47, Serial No. N4659, 28 pp.

Treble, M.A., 2009. Report on Greenland Halibut caught during the 2008 Trawl Surveys in NAFO Division 0A. NAFO Scientific Council Research Document 09/26, Serial No. N5661, 22 pp.

Treble, M.A., Brodie, W.B., Bowering, W.R., Jorgensen, O.A., 2000. Analysis of data from a trawl survey in NAFO Division 0A, 1999. NAFO Scientific Council Research Document 00/31, Serial No. N4260, 19 pp.

Wacasey, J.W., Atkinson, E.G., Kinlough, L., 1976. Zoobenthos data from James Bay, 1959, 1974. Fish. Mar. Serv. Res. Dev. Tech. Rep. No. 661.

Wacasey, J.W., Atkinson, E.G., Derick, L., Weinstein, A., 1977. Zoobenthos data from the southern Beaufort Sea, 1971–1975. Arctic Biological Station, Fisheries and Marine Service, Department of Fisheries and the Environment. Fish Mar Serv Res Dev Tech Rep 41. 187 pp.

Wacasey, J.W., Atkinson, E.G., Glasspoole, L., 1979. Zoobenthos data from upper Frobisher Bay, 1967–1973. Can Data Rep Fish Aquat Sci No. 164.

Wacasey, J.W., Atkinson, E.G., Glasspoole, L., 1980. Zoobenthos data from inshore stations of upper Frobisher Bay, 1969–1976. Can Data Rep Fish Aquat Sci No. 205.

Wareham, V.E., Edinger, E.N., 2007. Distribution of deep-sea corals in the Newfoundland and Labrador region, Northwest Atlantic Ocean. In: George, R. Y. and S. D. Cairns, eds. 2007. Conservation and adaptive management of seamount and deep-sea coral ecosystems. Rosenstiel School of Marine and Atmospheric Science, University of Miami.

Wareham, V.E, Ollerhead, L.M.N., Gilkinson K., 2010. Spatial Analysis of Coral and Sponge Densities with associated Fishing Effort in Proximity to Hatton Basin (NAFO Divisions 2G-0B). DFO Can. Sci. Advis. Sec. Res. Doc. 2010/058. vi + 34 p.

Wassmann, P., Duarte, C.M., Agusti, S., Sejr, M.K., 2011. Footprints of climate change in the Arctic marine ecosystem. Glob Change Biol 17:1235-1249.

Wilson, M.F.J., O'Connell, B., Brown, C., Guinan, J.C., Grehan, A.J., 2007. Multiscale terrain analysis of multibeam bathymetry data for habitat mapping on the continental slope. Marine Geodesy. 30 (1-2): 3-35.

Witman, J.D., Cusson, M., Archambault, P., Pershing, A.J., Mieszkowska, N., 2008. The relation between productivity and species diversity in Temperate-Arctic marine ecosystems. Ecology. 89 (11): S66-S80.