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Agenda item 4.1.2
Background Document

Bibliography for PAME Arctic Fact Sheet #2 - Food Security

Note on Sources: *The information below is presented from a range of sources, with a best effort to use the exact language from the original sources where possible. Sources are characterized as:*

Arctic Council Approved Reports and Summaries
Arctic Council Technical Reports
Traditional and Local Knowledge (including Workshop Reports)
Books, Other Technical Reports, and Review Articles

1. Food Security Overview

- Rapid social and environmental change in the Arctic – including climate change – affect the health and wellbeing of millions of humans and animals that call the Arctic home. To manage these risks effectively, one needs to look at the ecosystem as a whole – for a healthy environment, healthy humans and healthy animals. The core principle of One Health is to recognize that ecosystem linkages and interdependencies require a holistic approach to health issues.[1]
- Food security can be an indicator of the overall state of natural ecosystem health, at least in places where people are still heavily dependent on local, natural food sources. For these people, serious degradation of ecosystems immediately impacts their ability to access, harvest and prepare traditional foods.[2]
- The Arctic's Indigenous peoples continue traditional ways of life, including hunting, fishing, and gathering of marine resources, in addition to extensive travel on the ocean in the summer and on sea ice in the winter[3].
- Along the coasts and on islands, the marine environment plays a central role in food, housing, settlement patterns, and cultural practices and boundaries[3].
- Numerous criteria are used to identify food security. One assessment of Inuit food systems recognizes four main components: availability (sufficient quantities available consistently), accessibility (enough resources to obtain food), quality (adequate nutritional and cultural value), and use (required knowledge of how to utilize food)[4].
    - Climate change is affecting the availability of food as a result of shifts in biodiversity and the ranges of animal and plant species important to communities[4]. (*key message*)
- In another framework, Inuit food security is characterized by environmental health and is made up of six interconnecting dimensions:
    1. Availability

2. Inuit Culture
3. Decision-Making Power and Management
4. Health and Wellness
5. Stability
6. Accessibility[5].

- The repercussions of climate change have drastic effects on the four pillars of food security: availability, accessibility, utilization and food systems stability[6].
- Hunting, herding, fishing, and gathering continue to be of major significance to the indigenous peoples of the Arctic in providing food, social relationships and cultural identity[6–8].
- Traditional foods currently account for a smaller portion of Indigenous diets than in the past, but biodiversity and a healthy natural environment remain integral to the well-being of Arctic inhabitants[9].
- The impact of climate change is not always uniform and negative[10].
    - A study done in Naujaat and Kugaaruk in Nunavut (Canada) reported that climate change observed in the two communities was community specific[10].
- Recent studies indicate elevated rates of household food insecurity in many places in the Arctic[6].
    - For example, in Nunavut, Canada, nearly 70% of the Inuit preschoolers and in Chukotka, Russia, 45% of the indigenous people have been found hungry during recent years (Egelund et al. 2010)[6].

2. What climate factors are affecting food security?

- Climate change presents risks to food and water security through changes in access to hunting areas and the distribution range of traditional food sources, contamination of drinking water supplies (including by harmful algal species), changes in traditional food preservation techniques, and potential increases in food contaminants[11].
- The changes underway in the Arctic have altered fundamental characteristics of Arctic ecosystems and in some cases are causing the loss of entire habitats, with consequences for people who rely on and benefit from Arctic ecosystems[12].
- The changes underway are leading to range expansions of some species, contractions of others, loss of habitats, and a wide range of other impacts on the Arctic's interconnected ecosystems and the services they provide[12].
- It is important to note, however, that adaptation has its limits, both in the rate and the amplitude of change that can be accommodated[13].
- Traditional knowledge holders identified climate change as a contributing factor affecting food security citing: unpredictable weather patterns affecting the ability to successfully hunt; changes in ice levels affecting the ability to access wildlife; longer travel times to hunt and increased cost; and potential effects on species movements and migrations[14].
    - These all can potentially affect the ability of Inuit residents to successfully harvest country foods which, in turn, can affect mental and physical well-being[14].

Sea Ice Change

- Sea ice extent has shown decreasing trends in all months and virtually all regions of the Arctic (*Very likely*)[15,16]. Arctic sea ice extent will continue to decline in all months of the year (*High confidence*)[15].
- Sea ice is becoming more mobile as its extent and thickness decrease, increasing ice-related hazards[11].
- Some northern communities have found it harder to obtain wild sources of food due to the shorter snow cover season, which affects travel to hunting grounds as well as animal habitat. The thinning of sea ice and the lengthening melt season also affect access to resources[11].
- Sea ice provides important habitat for many species and is vital to the Arctic marine food web[9].
- Changes in the timing of the ice season have been reported to impact the frequency and timing of hunting activities with implications for food security and nutritional health among communities that rely significantly on subsistence[17].
    - Changing ice is a safety concern for hunters. Inuit hunters shared concern that some young hunters may not be able to adequately judge the quality of the ice[18].
    - It has long been reported that successful hunting depends on the hunters' understanding and knowledge of the ice[19].
- Sea ice has gone through a transition from mostly thick multi-year sea ice to younger and thinner seasonal sea ice[12].
- Declining coastal sea ice results in greater coastal erosion due to the effects of warmer air and water combined with increasing storm, wave, and tidal activity due to climate change[12].
- The thinning and loss of sea ice has many impacts on Arctic life, from promoting the growth of marine phytoplankton and creating more habitat for openwater species to loss of ice-associated algal species and disrupting the feeding platforms and life cycles of seals, polar bears and, in some areas, walrus[11].
- The locations of some communities [in the Baffin Bay/Davis Strait Region] with respect to animal migration patterns and access to hunting areas will exacerbate impacts related to long transportation distances and ice-dependent access routes[4].
- Baffin Bay/Davis Strait region hosts a number of sea ice-associated marine mammals year-round[4].
    - These include: bowhead whales, beluga whales, narwhals, polar bears, hooded seals, harp seals, walrus, ringed seals, and bearded seals[4].
    - Many of these species are harvested by Indigenous peoples living in the region[4].
- Food resources are being lost for many species in Arctic marine environments[20].
    - Many species have to travel further and expend more energy to feed, leading to concerns about individual health and potential effects at the population level[20].
    - Many of these cases are due to reduction of sea ice[20].
- Current trends indicate that species reliant on sea ice will experience range reductions as sea ice retreat occurs earlier and the open water season is prolonged[20].
    - Changes in sea ice conditions are probably linked to declines in the abundance of hooded seals, lower reproduction rates of Northwest Atlantic harp seals,

reduced body condition of Barents Sea harp seals, and changes in prey composition of bearded seals[20].

- While the climate change literature has focused primarily on potentially negative climate impacts, the effects on hunters are mixed[4].
    - For open water-dependent species (e.g., orcas), hunter access may increase due to a wider distribution of the animals, longer ice-free periods, and faster motorboats[4]. (*key message)*
    - However, Several Qikiqtaaluk communities have attributed an inability for hunters to access seals during the open water season to the presence of orcas[4].
- In the Barents region, ice-associated species will be negatively affected by the loss of sea ice, while open water species may benefit from the warming[21]. (*key messages*)
- In the Inuvialuit Settlement Region, Nunavut, and Nunavik (Canada), it has been observed that ice thickness is decreasing and the length of the ice-free season is extending as a result of warmer winter temperatures[10].
    - [Studies suggest that] this has increased the risks associated with hunting and reduced access by hunters to ice-based wildlife such as ringed seal, narwhal, and polar bear[10].
- Inuit and coastal communities around the Barents Sea are concerned about the potential impacts of increased shipping activities associated with reduced sea ice, which may impact and the marine environment they depend on for food, spirituality, etc as there are existing cases of shipping disrupting marine mammal migration[6,22]. (*summarized*)

Changes in Species Composition & Distribution due to Warming

- "The two most important parts of our food security were the availability of the animals and the hunter's ability to hunt. Over the past hundred years, this has changed. … Pollution and climate change have had an impact on wildlife." -Maggie Emudluk, Vice-President, Kativik Regional Government, Canada (Forward, V)[23]

- Sea surface temperatures are increasing over much of the Arctic Ocean, largely due to increased absorption of solar radiation as a result of sea ice loss (*Virtually certain*)[15].

- Changes to migration routes, population size and new disease incidences impact the overall health of northern food species[10]. (*key findings*)
- Some Indigenous communities have noted a change in walrus stomach contents, with more open water fishes and fewer clams, indicating that the distribution and availability of benthic resource species are changing in some areas[20].
- Some benefits of climate change to communities have been noted, including the expansion of open waters and new fisheries opportunities and an increasing abundance and availability of some marine mammals[13].
    - These benefits may be short-lived, depending on future changes to ecosystems as a result of continuing climate change[13].
    - In the short term, Inuit hunters have been successful with bountiful hunts, which means plenty of healthy food for the community. Between July and September 2014, Inuit in Ulukhaktok (Canada) harvested 32 beluga, its largest recorded catch of beluga[24]. (*Inuit Perspective*)

        - The likelihood that climate change is a factor in beluga moving north is strong but has yet to be substantiated with empirical evidence[24]. (*Inuit Perspective*)
    - Boreal-temperate species (e.g., harbour seals, harbour porpoises, sei whales) are already benefiting from climate change in northern areas of the Barents Sea[21].
- Some Arctic species are shifting their ranges northwards to seek more favorable conditions as the Arctic warms. These movements pose unknown consequences for Arctic species and their interactions, such as predation and competition[20].
    - The northward expansion of capelin has led to changes in seabird diet in northern Hudson Bay. It may also affect marine mammals[20].
    - Belugas in Hudson Bay (Canada) varied timing of migration in response to variations in temperatures. These migrations may affect the ability of people to find and use these resources[20].
    - Warming can have surprising and contradictory effects on species e.g. rising temperatures in the Chukchi Sea have been associated with an increase in nutritious copepods with high fat content[20].
    - Increasing numbers of southern species are moving into Arctic waters[20].
    - Potential changes to the availability of Arctic cod are of great importance to local communities, and there is already evidence of its distribution shifting northwards as the Arctic Ocean warms[25].
    - A general concern with respect to Arctic warming is the replacement of Arctic species of zooplankton and fish by less energy-rich southern species. These species may not allow sufficient accumulation of body reserves for capital breeding animals like seals[21]
- For example, in the Barents area:
    - The warming climate will cause many boreal species to shift northwards over the next few decades and within the Arctic some species will retreat or decrease in number. The incidence of invasive species, pests and diseases will increase[21]. (*key messages*)
    - Higher phytoplankton productivity in previously ice-covered waters has been observed, as well as northward shifts in boreal zooplankton, fish, benthos, seabirds and marine mammals at the expense of Arctic species[21].
        - Less ice algae, as well as reduced occurrence of other ice biota, represents a major qualitative change in the ecosystem in the northern Barents Sea[21].
        - An expansion of boreal zooplankton (e.g. *C. finmarchicus*) and a reduction in Arctic zooplankton (e.g. *C. glacialis*) have also been observed. Krill are expected to expand their distribution and increase in the Barents Sea[21].
        - The impacts of continued warming on capelin, herring, and polar cod are a key issue due to their importance in the ecosystem.The complex biological interactions involved make it difficult to develop predictions[21].
        - Projected warming may lead to a permanently reduced polar cod stock in the Barents Sea with consequences for the ecology of the northern and southeastern Barents Sea[21].

        - Some reports suggest since 2007, the size of the polar cod stock has decreased, apparently driven by poor recruitment related to warming and associated reductions in sea ice and the area of Arctic Water[21].
        - Expansion of Atlantic cod into the northern Barents Sea has also played a role, leading to increased spatial overlap between the two species and increased predation pressure from Atlantic cod on polar cod[21].
    - The restructuring of Indigenous cultures in response to changes in species composition and the availability of subsistence food resources appears to be inevitable[24]. (*Key messages)*
- Increasing numbers and diversity of southern species are moving into Arctic waters[20].
    - In some cases, southern species may outcompete and prey on Arctic species, or offer a less nutritious food source for Arctic species[20].
    - The expansion of southern species into northern regions may impact important food species and subsistence hunting (Humphries et al., 2004)[10].
    - The distribution of Atlantic cod is expanding in the Atlantic Arctic and increasing predation pressure on the polar cod, an important nutrient-rich prey fish, important for other fishes, seabirds and marine mammals, especially seals[20].
- Sami fishermen are concerned with changes in locations and abundance of cod, saithe, flounder, and halibut[26].
    - They are also concerned about the marine habitat and biodiversity, such as spawning grounds, kelp beds and sea-bottom conditions, and climatic aspects like wind, currents, and ice conditions[26].

Ocean Acidification

- Some of the fastest rates of acidification are occurring in the Arctic, due mainly to the higher capacity of colder water to absorb CO2, but also due to dilution by river run-off and ice melt, and the inflow of naturally low pH waters from the Pacific[25].
- Increased atmospheric carbon dioxide concentrations are leading to acidification of ocean waters worldwide, especially in colder Arctic waters that can absorb more carbon dioxide[9].
    - Arctic marine waters are experiencing widespread and rapid ocean acidification. The primary driver of ocean acidification is uptake of carbon dioxide emitted to the atmosphere by human activities[27].
- Ecosystem changes associated with ocean acidification may affect the livelihoods of Arctic peoples[27].
    - Marine species harvested by northern coastal communities include species likely to be affected by ocean acidification. Most indigenous groups harvest a range of organisms and may be able to shift to a greater reliance on unaffected species. Changing harvests might affect some seasonal or cultural practices[27].
- Ocean acidification poses a potential risk to Arctic food systems, cultures, and livelihoods[27].
    - Clams and scallops are harvested species that are extremely likely to be directly affected by ocean acidification[27].

    - Crab, shrimp, and Norway lobster/langoustine are harvested species that are very likely to be affected by ocean acidification[27].
    - The Atlantic wolffish is a harvested species that is at high risk of indirect (prey-related) effects because its diet includes animals deemed to be extremely or highly likely to experience acidification impacts[27].
    - Harvested species which feed on a mixture of directly impacted and non-impacted prey are at medium risk from indirect (prey-related) effects are:
        - Fish: rough dab; redfish; Arctic char; haddock; Atlantic cod; Greenland halibut; mackerel; salmon; blue whiting; herring; blue ling; muksun; Siberian sturgeon; tusk; capelin[27].
        - Crab[27]
        - Marine mammals: bearded, harbor, and hooded seals; walrus; narwhal; harp and ringed seals; bowhead whales; fur seals; pilot whales; sea lions[27].
        - Seabirds: Arctic tern, ducks, sea gulls, eider, dovekie, thick-billed murre, black guillemot[27].
- Arctic ecosystems are characterized by low biodiversity and simple food webs. This structure is more susceptible to disruption than are more complex arrangements[27].
- Future ocean acidification,in combination with other environmental stressors, particularly ocean warming, is likely to be sufficient to cause changes in Arctic organisms and ecosystems to an extent that will affect communities that depend upon them[25].
- The future effects of ocean acidification will not be uniform across the region, nor can they be reliably predicted[25].
    - Ocean acidification greatly increases the risk of fishery collapse in Northeast Atlantic cod, which otherwise has recently benefited from warming waters[25].
    - In the Baffin Bay/Davis Strait region, ocean water is expected to become more acidic as a result of increased melt run-off[4].
    - Freshening and warming of the Baffin Bay surface layer is expected to reduce convection depth in the winter and increase stability during ice-free months[13].
    - The continental shelves of the Beaufort and Chukchi Sea are especially vulnerable to ocean acidification compared with the central Arctic Ocean Basin, because of the low pH water from the Pacific and dilution by high freshwater inflows.[2]
- Ocean acidification will have direct and indirect effects on Arctic marine life. Laboratory experiments and field observations show a wide range of direct and indirect effects of acidification, some negative and some positive[25].
    - While some marine organisms will respond positively to new conditions associated with ocean acidification, others will be disadvantaged, possibly to the point of local extinction[25].
- Changes to lower-level organisms such as bivalves or mollusks could have cascading effects through the food chain and affect predators such as Pacific walrus and bearded seals[25].
- Many of the marine organisms likely to be most affected by ocean acidification, such as mollusks, are important to both highly productive commercial fisheries and to traditional subsistence ways of life[25,27].

    - Marine mammals, important to the culture, diets and livelihoods of Arctic Indigenous peoples and other Arctic residents could also be indirectly affected through changing food availability[27].
- Climate change and ocean acidification are likely to cause significant changes in species composition in the western Canadian Arctic, potentially leading to changes in ecosystem structure and in Inuit subsistence fisheries[25].
    - Arctic cod is a key forage species for the food that supports the Western Canadian Indigenous communities[25].
    - The abundance of Arctic cod could decline while other forage species, such as capelin and sandlance, are likely to migrate northwards into the region[25].
    - The decrease in Arctic cod abundance at lower latitudes as they shift northward could affect its predators including culturally important species hunted by Inuit, such as ringed seals and beluga[25].
        - However, if species that Indigenous people depend upon for food are able to adapt to alternative prey, climate change impacts could be positive in terms of food security[25].
- Ocean acidification is not likely to affect seabirds and marine mammals directly. The effects they might experience would be indirect, through food-web linkages[25,27].

3. Availability

Key Subsistence Species

- The decline of sea ice in the Arctic appears to be linked to a loss of biodiversity in sea ice habitats, although observations also show that some species are expanding their ranges or are present during a longer portion of the year[12].
- The number and type of species harvested, as well as the methods by which animals are hunted, vary by country, region, and community[19].
    - Understanding these regional differences is necessary in order to determine potential variations in the consequences of climate change for different groups and is a starting point for considering specific adaptation needs of each community[19].
- Key subsistence mammal species include cetaceans (bowhead whale, gray whale and beluga) and pinnipeds (walruses, sea lions, and four species of seal)[24].
    - The Pacific walrus is a critical species for people of Chukotka (Russia)[24]. (*Chukotka Perspective)*
        - The supply of protein and fat during the long polar winter depends on the success of the autumn walrus hunt[24].
        - The coastal inhabitants of Chukotka are highly vulnerable to any temporal or spatial changes in the migration of marine mammals[24].
- Context on marine mammal harvesting from a review article:
    - Greenland:
        - Greenlandic hunting communities hunt a number of pinniped species (including bearded, hooded, ringed, harp, and harbor seals, and walrus), polar bears, and whales, including fin and minke whales, beluga, narwhal, and a number of dolphin species[19].

        - In general, marine mammals are central to the Greenlandic way of life and are important contributors to the livelihoods, cultural identity, and socioeconomic well-being of Greenlanders[19].
        - Greenlandic hunters travel on ice, water, or land to catch desired animals[19].
    - Arctic Canada:
        - Communities in Nunavut and the Northwest Territories harvest a number of seal species, including ringed, bearded, harp, and small numbers of harbor and hooded seals[19].
        - Polar bears, beluga, narwhal, and occasionally bowhead whale are also important species in Arctic Canada[19].
    - Chukotka, Russian Federation
        - Chukchi and Yup'iit peoples of northeastern Russia engage in some small-scale, sustainable, traditional whaling and sealing activities[19].
        - The main targeted species are gray, bowhead, and beluga whales, walrus, and bearded, ringed, spotted, and ribbon seals[19].
        - The main method of seal hunting is netting, from the ice and in open water[19].
    - Alaska, USA
        - Inupiat and St. Lawrence Island Yup'iik harvest bowhead whales, beluga whales, bearded seals, ringed seals, and walrus[19].
- Important fish species include Arctic char, pink salmon, Arctic cod, other cods, flounders, and gobies[24].
    - In northern Norway, rural and indigenous coastal communities are dependent on the marine ecosystem and its ecosystem services, where the cod fishery is the single most important to small-scale and indigenous fishermen[26].
    - Salmon is an important resource for Sami and local populations on the coasts of Fennoscandia[28].
    - Many fish species are significant to the diets and cultures of Canadian First Nations, including Lake Trout, Char, Inconnu (Conny), White Fish, Pike, Burbot, and Salmon[7].
    - Arctic char is a culturally, nutritionally, and economically important species to northern communities.[35]
        - Community members from Arctic Bay, Clyde River, Grise Fiord, Iqaluit, Kimmirut, Pangnirtung, Pond Inlet, Qikiqtarjuaq and Resolute report harvesting Arctic char as a main staple of their diet year-round.[35]
- The Nenets (spanning the Nenets Autonomous Okrug, Arkhangelsk Oblast, Komi Republic and Murmansk Oblast in Russia) eat lots of fish, including white salmon and muksun[6].
    - Fishing accounts for most of their income, especially during the summer months when meat cannot be stored[6].
    - During the winter, Nenets fish through ice holes[6].
- The Pomors (shores of the White Sea) fish primarily for herring, navaga, and salmon[6].

- There are no other sources of existence or nourishment other than fish for the indigenous peoples in Kovran and other coastal villages[29].
- Sea squirts and other marine invertebrates (e.g., crab, shrimp, sea urchins and starfish, small octopus, mussels, and whelks) and seaweed are important in the daily diets of the Inuit Eskimo and coastal Chukchi people (U.S./Russia)[24].
    - Geese and ducks, as well as large sandpipers, are also important foods[24].

4. Accessibility

Hunting & Harvest

- Climate change is likely to alter patterns of subsistence use, which are already dynamic in nature[3]. (summarized)
- In the context of subsistence hunting, changes in temperature, seasonal patterns, sea ice and wind dynamics, and weather variability and extremes have already exacerbated risks associated with hunting and traveling, and have compromised travel routes to hunting and fishing areas. This has resulted in an increase in climate-related accidents while traveling on the land, water, and ice, often associated with thinning and earlier break-up of sea ice and more unpredictable weather. For example, hunters report that they are increasingly faced with changing sea ice conditions in the autumn, winter, and spring. Some areas of sea ice, over which hunters are accustomed to travel, are no longer stable, and in some instances the ice has not formed[24]. (*Inuit Perspective)*
- Serious degradation of ecosystems can immediately impact the ability of local peoples to harvest and prepare traditional foods[2].
- The environmental changes occurring in the Arctic as a result of climate change include changes in weather (precipitation, snow cover, fog), as well as sea-ice loss, which appear to be contributing to changes in the migration patterns and population health of wildlife, along with the introduction of new and invasive species. These changes are impacting the availability, quality, and accessibility of traditional/country food subsistence species[10].
- Climate change has implications for migration timing, population health, quality of meat and fur, and availability of some species of wildlife important for subsistence[24]. (*Inuit Perspective).*
    - A participant in a 2017 Eskimo Walrus Commission Focus Group Meeting noted, in 2017, all animals were available slightly earlier than expected[30].
        - The focus group report expressed frustration that there did not appear to be an effective way to change the regulatory seasons to accommodate the shifting availability and accessibility of resources in a timely manner[30].
- Access to traditional foods is being affected by climate change, with thinner ice, later ice freeze-up, earlier ice break-up, more variable snowfall, unpredictable weather, warmer temperatures, and more frequent and intense storms documented across the Baffin Bay/Davis Strait region[4]. (*key message)*
    - [Many studies suggest that] these changes are disrupting the semipermanent ice and snow-based trails used to access hunting and fishing areas and affecting the safety of using boats in the open water[4].

    - In the Bering-Chukchi-Beaufort region, hunters have reported that Autumn open water conditions have become more common and are less in line with longstanding traditional skill sets and patterns[24].
- Fuel economy, sea ice variability, ground stability, temperature changes, wildlife health, and contaminants have been identified as major sources of variation in subsistence harvests[5].
- Inuit communities have expressed concern that increasingly unpredictable weather patterns affect hunting and harvesting activities. Many have provided examples of changing weather conditions not aligning with traditional harvesting times[31].
    - For example, community members have noted that it is important to harvest salmon when the weather is conducive to drying the meat and before flies have arrived. Recently, there has been an increase in precipitation during a time that was once known to be dry - requiring people to adapt to the time of harvesting[31].
- Climate change affects the availability and the accessibility and safety of hunting areas[24].
    - In one year, four Alaska communities declared harvest disasters because they were unable to access walrus due to sea ice conditions[31].
    - Communities have reported that the spring hunt of walrus in Qaanaaq (northwest Greenland) used to be mainly over the sea ice at the edge of the North Water Polynya. However, with the reduction of sea ice, hunters are increasingly using skiffs to hunt walruses resting on ice floes[4,32].
    - Some communities have reported that accessibility to food sources has decreased due to erosion (inability to access or loss of hunting camps and grounds), late ice freeze-up, early ice breakup, change in movement of ice, and unsafe weather conditions.[31]
- For harvesting expeditions to be viable, [many studies suggest that] a well-developed understanding of ice conditions, weather patterns, and migratory routes of animals is required. Transmission of traditional environmental knowledge [may be] impacted by new and unreliable weather patterns and shifting environmental conditions, reinforcing reduced participation in hunting among youth[10].
- The effects of warming on extreme weather are hard to predict. It is unclear whether these changes will lead to more or fewer so-called synoptic storms in the Arctic, hazardous mid-latitude storms that bring high winds and waves, and which can disrupt transport and threaten infrastructure and human life[33].
- For coastal communities, changing coastal sea ice regimes, river runoff, and coastal erosion can impact community provisioning – for example, by blocking food and fuel shipments. In remote areas, imported food is limited in supply and is extremely expensive, creating greater reliance on subsistence hunting and fishing[24].
- In large measure, food insecurity can be attributed to reduced consumption of traditional foods because of the move away from hunting, fishing, and gathering[24].
- Reduced hunting and fishing yields as a consequence of climate change may severely affect the material and generational well-being of hunting households[7].

Changing Uses and Potential Impacts

- In addition to the changes in the marine environment that are affecting food security, the decline of sea ice makes way for new economic activities, particularly for shipping and resource extraction[12].
- With the retreat of ice cover, more mineral resources may be revealed. In addition, the seasonal window for exploration and drilling activities (i.e. the ice-free period) will increase in duration[4]. Previously inaccessible areas will open for increased and easier shipping due to the reduced need for icebreakers[4].
- Less sea ice in the Baffin Bay/Davis Strait region is extending the navigable season for shipping, creating opportunities for new shipping routes, increasing accessibility for larger fishing and cruise ships, and increasing the viability of northern ports[13].
- The potentially intensive future development of extractive industries in the region would increase the risk of cumulative impacts on hunted species. Currently, there is concern for cumulative impacts on some species (e.g., polar bear, narwhal, and thick-billed murre), related to hunting, climate change, oil pollution, seismic activity, and contaminants[4]. (*key message)*
- Oil and gas activities, mining, tourism, shipping, fisheries, economic development, and pollutants are just some of the other stressors faced by the Arctic today. Many of these factors interact with each other[11].
- The biggest concern related to oil and gas activities in the Arctic remains a catastrophic oil spill in the marine environment[34].
    - Oil spills and disturbances related to shipping or the construction and operation of shore-based facilities may affect marine subsistence hunting and fishing[3].
    - A recent dissertation, based on a year of fieldwork in the Alaskan coastal communities of Chenega and Tatitlek, on the shores of Prince William Sound, has examined the human dimensions of the Exxon Valdez disaster (Connon, 2013). Altogether, some 15 native Alutiiq villages along the coastline experienced some degree of oil pollution at their village beaches, lands, and waters, including in their traditional harvesting areas. The long-term impacts of the oil spill continue to affect the lives and subsistence economy of the community residents (Connon, 2013)[4].
- Increased shipping activity, if not regulated properly, can potentially have serious consequences for the Arctic environment and for the Indigenous peoples who live in the region and rely on the environment for subsistence and livelihoods. The possibility of an oil spill is a major concern for the fishing and hunting sector, including local Inuit who are especially concerned about the disruption of culturally important marine species. Impacts from shipping are potentially more hazardous in the Arctic than at lower latitudes due to the special adaptations of Arctic species and due to the low temperatures and the presence of ice, which hamper the degradation and removal of pollutants[4]. The associated noise and pollution will also add to stresses faced by ecosystems in the region[13].

5. Effects/Consequences

Food Storage and Processing

- Climate change may threaten the traditional food storage method of underground chambers cut into permafrost[24].
- [Several publications suggest that] because traditional foods are often transported and stored outdoors using traditional practices – and are also aged to make speciality and highly prized foods – rising temperatures may also increase the risk of food-borne disease[4].
    - Inuit communities are concerned about potential health impacts associated with new ways of storing food. A shift from traditional means of fermentation in wooden containers or the skin of an animal to fermentation in plastic containers may have been linked to outbreaks of botulism in the community[22].
- Ice cellars, which are cut into permafrost to keep food frozen in the ground, can play an important social role for some Indigenous communities, as they are used to store food for village feasts and family caches[22].
    - Inuit communities have expressed concern that the loss of permafrost and melting of ice cellars impact the communities' ability to keep food frozen, and may require them to find new ways of storing food[22].
    - Communities report that with the increase in rainy weather, people are finding meat becomes moldy before it can dry. This requires people to find alternative ways to dry fish like: bringing it inside, using fans, or using dehydrators[35].
- In one Inuit community, a decision was made not to harvest beluga because the animal could not be processed fast enough in the high temperatures[31].
- Inupiaq communities have pointed to the importance of considering the right weather conditions needed to dry fish in determining how much fish can be dried. If weather becomes too warm or wet, fish will not be properly preserved and there is an increased likelihood of bacteria build up on the fish[36].
- Inuit communities expressed concern that warmer temperatures have also changed the process of rendering and storing dipping oil from seals. There is greater concern that bacteria will grow during the aging process due to changes and timing of the weather[37].

Health

- Food security has been, and will likely continue to be, a key socio-economic concern of Arctic communities, as it has been identified as one of the major determinants of human health outcomes among Indigenous Peoples[5].
    - Traditional knowledge holders emphasize the importance of linkages between health, food security, and quality of life[14].
- Communities in the Baffin Bay/Davis Strait region (Canada/Greenland) have been characterized as having dual food systems composed of both traditional and store foods[4].
    - The traditional diet [has been noted to be] very important to the population both culturally and financially, in addition to being of importance to the provision of sufficient nutrients[4].
- The quality of food can be affected by environmental conditions[4].
    - Rising temperatures may also increase the risk of food-borne disease. Sensitivity to diseases is increased by the consumption of raw sea-mammal meat[4].

    - Research has found that climate change may lead to increased bioaccumulation of contaminants in the food chain[4].
- Despite the well-documented influx of imported foods, traditional foods remain an important part of the diets among the northern communities because of their high source of nutrients[6].
    - In addition to their contribution to total energy intakes, country foods are important sources of several key nutrients such as protein, vitamin A (derived primarily from marine mammal liver and fats), vitamin D, iron, zinc, potassium, phosphorus, selenium and omega-3 fatty acids. Also, many country foods provide protection against many diseases that are more prevalent among southern populations[23].
        - The Qikiqtani Inuit Association has noted that narwhal and Beluga maktak are very important sources of vitamin C intake[14].
- Community-driven reports have suggested that people who are food insecure are more susceptible to a range of physical and psychological issues, including, but not limited to: malnutrition, chronic health problems (obesity, anemia, cardiovascular disease, diabetes, stress, and child developmental issues), and mental health problems including depression and social exclusion[14].

Cultural Practices

- The value of traditional food is interlinked with self and cultural-identity[35].
- Arctic Indigenous peoples' uniqueness as people with cultures based on harvesting marine mammals, hunting, and fishing is at risk because climate change is likely to deprive them of access to their traditional food resources[8].
    - These activities can define a sense of family community and reinforce and celebrate the relationships between them and their surrounding natural environment upon which they depend[6].
    - Traditional harvesting in Nunavut is worth approximately $40million annually[14].
- The Arctic has extensive, valuable cultural sites and practices along nearly its entire coastline[3].
- Animals not only provide meat for food and fur, but skin and bones for clothing, tools, games, and art[14].
- Seals are critical to Inuit survival and culture. Seals have traditionally supplied food, oil for heat, skins for clothing and building materials, and medicines. Seals continue to be a critical source of food and clothing material for boots, coats, and mittens[14].
- Traditional foods currently account for a smaller portion of indigenous diets than in the past, but biodiversity and a healthy natural environment remain integral to the wellbeing of Arctic inhabitants. They provide not only food, but the everyday context and basis for social identity, cultural survival and spiritual life[9].
- Obtaining traditional foods has been characterized as a family oriented activity that connects people to their environment, builds bridges between generations through the passing of knowledge, encourages respect for life and the environment, and teaches how to monitor and what questions to ask of the environment[35].

    - Through harvesting and preparing foods many core values are taught, such as sharing, responsibility, and the inter-generational importance of our foods for future generations – passing on Indigenous Knowledge. Participants also commented on the role that marine animals and the harvesting plays in bringing communities together and helps to create strong bonds between community members[30].
- Participation in marine mammal harvesting among Arctic Indigenous groups is not only important for economic purposes, but is a crucial factor in the maintenance of cultural identity and social relationships[19].
    - The cultural, social, and economic significance of marine mammals varies across cultures and nations[19].
    - Seal harvesting plays a central role in Inuit culture, as it sustains traditional sharing customs, maintains knowledge of natural resources and the environment, and ensures the transfer of skills and values from elders to youth[19].
- In villages across northern Alaska and St Lawrence Island, whaling is at the center of Indigenous cultures, particularly the hunting of the bowhead whale[3].
    - Any vessel activity at times and places where bowhead whales migrate or feed is likely to disturb traditional hunting and have significant cultural impacts[3].
    - However, potential impacts are not restricted to bowhead whale hunting. Walrus, beluga, seals, salmon, herring and other fisheries in northern Alaska and along the Bering Sea coast and the Aleutian Islands provide critical resources to coastal peoples and in many cases result in long-distance travel along the coast or into the open ocean[3].
- Opportunities for younger generations to learn and transmit Indigenous knowledge about wildlife and harvesting are increasingly challenged by environmental changes[10]. (*key findings*)
    - Changing environmental conditions have made it more difficult for Inuit elders to share their predictive knowledge of the weather, which has contributed to growing uncertainty among young harvesters to access the land, sea, and ice (Holen, 2009)[7].
    - A significant amount of the time that the Inuit spend hunting is presently devoted to educating younger generations about weather, ice conditions, and the biology of marine species[19].
        - There is concern that the loss of traditional hunting grounds due to climate change will affect the transmission of Inuit culture to future generations[19].
        - Rapid changes due to climate change including changes in ice conditions, wildlife and fish migration patterns, and the type, timing, and location of hunt have compromised the reliability of Inuit Qaujimajatuqangit[14].

6. Shifting Management Towards Resilience (Retitle)

- Climate change magnifies threats to Arctic Indigenous peoples' hunting and fishing activities that exist in large part from resource management regimes and local, regional, and global economic market situationsg[8].

    - These existing threats reduce their ability to adapt and cope with climate variability and change[8].
    - Members of the Eskimo Walrus Commission have commented that management practices and regulations must be revised to remain current and relevant to the changing climate[30].
- Historically, Sami fishermen have had to employ a variety of strategies to adapt to changing environments and maintain the resilience of their social-ecological systems[26].
    - Political participation and financial and political support mechanisms have been integral to successful adaptation of coastal Sami communities to changing social-ecological conditions[26].
- Partnerships with Indigeous knowledge holders can provide a more robust understanding of the state of the changing ecosystem as compared to a traditional ecological knowledge reference point of a past ecosystem state[26].
    - Traditional ecological knowledge is defined as the knowledge, practice, and beliefs about dynamic relationships of living beings and the environment, a knowledge based on experience, which has evolved in adaptive processes between humans and nature and has been handed down from generation to generation[7].
    - Indigenous knowledge and observations provide an important source of information about climate change[38].
    - The Inuit hold specialized knowledge regarding the ocean and sea ice environment, but their knowledge is often absent in discussions of the effects of climate change on marine mammal harvesting[19].
    - One case study suggested that the inclusion of Inuit perspectives on climate change will enhance the development of credible indicators and measures of climate change and its effects on marine mammal harvesting activities. It will also greatly facilitate the identification and development of effective local adaptation strategies[39].
    - Indigenous communities have noted that Indigenous knowledge holders are on the land during all seasons and understand the changes that are occurring[40].
- In the Arctic, traditional ecological knowledge about animal migrations, ice patterns, vegetation and weather is used during hunting and harvesting, and may now supplement and enrich scientific data on climate change impacts[7].
    - Combining traditional and scientific knowledge about nature is an important part of understanding the resilience capacity of ecological and social systems in the Arctic, enhancing the potential for sustainable development and self-sufficiency[7].
- Case Study: The Pikialasorsuaq and the People of the Ice Bridge
        - Pikialasorsuaq means “great upwelling” and for thousands of years, this North Water polyna shared by Canada and Greenland has sustained Inuit subsistence culture. Today it is at risk from the impacts of climate change[41].
        - Inuit Qaujimajatuqangit (Inuit way of doing things: the past, present, and future knowledge, experience, and values of Inuit Society) identifies the Pikialasorsuaq (North Water Polyna) as a critical resource and habitat for

key marine species on which Inuit communities depend. Pikialasorsuaq has been an important hunting ground, providing Inuit with food and resources for making clothes and tools, and thus, deemed invaluable for cultural and spiritual well-being.

- In 2016, The Inuit Circumpolar Council created the Pikialasorsuaq Commission to develop recommendations consistent with existing Inuit governance for confronting climate change impacts[41].
- The Commission found a desire to rebuild a collective Inuit management regime between Indingeous communities in Canada and Greenland to monitor the living resources and the health of communities dependent on those resources in the Pikialasorsuaq region[41].
- Inuit want to ensure the future viability of this important area and are interested and invested in monitoring and managing changes in the region[41].

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