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Information in Support of the Identification of Ecologically Significant Species, Functional Groups and Community Properties (ESSCP) in the Western Arctic Biogeographic Region

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Foreword

This series documents the scientific basis for the evaluation of aquatic resources and ecosystems in Canada. As such, it addresses the issues of the day in the time frames required and the documents it contains are not intended as definitive statements on the subjects addressed but rather as progress reports on ongoing investigations.

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ABSTRACT

Under Canada's *Oceans Act*, Fisheries and Oceans Canada (DFO) is authorized to provide enhanced management to areas, species and community properties of the oceans. To accomplish this, DFO has adopted a scientifically defensible ecosystem-based approach to management (EBM). This approach assists to more effectively coordinate policies and key programs within DFO across all levels of Government and with collaborating stakeholders. The approach considers environmental and human components as a function of their effective relationships within the broader ecosystem.

To support the establishment of a Marine Protected Area Network (MPAN) DFO Science sector has been asked to provide advice on the identification of marine Ecologically Significant Species and Community Properties (ESSCP). The identification of ESSCP will add another scientifically defensible management dimension, particularly where spatially-based conservation tools are challenging to apply. The combination of ESSCPs and Ecologically and Biologically Significant Areas (EBSA) will inform the setting of conservation objectives for marine ecosystem-based management (such as MPAs and other effective area-based conservation measures) and the identification of conservation priorities for the MPAN development.

The purpose of this report is to review current ecological information for species, species groups or community properties for the Western Arctic bioregion, attempt to apply the ESSCP criteria, and provide an initial list of candidate ESSCP. Participants attending a Canadian Science Advisory Secretariat (CSAS) meeting will: review the criteria and the list of candidate ESSCP; decide upon a means to rank the ESSCP with respect to ecological significance; and provide a final ranked list of ESSCP. This working paper provide the background information to support the CSAS meeting.

INTRODUCTION

Under Canada's *Oceans Act* (1997), Fisheries and Oceans Canada (DFO) is authorized to provide enhanced management to areas, species and community properties of the oceans (DFO 2004, 2006). To accomplish this, DFO has adopted a scientifically defensible ecosystem-based approach to management (EBM). This approach assists to more effectively coordinate policies and key programs within DFO across all levels of Government and with collaborating stakeholders. The approach considers environmental and human components as a function of their effective relationships within the broader ecosystem.

In support of EBM, DFO has identified Ecologically and Biologically Significant Areas (EBSA) in the Canadian Arctic through a series of scientific and community workshops between 2011–2015 (DFO 2011a, 2014a, b, 2015a). EBSA call attention to areas that have particularly high ecological or biological significance. Ocean areas can be an EBSA because of the functions that they serve in the ecosystem and/or because of structural properties. They are essential management tools used to provide information about important species, habitat and ecosystem components. Complimentary to EBSA, DFO has also identified ecological units (eco-units) in the Western Arctic Biogeographic (WAB) region (Figure 1).

To support the establishment of a Marine Protected Area Network (MPAN) and inform Design Strategies in the WAB region (Figure 1), DFO Science sector has been asked to provide advice in support of the identification of marine Ecologically Significant Species and Community Properties (ESSCP). The identification of ESSCP will add another scientifically defensible management dimension, particularly where spatially-based conservation tools such as Ecologically and Biologically Significant Areas (EBSA) are challenging to apply (DFO 2011b). The combination of EBSA and ESSCP will inform the setting of conservation objectives for marine ecosystem-based management (such as MPAs and other effective area-based conservation measures) and the identification of conservation priorities for the MPAN development. The identification of ESSCP will help focus current and future national and international monitoring programs designed to track ecosystem change by focusing on functional properties in addition to structural and spatially-based ecosystem properties.

The purpose of this report is to review current (published or provided by knowledge holders) ecological information for species, species groups or community properties for the WAB region, attempt to apply the ESSCP criteria, and provide an initial list of candidate ESSCP. Participants attending a Canadian Science Advisory Secretariat (CSAS) meeting will review the criteria and the list of candidate ESSCP, decide upon a means to rank the ESSCP with respect to ecological significance, and provide a final ranked list of ESSCP.

Guidance for the application of criteria to assess ESSCP focusses on operationalizing the term "significant" from an ecological perspective (i.e., function) with the objective of drawing attention to species and community properties that warrant, from an ecological perspective, enhanced protection (DFO 2006).

It is recognized that the science basis for the application of ESSCP criteria is especially challenging in areas where data availability is scarce. Moreover, for many species it may be more appropriate for managers to apply the EBSA criteria, especially where spatial delineation of these areas has been determined with a high degree of certainty, rather than try to apply ESSCP criteria. The use of ESSCP is most useful for those species, which are important, but occur widely or are not distributed in a way (space and time) that can be easily mapped. Often scientific information is limited or non-existent or, as in the case of the WAB region, scientific programs have focused on areas of potential oil and gas exploration and development, thus, biasing our understanding of what constitutes an EBSA in a broader ecosystem perspective

(DFO 2006). In these cases, it may be more appropriate to manage for a species (or species group) at the bioregional scale. For single species, there may be existing management considerations that are better suited than ESSCP or EBSA, for example, the *Species at Risk Act* or integrated fishery management plans (including community management plans).

THE WESTERN ARCTIC BIOGEOGRAPHIC REGION

The Western Arctic Biogeographic (WAB) region (Figure 1) is one of 12 national and five Arctic regions identified by DFO for management and planning purposes (DFO 2009a). The Canadian Arctic biogeographic regions (or ‘bioregions’), were delineated based on bathymetry, water masses, and the distribution of multi-year sea ice (DFO 2009a). The WAB region encompasses about 550,000 km^2 and is bound to the west and northwest by the Arctic Basin Biogeographic region, and to the north and east by the Arctic Archipelago and Eastern Arctic bioregions, respectively (Figure 1). The boundary between the WAB region and the Arctic Basin biogeographic region occurs at approximately the 200 m depth contour of the Beaufort Sea.

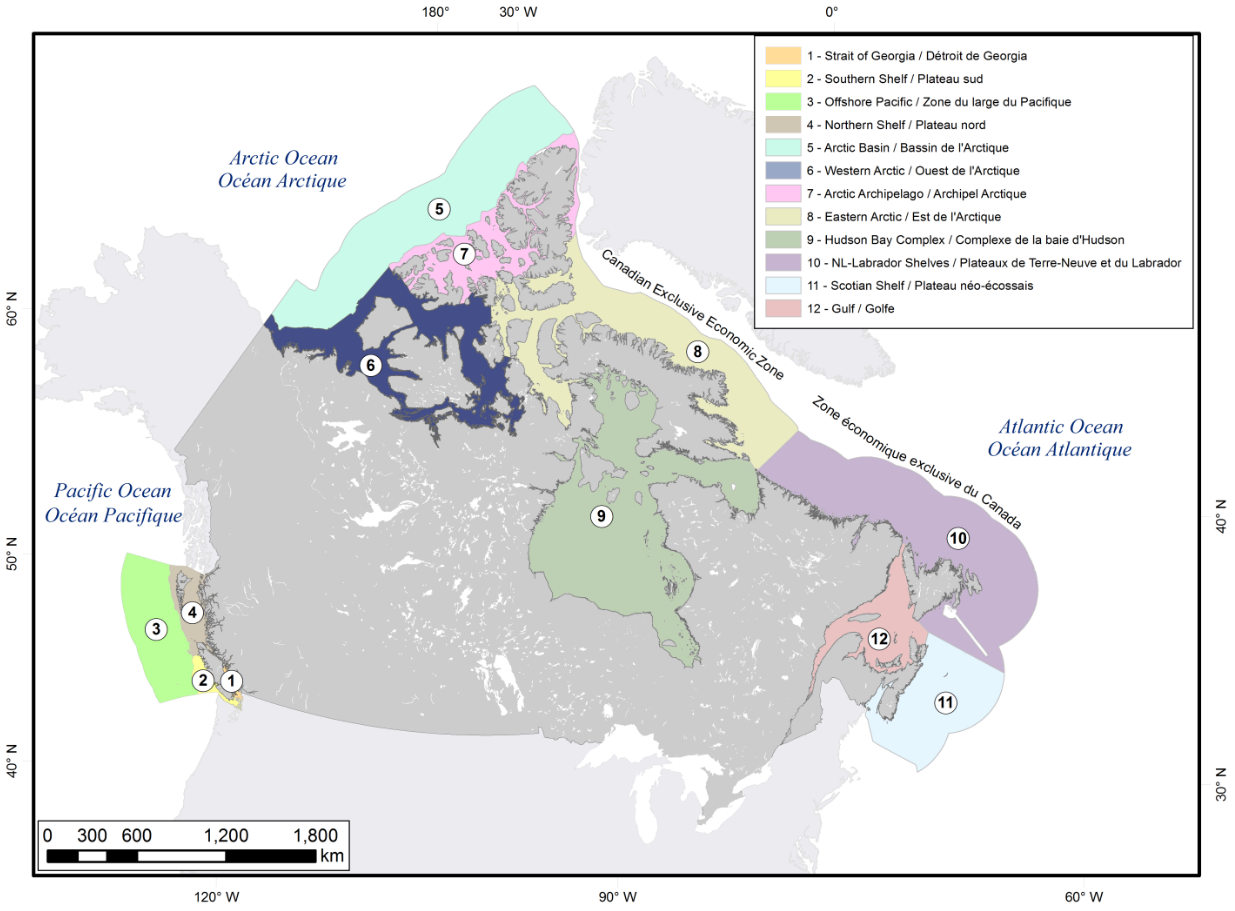

Figure 1. Canadian biogeographic regions, including the Western Arctic Biogeographic region (#6) (DFO 2009a).

The WAB region includes the Beaufort Shelf, Mackenzie Estuary, Amundsen Gulf, Viscount Melville Sound, Coronation Gulf, and McClintock Channel (Figures 2 and 3). Maximum water depths of the WAB region reach approximately 600 m in Viscount Melville Sound. Generally, the shelf waters extend through the Mackenzie River Estuary, surrounding Banks and Victoria islands, and the mainland coastal region (Figure 2 and 3). Discharge from the Mackenzie River dominates the Beaufort Shelf ecosystem throughout the year (Macdonald et al. 1989). Seasonal discharge from smaller, but locally important rivers establish coastal freshened waters elsewhere in the WAB region (Figure 2). These nearshore zones are critical for long-range movement of anadromous fishes between spawning, overwintering, rearing, and feeding areas (e.g., Paulic et al. 2011).

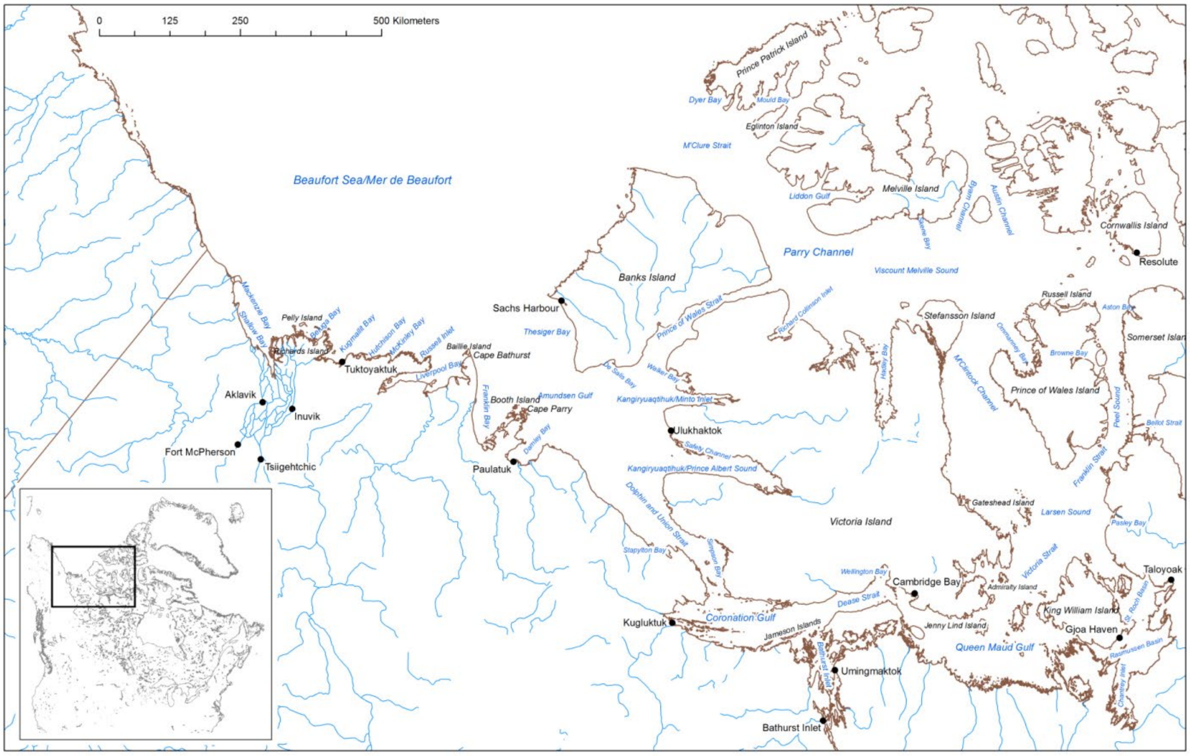

Figure 2. Place names, rivers, and communities within the Western Arctic Biogeographic region.

The WAB region is not homogeneous and it was recognized that further division into eco-units may be required at a later date for refining the scale for the objective of integrated ocean planning (DFO 2009a). For this purpose, 18 eco-units (Figure 3) were defined as a first step towards the identification of priority conservations areas in the WAB region (DFO 2015b). These eco-units were delineated based on dominant habitat features, bathymetry, and water masses.

Although 18 different eco-units of the WAB region have been described, the ecosystems of these eco-units do not function in isolation. Nutrients, invertebrates, fish, and marine mammals move either passively or actively between these areas. The complex nature of physical oceanography and ice regime means water masses are changing both seasonally and daily. The clockwise Beaufort Sea Gyre dominates the large scale movement of surface sea water over the Arctic Basin. However, the circulation below the surface, known as the Beaufort Undercurrent, follows a counter-clockwise direction along the continental slope. This flow results in the eastward movement of Beaufort Sea water masses comprised of Pacific and Atlantic origin through the rest of the WAB region (Aagaard 1984).

The Beaufort Shelf and Amundsen Gulf (i.e., eco-units #1–5) have received the greatest attention from management and research over the past number of decades, driven by the prospect of future oil and gas development, regional environmental assessments, and the prospect of emerging fisheries (Figure 3). This has included funding for government as well as university-based research initiatives (e.g., Canadian Arctic Shelf Exchange Study [CASES], International Polar Year – Circumpolar Flaw Lead System Study [IPY-CFL], ArcticNet-Canadian Coast Guard Ship (CCGS) *Amundsen* Scientific Program, Northern Coastal Marine Studies (NCMS), Beaufort Regional Environmental Assessment (BREA)). The amount of sampling, research and observations is substantially lesser for eco-units farther north and east (i.e., eco-units #6–18; Figure 3).

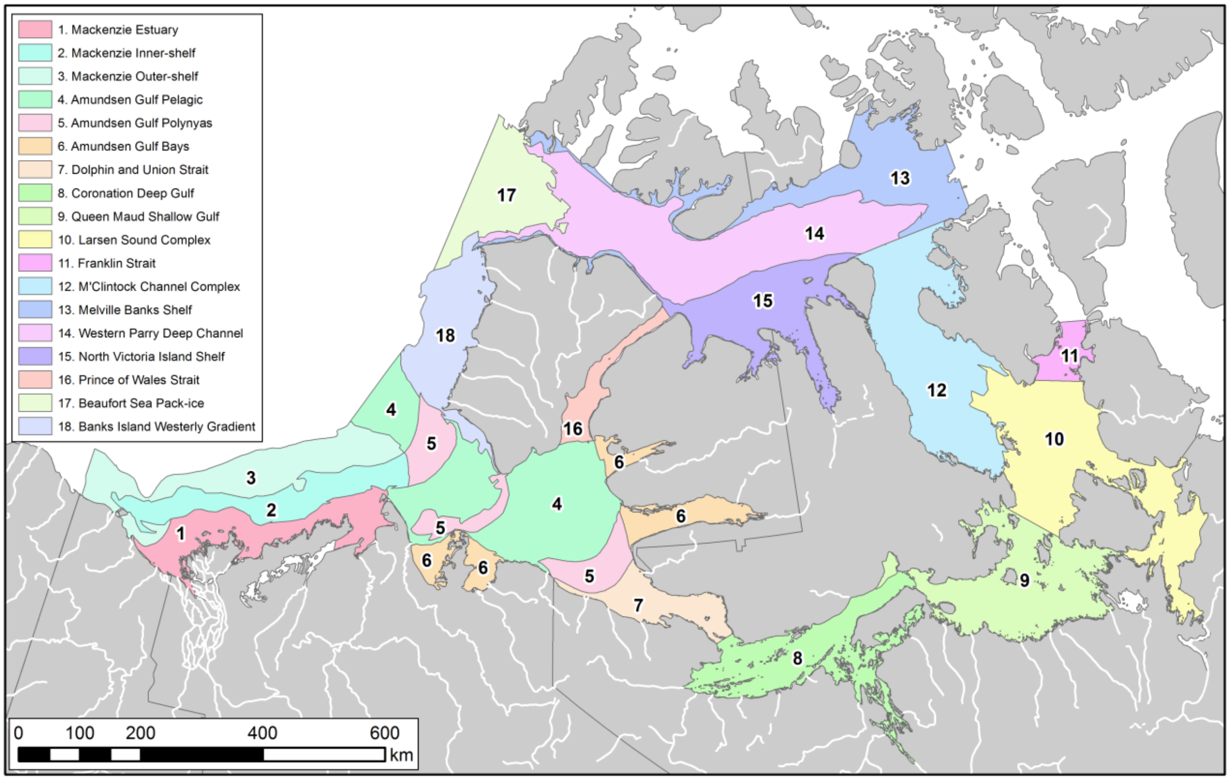

Figure 3. Eco-units identified in the Western Arctic Biogeographic region (DFO 2015b).

The near-shore low salinity zone is often interrupted by storm events, which result in a surge of deep oceanic (high nutrient, high salinity, low temperature) waters upon the shelf or against coastlines (Gordon et al. 2016). These surges also transport planktonic organisms from deep waters to shallow shelf areas, making them available as forage for fish and mammals.

Connectivity between environments within the WAB region is an important consideration. Animals often use different marine environments at different times of their life cycle for feeding, reproduction or migration into and out of the bioregion. Both horizontal and vertical passive and active movements also occur, resulting in the transfer of nutrients and biomass.

For the most part, the Canadian Arctic is considered remote and/or inaccessible in many areas, this means that our scientific understanding of the region is patchy and limited, compared to that of other marine regions of Canada. A majority of the region is ice-covered to some degree for at least eight and in some areas for almost twelve months of the year - although extent of ice and type of ice is going through drastic changes at decadal scales. In the WAB region, scientific data has been collected across various disciples extensively on the Beaufort Shelf relative to the north (e.g., Viscount Melville) and eastern (e.g., Victoria Strait) areas of the WAB region. This is due to the demand for knowledge and understanding associated with the risks of oil and gas development along the nearshore areas of the Beaufort Shelf. Research, data, and knowledge are therefore limited to small proportions of the region often located close to communities.

The features, which delineate the WAB region and its eco-units, provide the physical template that determines the diversity and distribution of marine species and communities. This is the first attempt to apply the national guidance on ESSCP criteria (DFO 2006) to determine ESSCP in the Canadian Arctic.

NATIONAL GUIDANCE FOR ESSCP CRITERIA

In 2006, a DFO CSAS meeting was held to establish criteria for determining ESSCP (DFO 2006). During this meeting a series of short papers were reviewed that purposed potential criteria (Rice 2006). From the thirteen papers submitted, the advice from the meeting selected four criteria (DFO 2006):

- Species that have important trophodynamic roles including important forage species, highly influential predator species, nutrient importing or exporting species, and species that carry out other important ecosystem functions, such as decomposers;
- Species that provide three-dimensional structure that is important for biodiversity or support species that provide three-dimensional structure;
- Aggregate and/or community groups and community properties essential for ecosystem structure and function; and,
- Species that if introduced by humans, would comprise a threat to ecosystem structure and function if abundant (such as harmful algal species).

Although these criteria were published, it has only been applied by DFO Science on one occasion, which was the consideration of eelgrass (*Zostera marina*) as an Ecologically Significant Species in eastern Canada (DFO 2009b). Additionally, an assessment of the applicability of the criteria to define Ecologically and Biologically Significant Areas (EBSA) and Ecologically Significant Species (ESS) in the Bay of Quinte was also completed (DFO 2014c).

There are several issues to consider when applying criteria to assess and identify ESSCP in the Arctic. The size of the WAB region under consideration is considerably larger (550,000 km^2) than many of the other biogeographic regions in Canada. This means that data and knowledge of each species, species group, and/or a community is not uniform across the entire bioregion, and therefore the understanding of how significant a species is to ecosystem structure and function may not be well understood, particularly, if it occurs in an area where little scientific data exists.

A second level for consideration of ESSCP is the scale of diversity between and within broad taxonomic groups. There are only nine marine mammal species to consider, several tens of marine fishes, several hundreds of pelagic macro-invertebrates and zooplankton species, however, there are estimates of over a 1000 species of benthic invertebrates, and thousands more species of phytoplankton, ice algae, bacteria, and other micro-organisms (CAFF 2013). It is highly unlikely that the ESSCP criteria will be able to adequately assess all species groups and/or communities equally. Many of the criteria are more relevant to higher trophic levels than to lower species level associations, and therefore some of the criteria were difficult to address in this context.

Finally, the Arctic marine ecosystem is unique compared to other Canadian marine regions, with seasonal extremes of daylight and darkness, sea-ice and open water, and large regional-scale variability in key ecosystem processes such as circulation patterns and nutrient dynamics (e.g., Michel et al. 2006, 2015). There is a wide range of productivity in Canadian Arctic marine ecosystems. Current estimates indicate that the Beaufort Sea is less productive than other areas (i.e., hot spots) in Lancaster Sound and northern Baffin Bay (Ardyna et al. 2011).

Sympagic-pelagic-benthic coupling dominate ecosystem transfers. Trophic interactions are complex but some species or species associations play pivotal roles (e.g., sea-ice species, micro zooplankton, *Calanus* spp., Arctic Cod [*Boreogadus saida*] [see Michel et al. 2012]). There is often little redundancy built into ecological systems in the pelagic Arctic marine environment, unlike the case of southern oceans (e.g., Reese and Brodeur 2015).

Due to a lack of data and a limited overall understanding of feedback responses within the food web, ecosystem models may be an important complementary tool to identify key ecosystem linkages and predict response to changes (e.g., Hoover 2013). The EcoPath model by Hoover (2013) for the Beaufort Shelf uses diet and biomass turnover estimates to identify keystone species and may provide valuable insight into ESSCP for the WAB region.

METHODS

A comprehensive list of aquatic marine species present in the WAB region was compiled from various sampling records, monitoring records, and published data sets (e.g., Stewart 2013). The list includes mammals, marine birds, marine and anadromous fishes, invertebrates, and algae. Shorebirds, waterfowl, and raptors were not included in the assessment. In general, most fishes, invertebrates, and algae were grouped and assessed as assemblages and/or communities (DFO 2019). This was generally due to high species richness and a lack of knowledge associated with a majority of individual species, and in some cases community structure. Additionally, colonizing species (e.g., Pacific salmons) or those considered non-indigenous were not assessed. The purpose of this assessment is to identify ESSCP within the current state of the biogeographic region.

Once the species list was compiled, each species, species group, and/or community properties was evaluated against the criteria. As previously mentioned, the Arctic is unique due to the influence of sea ice for much of the year. As a result, it was decided that some modification to the DFO (2006) national ESSCP criteria was needed to reflect this important component of the ecosystem to which many species are adapted. In order to assess each candidate ESSCP against the criteria, a number of attributes was also considered to add context for the ecological justification.

ASSESSMENT CRITERIA AND THEIR ATTRIBUTES

Distribution

Both spatial and temporal attributes were assessed under this criterion:

Spatial Distribution

Some species, species groups and assemblages that occur within the assessment area are widespread (ubiquitous), and therefore perform their ecological role at the bioregional scale. In contrast, other species may have specific, localized distributions and may fulfill an important ecological role locally, but do not necessarily contribute to the ecosystem at a broader scale. The spatial distribution of a species, species group or community property is important information to determine ecological significance within the assessment area.

Temporal Distribution

Some species, species groups or community properties are year-round components of the ecosystem, although they may occupy various habitats on a seasonal or diurnal basis (e.g., Arctic Cod, sympagic, pelagic, benthopelagic). In contrast, other ecosystem components undergo migrations in and out of the assessment area and only occur on a seasonal basis (e.g., Beluga Whale, *Delphinapterus leucas*). The temporal distribution of a species, species group or community property provides added information to determine ecological significance within the assessment area.

Habitat

Habitat Associations

Some species are restricted to a narrow range of habitat types, while others are widely distributed in various habitats. This association with specific habitats can contribute to their consideration as ESSCP. These species may fill a specific ecological function at specific, localized habitats. Although habitat features were considered in the examination of Arctic EBSAs (DFO 2011a), they were considered from a spatial analysis perspective. With respect to habitat association, this dimension describes that association from an ecosystem function perspective.

Habitat-creating or -modifying

Species that have a three-dimensional shape and occur in significant densities can be used by other species for refuge, providing hard substrate for anchoring or for spawning or nursery areas, and are considered habitat-creating species. Other species (mainly infauna in soft bottoms, but also some epifauna), modify their environment through bioturbation. These species perform important ecological services through the re-suspension of nutrients and essential chemicals and minerals that are then available to other species. Remineralization and resuspension of nutrients and materials is an important component of benthic-pelagic coupling (Renaud 2007).

Ecosystem Component Contribution

Several attributes were considered under this criterion which defines a species/species group dominant role within the ecosystem:

Biomass

Some species or species groups have high biomass due to large body size and/or high abundance, and therefore contribute proportionally more to ecosystem function than do other ecosystem components (Figure 4). The amount of biomass represented by taxonomic groups (e.g., all marine mammals, all marine fishes, all benthic invertebrates – see Figure 4), was calculated based on an EcoPath model for the Beaufort Shelf (< 200 m, C. Hoover, Fisheries and Oceans Canada, pers. comm.). The biomass for each group is represented as a percent of the total ecosystem biomass (i.e., percent contribution, %). Biomass estimates were not calculated for individual ESSCPs. Figure 4 shows that the bulk of the biomass falls within abundant, small species including primary producers, as would be expected from classical marine food web pyramids.

Groups with high percent contribution include keystone species, defined here as species having a disproportionately large regulating effect on a community or ecosystem relative to their abundance (Hoover 2013).

Centralized Ecosystem Component

Species, species groups, and/or community properties that control rates and directions of trophic ecosystem processes (productivity, respiration, waste production) were defined as centralized ecosystem components. This attribute also considers species which have multiple nodes or linkages in a food web. Some mid trophic-level ecosystem components exert top-down control on prey resources and bottom-up control on predators, and are described here as a "wasp waist" species (Rice 1995).

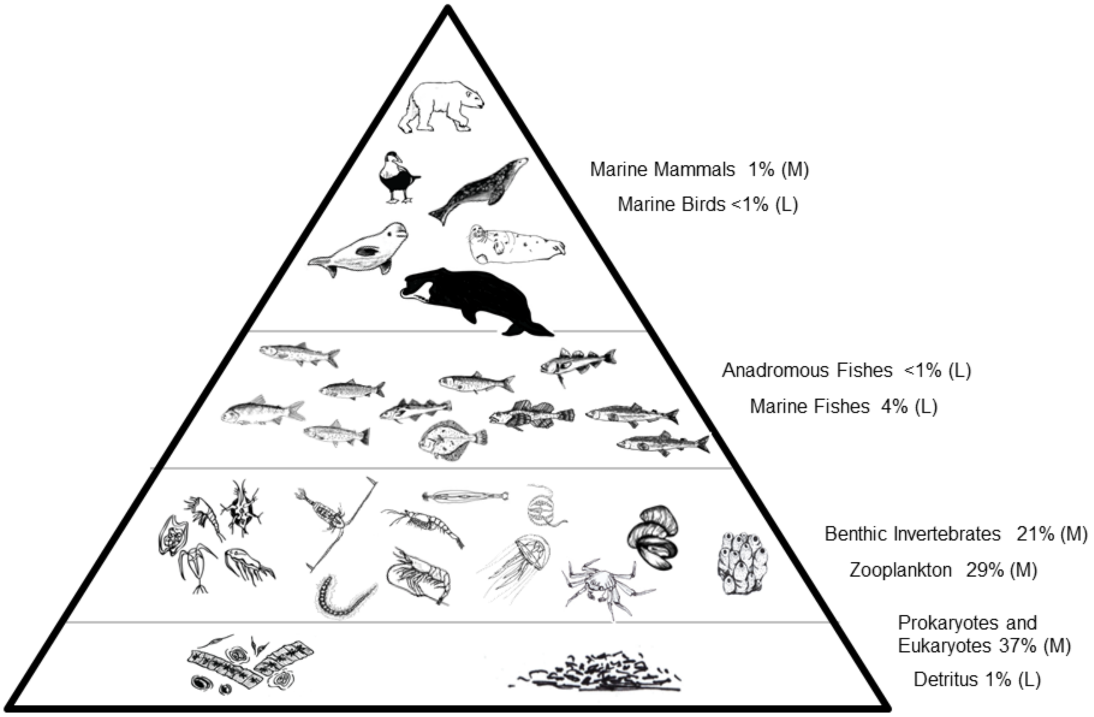

Figure 4. Percent biomass contribution for each trophic grouping assessed using EcoPath model for the Beaufort Shelf (C. Hoover, Fisheries and Oceans Canada, pers. comm.). Note the biomass values are approximations and do not total 100%. The degree of certainty for percent biomass model estimates are identified in parentheses (L or M) and are defined in Table 1. Macrophytes are included in the benthic invertebrates group.

Energy Transfer

Species that are considered under the energy transfer criterion fill an important role in the movement of energy within, or in and out of (import/export), the WAB region ecosystem. A number of categories were considered to describe various types of energy transfer that are important for ecosystem function:

Feeding Type (Active vs. Passive and Selective vs. Non-selective)

Degree of resource selectivity can influence how critical a prey item (or predator) is to the ecosystem function. If a predator actively selects only a single prey type, and that predator or prey were to be removed from the ecosystem, there would likely be a significant impact on the food chain overall. Therefore, feeding type can influence the likelihood of a predator or prey species being a candidate ESSCP.

Vertical Transfer of Energy and Material

In addition to physical oceanographic processes, species/species groups can play an important role in physically transferring large amounts of energy (and material) between vertical strata (e.g., water masses) through either active or passive vertical movements. This vertical movement can occur on a cyclical basis either daily (e.g., mysids diurnal movements between the seafloor and water column) or seasonally (e.g., *Calanus* spp. movement to deeper water for winter, and return to surface in spring). This can result in a significant movement of energy and material.

Active vertical feeding forays by fishes and marine mammals may also facilitate vertical energy transfers that are temporally and spatially variable. For instance, some benthic fish species actively move vertically into the water column to feed (e.g., Greenland Halibut; Jørgensen 1997), while deep dives have been observed in Beluga Whales in Viscount Melville Sound, likely to feed on benthic fishes (Richard et al. 2001).

Passive vertical movement of energy and material occurs when pelagic and sympagic organisms sink to deeper waters and/or to the seafloor (e.g., algae). The main contributors to the sinking export of organic material are primary producers (ice algae and phytoplankton cells) through direct sinking and indirect sinking of fecal pellets produced by herbivorous grazers. There is strong seasonality in these processes, linked to the timing of events (e.g., blooms) and food web interactions (e.g., Caron et al. 2004). The sinking of micro zooplankton by-products of respiration and eventual death plays a significant role in the vertical transfer of energy or material between the pelagic and benthic environments (Link et al. 2011).

Horizontal Transfer of Energy and Material

Most species remain in the WAB region year-round; however, some species move within the WAB region or leave it totally to overwinter in other ecosystems. Taxa that leave the WAB marine region include whales, some juvenile Ringed Seal (*Pusa hispida*), birds and anadromous fishes. The annual fall migration of species out of the WAB region can result in a significant export of energy and material (e.g., anadromous fishes that accumulated significant growth while feeding at sea), while the returning individuals in spring or summer results in an import of energy and material back into the WAB region. Depending upon the amount of feeding and growth rate that occurred in overwintering populations, this can lead to a net influx of energy and material to the WAB region.

Relative Importance to the Ecosystem

This attribute can be considered an integration of the other three energy transfer attributes and provides a relative ranking of overall energetic importance to the ecosystem. It best describes those species, species groups, and community properties that stand out above the rest of the ecosystem components in importance for the transfer of energy within the food web of the WAB region. It considers complexity of trophic interactions (e.g., predator/prey interactions, diversity of the community, importance of the interactions on the ecosystem as a whole) in specific habitats and ecosystem processes.

Since all species are of some ecological importance, ‘relative ecosystem importance’ was ranked as either High, Medium or Low. The highest score indicates that the species/species group plays a key central role in some energy transfer within the WAB region. In other words, if this species/species group were removed, there would be significant impacts to the ecosystem overall. Scoring for this component was by consensus based on expert opinion.

Other Considerations

Modifiers are not considered as stand-alone ESSCP criteria; however, they may be useful in ranking species based on the above criteria.

Functional Uniqueness

The term ‘uniqueness’ can have many interpretations depending on spatial scale of consideration. For example, it can apply to a species in the context of its presence/rarity in the circumpolar Arctic, the Canadian Arctic or the WAB region. The mere fact that a species is rare does not necessarily imply significance to the ecosystem. Of more relevance to the WAB region ecosystem is a species or species group's functional uniqueness. Species that fill an important and functionally unique role in the ecosystem, if lost, would not be easily replaced, and thus would likely impact the rest of the ecosystem. This can include species or species groups that inhabit a special place in the food web (e.g., relatively short trophic link) or occupy important by poorly populated habitats (e.g., water masses or sea ice).

Resistance

Resistance is the quality that leads species or species groups to withstand perturbations. It is the property of communities or populations to remain essentially unchanged when subject to disturbance. For example, a species might be able to tolerate high sediment load or loud marine noise. This species would be considered to have high resistance to these disturbances.

Resilience (*sensu* Holling 1973)

Resilience is the capacity of a species, species group or community property to recover quickly in response to a disturbance. Long-lived slow reproducing species generally are considered to have lower resilience than short-lived fast reproducing species. For example, some benthic communities consist of species that can recover quickly following ice scouring in near-shore habitats. This community is considered to be highly resilient. Species with more plasticity can be considered more resilient since they are likely to better adapt to a variable and changing environment than species with narrow tolerance and strict physiology or life history (Michel et al. 2012). For example, some copepod species show marked trophic plasticity, shifting from herbivory during the bloom to omnivory when preferred prey is less abundant. Predator fish species such as Arctic Cod also show high feeding plasticity, shifting predation patterns from fish to zooplankton in response to changes in the prey abundance. Such flexibility in feeding strategies may provide an advantage in highly variable environments (Tamelander et al. 2008).

Data Confidence

Managers are responsible to convey their decisions to stakeholders in a transparent fashion. When providing advice, scientists acknowledge that there are varying degrees of confidence in the information considered, because of insufficient sampling effort, high ecosystem or species population variability from year-to-year, and many other extraneous factors, which prevent a full understanding of the subject matter for which advice is being provided. To provide managers an indication of this confidence, a subjective ranking system for the level of confidence in data/information supporting the identification of the ESSCP was included in the current evaluation (Table 1).

For the purposes of the current analysis, only true marine species or species that spend significant time at sea for some part of their life history (e.g, feeding, reproduction, moulting etc.), including anadromous fishes, Polar Bear (*Ursus maritimus*), and marine birds, were considered. Waterfowl (e.g., shorebirds), reptiles, amphibians, and freshwater fishes were excluded. Where information on the ecological role of a species for the WAB region was missing, ecological information from other Arctic ecoregions was used and noted. For each of these major ecosystem components, the species, species group or community property was assessed against the criteria to identify ESSCP for the WAB region. When possible, additional information on the attributes was included to assist with the assessment.

Table 1. Certainty categories, their associated scoring and descriptions (modified from O et al. 2015).

Category	Description
Very High Certainty (VH)	Extensive peer-reviewed scientific information or data specific to the area including long-term relevant datasets.
High Certainty (H)	Substantial scientific information or recent data specific to the area. This includes both peer-reviewed and non-peer reviewed sources.
Moderate Certainty (M)	Moderate amount of scientific information mainly from non-peer-reviewed sources and first hand, unsystematic or opportunistic observations. This includes both scientific information and expert opinion. This may include older data from the area and may also include information not specific to the area.
Low Certainty (L)	Little scientific information but expert opinion relevant to the topic and area.
Very Low Certainty (VL)	Little or no scientific information. Expert opinion based on general knowledge.

RESULTS

MARINE VERTEBRATES

Marine Mammals

Nine species; eight truly marine mammals, plus the terrestrial Polar Bear (reproduces on land, but spends a large amount of time over marine waters and is consequently considered a marine mammal) have been recorded from the WAB region. Of these nine species, three have only been observed sporadically: Gray Whales (*Eschrichtius robustus*) have been observed during summer aerial surveys (Rugh and Fraker 1981) or from research vessel surveys (Iwahara et al. 2016), but is currently considered vagrant. Rare observations of Killer Whales (*Orcinus orca*) have been documented by Higdon et al. (2012). Walrus (*Odobenus rosmarus)* have been observed by community members on rare occasions (Harington 1966, Stirling 1974, R. Ruben, Paulatuk Hunters and Trappers Committee, pers. comm.) and are likely vagrants from the Alaskan Beaufort Sea. These rare occurrences may be a harbinger of future species distributions as sea ice conditions change, however, these species are not considered in the ESSCP evaluation since they are not established. Should conditions become more favorable for these species to frequent the WAB region in larger numbers, their status as ESSCP should be re-examined, as they would have the potential to play a significant role in the WAB region ecosystem, much as they do in other Arctic marine ecoregions.

Of the six marine mammals being considered under the ESSCP criteria, all species are abundant in the Eastern Beaufort Sea/Amundsen Gulf during summer. Beluga (*Delphinapterus leucas*) and Bowhead Whales (*Balaena mysticetus)* do not generally travel to the south-east beyond Dolphin and Union Strait. Historical records based on skeletal remains on perched beaches confirm that whales once used, but were rare in Coronation Gulf and Queen Maude Gulf and McClintock Channel, while they used to be more common in Parry Channel/Viscount Melville Sound (Heide-Jørgensen et al. 2012). Tagged individuals of Beluga, Bowhead Whale, and Ringed Seals have been tracked west and north of Banks Island as far east as Viscount Melville Sound. Narwhal (*Monodon monoceros*) are restricted to the very northeast area of the WAB region.

Polar Bear (*Ursus maritimus*)

Polar bears have a circumpolar distribution and are endemic to the Arctic. With a global population estimate of 20,000–25,000 individuals, approximately 2/3 of the world's polar bears are contained within (or shared with) the Canadian Arctic (approximately 15,500) (COSEWIC 2008). There are five sub-populations within the Canadian WAB region (Figure 5): the southern Beaufort Sea (population size of ~ 907), northern Beaufort Sea (~ 1200), McClintock Channel (~ 284), Viscount Melville Sound (~ 161), and a small area of the Lancaster Sound sub-population (~ 2541) (Taylor et al. 2001, COSEWIC 2008, Bromaghin et al. 2015). Individuals are known to travel between these sub-populations (Amstrup et al. 2004). In Canada, the Polar Bear is not managed as a marine mammal under Canada's *Fisheries Act*.

The Polar Bear is an iconic apex predator in the Arctic, occupying the top of the food chain and may therefore be useful in monitoring shifts in ecosystem function at lower trophic levels. Year-round inhabitants of the WAB region, they are intimately associated with the sea ice environment, using it as a platform for movement, mating, maternal denning in some areas, and to gain access to their primary prey, Ringed Seal (*Pusa hispida*) and Bearded Seal (*Erignathus barbatus*) (Stirling and Archibald 1977, Regehr et al. 2010). Sub-populations are typically dispersed across wide geographic ranges at low densities.

Sea-ice conditions and bathymetry are the primary determinants of Polar Bear habitat quality (Durner et al. 2009). Changes in sea ice coupled with snow cover affect primary production at lower trophic levels of the Arctic marine ecosystem (Welch et al. 1992, Barber et al. 1995). Sea ice productivity and physical characteristics in turn influence the distribution and productivity of Ringed Seal populations (Kingsley et al. 1985, Stirling 2002, Stirling and Lunn 1997, Barber and Iacozza 2004). In the Canadian Arctic, Polar Bear habitat is closely associated with that of the Ringed Seal (Stirling and Øritsland 1995). Prime Polar Bear habitat occur in areas of sea ice over the continental shelf that contain pressure ridges, cracks, polynyas and consistent flaw leads between pack and landfast sea ice (Stirling et al. 1982, Kingsley et al. 1985, Stirling and Derocher 1993, Stirling et al. 1993, Ferguson et al. 2000, Durner et al. 2009).

Polar Bear, being selective and active predators, prey mainly on Ringed Seal and Bearded Seal, with the blubber layer being preferentially consumed (Stirling and Archibald 1977, Bluhm and Gradinger 2008). Stirling and Øritsland (1995) reported a strong positive correlation between Polar Bear and Ringed Seal population densities across the Canadian Arctic. The relationship between Polar Bear and Ringed Seal population dynamics is further supported by previously documented synchronicity in natality of the two species in the WAB region by Stirling (2002). Depending upon the portion of the WAB region surveyed, Polar Bear consumed between 14.5–27.5% of the Ringed Seal population annually (Stirling and Øritsland 1995). Stirling and McEwan (1975) reported that 80% of Ringed Seal consumed in a season were < 2 years old; while Pilfold et al. (2012) reported that adults may comprise up to 44% of Ringed Seal kills in the WAB region. Polar Bear rarely feed on Beluga Whale and Bowhead Whale (Smith 1985), although with changing sea-ice conditions, it is suggested that feeding on Bowhead Whale carcasses along the shoreline could become an important alternative food source for the Beaufort Sea Polar Bear with reductions in sea-ice availability (Bentzen et al. 2007). Sea-ice mediated changes in Ringed Seal availability in the WAB region have been linked to reductions in Polar Bear growth (Rode et al. 2010) and survival (Regehr et al. 2010) as well as increased fasting rates (Cherry et al. 2009), providing evidence of the sensitivity of Polar Bear as an indicator species.

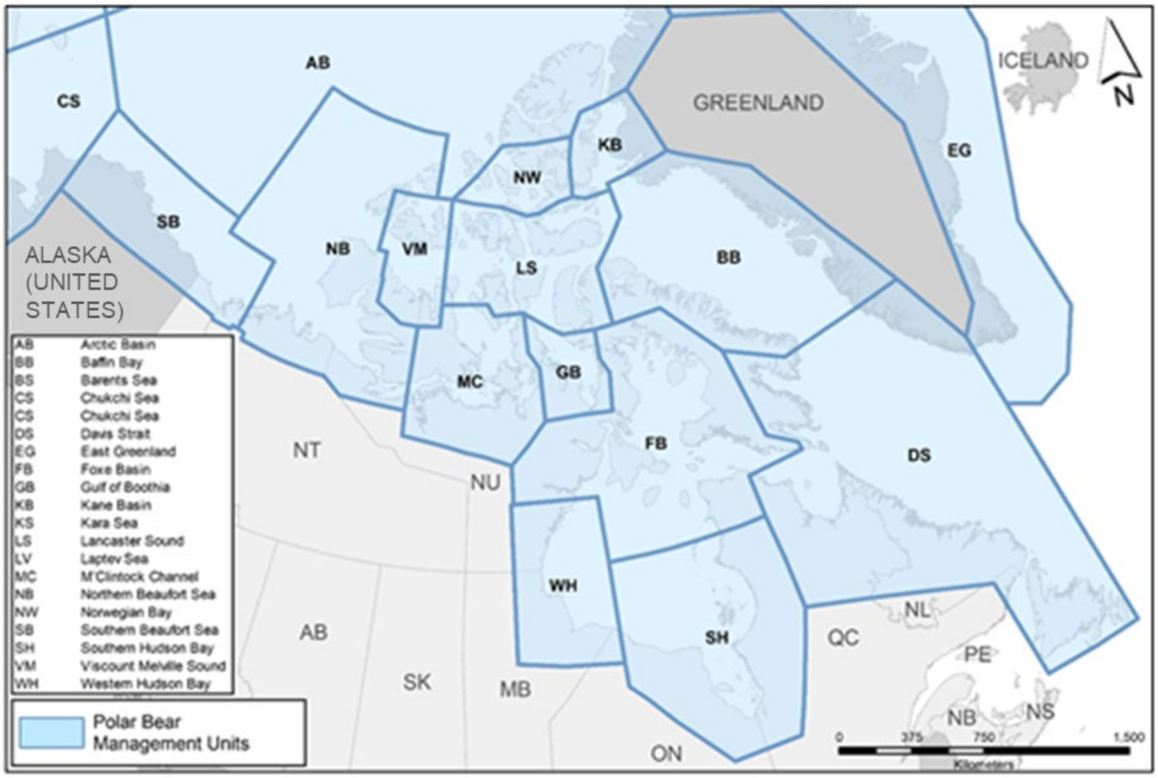

Figure 5. Canadian Polar Bear sub-populations, showing the five Western Arctic Biogeographic region sub-populations: Southern Beaufort Sea (SB), Northern Beaufort Sea (NB), Viscount Melville Sound (VM), Lancaster Sound (LS), and McClintock Channel (MC). (Environment and Climate Change Canada 2014).

Polar Bear are apex predators in the Arctic marine ecosystem. They have been shown to consume a relatively large portion of adult Ringed Seal annually, and as such, and in combination with other environmental factors related to sea ice, they exert a controlling influence on Ringed Seal populations. Both Polar Bear and Ringed Seal are ice obligate species (Laidre et al. 2008) and are likely to be impacted by diminishing sea ice in the WAB region (Regher et al. 2010, Harwood et al. 2012a). As long lived k-selected species, Polar Bear are sensitive to overharvesting, they are thought to have low resistance and resilience, and are considered a species of Special Concern by COSEWIC (2008) and under threat (Huntington 2009, Regehr et al. 2016). As an apex predator, they are considered an excellent indicator of ecosystem change in the Arctic (Lunn et al. 2010) and therefore may reflect shifts in trophic dynamics and prey populations. Hoover (2013) assigned a moderate to high Keystone value (impacting the food web disproportionately to their abundance or biomass) for Polar Bear in the Canadian Beaufort Shelf.

Bowhead Whale (*Balaena mysticetus*)

The Western Arctic Bowhead Whale population, referred to as the Bering-Chukchi-Beaufort (BCB) population, was depleted by commercial whaling between 1840 and 1907. The historic population for Bowhead is estimated between 10,400 and 23,000 and was reduced to approximately 3,000 individuals (COSEWIC 2009). As of 2001, the population was estimated to be between 8,100 and 13,500 individuals (COSEWIC 2009), increasing at a rate of 3.4% per year between 1978 and 2001 (George et al. 2004).

The BCB population overwinters (November to April) in the western and central Bering Sea amongst broken pack ice. In spring (April through June), individuals migrate north and east along the northern coast of Alaska to the eastern Beaufort Sea (Figure 6), initially appearing in western Amundsen Gulf in offshore lead areas (> 200 m) as break-up is occurring. During July Bowhead Whale are widely distributed throughout the offshore Canadian Beaufort Sea, alone or in small (2–3 surfaced animals) groups (Davis et al. 1982, Harwood and Borstad 1985). By mid-August, oceanographic conditions favour the concentration of the Bowhead Whale’s planktonic prey items (Thomson et al. 1986), and the individuals aggregate to feed in specific, recurrent areas on the summer range (Harwood and Smith 2002, Richardson et al. 1987). Their summer (June to September) distribution is centered in the southeastern Beaufort Sea, along the southern and western coasts of Banks Island, in Amundsen Gulf, and along the waters offshore of the Tuktoyaktuk Peninsula approximately 20–50 m in depth, Yukon coastal waters, the shelf break, and the Mackenzie and Kugmallit Canyon areas.

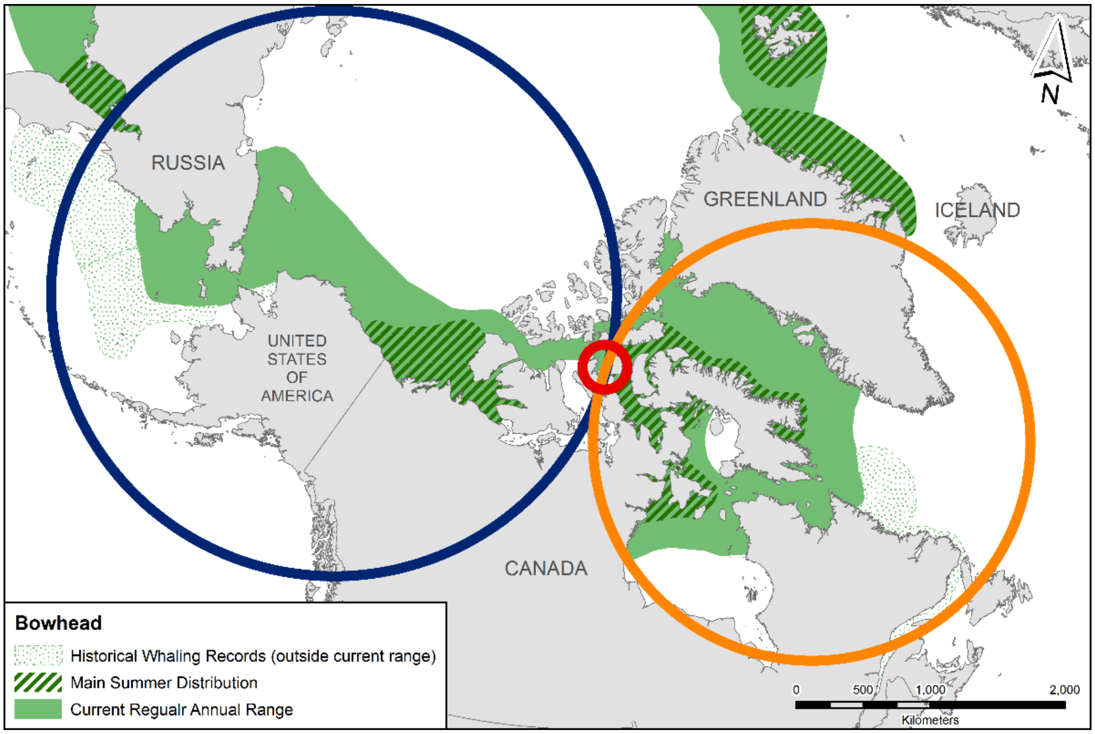

Figure 6. Distribution of Bowhead Whale, showing range and summer concentration areas in the Canadian Arctic. (dark blue circle represents the Bering-Chukchi-Beaufort population; orange circle represents the Eastern Canada-West Greenland population; red circle shows where tagged individuals from the two populations have recently overlapped in summer; dark hashed areas are the normal summer concentration areas (modified from Reeves et al. 2014).

Recent satellite tracking indicates that Bowhead Whale also occur around northwestern Banks Island and into Viscount Melville Sound (Heide-Jørgensen et al. 2012). During that same time, Heide-Jørgensen et al. (2012) reported that a whale tagged in Greenland (part of the Eastern Canada-West Greenland population) travelled to the same region of Viscount Melville Sound, suggesting that, depending upon the extent of ice in the Canadian Archipelago, the two populations can intermingle (Reeves et al. 2014). In the fall (September and October), Bowhead Whale migrate west from the Canadian Beaufort Sea into the Alaskan Beaufort Sea and the Chukchi Sea, and then back into the Bering Sea.

The Bowhead Whale is a culturally important species being used for food by Indigenous people. A limited and well-managed subsistence hunt has recently been revived in the Western Arctic (Harwood and Smith 2002). The Inuit's Bowhead hunt is an important event, with the whale 'muktuk' distributed/consumed among the community.

Bowhead Whale are the largest zooplankton predator in the Arctic (Laidre et al. 2007). Individuals that summer in the Canadian Beaufort Sea portion of the WAB region have been shown to exhibit high inter-annual site fidelity (Walkusz et al. 2012, Harwood et al. 2010). The annual movement of Bowhead Whale has been described by Citta et al. (2015). They aggregate in Cape Bathurst polynya in spring; their arrival is timed with the arrival of ascending zooplankton from depth into the euphotic zone. Once the zooplankton begin their annual descent in late July, the Bowhead Whale move to the Tuktoyaktuk Penninsula (including Cape Bathurst), where topographically enhanced shelf-break upwellings supply nutrients and lipid rich zooplankton from deep ocean waters (Williams and Carmack 2008, Walkusz et al. 2012, Citta et al. 2015). Bowhead Whale eventually depart the Canadian Beaufort Sea, once copepods descend to depths too deep for whales to access. A similar reliance by whales on zooplankton has been described at Disko Bay (Greenland) by Laidre et al. (2007), where it is estimated that *Calanus* spp. contributed 78% of the total biomass of Bowhead Whale diet with the population of Bowhead Whale consuming 220 T/day of zooplankton. Whales feeding at the upwelling sites are likely targeting pre-ascension stage copepods in high density patches. These sites are so important that it was estimated that during an upwelling event at Cape Bathurst in 2008, 1/3 of the total summer Beaufort Sea Bowhead Whale population was aggregated at this site feeding on the highly energetic and lipid rich *Calanus* spp. (Walkusz et al. 2012).

Five other aggregation areas have been identified as regular locations for Bowhead Whale late summer aggregations, including: offshore of Komakuk Beach, the Yukon coast, offshore of the Mackenzie Estuary, and Mackenzie and Kugmallit Canyon areas (Harwood and Smith 2002), all with some upwelling feature due to topography and oceanography. It is uncertain to what extent the two tagged Bowhead Whales that travelled to the north of Banks Island in 2006 and Viscount Melville Sound in 2010 were feeding, and whether they sought out specific food aggregating upwelling locals, but since tagged Beluga Whale also travel to this region of the WAB region, it will be of importance to continue to track the use of this area and its productivity.

BCB Bowhead is a top predator in the WAB region and is at the apex of one of the shortest marine food chains. Summer feeding aggregations at topographically enhanced shelf break upwelling sites allow this species to feed with maximum efficiency and minimum effort filtering sea water. This constitutes a major transfer of energy from zooplankton directly to a high food web level.

Recent research indicates that the Great Whale (Baleen Whale and Toothed Whale), with high metabolic demands likely played a historical role as ecosystem engineers with large populations prior to industrial whaling (e.g., consumers of fish and invertebrates; prey to large-bodied predators; reservoirs and vectors for nutrients; detrital sources of energy) (Roman et al. 2014). Population abundance for the BCB bowhead population appears to be increasing (COSEWIC 2009). Due to their slow growth and late maturity, Bowhead Whale have low resistance and low resilience to overharvesting or any large scale human perturbation.

Beluga Whale (*Delphinapterus leucas*)

The Eastern Beaufort Sea population is one of six Canadian populations of Beluga Whale (COSEWIC 2004). Within the WAB region, no tagged Beluga have ventured east of Dolphin and Union Strait or east of Stefansson Island (Viscount Melville Sound). The majority of the Eastern Beaufort Sea population (~ 39,258) (DFO 2000) uses a large area of the Canadian Beaufort Sea during the summer (Figure 7).

Eastern Beaufort Sea Beluga winter in the Bering Sea and migrate east through leads in the thick pack-ice to the Canadian Beaufort Sea in early spring. The Inuvialuit report first sighting of Beluga seasonally in the open-water ice shear zone off the west coast of Banks Island. Subsequently, Beluga concentrate at the seaward edge of a narrow bridge of land-fast ice that spans the waters offshore of the Mackenzie Estuary (DFO 2014b). Throughout the month of July, Beluga aggregate in the warm, shallow estuarine waters of the Mackenzie River (Harwood et al. 1996, Harwood et al. 2014, DFO 2014b). After spending time in the estuary, Beluga disperse into the adjacent offshore waters, including Viscount Melville Sound and east into Amundsen Gulf (Fraker et al. 1979, Harwood et al. 1996, Richard et al. 2001). The westward fall migration begins in late August to early September back to the Bering Sea (Byers and Roberts 1995, Richard et al. 2001).

Figure 7. Map showing the global distribution of Beluga Whale. The Eastern Beaufort Sea population (blue circle) summers in the Canadian Beaufort Sea (dark hashed shading) and winters in the Bering/Chukchi Seas (plain shading). (modified from Reeves et al. 2014).

Beluga Whale are considered dietary generalists over their range (Yurkowski et al. 2016). In the Bering and Chukchi seas, Beluga consumes Arctic Cod, Saffron Cod (*Eleginus gracilis*), Sculpin (Cottidae), Pacific Herring (*Clupea pallasii*), Rainbow Smelt (*Osmerus mordax*), Capelin (*Mallotus villosus*), Arctic Char (*Salvelinus alpinus*), octopus, and shrimp (Lowry et al. 1986). However, the Beaufort Sea Beluga primarily feed on the highly abundant Arctic Cod (Loseto et al. 2009). Habitat segregation by sex and size shows differences between inshore and offshore Beluga feeding on Arctic Cod populations (Loseto et al. 2009, Hauser et al. 2017). Other fish species, such as Arctic Cisco (*Coregonus autumnalis*) (Orr and Harwood 1998), Pacific Herring, and Least Cisco (*C. sardinella*) have been reported in Beluga stomachs of individuals sampled as part of the Inuvialuit Beluga harvest (Byers and Roberts 1995), suggesting a more generalist/opportunistic diet. Possible ecosystem changes (and dietary shifts away from Arctic Cod) somewhere within the annual range of Beluga is occurring, as evidenced by a subtle but sustained decline in growth rate of adult Beluga sampled immediately upon return to the Eastern Beaufort Sea in the spring (Harwood et al. 2015). It was estimated that in the Alaskan portion of the Beaufort Sea, Beluga consumed 5,875 T of Arctic Cod/year (Lowry and Frost 1984). Welch et al. (1993) estimated a maintenance ration for an 880 kg Beluga at 22 kg of cod daily. Based on this, a pod of 500 Beluga would consume 11 T of Arctic Cod/day.

Beluga Whale are top food web carnivores. They are active non-selective predators consuming large quantities of pelagic fish (mainly Arctic Cod) and, together with Ringed Seals, are likely major regulators of Arctic Cod abundance. They undergo large seasonal feeding movements within the WAB region. During the summer, males and large females travel between the Mackenzie River estuary and the Viscount Melville Sound, and into the ice pack off western Banks Island, where they conduct deep dives likely to feed on benthic fishes, and as such are exporters/importers of nutrients within the WAB region. Belugas are slow growing, long-lived, and therefore sensitive to overharvesting or other anthropogenic perturbations that would impact their populations. An Ecopath model for the Beaufort Sea assigned a high keystone score for Beluga (Hoover 2013).

Narwhal (*Monodon monoceros*)

Narwhal (*Monodon monoceros*) are primarily an eastern Canadian Arctic species, but have been observed in the extreme northeastern corner of the WAB region (Richard 2010). Narwhal in this area are part of the High Arctic Narwhal population. More recently, pods of Narwhal have been reported in consecutive summers in Dolphin and Union Strait, near the community of Cambridge Bay (Reeves et al. 2014). Narwhal are predators, feeding primarily on Greenland Halibut, shrimp, squid, octopus but Arctic Cod have also been found in stomach contents (Richard 2009, Watt et al. 2013). Tagged Narwhal have been tracked diving to depths of 1,500 m, which coincides with known depth range of Greenland Halibut (Watt and Ferguson 2015).

Narwhal occur in very low numbers in the WAB region and likely do not play an important role in regulating other trophic levels, particularly at the bioregional scale. Limited data are available for the WAB region. However, it is recognized that they undertake feeding movements within the WAB region during summer (Figure 8) and as such contribute to the transfer of energy (vertical and horizontal). Seasonal movements into and from the WAB region also contribute to the transfer of energy (net import/export).

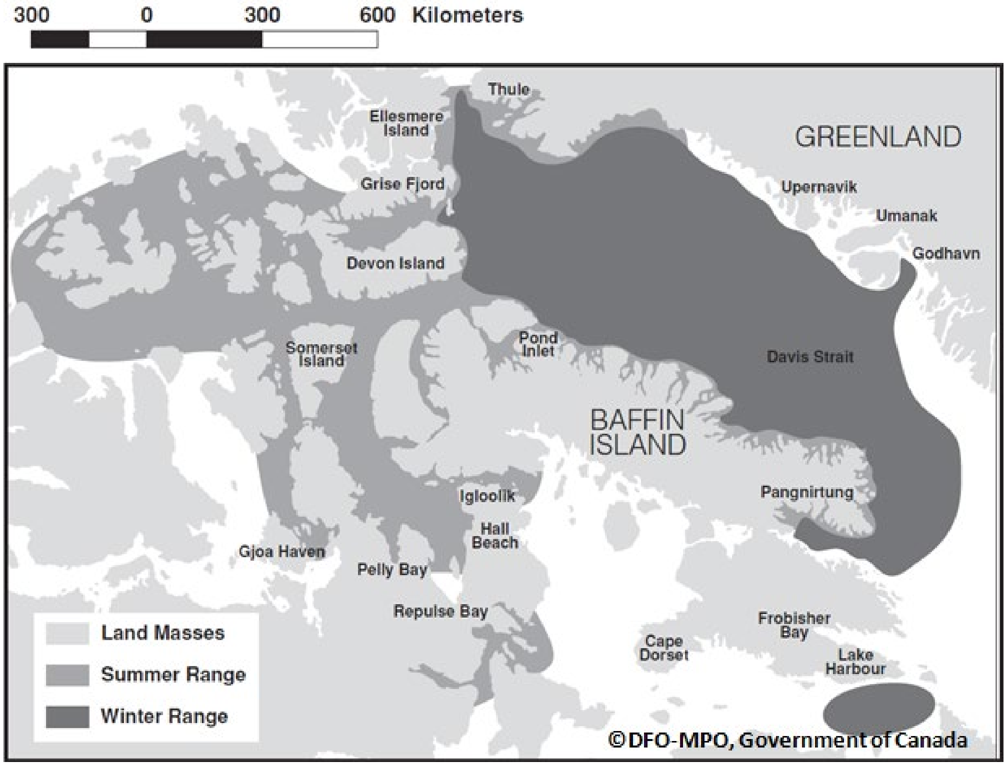

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Figure 8. Seasonal range distributions of the Narwhal in Canada.

Bearded Seal (*Erignathus barbatus*)

Bearded Seals, the largest northern phocid seal, occur throughout the WAB region (Figure 9), but naturally occur at quite low densities (Bengtson et al. 2005). They are typically solitary animals, but will form small, loose aggregations when ice availability is limited, such as at the time of moulting in midsummer. The availability of sea ice is a major habitat determinant for Bearded Seal. They are typically found in regions of broken free-floating pack ice; in these areas, Bearded Seal prefer to use small and medium sized floes, avoiding large floes (Simpkins et al. 2003). They rarely haul out more than a body length from water and use leads within shore-fast ice only if suitable pack ice is not available (Kovacs 2002).

Figure 9. Distribution range of Bearded Seal (The Canadian Biodiversity Website; Accessed March 2, 2016).

Bearded Seal are mainly benthic feeders, usually feeding at depths of less than 100 m, but extreme dives to depths of 500 m have been recorded for young-of-the-year (Gjertz et al. 2000). Bearded Seal use their elaborate whiskers to search for prey on and within soft bottom substrates (Marshall et al. 2008). In addition to surface feeding on substrates, infauna, and schooling and demersal fishes can form part of their diet (Burns 1981, Hjelset et al. 1999, Dehn et al. 2007). Crustaceans, bivalves, and octopus are important prey items in both the northern and southern Bering Sea and the Chukchi Sea. The diet is similar in the Beaufort Sea with the addition of Arctic Cod (Burns 1981). In contrast, Bearded Seal diet in the eastern Canadian Arctic is less dependent upon benthic prey; in the summer Bearded Seal consumed a minimum of 12 fish species, dominated by Sculpins and Arctic Cod, with fish prey accounting for greater than 90% of the wet weight of the stomach contents (Finley and Evans 1983).

Bearded Seal are ice-associated (typically found in regions of broken, free-floating pack ice, preferring to use smaller sized floes) and depend on sea ice for pupping. They are predominantly benthivores, thus, contributing to a vertical transfer of energy, and constitute an alternate prey source to Ringed Seal for Polar Bear. They undertake limited seasonal movement within the WAB region, determined primarily by suitability of ice conditions and access to food.

Ringed Seal (*Pusa hispida*)

Ringed Seal is the most abundant marine mammal species in the circumpolar Arctic and it is widespread throughout the WAB region (Figure 10). Ringed Seals are highly adapted to their variable polar environment, and they periodically undergo changes in abundance and distribution, apparently in response to changing sea ice conditions and marine productivity resulting from those changes in sea ice (Stirling et al. 1982, Smith 1987, Kingsley and Byers 1998, Harwood et al. 2000).

Figure 10. Distribution of Ringed Seal (The Canadian Biodiversity Website; Accessed March 2, 2016).

Ringed Seal in the WAB region appear to segregate into adult breeding populations occupying core stable fast ice areas such as Prince Albert Sound and Minto Inlet on western Victoria Island in the Beaufort Sea (Smith 1987). Bathurst Inlet and the area between Royal Geographical Society Island and King William Island of the Kitikmeot Region also support adult breeding populations (Nunami Stantec 2011). These two regions along with areas to the southeast in Queen Maud Gulf have been described by Inuit as important summer Ringed Seal concentration areas (Nunami Stantec 2011).

While adult Ringed Seals overwinter in the Beaufort Sea, tagged immature animals in the Beaufort Sea undertook large migrations to overwintering areas in the Chukchi Sea or beyond to the Bering Sea (Harwood et al. 2012b). New evidence strongly suggests that adult breeding

Ringed Seal are philopatric (Smith 1987, Kelly et al. 2010). After extensive summer and fall feeding, adults return to their winter breeding sites just before freeze-up to establish territories.

Throughout their entire geographic range, Ringed Seal consume a wide variety of prey items (Yurkowski et al. 2016). However, their diet is less diverse in the Canadian High Arctic (including the WAB region) than at lower latitudes (Hudson Bay). Ringed Seals selectively feed on energy-rich Arctic Cod (which Weslawski et al. (1994) calculated at 24.2 kJ/g dry weight) throughout the Western Arctic at all times of the year (Lowry et al. 1980, Bradstreet et al. 1986, Crawford and Jorgenson 1996, Bluhm and Gradinger 2008). There is evidence that marine invertebrates (Mysids and Euphausids) are an important supplemental diet item in summer and autumn for Ringed Seal of all age classes, although particularly for sub-adults, which have less experience capturing fish (Lowry et al. 1980, Smith 1987, Smith and Harwood 2001). Arctic Cod become more prevalent in the diet with increasing age of Ringed Seal (Dehn et al. 2007).

Ringed Seal may be one of several vertebrate species pointing to ecosystem shifts in the Beaufort Sea. A sustained temporal decline in spring body condition over 20 years of sampling suggests a shift in quality/quantity and or availability of prey (mainly Arctic Cod) during the preceding winter and spring (Harwood et al. 2015).

Ringed Seal are a centralized ecosystem component in the Arctic food web, and given their broad diet and importance to the diet of Polar Bears, they occupy a ‘wasp-waist’ position in the food-web. They provide a direct link between their main predator, the Polar Bear, and their main prey, the energy rich Arctic Cod. Polar Bears are so dependent on Ringed Seal, that fluctuations in Polar Bear body condition and reproductive output in the WAB region have been linked to temporary declines in Ringed Seal productivity in years with major changes in sea ice and the marine environmental conditions (Stirling et al. 2008, Harwood et al. 2015). In the Alaskan Beaufort Sea, Ringed Seal are estimated to eat 21,203 T/year of Arctic Cod (Lowry and Frost 1984), and along with Beluga, likely constitute the major regulator of Arctic Cod populations. Ringed Seal conduct seasonal movements within the WAB region and as such import and/or export nutrients between habitats.

Marine Birds

Millions of birds arrive in the Canadian Arctic each year to breed, nest, rear young, and feed. During the spring migration, birds stop along their route in open water areas to rest and forage before arriving at the colony. A number of key marine and terrestrial areas, including the location of colonies have been identified in the Canadian Arctic (Mallory and Fontaine 2004, Latour et al. 2006, Gaston et al. 2012). Some colonies hold a significant proportion of the Canadian population in one location at any given time (Mallory and Fontaine 2004). Many of these key areas have been identified within the Arctic EBSA evaluation processes (DFO 2011a, 2014b) and represent areas that are important habitat for a number of species, including unique species. However, marine birds also play an important role in ecosystem structure and function based on their trophic role, particularly those species that rely on the marine environment (benthic and pelagic) for foraging.

The WAB region has a different community of marine birds compared to the eastern Arctic, with no large colonies of fish-eating cliff-nesting birds (e.g., kittiwakes and murres), but rather the WAB hosts large numbers of ground-nesting species that forage on nearshore benthic communities (Appendix 1). Arriving from wintering grounds in the Bering Sea, hundreds of thousands of Common Eider (*Somateria mollissima*), King Eider (*Somateria spectabilis*), and Long-tailed Duck (*Clangula hyemalis*), migrate each spring to open water areas off Cape Bathurst, western Banks Island and Lambert Channel (Dickson and Gilchrist 2002, Dickson 2012a, 2012b). Some of these migrate further into the central Arctic, however, most remain in the WAB region throughout the open water season. After breeding, these sea ducks return to marine areas to moult and prepare for fall migration, using similar areas as those used on spring-migration; notably western Banks Island, Prince Albert Sound, Bathurst Inlet, Dolphin and Union Strait, Cape Parry and Cape Bathurst (Dickson 2012a, 2012b). Additionally, thousands of birds of other species (e.g., scoters, gulls, and terns) make overland migrations to arrive at various sites throughout the WAB region to nest and moult.

Polynya and lead habitats are important to Glaucous Gull (*Larus hyperboreus)* during spring migration. They are common in the open-water leads throughout the Beaufort Sea, peaking in number in the last week of May (Alexander et al. 1997). They are known to concentrate along the margins of sea ice in the Arctic before returning to breeding sites (Gilchrist 2001), which suggests that the entire local breeding population of Glaucous Gull is present offshore in the Beaufort Sea for a period in spring.

A list of bird species for the WAB region was populated based on existing lists compiled by Cobb et al. (2008) and Ganter and Gaston (2013). Sandpipers, plovers, geese, swans, and other land birds were not considered further because the focus is on those species that were feeding predominantly in the marine environment. In the WAB region, Dickson and Gilchrist (2002) have identified the most abundant species using spring leads as the Common Eider, King Eider, Long-tailed Duck, Glaucous Gull , Red-throated Loon (*Gavia stellata*), Yellow-billed Loon (*Gavia adamsii*), and Pacific Loon (*Gavia pacifica*). These species are also present in the WAB region after leaving terrestrial breeding areas, to moult and/or prepare for fall migration (North 1994, Barr et al. 2000, Russell 2002, Dickson 2012a, 2012b).

Marine birds were considered as ESSCP because thousands migrate to the WAB region each spring and spend time feeding on soft-bottom invertebrates and fishes in the coastal marine environment. They are particularly associated with highly productive shallow areas, including leads and polynyas in the springtime. Specifically, sea ducks (eiders), loons and gulls use the WAB region for staging, moulting, and for some species (e.g., Common Eider), breeding. Thick-billed Murre (*Uria lomvia*), Black Guillemot (*Cepphus grylle*), and Black-legged Kittiwake (*Rissa tridactyla*) were not included in the assessment because they do not occur in significant numbers within the WAB region. Sea ducks may alter nearshore benthic community structure by heavy grazing. The abundance of eiders may change the benthos in certain areas of WAB region (e.g., parts of Western Banks Island, Cape Bathurst, Lambert Channel; Derksen et al. 2015).

Fishes

Freshwater fishes (25 species) make only rare appearances in coastal areas, and will therefore not be assessed as an ESSCP. Anadromous fishes (10 species) spend at least some of the summer migrating through or feeding within low salinity (0-20 ppt) in coastal waters (Coad and Reist 2004). The diversity of marine fishes within the WAB region has not been fully assessed. To date, ~ 62 species, representing 16 families have been reported from the Canadian Beaufort Sea and Amundsen Gulf (Fortier et al. 2015, Majewski et al. 2017). Limited data on distribution, diversity, and the ecological function of individual species exists for fishes throughout the WAB region. Given the high diversity of fishes relative to higher trophic level species, fish will be assessed as ESSCP based on ecological groupings within both anadromous and marine forms. In general, these groupings are based on species that exhibit similar feeding strategies and/or occupy similar habitats and are therefore presumed to fulfill comparable ecological roles.

Anadromous fishes

Of the approximately 10 anadromous fish species in the WAB region, 7 species, representing the families Salmonidae (6 species) and Osmeridae (1 species), numerically dominate coastal waters during the brief summer period (Bond and Erickson 1989, Bond and Erickson 1993). Based on their salinity tolerances, anadromous fishes can be divided into two groups. The first group consists of pelagic feeding species that occur mainly from shore to 5 m depth, but can venture beyond 5 m water depth when conditions are favourable (e.g., up to 20 m water depths). The second group consists of species that are nearshore and restricted from 0-5 m depth. This non-mobile group generally occurs in estuaries where warm, relatively freshened waters are found.

Nearshore Pelagic Anadromous Fishes (0–5 m+ depth)

Arctic Char (*Salvelinus alpinus*), Dolly Varden Char (*S. malma*), Arctic Cisco (*Coregonus autumnalis*), and Rainbow Smelt (*Osmerus mordax dentex*)

Chars west of the Mackenzie River were originally considered to be a distinct form (West Arctic Bering Sea) of Arctic Char (*Salvelinus alpinus*) (DFO 2001). Re-evaluation of the taxonomic identify with genetic and morphological criteria confirmed that char found in high gradient rivers west of the Mackenzie River are Dolly Varden (*S. malma*) (Reist et al. 1997). Arctic Char typically occur in mainland river systems of the WAB region east of the Mackenzie River and in major rivers of Banks and Victoria islands. Chars form an important subsistence fishery for all communities in the WAB region, and a commercial fishery is based out of Ulukhaktok, Northwest Territories, and Cambridge Bay, Nunavut. Anadromous forms of both Char species spend several months during the summer feeding in estuarine and coastal waters of the WAB region. Depending upon local conditions, Chars utilize a fairly extensive portion of low salinity coastal waters for summer feeding (Bond and Erickson 1989, Paulic et al. 2011).

Arctic Char can be anadromous, moving downstream to the sea in spring and returning in the fall or remain permanently in freshwater (i.e., resident). Spawning takes place over gravel beds in fresh water in September or October. Females typically spawn every two to three years (DFO 2014d). In most river systems, anadromous Arctic Char first migrate to sea when they are four to five years of age and reach a size of 150 to 250 mm. Once at sea, Arctic Char feed on invertebrates and fish, and it is during this time that they have the greatest annual growth rate. In the fall, Arctic Char return to freshwater to overwinter and escape from freezing in the sea (DFO 2014d). Most watersheds that support Arctic Char populations have lakes, which provide for overwintering and spawning habitat.

Arctic Char have a diverse diet: Amphipoda, other crustaceans, and fish (total of 30 species) have been collected from Arctic Char stomach contents in Frobisher Bay (Grainger 1953), while Spares et al. (2012) reported 22 taxa in Arctic Char stomachs. The importance of feeding in the productive marine environment during the two month summer period has been demonstrated in the Kuujjua River Arctic Char study (Harwood et al. 2013). Harwood et al. (2013) suggested that the early onset of marine productivity in years of early ice-off resulted in higher quality and more available food for sea-run individuals, resulting in higher body condition. A stomach content analysis of Arctic Char (n = 220) in summer of 1977-78 found that Arctic Cod contributed 91% by weight and occurred in all stomachs. Other taxa found in stomachs included Mysids and Amphipods (Harwood et al. 2015). More recent observations by fishers provide evidence that a dietary shift in Arctic Char may be occurring. More stomachs in the Kuujjua River stock contained Sandlance (*Ammodytes* spp.) (Harwood et al. 2015), while in Darnley Bay, 300 km south of Kuujjua River, Arctic Char of the Hornaday River were feeding heavily on Capelin (Harwood and Babaluk 2014).

Based on observations of stomach contents and feeding behaviour in Ulukhaktok and Paulatuk, respectively, Arctic Char appear to be preyed upon opportunistically by Beluga (Loseto et al. 2017). Although highly prized for commercial or subsistence purposes by communities throughout the WAB region, Arctic Char do not appear to otherwise play a dominant role as a forage species in the ecosystem.

The distribution of Dolly Varden in fresh water in the northwestern Canadian Arctic is restricted to high gradient rivers, which provide habitat for spawning, overwintering, and rearing. Dolly Varden are present as anadromous (i.e., sea-run) fish in coastal waters of the Beaufort Sea for about two months during the summer and early autumn. Offshore distribution is poorly known mostly due to low sampling effort; however, present understanding suggests that Dolly Varden primarily occur in nearshore waters within the 0-5 m, but have been recorded out to the 10 m isobath. In the Alaskan Beaufort Sea, tagged Dolly Varden migrated long distances to areas in Russia (DeCicco 1992).

Dolly Varden populations are found year round in association with rivers in the WAB region which have perennial groundwater inputs that provide spawning and overwintering habitat (Stewart et al. 2009). Anadromous individuals use groundwater-fed habitat seasonally for reproduction and overwintering depending upon life stage, whereas all stages of pre-smolt fish and also residual life history types remain in such areas year round.

Dolly Varden are considered as Special Concern by COSEWIC (2010); with their main threats being overharvesting (there are integrated fishery management plans in place to prevent overharvesting), climate change, and development activities that could affect habitat and flow regimes within their natal streams.

Dolly Varden are mainly piscivores, feeding on small forage fishes such as Rainbow Smelt (*Osmerus mordax*), Four-horned Sculpin (*Myoxocephalus quadricornis*), Arctic Cod and Least Cisco (*Coregonus sardinella*) (Bond and Erickson 1989, Stewart et al. 2009); however marine invertebrates (e.g., Amphipoda) also form a significant portion of their diet during their time at sea (Bond and Erickson1989).

Dolly Varden are preyed upon by Beluga in Alaska (Seaman et al. 1982), and presumably along the Yukon North Slope where they travel close to shore. Based on observations of seal scars on returning Dolly Varden (4% reported by Sparling and Stewart [1986]; 6% reported by Sandstrom et al. [1997]), Ringed seals appear to feed on these fish along the Yukon North Slope (COSEWIC 2010).

In the WAB region, Arctic Cisco occurs along the coastal mainland east to Bathurst Inlet (Scott and Crossman 1973). Major summer feeding and rearing areas for Arctic Cisco are located in the many bays and lagoons along the Beaufort Sea coast (Lawrence et al. 1984, Bond and Erickson 1989). Arctic Cisco occupy a variety of coastal near shore habitats, but seldom enter freshwater except for spawning and overwintering (Craig and Mann 1974). They are generally more tolerant of saline water than other coregonid species found in the area (Galbraith and Hunter 1975). Spawning takes place during fall in the major tributaries of the Mackenzie River. During late summer and fall, Arctic Cisco pass through the Mackenzie River delta, migrating upstream to overwintering sites located throughout the Mackenzie system.

Rainbow Smelt has a complex taxonomy. However, the Pacific-Arctic form, ranging from Vancouver Island to Cape Bathurst, is considered *O. mordax dentex* (Haldorson and Craig 1984). In the Canadian Beaufort Sea, Rainbow Smelt have been collected in test nets from Phillips Bay (9% total catch; Bond and Erickson 1989) on the Yukon North Slope (9% total catch; Bond and Erickson, 1989), Tuktoyaktuk Harbour (34% total catch; Harwood et al. 2008), and Liverpool Bay (6% total catch; Bond and Erickson, 1993). Rainbow Smelt overwinter in the Beaufort Sea and spawn in the Mackenzie River just prior to spring break-up; spent adults then drift out to sea to forage, and newly emerged fry drift out to sea and disperse to known coastal locations.

Rainbow Smelt are one of the few forage species that are mainly piscivorous. Rainbow Smelt were reported to feed on juvenile fish and mysids at Phillips Bay, Yukon (Bond and Erickson, 1989). Fish (mainly Arctic Cod, as well as Four-horned Sculpin, Arctic Cisco, Rainbow Smelt, and Eelpout) constituted 78% of the diet. Similar results were reported by Lawrence et al. (1984) along coastal areas of southeastern Beaufort Sea, where fish were present in 65% of Rainbow Smelt stomachs. However, mysids occurred in 77% of stomachs sampled by Bond and Erickson (1989), and 20% of stomachs sampled by Lawrence et al. (1984), so they are an important prey in addition to fish. Based on food web analyses, Loseto et al. (2009) suggested that Rainbow Smelt could form part of the diet of beluga feeding in the nearshore Beaufort Sea.

Anadromous fishes of this grouping occupy a specific habitat, being restricted to coastal, relatively low salinity waters. They are net exporters of marine energy and nutrients from the WAB region because they migrate into fresh water to spawn and overwinter where they deposit energy in form of reproductive products, excretory products, and carcasses of dead individuals. Once they mature, chars spend months each summer feeding in the productive coastal marine waters. Bond and Erickson (1989) reported an increase of 46% in fork length of Dolly Varden returning to their natal streams following two months of feeding at sea. Rainbow Smelt are active selective feeders (mainly piscivorous).

Nearshore “Less-Mobile” Anadromous Fishes (0–5 m depth and estuaries)

Broad Whitefish (*Coregonus nasus*), Lake Whitefish (*C. clupeaformis*), and Least Cisco (*C. sardinella*)

Mackenzie Delta channels and the coastal nearshore Beaufort Sea function for Coregonids mainly as migratory corridors between spawning habitats in the Mackenzie River and nursery, feeding, and overwintering habitats located in suitable Delta lakes or in coastal watersheds (Chang-Kue and Jessop 1992). For example, of the approximately 1.35 million fish counted in two-way fish fences in a small watershed along coastal Tuktoyaktuk peninsula during 1978 and 1979, 94% were Broad Whitefish. Bond and Erickson (1985) described the life history of Coregonids using small freshwater systems flowing into Tuktoyaktuk Harbour, confirming the importance of coastal, freshened waters for early life history feeding and migration of these fish.

Coastal summer feeding by Broad Whitefish and Lake Whitefish displayed a benthic generalist feeding preference (Amphipods, Annelids, and Molluscs) (Lawrence et al. 1984). Although many stomachs were empty in the captured fish, it was suggested that the coastal area is likely very important for small bodied Coregonids, which were absent in nets using the gear employed during these studies (Bond and Erickson 1985). Studies in the mid-1970's indicated that large numbers of Coregonids entered the southern Beaufort Sea each summer and dispersed along the coastal margin (Galbraith and Hunter 1975). Most of the fish encountered appeared to be juveniles on feeding migrations, suggesting an important role for coastal habitats as feeding and rearing areas.

Least Cisco occurs along coastal mainland of the WAB region and also in larger rivers on Banks, Victoria, Prince of Wales and King William islands (Stephenson 2010). Both lake-resident and “sea-run” (anadromous) populations of Least Cisco occur in the WAB region. The anadromous populations overwinter in river deltas and feed in brackish nearshore waters during summer. Anadromous forms of Least Cisco spawn in the Mackenzie River watershed. Least Cisco can withstand salinity concentrations of about 25 ppt, and feed along the barrier islands of the Beaufort Sea. Great numbers of Least Cisco overwinter in brackish river deltas, where they tend to use areas where salinity is less than 15 ppt.

Based on diet studies, Least Cisco captured along the coastal southeast Beaufort Sea are generalists; depending upon their size, they feed on Amphipods, Mysids, Isopods, and

Copepods and other fish (Lawrence et al. 1984). A high proportion of Least Cisco stomachs of fish captured in the coastal environment were empty.

Least Cisco are fed upon by Beluga and Ringed Seal on an opportunistic basis, but are not the primary species of interest. Inconnu (*Stenodus nelma*) may feed on Least Cisco when they co-occur in brackish deltas and freshwater rearing and spawning habitat (Pirtle and Mueter 2011).

Similar to the nearshore “mobile” anadromous fishes, the nearshore “non-mobile” anadromous fishes” feed extensively and accumulate a large proportion of their biomass in the marine environment. These species therefore have the potential to export significant nutrients from the coastal nearshore to overwintering rivers in the upper Mackenzie River.

Marine Fishes

Marine fishes are found throughout the WAB region in coastal, nearshore, and offshore habitats. They exhibit a variety of ecological types including pelagic (living in the water column), benthic (restricted to living on the bottom), and bentho-pelagic (bottom-associated, but with movement throughout the water column) that are linked to their functional role in the ecosystem. The spatial (nearshore-offshore) or vertical (benthic, pelagic) movement of marine fishes across habitats at various life stages or for activities such as feeding and reproduction, likely plays an important role in the transfer of energy and biomass both within and between biogeographic regions. While marine fishes are known to be prey for anadromous species that inhabit coastal waters during the open water season (e.g., Craig 1984) and have been identified as important components of the diet of Arctic marine mammals (Laidre et al. 2008), relatively little is known about their ecology beyond that of a few commercial and keystone species, i.e., Greenland Halibut (*Reinhardtius hippoglossoides*) and Arctic Cod (*Boreogadus saida*), respectively.

Recently, Majewski et al. (2017) described the regional-scale community structure of benthic marine fishes for the shelf and slope of the Canadian Beaufort Sea (~ 20–1000 m depth) and identified four distinct assemblages associated with distinct habitats defined by depth and water mass along a nearshore-offshore gradient. Arctic Cod were widely distributed among habitats, but were most abundant along the thermohalocline (Figure 11). While the ecological role of the majority of these fishes is poorly known, recent studies suggest that different trophic processes occur across habitats that correspond with marine fish community structure (Giraldo et al. 2015, Stasko et al. 2016). Thus, marine fishes are evaluated with species-groupings for candidate ESSCP based on a combination of depth distribution and ecological type, as follows: coastal (0-10 m), nearshore benthic (10-50 m), benthic or bentho-pelagic (50–200 m), benthic (> 200 m), and pelagic (> 50 m). Arctic Cod and Greenland Halibut are treated individually because their ecology is more fully described.

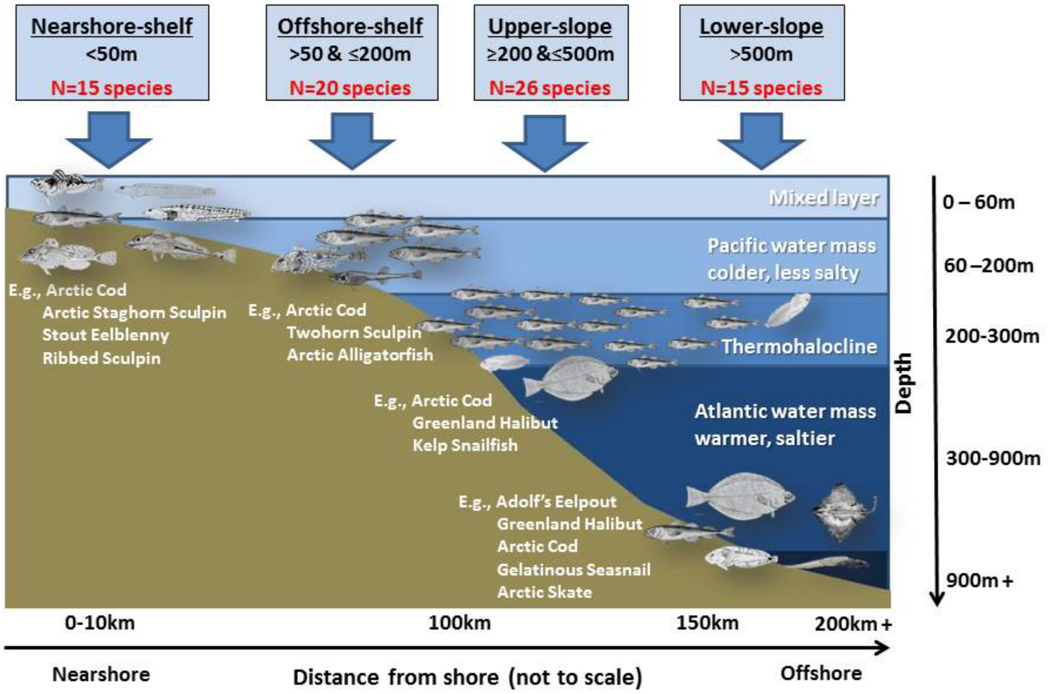

Figure 11. Schematic of water masses and associated marine fish assemblages in the Canadian Beaufort Sea (adapted from Majewski et al. 2017).

Coastal (0–10 m) Marine Fish Assemblage

The coastal shallow zone of the WAB region is highly dynamic and responds rapidly to changes in air temperature, precipitation, wind speed and direction, river discharge, oceanographic conditions, and ice dynamics. Subsequently, the marine fish assemblage of this area includes species that are able to tolerate fluctuating environmental conditions (Bond and Erickson 1989). Dominant species captured in the coastal fish assemblage along the Yukon North Slope included Arctic Flounder (*Liopsetta glacialis*), Fourhorn Sculpin (*Myoxocephalus quadricornis*), and Saffron Cod (*Eleginus gracilis*) (Bond and Erickson 1989). These species are excluded from the coastal zone in winter by bottom-fast ice and freshened conditions, but move inshore following spring break-up to feed on benthic invertebrates (mainly the Isopod *Mesidotea entomon*) and return to deeper marine waters to overwinter with the onset of landfast ice formation.

The coastal zone includes many significant energy transfers (terrestrial to marine, fresh water to marine, nearshore to offshore), of which coastal fishes play a significant role. Depending upon size and life stage, coastal marine fishes can be important forage species for other anadromous fishes using the coastal zone. Their life cycle is tightly linked to the life cycle of their prey (e.g., isopods) that inhabit coastal waters. The ability of these species to adapt to a dynamic rapidly changing environment makes them highly resilient.

Nearshore (10–50 m) Benthic Marine Fish Assemblage

The majority of marine fishes reported to occur from the inner shelf (< 50 m) of the Canadian Beaufort Sea are small benthic feeders (Majewski et al. 2013). In a recent offshore ecosystem survey, Majewski et al. (2017) found the marine fish assemblage of the inner Beaufort Shelf (< 50 m depth) to include 15 species with a combined CPUE estimate of 1535.1 fish/km^2. This assemblage was mainly characterized by Arctic Cod along with other small-bodied demersal fishes, including Arctic Staghorn Sculpin (*Gymnocanthus tricuspis*) and, to a lesser extent, Stout Eelblenny (*Anisarchus medius*), Spatulate Sculpin (*Icelus spatula*), and Ribbed Sculpin (*Triglops pingelli*). Previous work by Majewski et al. (2013) also found that Canadian Eelpout (*Lycodes polaris*) typified the marine fish assemblage at this depth. Many of these small epi-benthic feeders occur in nearshore habitats throughout the WAB region (Coad and Reist 2004).

Small benthic marine fishes from nearshore habitats are important prey items for anadromous fishes that migrate to marine coastal areas annually for feeding (e.g., Craig 1984). Small benthic marine fishes feed primarily on benthic invertebrates and therefore convert energy from invertebrate prey into a form that is available to larger predators. Fatty acid and stable isotope analyses for some of the most abundant species collected between 20 and 75 m depths on the Beaufort Shelf (Arctic Staghorn Sculpin, Arctic Alligatorfish (*Aspidophoroides olrikii*), and Canadian Eelpout) suggested a prevalence of low-trophic, generalist benthic feeding (Giraldo et al. 2015). Ribbed Sculpin, in contrast, appeared to be a pelagic feeder despite its demersal habitat association (Giraldo et al. 2015). Some species, such as lumpfishes (Kennedy et al. 2015) and possibly Ribbed Sculpin (*Triglops pingeli*) (Giraldo et al. 2015), undertake vertical movements off the bottom to feed on pelagic prey in the water column.

Benthic or Bentho-Pelagic Marine Fish Assemblage (50–200 m)

Similar to the nearshore-shelf assemblage, the marine fish assemblage of the outer Beaufort Shelf (50–200 m depth) is characterized by a suite of small-bodied benthic fishes. Majewski et al. (2017) found that Arctic Alligatorfish and Twohorn Sculpin (*Icelus bicornis*) typified this assemblage, which included 20 species overall and an estimated total CPUE of 568.8 fish/km^2. At least a further 24 species are likely to have membership in this assemblage throughout the WAB region, given depth distributions reported across known geographic ranges (Mecklenburg et al. 2016).

Using a combined stable isotope and fatty acid approach, Giraldo et al. (2015) found that while the majority of small benthic marine fishes were low to mid-trophic generalist benthic carnivores able to feed on a wide variety of prey items, certain species were highly specialized, and these species tended to occur over shelf habitats. In particular, Arctic Alligatorfish appeared to feed primarily on bivalves and Ribbed Sculpin utilized pelagic prey. This contrasts highly variable diets inferred for benthic marine fishes that occur in deeper habitats along the slope (Giraldo et al. 2015). The ecological role of specialized marine fish predators is poorly known, but specialization is likely promoted where the availability of organic carbon is not limited at shallower depths (Stasko et al. 2016).

It is not known whether this assemblage is functionally different from the inner-shelf assemblage, but it includes a different fish community associated with the Pacific water mass (Majewski et al. 2017).

Benthic Marine Fish Assemblage (> 200 m)

The majority of information available for > 200m depth in the western Canadian Arctic is from the Canadian Beaufort Sea in the adjacent Arctic Basin Biogeographic region, although deep areas of Amundsen Gulf have also been sampled within the WAB. In the Beaufort Sea, Majewski et al. (2017) identified a distinct fish assemblage associated with the upper slope at > 200 m water depth that had the highest species diversity (n = 26) and a total CPUE of 2137.1 fish/km^2 of four fish assemblages identified for the Canadian Beaufort Sea. CPUE was largely driven by the high abundance of Arctic Cod (94% of total fish CPUE) aggregating along the thermohalocline between the Atlantic and Pacific water masses and was associated with dense concentration of pelagic prey items (Majewski et al. 2015). Arctic Cod biomass also peaked along the continental slope (Crawford et al. 2012, Geoffroy et al. 2011). Apart from Arctic Cod, the upper slope assemblage was unique including a diverse number of larger and smaller-bodied species such as Greenland Halibut, Longear Eelpout (*Lycodes seminudus*), Gelatinous Seasnail (*Liparis fabricii*), and Kelp Snailfish (*Liparis tunicatus*). While the majority of species are primarily benthic feeders, this assemblage included bentho-pelagic species. Based on their occurrence at depths > 500 m in the Beaufort Sea, deepwater species such as Arctic Skate (*Amblyraja hyperborea*) and Greenland Halibut are likely present in deeper areas of the WAB region, although this remains to be explored. While the fish assemblage described above is associated with oceanographic conditions along the Beaufort Sea slope, some of the species within the assemblage occur in deep water areas of the WAB (Coad and Reist 2017).

Some large benthic fishes in this assemblage are known to actively feed in the pelagic zone. For example, Giraldo et al. (2015) found that Adolf's Eelpout (*Lycodes adolfi*) and Longear Eelpout contained high levels of *Calanus* spp. related fatty acid markers. This suggests either direct consumption of copepods, or more likely consumption of copepod predators, indicating the role of these large benthic marine fishes in benthic-pelagic coupling through the consumption of pelagic-derived energy. Stasko et al. (2016) quantified biomass-body size relationships (i.e., size-spectra) in the Beaufort Sea and suggested that high biomass production, especially for Greenland Halibut, is maintained in larger size classes of fishes in deeper waters by swimming to obtain pelagic prey subsidies ('active biological transport'). In contrast, biomass production of smaller size classes of fish with reduced swimming capability was limited by the availability of benthic resources passively transported to the sea floor.

The presence of large-bodied fishes (Greenland Halibut, Arctic Skate, eelpouts) over the lower-slope combined with the presence of dense Arctic Cod aggregations along the thermohalocline may make it energetically worthwhile for marine mammals to undertake deep dives. For example, satellite-tagged male Beluga traveled great distances and undertook deep dives at Viscount Melville Sound (Richard et al. 2001). Beluga selected habitat along the Alaskan shelf break (Moore 2000) and were observed making frequent dives at depth corresponding to the shelf break and upper slope of the Beaufort Sea (Hauser et al. 2015).

Pelagic Marine Fish (> 50 m) assemblage

There are few truly pelagic species of marine fishes in the WAB region, making this assemblage functionally unique based on feeding strategy and habitat orientation. About five species are included in this assemblage: Capelin (*Mallotus villosus),* Pacific Herring (*Clupeus pallasii*)*,* Polar Cod (*Arctogadus borisovi*)*,* Gelatinous Seasnail (*Liparis fabricii*), and Arctic Cod (treated elsewhere). They are consumed by other fishes, marine birds, and marine mammals.

Capelin are pelagic, planktivorous forage fish that feed almost exclusively on calanoid copepods and amphipods and occupy dietary niches similar to those of Arctic Cod (McNicholl et al. 2015). Although not widely occurring in the WAB region, they can be locally abundant (e.g., Darnley Bay [Harwood and Babaluk 2014, McNicholl et al. 2015], Queen Maud Gulf [Nunami Stantec 2011]). Pacific Herring occur at depths < 50 m and form dense late-spring spawning aggregations in coastal areas near the Mackenzie River, Tuktyaktuk Harbour, Liverpool Bay (Paulic and Papst 2012), and further east around Cape Bathurst, Coronation Gulf, Bathurst Inlet, Melville Sound, and Victoria Island (Stewart et al. 1993). Pacific Herring larvae were dominant in the "intense Mackenzie plume waters" during transect sampling across the Beaufort Shelf (Paulic and Papst 2012, Wong et al. 2013). Pacific Herring have a diverse diet consisting of copepods, and benthic fauna, but are primarily dependent upon a copepod-based food web (Loseto et al. 2009). Pre-spawning aggregations are preyed upon by co-occurring fishes (e.g., Inconnu). They are also consumed by Beluga feeding in the nearshore (Loseto et al. 2009) and marine birds.

Polar Cod and Gelatinous Seasnail are relatively minor components of this assemblage. The Gelatinous Seasnail occurs frequently in larval fish communities (Paulic and Papst 2012, Wong et al. 2013).

Pelagic marine fishes are considered as ESSCP because of their importance in the transfer of energy between pelagic prey and higher trophic levels, including larger anadromous fishes, Ringed Seal, Beluga and marine birds. This group is also functionally unique in that it contains relatively few species compared to the benthic marine fishes.

*Arctic Cod (*Boreogadus saida*)*

Arctic Cod occurs in a wide range of environments throughout the WAB region. Arctic Cod spawn beneath the ice in winter and are primarily pelagic throughout larval and early juvenile life (Sameoto 1984). Arctic Cod seek the thermal advantage and productivity of warm shallow shelf waters during the open water season, where larval (pelagic) and demersal (0+) stages dominate ichthyoplankton samples along the Beaufort Shelf (Chiperzak et al. 2003, Paulic and Papst 2012, Walkusz et al. 2012, Majewski et al. 2015). As they mature, Arctic Cod migrate down to deeper oceanic waters, perhaps to avoid marine mammal predators (Benoit et al. 2008, Geoffroy et al. 2011) or to seek the relatively warm, food rich Atlantic layer of sea water (depths ranging from 200–350 m) (Benoit et al. 2008, Crawford et al. 2012, Majewski et al. 2015). In late winter, Arctic Cod begin a migration back to surface waters. This vertical migration coincides with the vertical migration of zooplankton, which having overwintered in the deep waters, move toward the surface to take advantage of the intense late winter/spring pulse of sea ice associated productivity (Benoit et al. 2010).

Depending upon body size and location, Arctic Cod mainly consume zooplankton and several species of Amphipods and Mysids. For example, the Arctic Cod in the nearshore Canadian Beaufort Sea sampled during the summers of 2006–2009 (82 stations, ranging in depth from 8 to 128 m), fed mainly on copepods (*Pseudocalanus* spp., *C. glacialis*, *C. hyperboreus*, *L. macrurus,* and *Jaschnovia tolli*), amphipods (*Apherusa glacialis* and *Themisto libellula*) and mysids (*Mysis oculata*) (Walkusz et al. 2012). Similarly, Arctic Cod captured in shelf and slope habitats (20–1000 m) had stomach contents dominated (86% total gut biomass) by *C. glacialis, C. hyperboreus, T. libellula and T. abysssorum*. Shifts in prey were noted in size with increasing fish length and depth of station, with smaller cod feeding on zooplankton, and larger cod feeding on *Themisto* spp. (Majewski et al. 2015). McNichol et al. (2015) reported that cod of age 1+, sampled in Darnley Bay during August fed extensively on copepods (*C. hyperboreus, C. glacialis*, and *M. longa*), and amphipods (*T. libellula*).

Lowry and Frost (1981) list Arctic Cod as important prey for marine fishes, marine birds, and marine mammals in the Canadian Arctic. For example, Arctic Cod contributed to 50% of the biomass of Rainbow Smelt summer diet along the Yukon North Slope (Bond and Erickson 1989). It has been estimated that marine birds, Beluga, and Ringed Seal consume 1,552 T, 5,875 T, and 21,203 T of Arctic Cod per year, respectively (Lowry and Frost 1984). Welch et al. (1993), using a maintenance ration of 22 kg cod/day for an 880 kg Beluga, estimated that a pod of 500 Beluga would consume 11 T of Arctic Cod per day. Ringed Seal are opportunistic predators, but adults prey mainly on Arctic Cod throughout the WAB region at all times of the year (Johnson et al. 1966, Smith 1987, Smith and Harwood 2001).

Arctic Cod availability may at least partly contribute to the intimate association between Beluga and heavy ice concentrations during foraging periods, particularly at depths where Arctic Cod concentrate (200–500 m) (Asselin et al. 2011). It is suggested that male Beluga that travel to Viscount Melville Sound during the summer and demonstrate deep diving behavior (Richard et al. 2001) may be feeding on aggregations of Arctic Cod. While the distribution of Arctic Cod in the Eastern Beaufort Sea in the spring is not known, they are generally associated with sea ice

(Sekerak and Richardson 1978) and are often reported within the cracks and crevices or beneath the sea ice (Bradstreet 1982, Gradinger and Bluhm 2004).

On the basis of the analysis of the stomach content of predators, Welch et al. (1992) estimated that in the Canadian Archipelago, Arctic Cod funneled 93% of the estimated energy flow between zooplankton and pelagic vertebrates. This finding supports earlier studies pointing to the central importance of the species in the Arctic marine ecosystem (e.g., Craig et al. 1982, Lowry and Frost 1981, Bradstreet et al. 1986) with a ‘wasp-waist’ position in the food web. Arctic Cod fulfill a significant role as key predators of high lipid containing zooplankton and other invertebrates, and as a main forage species for marine birds and mammals. As an R-selected species, Arctic Cod are controlled by variable and unpredictable or catastrophic mortality factors (Bradstreet et al. 1986), but are expected to be somewhat resilient to environmental perturbations. As such they are less limited by density dependant factors (e.g., resources or predators). In fact, Bradstreet et al. (1986) conclude that if a “regulatory effect” does exist, it is likely from Arctic Cod on their predators. This is a key factor in understanding the critical importance of this species in the WAB region.

The movement of Arctic Cod between shelf and deep-ocean waters beyond the boundaries of the WAB region likely represents an important nutrient importing/exporting role both within and between biogeographic regions.

Locally high density of fishes, in particular Arctic Cod, likely support marine mammals that have been observed diving at depths coinciding with the upper slope (Moore 2000, Hauser et al. 2015). Geoffroy et al. (2016) observed wide inter-annual variability in Arctic Cod biomass over the upper-slope over a three-year period (2012–2014). The consequence of this variability to other components of the food web are unknown, but may involve a shift to different prey items that may be less energetically rewarding, such as the observed shift from a diet dominated by Arctic Cod to Sand Lance (*Ammodytes* spp.) for Arctic Char (L. Harwood, DFO Yellowknife, NT, unpublished data) and Beluga near Ulukhaktok, NT (L. Loseto, DFO Winnipeg, MB, unpublished data). The importance of regionally high diversity and a fish community associated with the thermohalocline is unknown.

*Greenland Halibut (*Reinhardtius hippoglossoides*)*

Greenland Halibut (*Reinhardtius hippoglossoides*) occurs in Atlantic and Pacific arctic and boreal marine waters, typically along the continental slope from 50–650 m depth (Mecklenburg et al. 2011). In the WAB region, Greenland Halibut is known from the Beaufort Sea-Amundsen Gulf and High Arctic Archipelago ecozones, but have not been recorded from the shallower waters of Viscount Melville Sound or Queen Maud Gulf (Coad and Reist 2004). Halibut have been sampled by long-line at ~ 450 m depth offshore of Sachs Harbour (Chiperzak et al. 1995) and along the continental slope of the Beaufort Sea by bottom trawling, with greatest abundance (catch-per-unit-effort) at depths > 500 m (Majewski et al. 2017). Although this species tends to be found at depths exceeding the bounds of the WAB region (i.e., > 200 m), it may occur in deep water (~ 600 m) of Viscount Melville Sound, and its full depth range has been reported as 14–2000 m (Mecklenburg et al. 2011). Further, knowledge on the distribution of juveniles is lacking for the WAB region, but information from the Bering Sea suggests they may be associated with shallower habitats over the continental shelf (< 200 m), later migrating to slope habitats at 4–5 years of age (Alton et al. 1988, Kodolov and Matveychuk 1995). While an estimate of the distribution of Greenland Halibut biomass is unknown for the WAB region, it is one of the largest fishes known from the Canadian Beaufort Sea and specimens sized 40-60 cm length were captured at 38 deepwater stations over a three year fishing program in the Beaufort Sea and Amundsen Gulf (M. Majewski, DFO Winnipeg, MB, unpublished data).

Unlike other flatfishes, Greenland Halibut swim with their ventral side downward. It demonstrates a bentho-pelagic feeding strategy and is known to move vertically between benthic and pelagic habitats to obtain pelagic prey such as cephalopods and other fishes (Jørgensen 1997). Combined evidence from stable isotopes, fatty acids, and stomach contents suggest that Greenland Halibut forages across various depths (C. Giraldo, DFO Winnipeg, MB, unpublished data). In waters < 500 m deep, Arctic Cod (up to 90% in the Canadian Beaufort Sea) and eelpouts were the predominant prey, while in waters > 500 m, Snailfish, Eelpouts and Arctic Cod, and Gelatinous Seasnail made up over half of the diet (C. Giraldo, DFO Winnipeg, MB, unpublished data).

Greenland Halibut is included as an ESSCP because of its specialized role in utilizing pelagic subsidies through vertical feeding migrations. Stasko et al. (2016) quantified biomass-body size relationships in the Beaufort Sea and found that Greenland Halibut obtained pelagic subsidies through ‘active biological transport’, a process that may be important in supporting demersal fish communities in deep water habitats with limited flux of organic material to the benthos.

As a relatively large Arctic marine fish, Greenland Halibut is also a preferred prey item of marine mammals (Laidre et al. 2008). It is unclear to what extent the Greenland Halibut is preyed upon by higher trophic levels in the WAB region, however, tagged Beluga have travelled to deep water areas along west Banks Island and Viscount Melville Sound and conducted deep dives, suggesting feeding on deep water species (Richard et al. 2001). The ecological importance of this species as a predator in deep waters of the WAB region will become clearer with further studies aimed to understand its role in the food web.

MARINE INVERTEBRATES

Marine invertebrates are characterized as either benthic (with those living on the sea floor referred to as epifauna, and those living within the sediment as infauna) or as pelagic (living mostly in the water column). Benthic invertebrates can be further divided based on size into microfauna (< 20 µm), meiofauna (20–500 µm), macrofauna (> 500 µm), and megafauna (mostly caught by trawls and visible on seafloor images with depth-association as a key habitat feature . Pelagic invertebrates are commonly further separated for specialist examination into zooplankton and other pelagic invertebrates. (Note: Mysidacea can be both benthic and pelagic; for this report they are considered as pelagic).

Benthic Invertebrates

When considering benthic marine invertebrates, there are thousands of species in the Canadian Arctic. The southeastern Beaufort Sea is one of the most diverse Arctic shelf regions (Piepenburg et al. 2011), but community composition is highly variable. Controlling factors include water depth, sediment grain size, bathymetry features, and influence of riverine sediment and nutrients (Cusson et al. 2007, Conlan et al. 2008, Nephin et al. 2014, Roy et al. 2014) that contribute to differences in density, biomass, and diversity of macrofauna (Conlan et al. 2008, Conlan et al. 2013, Nephin et al. 2014) and of megafauna (Nephin et al. 2014, Roy et al. 2014).

There have been few studies of Arctic micro- and meiofauna (Bessiere et al. 2007), however, it is known that these groups are very important to the productivity of the marine environment, contributing from 31–75% of the overall benthic community carbon demand, compared to 25–69% community carbon demand for macrofauna and 41% for megafauna (Renaud et al. 2007). Total benthic community carbon demand in the Canadian Beaufort Sea was estimated to account for approximately 60% of the annual new production in the region (Renaud et al. 2007).

Since the 1970s, a number of species compilations (Wacasey et al. 1977, Hopky et al. 1994, Chapman and Kostylev 2008, Piepenburg et al. 2011, Roy et al. 2015, Roy and Gagnon 2016) and analyses of physical and chemical factors relating to diversity, density or biomass of benthic marine invertebrates have been conducted (Cusson et al. 2007, Conlan et al. 2008, Roy et al. 2014).

Across the Canadian Arctic, and likely within the WAB region, the distribution of megabenthic communities are associated with large-scale (100–1,000 km) environmental gradients defined by depth, physical water properties, and meso-scale (10–100 km) environmental gradients defined by substrate type (i.e., hard vs. soft bottom) and sediment organic carbon content (Roy et al. 2014). Moreover, areas of biomass-rich communities are maintained by local to meso-scale conditions (bottom currents, upwelling areas, and polynyas), such as the ampeliscid amphipod hotspot located in the upwelling area of Cape Bathurst (Conlan et al. 2008, Conlan et al. 2013). Following these relationships between benthic communities and their habitats, six habitat associations of epifauna and three habitat associations of infauna are proposed to allow a means of assessing the nearly one thousand species of benthic invertebrates for the WAB region (CAFF 2017). The classification method is based on habitat association (infauna/epifauna, soft/hard substrate, depth zone), and is consistent with the approach used to classify fishes into groups.

Benthic invertebrates are critical components of the ecosystem, not only as food for fishes, marine birds, and even marine mammals, but they play a key role in benthic carbon remineralisation (Link et al. 2013a, b). In a large diverse ecosystem such as the WAB region, the relative abundance of individual species changes within the community both spatially and temporally (Conlan et al. 2008, Conlan et al. 2013, Roy et al. 2015). Therefore it would be impossible to characterize individual species from all assemblages. Instead, we provide example species from within coarser taxonomic groupings that typify a community assemblage in a particular environment.

Epifaunal Benthic Invertebrates (Mostly Megafauna)

Nearshore Hard Bottom Assemblage (0–50 m)

This nearshore hard bottom epifauna invertebrate assemblage is relatively restricted in its distribution within the WAB region (Roy et al. 2014), since much of the region is dominated by the influence of the Mackenzie River, which distributes sediment laden waters widely throughout the southern Beaufort Sea, resulting in mainly soft sediments (Jerosch 2013). Areas where nearshore hard bottom assemblages do occur are primarily where bedrock is exposed and maintained by waves or currents. Currents and hard substrates create ideal conditions such as for crinoids and cnidarians (e.g., anemones).

These spatially localized environments within the WAB region support dense aggregations of filter and suspension feeding invertebrates. This assemblage type is well known as an important component of the marine ecosystem in general as it provides three-dimensional habitat for fishes and other invertebrates to use for spawning, feeding or cover. It should be noted that this assemblage type has not been subject to a focussed survey in the WAB region, because it requires special equipment and logistics such as scuba divers or a ROV (Remotely Operated Vehicle).

Nearshore Soft Bottom Assemblage (0–50 m)

To our knowledge, the nearshore epifauna (0–50 m) inhabiting soft bottoms have not been extensively sampled across the entire WAB region, although parts of the Beaufort Shelf have been surveyed at these depths (Wacasey et al. 1977, Conlan et al. 2008). We have therefore no specific information related to this faunal assemblage, but we know that soft bottoms are widespread across the WAB region. The nearshore (0-50 m) of the WAB region is a highly dynamic region (as was discussed for marine fishes). Coastal areas of the WAB region are subject to seasonal extremes of ice coverage, ice scour, low salinity during peaks of river discharge, and periodic intrusions of highly saline cold marine waters during storm surges or upwelling events. The nearshore epifauna is presumably uniquely adapted to these conditions through life cycle adaptations or having other strategies to allow survival during ice cover. This assemblage is important in converting primary productivity to a form usable by higher trophic levels.

Benthic invertebrates of this zone were assessed as moderately-highly important for functioning of the WAB region ecosystem. In spite of the limited data available for this assemblage, the unique life history strategies and adaptations of some species allows for rapid recolonization of disturbed areas and this feature contributes to their justification as an ESSCP.

Shelf Hard Bottom Assemblage (50–200 m)

As was the case for the shallow hard bottom epifaunal assemblage, the shelf hard bottom assemblage is relatively restricted within the WAB region (Roy et al. 2014). Much of the region is under the influence of the Mackenzie River which supplies large fine sediments, and hard bottom shelf environments occur where bedrock is exposed and maintained by currents (Jerosch 2013). This is more common in the eastern part of the WAB region. Common epibenthic invertebrates in these areas include echinoderms, cnidarians, and sponges (Roy et al. 2014). These organisms require stable substrates to attach to and grow on. Where they occur, dense aggregations create three-dimensional habitat for use by fishes and other invertebrates for feeding.

The creation of three-dimensional habitat justifies consideration of this assemblage as an ESSCP, however, these areas are not common within the WAB region and their overall contribution to the functioning of the ecosystem was assessed as small. Limited data exist for this assemblage because sampling of this type of substrate requires special equipment and logistics (e.g., ROV).

Shelf Soft Bottom Assemblage (50–200 m)

This assemblage occurs widely throughout the WAB region, with moderate biomass and productivity (Conlan et al. 2008, Conlan et al. 2013, Roy et al. 2014). The 50–200 m depth category is beyond the average ice scouring zone (Gutt 2001) but the environment can be highly dynamic in some areas (e.g., Cape Bathurst) where the influence of upwelling, which periodically thrust nutrient-rich deep ocean waters onto the shelf, increase the ecosystem productivity (Tremblay et al. 2011). Typical species groups inhabiting soft bottoms of this depth category are echinoderms (e.g., brittle stars), arthropods (e.g., amphipods), and bivalves.

This shelf soft bottom assemblage contributes overall to a moderate amount of the productivity in the WAB region, but productivity is particularly high is some areas (e.g., Cape Bathurst). Soft-bottom macroinvertebrates play a key role in nutrient recycling via filter-feeding and/or the release and remineralization of nutrients from detritus by deposit feeders reworking organic carbon (Link et al. 2013). Many of the deposit-feeding invertebrates are also likely an important link between benthic microbial communities and higher trophic levels (Bell et al. 2016). Further, many species in this group (especially bivalves, amphipods, and molluscs) are important prey for marine fishes (Coad and Reist 2004). This assemblage type is regularly surveyed for diversity, abundance, and biomass in the WAB region by the ArcticNet-CCGS *Amundsen* scientific program, but its overall productivity and contribution to lower and higher trophic levels have been not assessed at the scale of the WAB region.

Deep Hard Bottom Assemblage (> 200 m)

Relative to the rest of the Canadian Arctic, the deep areas of the WAB region that have hard bottoms, and therefore the epifaunal assemblage that inhabit them, are relatively sparse (Roy et al. 2014). Where this habitat exists, strong bottom currents would have to maintain the bedrock exposure. The epifaunal assemblage typical of this zone includes echinoderms, cnidarians, and sponges. These organisms require hard substrates to attach to and currents supplying food particles. Where conditions allow this assemblage to exist, they provide three-dimensional habitat for fish and other invertebrates to use for feeding, cover or reproduction.

Species comprising this assemblage use the hard substrates as attachment points. They provide three-dimensional habitat for use by other species. This assemblage is rare in the WAB region, and as such plays a low role in the overall functioning of the ecosystem.

Deep Soft Bottom Assemblage (> 200 m)

The deep areas of the WAB region are influenced heavily by warmer bottom water temperatures than on the shelf, and reflects the presence of different water masses (Atlantic deeper and Pacific shallower) (Roy et al. 2014). Beyond the shelf (~ 200 m across the WAB region), diversity, abundance, and biomass drop off precipitously such as on the Beaufort Sea slope (Nephin et al. 2014) and in deep areas of the Amundsen Gulf, M'Clure Strait, and Viscount-Melville Sound (Roy et al. 2014). Strong pelagic interception of organic matter fluxes in the productive Cape Bathurst polynya (Darnis et al. 2012) precludes high epibenthic biomass in the deep Amundsen Gulf (Roy et al. 2014).

Deep soft bottom epibenthic invertebrates play a role in conversion of organic matter into usable energy to higher trophic levels (e.g., marine fishes). However, the deep epibenthic productivity of the WAB region is presumably of minor importance due to the lower density and biomass of this assemblage. [Note that the 21% value for benthic invertebrate biomass (Figure 4) is for all benthic invertebrate groups combined].

Infauna Benthic Invertebrates

Nearshore Soft Bottom Assemblage (0–50 m)

The nearshore (0–50 m) soft bottom infauna assemblage is widespread throughout the WAB region, and consists of species that are adapted to an environment that undergoes extremes of temperature, salinity, and disturbance (ice scour). These species have life cycle or behavioural strategies that allow them to rapidly re-establish in the nearshore zone. This assemblage plays a crucial role in the ecosystem of the WAB region. Degradation of organic matter and coupled inorganic nutrient fluxes from the sediment back to the water column is a critical ecosystem function carried out by shallow-water soft bottom benthic infauna (Link et al. 2013a, b). Many species of polychaetes with mixed feeding strategies and motility abound in this assemblage. Burrowing worms contribute significantly to the bioturbation of sediment which influence the release of nutrients in the water. Typical fauna of the nearshore infauna assemblage include bivalves (e.g., *Portlandia arctica*), and polychaetes (e.g., *Micronephthys minuta, Cossura* sp. and *Tharyx* spp.) (Conlan et al. 2008), and isopods (e.g., *Saduria* spp.). Localized highly productive areas (e.g., Cape Bathurst) may have specific dominant species such as the burrowing polychaete *Barantolla americana* (Conlan et al. 2008).

Very high productivity occurs around the 35 m contour at Cape Bathurst, where oceanographic/bathymetric upwellings occur. The benthos of this region reflects this productivity, where several taxa dominate the assemblage by taking advantage of the rich food supply afforded by upwelling events/processes. Conlan et al. (2008) reported very high densities of the surface tube dwelling amphipod *Ampelisca macrocephala* at Cape Bathurst.

This and other species occurring at Cape Bathurst are reported to be part of Grey Whale diet in other Arctic regions (Conlan et al. 2013).

The widespread, high biomass, and contribution to the productivity (including bioturbation and remineralization) of the WAB region by this assemblage makes it a candidate ESSCP. Bioturbation processes driven by soft-bottom infauna, such as nutrient cycling, detrital mixing and bacterial production are also habitat-forming. These taxa are important forage species for fish, marine birds and mammals. It is worth noting that species description of infaunal assemblages and their relative importance to the marine ecosystem has not been fully evaluated in WAB areas outside of the southeastern Beaufort Sea and the Amundsen Gulf.

Shelf Soft Bottom Assemblage (50–200 m)

The shelf soft bottom infauna assemblage of the WAB region has a large mix of species. Some of the offshore dominants are the deposit feeding polychaetes (e.g., *Tharyx* spp., *Levinsinia gracilis*, *Prionospio cirrifera* and *Maldane sarsi*). *M. sarsi* is a deep burrowing, head-down, non-selective deposit feeder which defecates at the surface and therefore likely is important in sediment mixing, pore water oxygenation, and surface nutrient replenishment (Conlan 2008). This assemblage plays a crucial role in the ecosystem of the WAB region. Degradation of organic matter and coupled inorganic nutrient fluxes from the sediment back to the water column is a critical ecosystem function carried out by shelf soft bottom benthic infauna (Link et al. 2013a, b).

This assemblage plays a crucial role in the WAB region ecosystem. Species are important for bioturbation and remineralization of nutrients. The assemblage is tightly coupled to the productivity of the sea ice and pelagic zones and converts organic matter falling to the bottom into energy that can be fed upon by fish. It is important to note that species description of infaunal assemblages and their relative importance to the marine ecosystem has not extensively been undertaken in the WAB region outside of the southeastern Beaufort Sea and the Amundsen Gulf.

Deep Soft Bottom Assemblage (> 200 m)

The deep areas of the WAB region are heavily influenced by the Atlantic water mass, which is warmer and more saline than waters of the Beaufort Shelf (Carmack et al. 1989). Benthic diversity and abundance decreases beyond 200 m. However, this pattern is less pronounced for soft bottom assemblages than for epifauna, possibly because of the substantial metabolic energy required by large organisms (Nephin et al. 2014). In waters > 200 m, species composition shifts to be dominated by polychaetes (*Onuphis quadricuspis*, *Laonice cirrata*) and amphipods (*Haploops tubicola* and *Hippomedon abyssi*) (Conlan et al. 2008). As for the deep epifaunal soft bottom assemblage, strong pelagic interception of organic matter fluxes in the productive Cape Bathurst polynya lead to low infaunal abundance and low benthic remineralization rates in the deep areas of the Amundsen Gulf (Darnis et al. 2012).

Deep soft bottom infauna play a role in conversion of organic matter into usable energy for marine fish. However, the deep soft bottom infaunal productivity of the WAB region is presumably of minor importance due to the lower density and diversity of this assemblage. It is worth noting that species description of infaunal assemblages and their relative importance to the marine ecosystem has not been fully investigated in the WAB region outside of the southeastern Beaufort Sea and the Amundsen Gulf.

Zooplankton

Approximately 95 species of zooplankton have been recorded from the Canadian Beaufort Sea (Grainger 1965) and this number of taxa likely occurs throughout the WAB region. The distribution and life cycle of zooplankton is tuned to seasonal changes in ice, nutrients, and sunlight (The Research Council of Norway 2011, Darnis and Fortier 2014). Because of this relationship, the relative contribution of a given species within the overall zooplankton community at any particular location changes over a year. The zooplankton of the WAB region are tightly linked to water masses, with different species dominating coastal (low salinity), shelf (mixed salinity), and Atlantic and Pacific water masses, which occur at varying depths in the deep waters (Walkusz et al. 2010).

There are some groupings of zooplankton and species within those groups which seem to be of higher ecological importance due to their overall abundance in the zooplankton community and their roles in transferring energy from lower primary production to higher trophic levels in the form of energy rich lipids. These species are considered candidate ESSCP and will be examined further using the criteria.

Microzooplankton

Microzooplankton (< 200 µm in size), include mainly flagellates, dinoflagellates, and ciliates, but also may include acantharids, radiolarians, and foraminiferans. They have a central role in pelagic food webs as herbivores and as food for larger zooplankton such as copepods (Sherr et al. 2009). Microzooplankton also play an important role in microbial processes through feeding on bacteria and other small protists. Phagotrophic ciliates and dinoflagellates are known to be abundant in Arctic marine systems (Sherr et al. 1997, 2003). Sherr et al. (2003) reported that the biomass of microzooplankton increased along with the biomass of phytoplankton during spring and summer in the central Arctic and had the potential to consume a large fraction of phytoplankton production. In the Barents Sea during early summer, phytoplankton growth and micro zooplankton grazing were closely coupled, and grazing losses accounted for 64-97% of growth (Verity et al. 2002). These studies suggest that microzooplankton may be as important in Arctic ecosystems as they are in other parts of the world ocean.

Sherr et al. (2009) found that in the Western Arctic Ocean, micro zooplankton grazing impact was highly variable and accounted, on average, for only about one fifth of daily phytoplankton production, rather than the 60-70% of production found in other marine systems. A potential explanation for this observation is the strong top-down control of micro zooplankton stocks due to preferential predation on ciliates and heterotrophic dinoflagellates by arctic copepods.

Microzooplankton consume a large portion of pelagic primary production. This energy is then transferred to the bottom either directly via fecal pellets or indirectly through predation by larger copepods, which in turn transfer the energy to the benthos. The microzooplankton species assemblage in the vertical transfer of energy contributes to the pelagic-benthic coupling of the WAB region.

Mesozooplankton

Mesozooplankton include copepod species (adult size of 0.2–5.0 mm). Species of this assemblage play an important ecological role in spatially and temporally explicit ways. They are spatially distributed throughout the WAB region based on water masses, forming an onshore (shallow, warm, low salinity water) to offshore (deep, cold, high salinity) gradient. The genus *Calanus* spp. is such an ecologically relevant taxon that it will be treated separately below.

Walkusz et al. (2010) described three zones and associated zooplankton species assemblage on the Beaufort Shelf based on the effects of the plume of sediment laden Mackenzie River discharge. The coastal zone nearest to the Mackenzie River defined as “intense plume” was dominated by the copepod *Pseudocalanus* spp. and *Limnocalanus macrurus* and the cladoceran *Podon leuckarti*. These species are adapted to freshwater-influenced water. *Pseudocalanus* spp. dominate the biomass of zooplankton in areas where they occur, and are an important primary food source of coastal fish larvae (e.g., Pacific Herring). Due to its high lipid content, *L. macrurus*, a much larger species than *Pseudocalanus* spp., is regarded as an important element in the diet of fish and marine mammals, such as the pelagic feeding Bowhead Whale (Walkusz et al. 2010). Further offshore from the Mackenzie River is a transition zone (frontal zone) between the river and open sea defined as the "diffuse plume zone". Here diversity is highest and consists of eurythermal, euryhaline, and omnivorous species. Relatively high biomass of marine taxa varies depending upon the establishment and strength of frontal water masses. Depending upon the transect sampled, high biomass of a mixture of low salinity-tolerant and low salinity-intolerant species, including *Pseudocalanus* spp*., Oithona similis, L. macrurus,* and *C. hyperboreus* are observed (Walkusz et al. 2010). These species likely contributed significantly to production of Beaufort Sea ichthyoplankton (Paulic and Papst 2012). The final zone is the "oceanic zone", located furthest offshore, consisting of high abundances of *Calanus* spp., *Microcalanus* spp, and *Triconia* (Oncea) *borealis* (Walkusz et al. 2010).

Zooplankton provide an important link between phytoplankton production and higher trophic level fauna. They are key prey items for a number of anadromous and marine fish (Walkusz et al. 2012), birds (Kwasniewski et al. 2010), and whales (Laidre et al. 2007, Walkusz et al. 2012), providing highly energetic and lipid rich food to these higher trophic levels. Different species and sizes of zooplankton are usually associated with different water masses and these differences are important for feeding of different life stages of fish.

Macrozooplankton

Macrozooplankton (including gelatinous Medusa, Pteropods, Amphipods, and Euphasiids) and their role in the WAB region ecosystem are generally poorly understood. There have been few comprehensive studies of macrozooplankton, although they are captured during pelagic sampling as part of the planktonic component and likely are important predators of pelagic organisms.

Based on dietary studies of fish and marine mammals, of special importance in the food web of the WAB region are Mysids, pelagic Amphipods, and Euphausiids. Areas where Ringed Seal aggregate are known to have oceanographic characteristics favourable for macrozooplankton production; here mean densities of Euphausiids (e.g., *Thysanoessa* spp.) are much higher than elsewhere. Ringed Seal along the Yukon North Slope fed heavily on the Mysid *Mysis littoralis* (Harwood 1989). Smith (1987) found that juvenile Ringed Seal collected from aggregation areas during fall in the Prince Albert Sound also had full stomachs containing the Amphipod *Themisto* spp., *Thysanoessa* spp., and *Mysis* spp. Kingsley and Byers (1998) reported similar Ringed Seal feeding heavily on these same taxa at Thesiger Bay. Although Ringed Seal are reported to feed primarily on Arctic Cod, pelagic invertebrates are an important diet item in summer and autumn for Ringed Seal of all age classes, although particularly for subadults, which have less experience capturing fish (Lowry et al. 1978, 1980, Smith 1987, Smith and Harwood 2001). Large numbers of pteropods have been observed in stomachs of Beluga Whales in some years (Annie Goose, Olokhaktomiut Hunters and Trappers Committee, pers. comm.). In addition to Ringed Seal, several fish species have been reported to prey heavily on macrozooplankton. Older Arctic Cod feed on *Themisto* spp. and mysids, Dolly Varden and Arctic Char feed on pelagic Amphipods (e.g.,*Themisto* spp.) during their intense marine summer feeding period, and Capelin feed on *Themisto* spp. (McNicholl et al. 2015).

Mysis spp. have been described as pelagic, bentho-pelagic or necto-benthic species, and are omnivorous, planktivorous, and benthivorous (Viherluoto et.al. 2000). *Mysis* spp. are capable of both filter feeding and raptorial feeding (Viherluoto et. al. 2000), confirming their versatile nature. The ratio of pelagic:benthic food in the diet of *Mysis* spp. is dependent on species, size (higher for larger individuals) and season (higher in summer than in winter) (Viherluoto et. al. 2000).

Mysids are prey for fish (Arrhenius & Hansson 1993). They spend the daylight hours near the seabed but ascend to the thermocline at night (Rudstam et. al. 1989). In addition to being links between the trophic levels, diurnal migration between the pelagic and benthic systems makes them important links between the two habitats and important in the vertical transfer of energy (Rudstam et. al. 1989).

Macrozooplankton play a moderately important role in the transfer of energy within the WAB region. They consist of herbivorous and carnivorous species. They likely influence the pelagic food web through pelagic feeding and sedimentation of particulate matter, which strengthens pelagic-benthic coupling (Raskoff et al. 2005).

Calanus spp.

Calanus spp. is treated separately because of its well established importance as a critical ecosystem component throughout the Arctic. Large phytoplankton cells, such as diatoms and dinoflagellates (derived from under the sea ice or in the water column as sea ice melts in spring), are the primary food of *Calanus* spp., the biomass of which is dominated by the large suspension feeders *C. glacialis* and *C. hyperboreus* in all Arctic seas (Arashkevich et al. 2002, Auel and Hagen 2002, Darnis et al. 2008, Smoot and Hopcroft 2017). By exerting heavy grazing pressure on micro-algae, which are rich in omega-3-fatty acids, large herbivorous copepods have the capacity to build in a few weeks huge lipid reserves, mostly as wax esters, that often exceed 70% of their dry mass at the end of the feeding season (The Research Council of Norway 2011).

Calanus spp. are key prey items for a number of anadromous and marine fishes (Walkusz et al. 2012), birds (Kwasniewski et al. 2010), and whales (Laidre et al. 2007, Walkusz et al. 2012) providing high energy, lipid-rich food to these higher trophic levels. Different species and sizes of zooplankton are usually associated with different water masses and these differences are important for feeding of different life stages of fish.

Calanus spp. undergo seasonal, ontogenetic migrations and aggregate at depths after collecting enough lipid reserves for overwintering (Madsen et al. 2001). The resting copepods in Amundsen Gulf may be somewhat concentrated in deep layers due to their ontogenetic migration (Hirche 1997). In spring, they migrate to surface waters and feed on the nutrients provided by the intense ice algae blooms and other associated sympagic organisms.

C. glacialis and *C. hyperboreus* are two key species in the offshore waters of the WAB region; they fulfill an essential predatory role in consuming primary production (Walkusz et al. 2012). Moreover, these two species are key prey for Arctic Cod. Majewski et al. (2015) found that Arctic Cod fed primarily on *C. glacialis* and *C. hyperboreus* along the shelf, with a shift to the amphipods *Themisto libellula* and *T. abyssorum* as fish size increased off the Beaufort shelf to slope (> 200m). Combined, *Calanus* spp. and the two *Themisto* species comprised 86% of the biomass of Arctic Cod diet.

The annual timing of Bowhead Whale migration coincides with the annual ascent of zooplankton (Citta et al. 2015). During an intense upwelling event at Cape Bathurst in 2008, Bowhead Whale feeding aggregations were associated with *Calanus* spp. aggregations (Walkusz et al. 2012). Walkusz et al. (2012) suggested that the upwelling at Cape Bathurst advected the *Calanus* spp. that had already migrated to deeper waters at this time of the year back onto the northeastern end of the Canadian Beaufort Shelf. Once on the shelf, they suggested that the copepods attempting to return to their resting depth by swimming away from the sunlight, concentrated near the sea floor. Based on Williams and Carmack (2008), the area covered by upwelled water over the Canadian Beaufort Shelf during this event approached approximately 2800 km^2, and included an estimated water volume of 90 km^3. It was estimated that approximately 39 teracalories were imported to the area. *Calanus* spp. were estimated to contribute 21,000 US tons of zooplankton or 78% of the total biomass of food consumed by Bowhead Whale during their four month stay at Disko Bay in Greenland (Laidre et al. 2007).

Zooplankton (and associated fish populations feeding on them) likely involve the largest displacement of biomass on Earth, both as diel and seasonal vertical migrations (Benoit et al. 2010). Diel vertical migrations typically bring migrants from the bathypelagic or mesopelagic zones into the epipelagic zone at night to feed, and back to depth in daytime to avoid visual predators (Benoit et al. 2010). The amount of carbon taken in the surface layer and carried to depth by these migrations (either as respired, excreted or egested carbon) represents up to 70% of the particulate organic carbon flux (Ducklow et al. 2001).

Calanus spp. perform seasonal vertical migrations to depths of several hundred meters where the late developmental stages overwinter in a resting state for much of the ice-covered period (Ashjian et al. 2003, Hirche 1997). Mortality and respiration in the populations of *Calanus* spp. overwintering at depth are suspected to contribute significantly to the biogeochemical cycle of carbon, particularly the export of carbon to the deep Arctic Ocean, thus, they play a role as vertical “nutrient importers”.

The role *Calanus* spp. play in the transfer of energy within the WAB region between primary production and higher trophic levels makes it a centralized ecosystem component. Members of this species convert primary production into high quality lipid reserves, which are then transferred to fish, marine birds, and marine mammals. *Calanus* spp. also actively and passively transfer tremendous amounts of energy vertically within the WAB region.

MARINE PROKARYOTES AND EUKARYOTES

Small (< 5 micron) Pelagic Phytoplankton

Small phytoplankton are important components of pelagic marine ecosystems. They are responsible for significant global photosynthetic production and as bacterial grazers much of the global heterotrophic production, and therefore, they have a major impact on marine carbon and energy budgets (Sherr et al. 2007). Small phytoplankton generally dominate the overall phytoplankton biomass in the WAB region, except for the Amundsen Gulf and upwelling areas, where large phytoplankton cells dominate (Ardyna et al. 2011).

Pelagic picophytoplankton are tiny (< 2 micron) photosynthetic, single-celled organisms. The growth of pico and larger-sized phytoplankton is controlled by the availability of nutrients (e.g., nitrogen) and/or light (Carmack et al. 2004). Sea ice reduces the amount of light reaching surface waters such that maximum growth/biomass (i.e., phytoplankton bloom) generally occurs after the loss of the sea-ice cover. However, recent studies have shown the presence of under-ice blooms in the Western Arctic (e.g., Arrigo et al. 2012). Areas of increased phytoplankton production or biomass in the WAB region can be associated with occurrences of upwelling or other mixing processes where nutrient rich waters are transported to surface layers. The amount, timing, and location of pelagic phytoplankton production is closely linked to multiple physical oceanographic variables including stratification, water masses, mixing processes, sea-ice dynamics, water temperature, and salinity.

DNA and taxonomic studies have identified diverse assemblages of small phytoplankton, including many genotypes of photosynthetic flagellates. The picophytoplankton in the Beaufort Sea are less diverse than at lower latitudes and are dominated by a species of green algae *Micromonas* spp. (Balzano et al. 2012). The small phytoplankton may contribute only a moderate amount to total primary productivity in the Beaufort Sea. However, studies in the Beaufort Sea suggest a shift from larger cells to picophytoplankton in response to changing oceanographic conditions (Li et al. 2009). During summer, phytoplankton communities in the WAB region are comprised primarily of pico-sized cells (76%) relative to nano- (23%) or micro-sized (1%) phytoplankton (Ardyna et al. 2011).

Photosynthesis by phytoplankton and ice algae (see below) is the overarching process through which inorganic carbon is transformed into organic matter, supporting energy transfers and the build-up of biomass of keystone species including fishes and marine mammals. It is through fundamental properties of pelagic- (grazing, Forest et al. 2011) and benthic- (sedimentation, Sallon et al. 2011) coupling that primary production fuels marine food webs. Small phytoplankton have a key role in energy transfer between primary producers and consumers, especially under conditions of low nutrient concentrations. These small-sized cells are found throughout the WAB region in near-shore and off-shore waters and can respond quickly to changing growth conditions. For much of the year, and in many locations, pico phytoplankton can be the numerically dominant form of pelagic primary producers in the WAB region.

Nano and Micro (> 5 microns) Pelagic Phytoplankton

The larger phytoplankton community assemblage (> 5 micron) plays a significant role in the primary productivity of pelagic waters in the WAB region (Sherr et al. 2007). The larger phytoplankton cells are major contributors to total primary productivity, especially on the shelf and in the Amundsen Gulf. Relative to other regions of the Arctic, the surface waters of the WAB region are considered to be oligotrophic, with relatively low total primary productivity. During the summer, total phytoplankton production in the WAB region is ~ 170 mg C m^{-2} d^{-1} compared to ~ 450 mg C m^{-2} d^{-1} in Baffin Bay (Ardyna et al. 2011). There is high spatial and temporal variability in the production of large phytoplankton in the WAB region with high production associated with upwelling on nutrient-rich waters (Tremblay et al. 2011).

Highest phytoplankton biomass is found in layers called sub-surface chlorophyll maxima (SCM), identified as the depth in the upper water column where the concentration of chlorophyll *a* (i.e., pigment used as proxy for phytoplankton biomass) is highest. In the WAB region, maximum biomass is generally not detected directly at the surface of the ocean but rather at depths from ~ 5-50 m below the surface (Martin et al. 2010). Surface waters can be dominated by prasinophyte and chlorophyte species whereas pelagic phytoplankton blooms may be dominated by centric diatoms (e.g., *Chaetoceros*) or nanoflagellates (Coupel et al. 2015). Species assemblages and relative abundance varies seasonally and spatially. Larger phytoplankton cells generally dominate where nutrient concentrations are highest.

Nano- and microphytoplankton are the key food sources for zooplankton grazers such as *Calanus* (Forest et al. 2011). Energy transferred from phytoplankton production can be retained within the pelagic food-web if grazed on by consumers or can be transferred to benthic communities by the vertical flux of intact cells or via the sinking of zooplankton fecal pellets. Recent studies have shown the importance of regional processes in determining the sinking export of phytoplankton to the benthos (Juul-Pedersen et al. 2008a, 2010, Sallon et al. 2011). Phytoplankton can be mineralized by microbial processes within surface waters or during the sinking processes (Lapoussière et al. 2011). The transfer of energy from phytoplankton to higher trophic levels is influenced by a variety of factors including the species composition and timing of phytoplankton blooms which impacts the efficiency of the energy transfer to pelagic grazers.

Nano- and microphytoplankton are the key food sources for pelagic zooplankton and forms the energetic basis driving marine food webs. They are the major contributors to primary productivity in the WAB region. These phytoplankton are also sentinel species as they respond first, and quickly to environmental changes.

Ice-associated Algae

Ice algae species are a key component in the ecosystem of the WAB region. Sea-ice algae are present in newly formed ice and persist throughout the dark winter period (Riedel et al. 2007a, Niemi et al. 2011). In the spring when light levels are sufficient, an ice-algal bloom forms in the bottom layers of the sea ice. This bloom represents an early source of carbon for water column grazers (Michel et al. 1996, 2002) and can contribute 25% or more to total Arctic primary production (Legendre et al. 1992, Gosselin et al. 1997). Hundreds of species of ice algae are found in the WAB region, making up a unique and highly diverse assemblage (Rózanska et al. 2009). The ice algal assemblage is responsible for most of the production and food web transfers in the presence of ice until conditions allow for the development of phytoplankton. Ice algae contribute energetically to sub-ice sympagic invertebrate communities, including zooplankton, and are an important high quality food source for benthic communities, especially early in the season before pelagic production increases (Renaud et al. 2007). Studies using a specific ice algal biomarker (IP25) have shown that in the WAB region and elsewhere on Arctic shelves, ice algae constitute an important link and food source for benthic and pelagic communities (Belt et al. 2007). Ice algae have a unique lipid composition and contain essential amino acids for the reproduction of zooplankton grazers (Søreide et al. 2010). In the WAB region, photosynthetically-competent ice algae are exported from the ice (Yamamoto et al. 2014) to the benthos, providing a valuable food source for the benthic community (Juul-Pedersen et al. 2008b), and they elicit a rapid benthic response upon arrival at the sediment surface. There are also potential indirect effects of ice algae productivity as it reaches the benthos, including enhanced burrowing during feeding, and onset of reproductive activities (Renaud et al. 2007). Ice-algae are also part of an active microbial community within the sea ice, being closely associated with bacterial and heterotrophic micro zooplankton (e.g., flagellates) activities through a complex microbial food web.

Sea-ice algae communities in the WAB region are generally dominated by pennate diatoms with over 100 different species of this group occurring (Rózanska et al. 2009). A key pennate diatom species found at the bottom of sea ice is *Nitzschia frigida*. Centric diatoms also occur in the sea ice, and the species *Melosira arctica* can form dense aggregates and long mats beneath the ice, providing a three-dimensional structure for other phytoplankton and invertebrate species.

Ice-associated algal species play a fundamental role as a source of energy for the arctic marine food web. The ice-algae are an important source of essential fatty and amino acids for pivotal zooplankton species (e.g., *Calanus* spp.), supporting key ice-associated fish species such as Arctic Cod in the WAB region. Ice algae are also important contributors of energy fluxes to benthic food webs and stimulate benthic consumers in the WAB region. Ice-associated blooms in the WAB region contribute an important part of overall primary production.

Heterotrophic Microbes

Heterotrophic microbes (bacteria) are ubiquitous in marine ecosystems and they have a key role in controlling organic and inorganic carbon fluxes in the ocean (e.g., CO_2 cycling). They are also important components of pelagic and ice-associated food webs. The microbial food web is often referred to as the “microbial loop”, which includes:

1. the production of dissolved organic material (DOM) by phytoplankton and other organisms;
2. uptake of DOM by heterotrophic bacteria;
3. the consumption of bacteria by microzooplankton (protist grazers).

The material and energy consumed by the microzooplankton may be transferred to larger organisms (e.g., meso and/or macrozooplankton) or may be exported to deep waters or the ocean bottom. However, much of the organic carbon consumed by bacteria or their grazers is respired as carbon dioxide, whereas other organic components are mineralized back to essential nutrients.

In a typical water or sea-ice sample from the WAB region, there are usually 10^5 to 10^6 bacteria per ml of water (Riedel et al. 2007b, Belzile et al. 2008). There are hundreds of different species with diversity indices and ecological strategies (e.g., particle attached cells) differing between coastal and offshore areas (Ortega-Retuerta et al. 2013). The heterotrophic microbes and the functioning of the microbial loop is important to consider because together they can divert energy away from higher trophic levels such that increased ocean productivity (i.e., phytoplankton) may not result in more fish biomass, but rather increased biomass of microbes (Kirchman et al. 2009).

Bacteria play a key role in the uptake and recycling of energy within the marine food web of the WAB region. Their activity impacts the carbon budget of the system and influences energy flow towards higher trophic levels. They are essential for the recycling of essential elements (e.g., nutrients).

Toxin-producing Algae

Specific species of phytoplankton can produce toxins that can be harmful to higher trophic levels, including humans (Lelong et al. 2012, Harðardóttir et al. 2015). Key groups of potentially toxin-producing phytoplankton include saxitoxic dinoflagellates, e.g., *Alexandrium* spp. and *Gymnodinium catenatum*, and the pennate diatom *Pseudo-nitzschia* (Rusz Hansen et al. 2011, Walsh et al. 2011, Tillmann et al. 2014). Some *Pseudo-nitzschia* species can produce domoic acid, a biotoxin that is passed through the food web to key zooplankton species such as *Calanus* spp., shellfish and potentially some fish (Tammilehto et al. 2012). The toxin can cause amnesic shellfish poisoning (ASP) in humans.

Pseudo-nitzschia has been known to produce the biotoxin ASP and is known to exist in arctic seawater and sea ice. The first documented bloom of *Pseudo-nitzschia* (group *Delicatissima*) in the Canadian Beaufort Sea was reported in 2014 in Walker Bay. Scallop samples collected within the vicinity of the bloom were found to contain low levels of domoic acid ($< 1\ \mu g \cdot g^{-1}$) confirming, for the first time, that a *Pseudo-nitzschia* bloom in the Beaufort Sea could produce domoic acid, which is transferred through the food web to shellfish. Further work is required to determine if such a bloom constitutes the designation of a Harmful Algal Bloom (HAB) and the extent (spatially and temporally) to which potentially harmful phytoplankton blooms could occur in the WAB region.

Phytoplankton species capable of producing biotoxins exist in the waters and sea ice of the WAB region. Blooms of such species, with concurrent production of the biotoxins, pose a potential risk to the health of the marine food web and local communities that may harvest shellfish within the vicinity of the bloom.

Detritus

Detritus is organic material, including both living and non-living aggregates (e.g., dead plankton, zooplankton fecal material), that is suspended in the water column or settles to the seafloor. Detritus plays an important role in the passive vertical flux of organic material from the upper water column to the benthos. However, in the Beaufort Sea, rather than being predominantly exported to the benthos, detritus is generally cycled in the upper 100 m of the water column where it provides habitat for bacteria and plays an important role in heterotrophic productivity.

The amount and type of detritus that reaches the benthos or is used higher in the water column is dependent on environmental factors that influence primary production and zooplankton grazing (Forest et al. 2010). The flux of sinking particulate organic carbon (POC) varies on a seasonal basis in the eastern Beaufort Sea (Juul-Pederson et al. 2010). Detritus is also likely exported from shallower to deeper waters within the WAB region and from the Beaufort Sea to the Arctic Ocean (Macdonald et al. 1987).

Detritus may allow material to be cycled in the pelagic rather than being exported to the benthos and is an important habitat-creating feature for bacteria (Morata and Seuthe 2014). Detritus also supplies organic matter to the benthos that is used by different functional groups of benthic invertebrates as well as benthic bacteria.

MACROPHYTES

Macrophytes provide three-dimensional habitat for spawning, nursery, and rearing, and also provide cover for a number of adult fish and invertebrate species, and are considered an important component of the marine ecosystem.

Very few historical records of macrophytes exist for the WAB region. There have been a few reports of localized kelp beds along Herschel Island and in Darnley Bay (Cobb et al. 2008). However, no detailed surveys of these areas have been conducted with the purpose of documenting species or density of occurrence. At the M'Clure Strait and Amundsen Gulf portions of Banks Island, viable unattached communities were found lying on the silt and clay bottoms of calm bays due to both transport by currents and *in situ* growth (Lee 1973). Some of the identified forms included a dwarf *Fucus* species, *Desmarestia aculeata*, *Sphacelaria plumosa*, *Halosaccion ramentaceum*, *Phyllophora truncate*, and *Chaetomorpha melagonium*. Lee (1973) reported that there were three environmental conditions common to the different bays: low temperatures, low salinities, and one or more freshwater inflows. The low salinity was more likely a limiting factor but the low temperature and apparently ample transport of nutrients from land probably contributed to the survival and growth of the unattached populations. Dunbar (1968) has emphasized the problem of nutrient replenishment and its significance over temperature and light in affecting the production of phytoplankton in the Arctic. Nutrient supply seems to be equally as important for the establishment and production of benthic algal communities. The absence of an algal community in an otherwise suitable habitat could be directly related to an inadequate supply of nutrients.

Recent surveys have resulted in new distribution records for macrophytes. In 2015, during the Beaufort Sea Marine Fishes sampling program, macrophytes were collected in trawls from much deeper and broader geographical areas in northern Amundsen Gulf, south of Banks Island than previously reported for this part of the Canadian Arctic (A. Majewski, Fisheries and Oceans Canada, pers. comm.). Monitoring of the marine ecosystem in 2014 and 2015 in Browns Bay and Bennet Point, Darnley Bay, in support of the new Anguniaqvia niqiqyuam Marine Protected Area confirmed the existence of kelp beds (McNicholl et al. 2017). It is likely that other bays within the WAB region that are outside the influence of the Mackenzie River, and which have sufficient nutrients, suitable substrate and light conditions will support kelp beds. The degree to which these beds are utilized by invertebrate or fish species or their importance to these species is unknown, although some marine fish species are preferentially associated with macrophytes.

Macrophytes represent vertical structural habitat for fishes and invertebrates, and are considered as ESSCP due to their habitat-creating and -modifying properties. There are insufficient data to evaluate whether or not these species or communities are rare at the scale of the WAB, although they likely have a patchy distribution due to limited areas with conditions favourable to their growth (i.e., hard substrate with sufficient light and nutrients).

CONCLUSIONS

- A unique list of candidate ESSCP was compiled for the WAB region. A brief summary of current information, including science and traditional ecological knowledge where available, was provided to support the identification and assessment of ESSCP.
- Modification of the national guidance criteria (DFO 2006) was necessary to assess species, functional groups, and community properties in the Arctic. The new criteria developed for the WAB region are potentially applicable to other Arctic regions. The assessment included a category of uncertainty to highlight knowledge gaps and indicate confidence.
- The process to identify and assess ESSCP was challenging. In particular, the availability of information was not evenly distributed across the WAB region. For example, eco-units 10–17 (Figure 3) are infrequently visited for the purposes of research and community use, and little is known about the taxa residing within those areas. The examination of information gaps will provide a means of prioritizing future scientific research efforts in these eco-units. Similarly, information was not evenly distributed across trophic levels (e.g., marine mammals vs. detritus).
- Connectivity, both within and between Arctic biogeographic regions, is a key property that influences biological diversity, biomass productivity, and therefore the ecological significance of species and functional groups. Connectivity among different regions in the Arctic Ocean and adjacent seas can, depending on water depth, be highly variable. Within the WAB region, the Mackenzie River system represents a significant feature that modifies the biota and fundamental processes in the Beaufort Shelf. Connectivity was considered within the criteria for distribution (e.g., migratory species), energy transfers (e.g., pelagic-benthic coupling), and key habitat associations (e.g., sea ice).
- The criteria to identify ESSCP also addressed the importance of habitat creating or modifying species, supporting the policy to identify and protect Sensitive/Significant Benthic Areas.
- The identification of ESSCP should be considered a living process, with periodic re-evaluations as new information becomes available. Therefore, directed surveys, monitoring, and/or research would benefit future assessments.
- ESSCP fill an important gap in the existing tools that support an ecosystem-based approach to oceans management. The tool highlights species and processes that are poorly represented by spatial information layers (e.g., Ecologically and Biologically Significant Areas), are not necessarily part of commercial, recreational or Aboriginal fisheries (e.g., Integrated Fisheries Management Plans), and are not listed as a species at risk (e.g., SARA Recovery Plan), but nonetheless are extremely important to ecosystem structure and function.

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APPENDIX 1. LIST OF SEABIRD SPECIES PRESENT IN MARINE HABITATS OF THE WESTERN ARCTIC BIOGEOGRAPHIC REGION

*Excludes sandpipers, plovers and geese

Common Name	**Species Name**	**Comments**	**Assessed**
Greater Scaup	*Aythya marila*	-	-
Common Eider	*Somateria mollissima*	• Staging during the spring migration, leave by mid-June to either nest inland or farther east in central Arctic Canada (Dickson and Gilchrist 2002), although some stay to nest (e.g., McKinley Bay) • 15 m water depth • Benthic invertebrates	√
King Eider	*Somateria spectabilis*	• Staging during the spring migration, leave by mid-June to either nest inland or farther east in central Arctic Canada (Dickson and Gilchrist 2002), although some stay to nest (e.g., McKinley Bay) • 15 m water depth • Benthic invertebrates	√
White-winged Scoter	*Melanitta deglandi*	• Staging during the spring migration, leave by mid-June	-
Surf Scoter	*Melanitta perspicillata*	• Staging during the spring migration, leave by mid-June	-
Long-tailed Duck	*Clangula hyemalis*	• Staging during the spring migration, leave by mid-June to either nest inland or farther east in central Arctic Canada (Dickson and Gilchrist 2002) • Moulting seaducks feed on inverts in sheltered areas and suggests productive nearshore areas that support high densities of benthic fauna • > 15 m water depth	√
Red-breasted Merganser	*Mergus serrator*	-	-

Common Name	**Species Name**	**Comments**	**Assessed**
Red-necked Phalarope	*Phalaropus lobatus*	-	-
Red Phalarope	*Phalaropus fulicarius*	-	√
Red-throated Loon	*Gavia stellata*	• Staging during the spring migration, leave by mid-June • Require fish to feed their young	-
Pacific Loon	*Gavia pacifica*	• Staging during the spring migration, leave by mid-June • Less reliant on the ocean to feed its young since they typically nest at lakes	-
Yellow-billed Loon	*Gavia adamsii*	• Staging during the spring migration, leave by mid-June • Nest inland on lakes	-
Parasitic Jaeger	*Stercorarius parasiticus*	• Offshore • General Predator	-
Long-tailed Jaeger	*Stercorarius longicaudus*	• Offshore • General Predator	-
Black-legged Kittiwake	*Rissa tridactyla*	• Few small colonies • Nearshore • General Predator	-
Ivory Gull	*Pagophila eburnea*	• Tagging data indicates they are north of the Western Arctic Biogeographic Region • Species at Risk	-
Sabine’s Gull	*Xema sabini*	• Insect invertebrates found in fresh- or brackish water (Day et al. 2001) • Nearshore	-
Ross’s Gull	*Rhodostethia rosea*	• Nesting is in central Arctic Archipelago • Species at Risk	-

Common Name	**Species Name**	**Comments**	**Assessed**
Glaucous Gull	*Larus hyperboreus*	• Staging during the spring migration • Insects, fish and the eggs and chicks of other birds	√
Thayer’s Gull	*Larus thayeri*	• Nearshore	-
Arctic Tern	*Sterna paradisaea*	• Rely on freshwater and saltwater ponds • Nearshore	-
Thick-billed Murre	*Uria lomvia*	• One small colonies • Offshore • Piscivore	-
Black Guillemot	*Cepphus grylle*	• Two small colonies • Offshore • Piscivore	-