CAPARDUS - Capacity-building in Arctic standardization development

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EXECUTIVE SUMMARY

The Arctic has warmed almost four times faster than the rest of the Earth over the past 43 years. This is causing rapid and severe changes in the oceans and cryosphere with cascading ecological effects along the food webs. These changes may pose a threat or an opportunity to the welfare of Greenlandic hunters and fishers who depend on these resources for food and income.

Synthesising knowledge about expected developments and plausible future scenarios will enable the Greenlandic Self-Rule Government, relevant sectors of industry and communities to address these changes proactively. Combining a systematic literature review, forecasts of catch data (where feasible and meaningful), focus group discussions with local hunter's associations and interviews with scientific experts, we strive to develop plausible scenarios for future developments and otherwise relevant scenarios whose welfare implications can be explored in subsequent analysis in the project FutureArcticLives. However, in this report, we limit the work to selected species, include only focus group discussions with hunter's organisations in East (Ittoqortoormiit and Tasiilaq) and North West Greenland (Upernavik and Ilulissat) and do not yet incorporate interviews with scientific experts. This report is an exploitable result meant as a tool for developing future scenarios for simulation analysis in the FutureArcticLives project. Hence, this volume is the first iteration in the process and will be updated and expanded with data from additional locations and input from the scientific experts. Hence, the future scenarios are preliminary.

The literature review shows a mixed picture of how Arctic species populations will evolve. For instance, some polar bear sub-populations appear to increase while others are declining. The bowhead whale population shows improved body condition and increasing abundance, likely

due to increased primary production and access to new ice-free foraging areas. Many seabird populations are increasing, and their ranges are shifting northwards.

One of the most pronounced climate-driven Arctic biodiversity changes is a process called the "borealization" of Arctic communities. Borealization describes an influx of boreal species pushing Arctic species further northward. For example, boreal fish species now entering the Arctic are typically larger mobile generalists with high fecundity, slow life history strategies, and a preference for pelagic resources that are out-competing bottom-dwelling Arctic specialist benthivores. This process leads to declines of resident ice-associated and benthic fish species populations, including Arctic cod (*Boreogadus saida*), sculpins (Family: *Cottidae*), and Zoarcids (Family: *Zoarcidae*) and growing populations of pelagic fish species such as capelin (*Mallotus villosus*), sand lance (*Ammodytes* spp.), Atlantic cod (*Gadus morhua*) and haddock (*Melanogrammus aeglefinus*). In regions including East Greenland, clear indications of taxonomic and functional borealization are emerging as Arctic marine ecosystems rapidly shift towards higher latitudes.

Moreover, several boreal cetaceans are expanding their ranges into new ice-free habitats. This includies rorquals such as minke whales (*Balaenoptera acutorostrata*), fin whales (*B. physalus*), blue whales (*B. musculus*), humpback whales (*Megaptera novaeangliae*), and to a lesser extent sei whales (*B. borealis*)), and toothed whales such as harbor porpoise (*Phocoena phocoena*), white-beaked dolphin (*Lagenorhynchus albirostris*), white-sided dolphin (*L. acutus*), long-finned pilot whale (*Globicephala melas*), killer whale (*Orcinus orca*), sperm whale (*Physeter microcephalus*), and bottlenose dolphin (*Hyperoodon ampullatus*). Many of these species are formidable, highly mobile predators occupying upper trophic levels in the food web. They profoundly influence species communities, biodiversity-function relationships, and behavioural dynamics, which cascade down to lower trophic levels in the Arctic's food webs.

Many Arctic seabirds, such as thick-billed Murre (*Uria lomvia*) and black-legged kittiwake (*Rissa tridactyla*), are sensitive to rapid changes in sea surface temperature in both directions, which can lead to massive population declines. These negative population trends are thought to reflect changes in the underlying food web and its variability in response to climate change. In general, populations of piscivorous and planktivorous surface-feeding seabirds, including kittiwakes and murres, are more sensitive to climate change than diving planktivorous birds. Many gulls, for example, such as the glaucous gull (*Larus hyperboreus*), the Icelandic gull (*Larus glaucoides*), and the great black-backed gull (*Larus marinus*), show positive population trends. Non-Arctic species that are poorly adapted to foraging in Arctic waters, such as the great cormorant (*Phalacrocorax carbo*), whose plumage is only partially waterproof, and the mallard (*Anas platyrhynchos*), are expanding their range into Greenland. Geese such as Canada goose (*Branta canadensis*), Greenland barnacle goose (*Branta leucopsis*), and pink-footed goose (*Anser brachyrhynchus*) are benefiting greatly from the warmer climate, reduced snow cover, and early spring. Their numbers have increased by a factor of two to six, and they continue to spread to new breeding areas.

These research-based observations and predictions suggest a scenario likely to become more prevalent in the future Arctic ecosystem. The range of the nine mammal species native to the Arctic, the Bowhead whale (*Balaena mysticetus*), narwhal (*Monodon monoceros*), beluga (*Delphinapterus leucas*), walrus (*Odobenus rosmarus*), polar bear (*Ursus maritimus*), and the sea-ice associated seals, bearded seal (*Erignathus barbatus*), ringed seal (*Pusa hispida*), hooded seal (*Cystophora cristata*) and harp seal (*Pagophilus groenlandicus*) will shift northward following their preferred temperature ranges and available sea ice habitat. In general, the process of borealization in Arctic communities is expected to intensify if ocean warming continues, accompanied by an increase in extreme events. This acceleration is partially attributed to the behavioural responses of individual species that will impact the structure of the food web and species interactions.

South-East Greenland has already experienced a regime shift in oceanographic and ecological conditions due to the occurrence of a crucial tipping element, the absence of summer sea ice, since 2003. As invading boreal species have a competitive advantage due to their broader physiological and trophic range, most relevant studies predict obligate Arctic species abundances to decrease. Ultimately, these changes will result in a profound transformation of the Arctic marine ecosystem, characterized by subarctic conditions, subarctic species, and corresponding interactions.

Consequently, there will be a decline in both taxonomic and functional diversity, which will diminish the ecosystem's adaptive capacity. Reduced adaptive capacity may have detrimental effects on the resilience of the ecosystem to further environmental changes and extraction, including fisheries. According to some studies, we are already witnessing the consequences of these shifts, with observed collapses in narwhal stocks in East Greenland and unexplained declines in mackerel stocks.

Communities in East and North West Greenland are cognizant of climate change and have observed some detrimental impacts (increased unpredictability of travelling on sea ice). In contrast, other changes offer future opportunities for improved access to certain species and the possibility of more intensive fishery. However, living in a highly fluctuating and unpredictable environment, climate change is often seen as something that one adapts to and less of a problem than poor infrastructure and the management regulations imposed by the Self-Rule Government and international organisations. Hence, the scenarios proposed to be explored by focus groups centre more around these aspects than climate change.

Proposed changes include establishing local trading and processing facilities for various products, repealing the ban on international trade of polar bear products, larger quotas on some species and banning recreational hunters from hunting certain species to increase local trade options. The welfare consequences of these and other scenarios will be explored in the project FutureArcticLives.

Acknowledgements

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1. Introduction

1.1. Need for synthesis

The Arctic has warmed nearly four times faster than the rest of the globe during the past 43 years (Rantanen et al., 2022). Warming has led to several changes in the atmosphere, ocean and cryosphere, which triggers ecological changes in the food web (Emblemsvåg et al., 2022a; Heide-Jørgensen et al., 2022; IPCC, 2021a), making the Artic a rapidly changing and highly variable environment. Proactively addressing these challenges to ensure the welfare of Greenlandic communities that depend on game and fish resources and selecting appropriate management strategies requires insights into plausible future developments. This report aims to provide an overview of the likely development of populations of selected species important to the welfare of hunter and coastal fisher families in Greenland by evaluating plausible future scenarios with likely climate change-driven impacts as the primary focus.

Hunting and small-scale fishing are crucial to ensure food security, maintaining health and generating income for families, particularly in Greenland's many smaller settlements. Historically, people in Greenland adapted to changing circumstances by shifting their reliance to alternative species when populations declined, or management regulations became stricter. However, the effectiveness of such adaptive strategies is now constrained by climate-induced changes. Climate change, conservation initiatives, or a combination of both are leading to reduced yields from hunting and fishing activities. Consequently, this can have severe repercussions on the economic well-being and overall quality of life for hunting households, even though these impacts may go unnoticed in national income statistics.

However, synthesis of the scientific and management literature evaluating and predicting population trends is needed to facilitate planning and holistic management interventions. Similarly, dialogue with hunters and fishers is needed to obtain their perspective on the development of various populations and the perceived barriers to adapting to these challenges and opportunities. From these insights, plausible future scenarios can be developed for individual species that will subsequently be used to explore the welfare consequences for the hunter and coastal fisher families throughout Greenland in the project FutureArcticLives.

Hence, this report constitutes the first step in a range of activities and will focus on synthesising scientific studies about population trends and species-specific vulnerability to climate change and the outcome of workshops conducted with hunters' organisations.

1.2. Climate Change in the Arctic

Human influence has warmed the atmosphere, ocean and land, leading to widespread and rapid changes in the atmosphere, ocean, cryosphere and biosphere (IPCC, 2021a). The Arctic has warmed nearly four times faster than the rest of the globe during the past 43 years (since 1979), a phenomenon known as Arctic or polar amplification (Rantanen et al., 2022). Some areas in the Eurasian sector of the Arctic Ocean have warmed even up to seven times as fast as the rest of the globe (Rantanen et al., 2022). This phenomenon is considered driven by multiple factors, including enhanced oceanic heating and ice-albedo feedback due to diminishing sea ice, Planck feedback, lapse-rate feedback, near-surface air temperature inversion, cloud feedback, ocean heat transport and meridional atmospheric moisture transport (Rantanen et al., 2022).

Although the reasons for this rapid warming are not yet fully understood, the effects on physical and chemical conditions, cryosphere and biodiversity, and human populations in the Arctic have been increasingly evident for at least three decades (Hoegh-Guldberg et al., 2018; Nichols et al., 2013; Schlegel et al., 2023). For example, a robust linear relationship exists between the increased atmospheric CO^2 and the decreased sea-ice extent (Schlegel et al., 2023). The total volume of Arctic sea ice in September has decreased by 75% since 1979, and there has been a continuous regime shift from multi-year to seasonal sea ice with reduced extent and thickness (Overland et al., 2019). Also, the extent of snow, especially in the spring, has decreased in recent decades (Overland et al., 2019).

Extreme warm temperature anomalies are becoming more frequent, such as nearly double (+6 °C) those of previous record highs in the winters of 2016 and 2018 (Overland et al., 2019) and temperature anomalies of between 15 to 40 C in 2022 (Lu, 2022). Changes in seawater temperature are not always linear nor uniform over time and space (Schlegel et al., 2023). In Greenland, the annual coastal temperature increased at a rate of 0.23 °C decade^{-1}, especially in the southeastern (0.70 °C decade^{-1}) and northern (0.42 °C decade^{-1}) regions during 1952–2017 (Jiang et al., 2020). During 2013–2017, this temperature rise accelerated, particularly in the northeastern and northern regions of the island (Jiang et al., 2020). The open water season in Greenland has lengthened by about ten days per decade since the 1970s (Stern and Laidre, 2016). In South Greenland, a significant cooling trend in Sea Surface Temperature (SST) was observed from 1958 to 2001 (-1.22 °C in 44 years), while the rest of the world became warmer (+0.55 °C in 44 years), but after 2001, air and seawater temperatures in South Greenland started to increase (Jiang et al., 2020; Schlegel et al., 2023).

In many areas of the Arctic, a process called "Atlantification" is observed, where warmer and more nutrient-rich Atlantic water is taking up an increasing proportion of the water column compared to Arctic water (Schlegel et al., 2023). For example, the south of the Denmark Strait in East Greenland likely went through a process of Atlantification, with a stronger influence of Atlantic water in the Irminger Current (Emblemsvåg et al., 2022a). This process has caused a reduction in sea ice, less stratification, higher surface salinity and more mixing in the water column, increasing temperatures by 0.2-0.5°C (bottom) and SST in the Irminger Current by 1°C since 1990 (Emblemsvåg et al., 2022a). In the coastal areas of Southeast Greenland, the amount of drift- ice exported from the Fram Strait and transported by the East Greenland current has decreased significantly over the past two decades, and summer sea ice has been almost nonexistent since 2003 (Heide-Jørgensen et al., 2022).

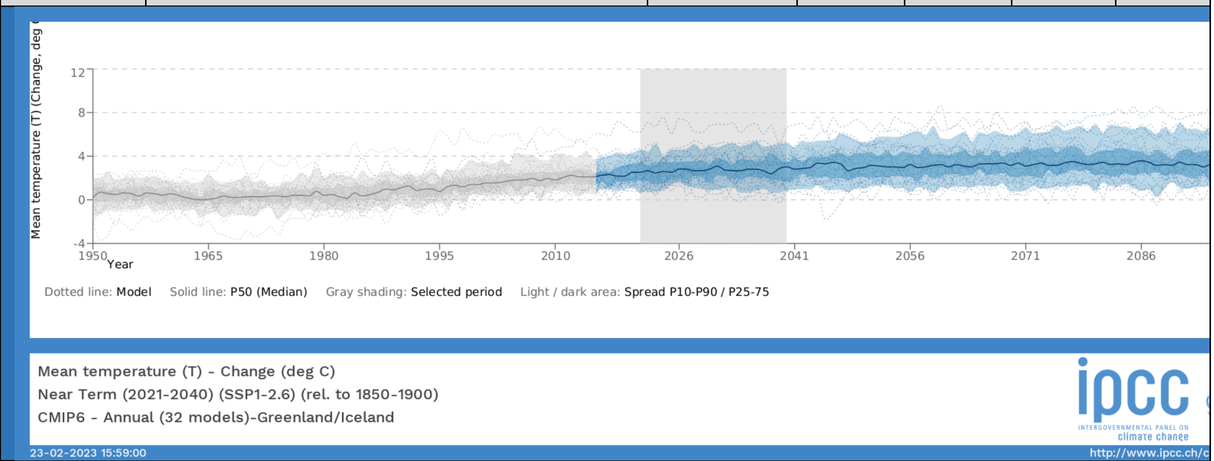
Near-term (2021-2040) projections for the most optimistic emission scenario (SSP1-2.6) for Greenland and the adjacent sea suggest an increase of the Mean temperature (T) by 2,8 C, a further decline of sea ice concentration by -8.1 % and an increase in SST by 1,1 C in the period until 2040 (Table 1.1-Table 1.3). The values indicate high deviations from the worst-case scenario (SSP5-8.5), which is the most likely scenario at present (Overland et al., 2019), and for the long-term projections (2081-2100) (Table 1.1-1.3 Source: IPCC, 2021b). In the second half of the 21st century, projections based on pathways with different greenhouse gas concentrations (Representative Concentration Pathways, RCPs) diverge increasingly from each other (Table 1.1-1.3) (IPCC, 2021b; Overland et al., 2019). For the Arctic, a loss of important cryospheric features, such as sea ice, snow, permafrost and land ice, is projected for the next half century and strongly depends on the emissions scenario, especially after 2040 (Overland et al., 2019).

Depending on the emission scenario and projections, a seasonally ice-free Arctic Ocean is expected near the end of the century or within the following decades (Overland et al., 2019). Projected changes in Arctic snow cover show a 10–20% duration decrease over most of the

Arctic by mid-century and an increase in precipitation and a larger fraction of the precipitation as rain rather than snow (AMAP, 2017). Towards the end of the 21st century (2091-2100), Arctic precipitation rates are expected to increase by 50-60%, and the snowfall fraction will decrease dramatically, although Greenland may continue to experience snowfall fractions above 80% (Bintanja and Andry, 2017).

Given current temperatures, Arctic glaciers will lose an additional ~35% of their volume (Overland et al., 2019). Eighty-two percent of Greenland is currently covered by an ice sheet (Jiang et al., 2020). However, early-warning signals indicate that the western Greenland Ice Sheet is reaching a tipping point, where melting reduces ice sheet height, exposing the ice sheet surface to warmer temperatures and further accelerating melting (Boers and Rypdal, 2021). Recent reviews suggest that Arctic climate change may be occurring at a rate that is greater than that projected by global climate models (AMAP, 2017). What is obvious is that the Arctic is changing, multifaceted and possibly irreversibly, which will further strain Arctic ecosystems and social systems, with probable global impacts (AMAP, 2017; IPCC, 2018; Overland et al., 2019).

Table 1.1 Near Term (2021-2040), Medium Term (2041-2060), and Long Term (2081-2100) projections for the change in the Mean temperature (T) (Change deg C) in Greenland and Iceland for the most optimistic (SSP1-2.6), and the worst case emission scenario (SSP5-8.5). Source: (IPCC, 2021b)

<table>
<tr><th></th><th>Scenario</th><th>Period</th><th>Median</th><th>P25</th><th>P75</th><th>P10</th><th>P90</th></tr>
<tr><td rowspan="8">Mean temperature (T) Change deg C</td><td rowspan="3">SSP1-2.6</td><td>Near Term (2021-2040)</td><td>2.8</td><td>1.9</td><td>3.4</td><td>1.5</td><td>4.0</td></tr>
<tr><td>Medium Term (2041-2060)</td><td>3.0</td><td>2.2</td><td>4.2</td><td>1.6</td><td>4.8</td></tr>
<tr><td>Long Term (2081-2100)</td><td>3.2</td><td>2.4</td><td>4.4</td><td>1.5</td><td>6.0</td></tr>
<tr><td colspan="7">
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<tr><td rowspan="3">SSP5-8.5</td><td>Near Term (2021-2040)</td><td>2.8</td><td>2.2</td><td>3.5</td><td>1.7</td><td>4.4</td></tr>
<tr><td>Medium Term (2041-2060)</td><td>4.3</td><td>3.3</td><td>5.1</td><td>2.8</td><td>6.1</td></tr>
<tr><td>Long Term (2081-2100)</td><td>7.5</td><td>6.2</td><td>9.2</td><td>5.2</td><td>10.4</td></tr>
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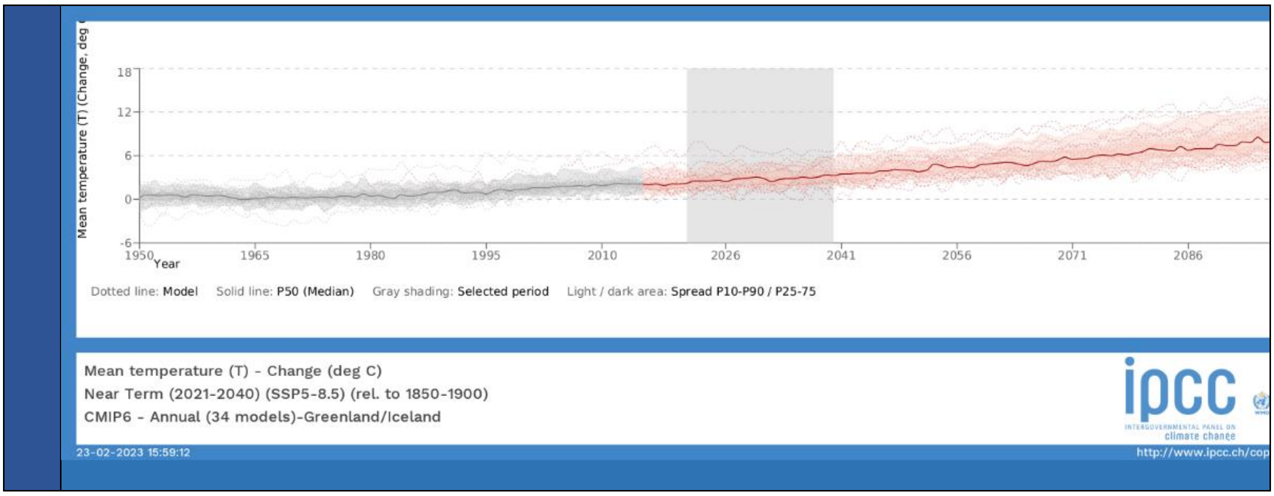
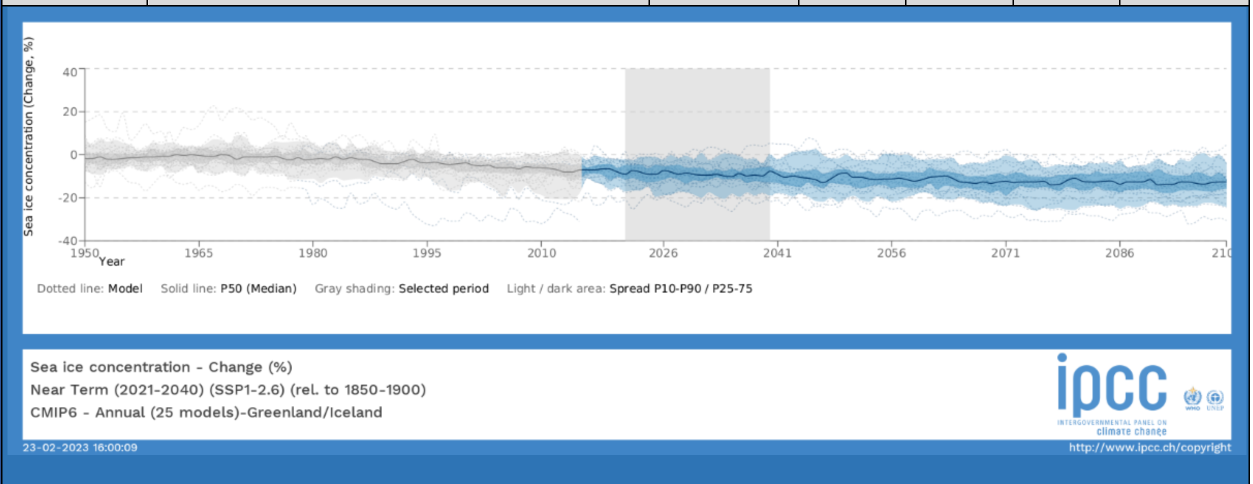


Table 1.2 Near Term (2021-2040), Medium Term (2041-2060), and Long Term (2081-2100) projections for the change in Sea ice concentration (Change %) in Greenland and Iceland for the most optimistic (SSP1-2.6), and the worst case emission scenario (SSP5-8.5). Source: (IPCC, 2021b)

	Scenario	Period	Median	P25	P75	P10	P90
Sea ice concentration Change %	SSP1-2.6	Near Term (2021-2040)	-8.1	-11.1	-6.9	-13.6	-4.0
		Medium Term (2041-2060)	-10.5	-13.3	-8.4	-16.5	-2.6
		Long Term (2081-2100)	-11.8	-16.2	-9.4	-20.4	-4.9



	Scenario	Period	Median	P25	P75	P10	P90
	SSP5-8.5	Near Term (2021-2040)	-9.7	-11.5	-7.3	-16.4	-4.1
		Medium Term (2041-2060)	-14.0	-16.8	-11.1	-23.2	-6.2
		Long Term (2081-2100)	-24.6	-30.9	-20.9	-37.4	-18.7

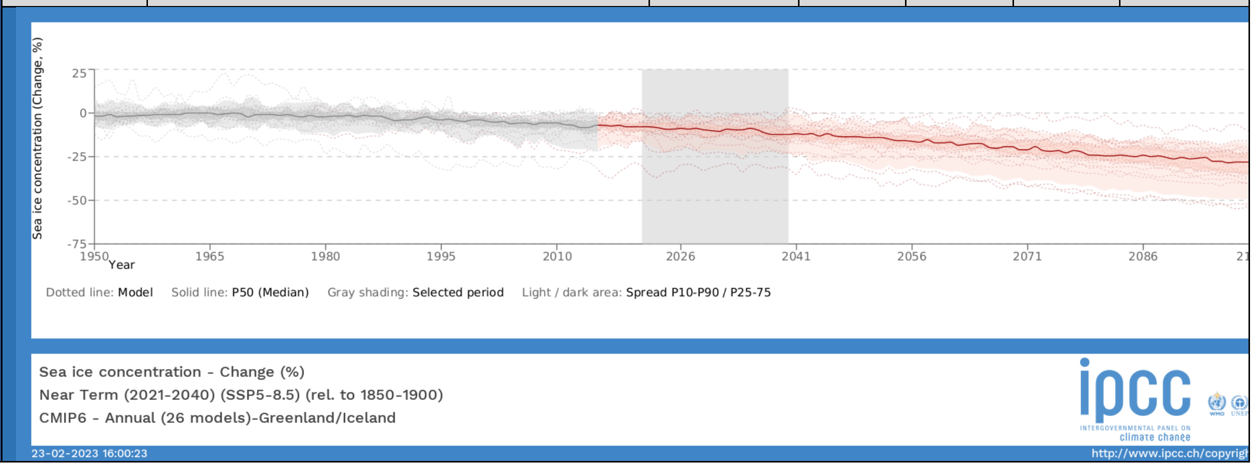
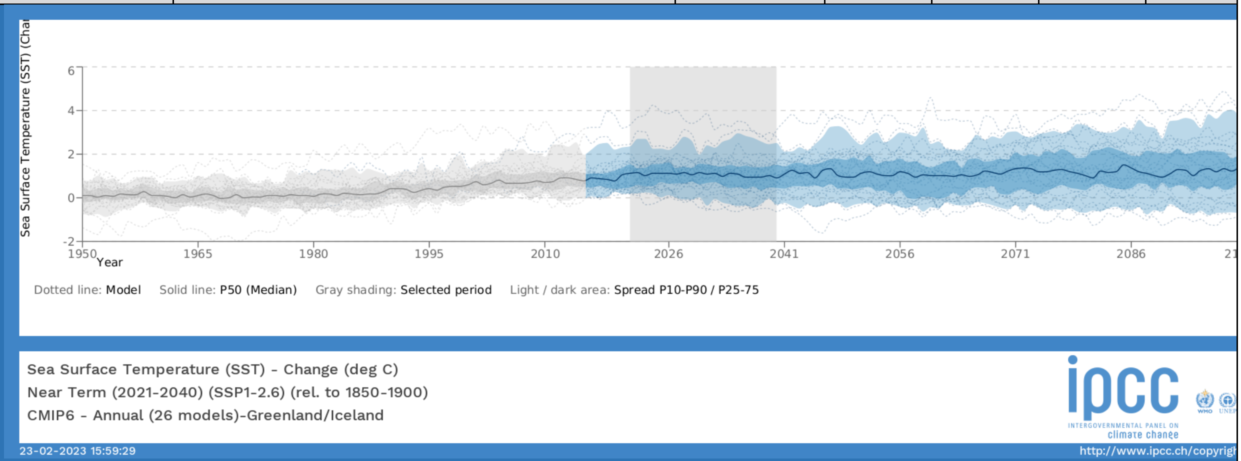
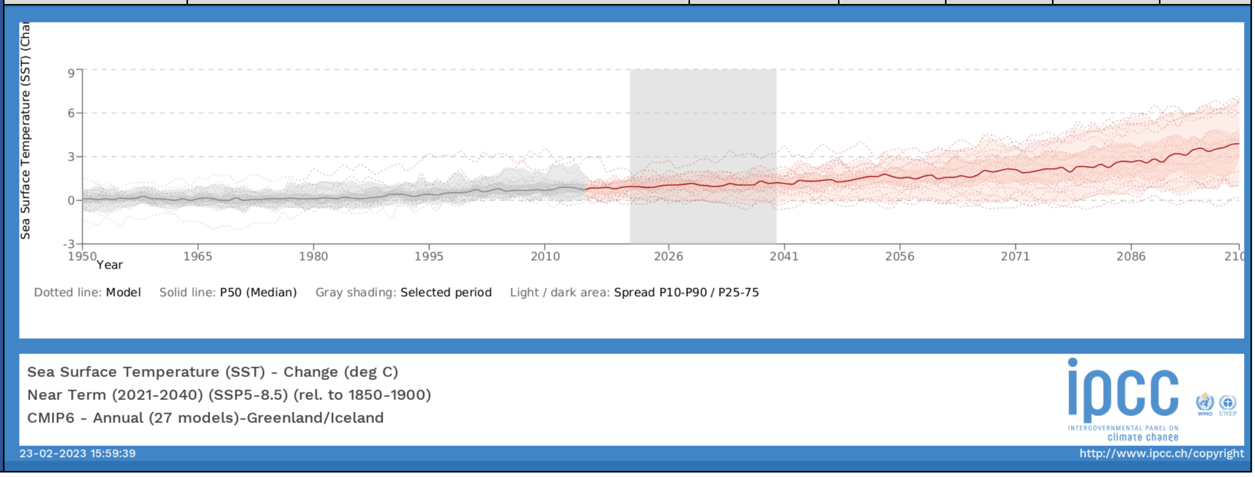


Table 1.3 Near Term (2021-2040), Medium Term (2041-2060), and Long Term (2081-2100) projections for the change in Sea Surface Temperature (SST) (Change deg C) in Greenland and Iceland for the most optimistic (SSP1-2.6) and the worst case emission scenario (SSP5-8.5). Source: (IPCC, 2021b)

	Scenario	Period	Median	P25	P75	P10	P90
Sea Surface Temperature (SST) Change deg C	SSP1-2.6	Near Term (2021-2040)	1.2	0.7	1.4	0.2	1.6
		Medium Term (2041-2060)	1.1	0.5	1.6	-0.1	2.2
		Long Term (2081-2100)	1.3	0.6	2.0	-0.4	2.6



	Scenario	Period	Median	P25	P75	P10	P90
Sea Surface Temperature (SST) Change deg C	SSP5-8.5	Near Term (2021-2040)	1.1	0.9	1.4	0.2	1.6
		Medium Term (2041-2060)	1.5	1.1	1.9	0.3	2.4
		Long Term (2081-2100)	3.0	1.5	4.1	0.9	5.6



1.3. Species Vulnerability to Climate Change

Climate change vulnerability differs between species, subspecies, populations, subpopulations and individuals. Generally, vulnerability to climate change is viewed as 'the degree to which a system is susceptible to and unable to cope with the adverse effects of climate change' (IPCC, 2007). Even though definitions of 'species' vulnerability' vary, it is generally described as a function of intrinsic and extrinsic factors (Foden et al., 2019; IPCC, 2007; Pacifici et al., 2015). According to the Intergovernmental Panel on Climate Change (IPCC), it is 'a function of the character, magnitude and rate of climate change to which the system is exposed, its sensitivity and its adaptive capacity' (IPCC, 2007) (Fig.2.1).

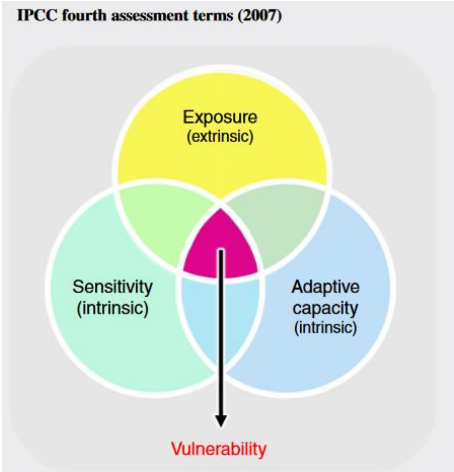


Figure 1.1 Definition of climate vulnerability, Source: Foden et al., 2019.

Exposure is defined here as the magnitude of climatic variation in the areas occupied by the species. Sensitivity is determined by specie intrinsic traits and is the ability to tolerate climatic variations. Adaptability is the inherent capacity of species to adjust to those changes (Foden et al., 2019; IPCC, 2007; Pacifici et al., 2015). Variations in exposure, sensitivity, and adaptive capacity between regions, species and populations will likely result in differential impacts of climate change on both ecological and socio-economic factors across Greenland.

A pan-Arctic assessment identified 98 footprints of climate change on Arctic marine ecosystems described in the scientific literature between 2011 and 2021. Primary footprints, directly caused by climate drivers, including range shifts, changes in production and stock size, community changes, phenological changes, physiological changes, and behavioural changes, were observed in primary production, zooplankton, benthos, fish, birds, and mammals across various Arctic regions (Brandt et al., 2023). Moreover, secondary footprints, caused by primary footprints in a cascading-impact chain, such as diet changes, changes in competition structure and changes in pathogen load, were reported for several regions of the Arctic for fish, benthos birds and mammals (Brandt et al., 2023).

Our assessment focuses mainly on primary footprints, as they more clearly affect hunting and fishing success and, thus, welfare. Nevertheless, some secondary footprints, such as a shift in prey species, are also relevant since they can change the abundance of target species.

1.4. Ecological Changes

The ecology of most Arctic life is directly linked to sea ice, and changes in the cryosphere affect the ecosystem at all levels. The response of an ecosystem can be gradual, evolving through the food web, or rapid, with abrupt behavioural responses that change the distribution of species (Emblemsvåg et al., 2022b). In south-east Greenland and the Pacific Arctic in the northern Bering and Chukchi seas, the Arctic ecosystem is undergoing rapid changes and regime shifts (Emblemsvåg et al., 2022b, 2022a; Heide-Jørgensen et al., 2022; Huntington et al., 2020).

A critical process in the Artic for functions ranging from nutrient cycling to energy transfer in food webs is benthic-pelagic coupling, which describes the exchange of energy, mass, or nutrients between benthic and pelagic habitats through sedimentation (Griffiths et al., 2017). In spring, the return of sunlight initiates snowmelt, the growth of sea ice algae and a phytoplankton bloom that usually exceeds the uptake capacity of pelagic consumers, resulting in carbon falling to the seafloor supporting rich benthic communities (Huntington et al., 2020). Frozen algae released from brine channels into the water column during ice growth and melting serves as a food source for lower trophic levels from winter into spring (Hoover et al., 2013a).

With decreasing annual amounts of ice and earlier annual melting, fewer ice algae are exported to the benthos (Hoover et al., 2013a). As a result, the benthic biomass decreases along with the fish, mammals and invertebrates reliant on benthic food sources (Hoover et al., 2013a). Ultimately, this favours a phytoplankton and zooplankton-dominated system over the ice-algal benthic ecosystem typical of the Arctic (Hoover et al., 2013a). In the southeastern Chukchi Sea, for example, changes in historically strong benthic-pelagic coupling have led to a decline of overall epibenthic biomass by an order of magnitude between 2004 to 2017 (Huntington et al., 2020).

Moreover, climate change is affecting primary production. In spring, the sea-ice break-up spurs a productive phytoplankton bloom, and its timing, together with ocean temperatures, determines phytoplankton species composition, carbon export to the benthos and food quality for zooplankton (Huntington et al., 2020). An earlier sea ice melt can result in earlier stratification and, thereby, earlier phytoplankton spring bloom and can lead to a change in production depending on the subsequent mixing that brings nutrients to the surface layers (Møller and Nielsen, 2020). Warm-water anomalies and declines in sea ice cover in West Greenland have resulted in a dominance of boreal warm-water zooplankton communities, smaller subarctic/boreal species and an increase in lipid-poor zooplankton communities rather than Arctic cold-water zooplankton communities with larger Arctic species (Møller and Nielsen, 2020). These changes towards lower-lipid zooplankton can reduce the over-winter survival of fish species such as salmon and Arctic cod (Huntington et al., 2020).

One of the most pronounced climate-driven changes in biodiversity in the Arctic is the process called "borealization" of Arctic communities (Emblemsvåg et al., 2022a). Borealization describes an influx of boreal species currently pushing Arctic species further northward (Emblemsvåg et al., 2022a; Heide-Jørgensen et al., 2022; Møller and Nielsen, 2020; Schlegel et al., 2023). Due to the influx of warmer waters, the Atlantification process, the retreat of sea ice and changes in primary production, a growing number of boreal fish species are entering the Arctic (Emblemsvåg et al., 2022a, 2022b; Pecuchet et al., 2020). Increased pelagic productivity attracts zooplankton, forage fish and ultimately predators of higher trophic levels, like the boreal Atlantic argentine, black dogfish (*Centrocyllium fabricii*) and black scabbardfish (*Aphanopus carbo*), with a broad diet that includes pelagic prey (Emblemsvåg et al., 2022b).

Arctic species have adapted to highly seasonal and harsh environments where specialisation in a rich community of benthic prey, sustained by organic deposition from a pelagic compartment, relatively low fecundity and investment in single, larger offspring increased their chances of survival (Emblemsvåg et al., 2022a, 2022b). The current changes in primary production due to biophysical changes in the sea surface layers can reduce the organic matter and resources of fish communities in the deep sea (Emblemsvåg et al., 2022b). Moreover, the boreal species entering the Arctic are typically larger and mobile generalists, with higher fecundity, slow life history strategies, and a preference for pelagic resources that invade and outcompete the bottom-dwelling Arctic specialist benthivores (Emblemsvåg et al., 2022a; Pecuchet et al., 2020). Mobile generalists such as cod (*Gadus morhua*) and haddock (*Melanogrammus aeglefinus*) can shift their range rapidly and are entering Arctic regions (Emblemsvåg et al., 2022a). Boreal species such as Atlantic cod or redfish are generalists that feed on both benthic and pelagic prey or practice diel vertical foraging migrations (e.g. Greenland halibut), so food availability in the upper or lower water column can determine the occurrence and success of these predators (Emblemsvåg et al., 2022a). Shifts such as declines in ice-associated and benthic fish species such as Arctic cod (*Boreogadus saida*), sculpins (Family: *Cottidae*), and Zoarcids (Family: *Zoarcidae*) and increases in pelagic fish such as capelin (*Mallotus villosus*) and sandlance (*Ammodytes* spp.) are observed in the Arctic (Hoover et al., 2013b).

Subarctic invaders such as walleye pollock and Pacific cod could fundamentally transform interactions among pelagic species, benthic invertebrates, groundfish, seabirds and marine mammals by exerting strong predation pressure on forage fishes and benthic crab, worm and shrimp communities (Huntington et al., 2020). Areas such as East Greenland, for example, show signs of a taxonomic and functional borealization, where Arctic marine ecosystems are quickly redistributing poleward with a loss in functional diversity characterized by an increase in boreal fish species (Emblemsvåg et al., 2022a).

Boreal fish species such as capelin are important prey for some boreal cetaceans (Heide-Jørgensen et al. 2022). With the removal of thermal barriers, a spatiotemporally wider open-water season and increased primary production, several boreal cetaceans are expanding their ranges into new ice-free habitats (Heide-Jørgensen et al. 2022). Next to the Bowhead whale, narwhal and beluga, which are cold-water species endemic to the Arctic and often associated with sea ice, boreal cetaceans usually visit the ice-free waters of the Arctic during summer and migrate to warmer waters during winter (Ugarte et al., 2020). This includes rorquals (minke whales (*Balaenoptera acutorostrata*), fin whales (*B. physalus*), blue whales (*B. musculus*), humpback whales (*Megaptera novaeangliae*), and to a lesser extent sei whales (*B. borealis*)), and toothed whales such as harbour porpoise (*Phocoena phocoena*), white-beaked dolphin (*Lagenorhynchus albirostris*), white-sided dolphin (*L. acutus*), long-finned pilot whale (*Globicephala melas*), killer whale (*Orcinus orca*), sperm whale (*Physeter microcephalus*), and bottlenose dolphin (*Hyperoodon ampullatus*). Many of these species are large mobile predators occupying high levels in the food web, shaping species communities and biodiversity–functional relationships and behaviours through cascading effects on lower trophic levels in the food webs (Heide-Jørgensen et al., 2022; Matthews et al., 2020). For instance, killer whales as new apex predators increase predation pressure on resident species. In the Canadian Arctic, it is estimated that they could consume 1290 ±214 narwhals during their residency in Arctic waters (Lefort et al., 2020).

In the South of Greenland, a regime shift in oceanographic and ecological conditions has taken place after the occurrence of a main tipping element (absence of summer sea ice) in 2003 (Heide-Jørgensen et al., 2022). Combined with a warming ocean, this resulted in an influx of boreal fish species in the south, the subarctic capelin further north and several boreal cetaceans at higher trophic levels (humpback, fin, killer, and pilot whales and dolphins) that are either new to this area or historically have not occurred in large numbers (Heide-Jørgensen et al. 2022). These new cetacean species are responsible for the predation of 700,000 tons of fish and >1,500,000 tons of krill annually - species mainly consumed by fin whales (Heide-Jørgensen et al., 2022). Hence, it seems likely that the abundance of boreal cetaceans and fish will increase, whereas Arctic species such as narwhals will disappear from South East Greenland (Heide-Jørgensen et al., 2022). These predictions are likely to be the first signal of what will become an increasingly common scenario in the Arctic (Heide-Jørgensen et al., 2022).

The range of the nine mammal species native to the Arctic, the Bowhead whale (*Balaena mysticetus*), narwhal (*Monodon monoceros*), beluga (*Delphinapterus leucas*), walrus

(*Odobenus rosmarus*), polar bear (*Ursus maritimus*), and the ice seals, bearded seal (*Erignathus barbatus*), ringed seal (*Pusa hispida*), hooded seal (*Cystophora cristata*) and harp seal (*Pagophilus groenlandicus*) will likely shift northward following their preferred temperature ranges and available sea ice habitat . All of these marine mammals are strongly connected to sea ice and use it as a breeding ground (Ugarte et al., 2020). Simultaneously, boreal species will extend the period they reside in Greenland and expand into newly available habitats (Heide-Jørgensen et al., 2022; Ugarte et al., 2020a). Moreover, body conditions, reproduction, survival, and abundance of ice-dependent species, such as the ice seals and the polar bear, will likely further decline as sea ice declines (Laidre et al., 2008; Ugarte et al., 2020a).

Borealization of these Arctic communities is likely to accelerate if the ocean continues warming and extreme events increase in frequency, partly due to fast behavioural responses that will affect food web structure and species interactions. (Emblemsvåg et al., 2022b). Ultimately, this will transform the Arctic marine ecosystem into a new state characterized by subarctic conditions, species, and interactions (Huntington et al., 2020). Borealization will also lead to a decline in taxonomic and functional diversity resulting in a reduced adaptive capacity that may negatively affect ecosystem robustness to environmental change and fisheries (Emblemsvåg et al., 2022a).

1.5. Climate Change and Fisheries

The fishery sector account for one-third of Greenland's annual revenue and is the second largest employer after the public sector (Statistics Greenland, 2023). The offshore fishery consists of large corporately owned vessels mainly trawling for shrimp and halibut. Inshore, within three nautical miles, the coastal fishery includes more than 1,700 small boats, often owned by Individuals, that fish for Greenland halibut, Atlantic cod, snow crab, and lumpfish (Straneo et al., 2022).

Cod is the most common fish caught in East Greenland, particularly in transition areas with Atlantic water (Straneo et al., 2022). East Greenland offshore fisheries have yielded most of the annual cod and pelagic species' landings in recent years (Straneo et al., 2022). Catches of Greenland halibut, both inshore and offshore, dominate in West Greenland (Nuttall, 2020). The Greenland Halibut (*Reinhardtius hippoglossoides*) fishery is currently the largest and most valuable fishery in the Baffin Bay-Davis Strait region (Government of Nunavut, 2016). The inshore coastal fishery for Greenland halibut in Upernavik and Qaanaaq utilizes long lines from small open boats during the summer and dog sledges through holes in the sea ice during the winter. This fishery generates important income and employment opportunities in production and processing (Nuttall, 2020). The value of the commercial Greenland halibut fishery now accounts for almost half of the economy in Southeast Greenland (47%), outpacing the historically most important species, the ringed seal (31%) and harp seal (11%) (Nuttall, 2020).

Due to climate change and northward shifts in the distribution of commercially harvested species into newly productive waters, the Greenland fisheries sector, particularly on the east coast, is poised to grow in the coming years (Straneo et al., 2022). Over the past decade, East Greenland has also seen an increase in offshore catches of other pelagic species, such as capelin, blue whiting (*Gadus poutassou*), herring (*Clupea harengus*) and mackerel (*Scomber scombrus*) (Straneo et al., 2022). In addition, cod catches are expected to increase as new spawning grounds have been discovered and cod eggs, larvae, and juveniles are increasingly transported and migrate from Icelandic waters. Offshore fisheries, however, do not benefit the population in East Greenland. All fish processing plants are located in West Greenland, although Tasiilaq in East Greenland is now considered a site for a new processing industry (Straneo et al., 2022).

How new offshore fisheries (e.g., mackerel and other pelagic fish) or existing ones (cod) will evolve is unclear. For example, projections were made in 2014 for moderate and high CO^2 emission scenarios indicating that mackerel habitat availability may increase in space and time. These projections suggested that the stock will continue to remain large, productive, and follow its current migration pattern, suggesting that climate change will provide Greenland with a new unique opportunity for commercial exploitation (Jansen et al., 2016). Such hopes are, however, challenged by the recent collapse of mackerel stocks in 2020/21 in South East Greenland due to unknown reasons (Heide-Jørgensen et al. 2022). In general, however, an increase in offshore catch of pelagic species, including capelin, blue whiting, herring, and mackerel, was reported in the last decade (Straneo et al., 2022). These changes carry the potential to impact the economy, although mainly in larger towns possing the necessary fish processing infrastructure. Another source of uncertainty, particularly concerning the welfare of smaller communities, is the fishery commission's (i.e. Fiskerikommisionens) recommendation to instate Individual Transferable Quotas in the coastal small boat segment of the halibut and cod fishery.

1.6. Climate Change and Hunting

Hunting of marine mammals has a long tradition in Greenland. The ancestors of Greenlanders were Inuit that migrated from Arctic Canada, travelling over sea ice with dog sledges and by sea with kayaks and umiaqs (women's boats), relying heavily on marine mammals for sustenance (Ugarte et al., 2020). While modern Greenlandic diets now incorporate imported products and there is agriculture in southern Greenland, hunting marine mammals for subsistence and as a vital part of the local economy continues (Ugarte et al., 2020). Subsistence hunters rely on hunting for food for their families and their sledge dogs. Additionally, the sale of animal products, such as meat, mattak (whale skin and blubber), fur from seals, muskoxen, polar bears, and sculls, claws and tusks from walruses and narwhals, provides a source of revenue (Ugarte et al., 2020). However, climate change presents several challenges for subsistence hunters, such as unpredictable weather and ice conditions with a shorter safe travel season over sea ice with dog sledges and snow scooters, with some winter routes now deemed unsafe (Huntington et al., 2017; Laidre et al., 2018b). As a result of decreasing sea ice, skiffs are being used more frequently for fishing and hunting, and the sledge dog population is dwindling. In Southeast Greenland, hunting during summer is slowly shifting from narwhals to dolphins, pilot whales, and killer whales (Ugarte et al., 2020).

1.7. Resource Management

Greenland, as part of the Kingdom of Denmark, has had significant autonomy in wildlife management since 1979 (Ugarte et al., 2020). The Greenland Institute of Natural Resources (GINR) was established in 1993 to ensure sustainable hunting and fishing. GINR conducts research and monitoring of Greenlandic wildlife and fish stocks.

Much of the research and monitoring of marine mammals is conducted in collaboration with international organizations regulated by international government agreements (Ugarte et al., 2020). GINR presents its findings to relevant scientific working groups of these organizations, which then advise the management authorities of the Greenland government after reviewing the results and the assessment process. The Self-Rule Government, with input from hunters and fishers (i.e. through Fangstrådet and Fiskerirådet), makes decisions on regulations such as hunting seasons and quotas based on this advice. (Ugarte et al., 2020).

Fisheries management is advised by two international organizations, the North Atlantic Fisheries Organization (NAFO) and a working group under the International Council for the Exploration of the Seas (ICES). Advice is developed in collaboration with the GINR. Advice for catch levels is given annually for different species and different fishing diversions along the West and East Coast. Several other international organizations provide advice to Greenland's stock management, including the International Whaling Commission (IWC) for large whales; the North Atlantic Marine Mammal Commission (NAMMCO) for pinnipeds and cetaceans; the Canada/Greenland Joint Commission for the Conservation of Narwhal and Beluga (JCNB) for narwhals and belugas in West Greenland and the Canada-Greenland Joint Commission on Polar Bear for polar bears in Baffin Bay and Kane Basin (Ugarte et al., 2020). Management of Polar bears is further advised by the Polar Bear Specialist Group of the International Union for the Conservation of Nature (PBSG). The Council for International Trade of Endangered Species (CITES) controls the trade of endangered species (Ugarte et al., 2020).

2. Methodologies

In this report, we work with scenarios. Scenarios are representations of possible futures for one or more system components, particularly for drivers of change in nature and nature's benefits, including alternative policy or management options (IPBES, 2016). Scenarios can effectively address the relationships between nature, nature's benefits to people and good quality of life. Scenarios can thus add considerable value to the use of the best available scientific, indigenous and local knowledge in assessments and decision support options (IPBES, 2016).

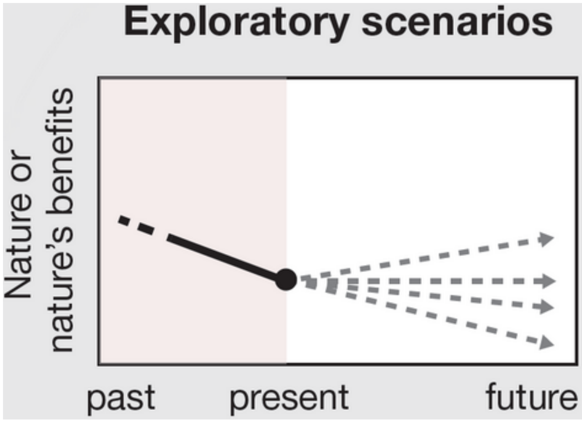


Figure 2.1 Description of an explanatory scenario source: (IPCC, 2001, IPBES 2016)

Different types of scenarios are used at different stages of the policy cycle: (i) agenda setting, (ii) policy design, (iii) policy implementation, and (iv) policy review options (IPBES, 2016). Here we use exploratory scenarios (also called 'descriptive scenarios'), which describe a range of plausible futures according to known change processes or as extrapolations of past trends (IPCC, 2001, IPBES 2016) (Figure 3.1). Exploratory scenarios are used in the agenda-setting phase for areas where specific policy responses have not yet been formulated or the nature of the problem remains unclear. They can identify and promote the need for action and opportunities to address adverse changes in nature and its benefits (IPBES, 2016). As such, they contribute significantly to high-level problem identification and agenda setting (IPBES, 2016). This type of scenario explores a range of plausible futures based on potential trajectories of either indirect (e.g. socio-political, economic) or direct (e.g. climate change) drivers (IPBES, 2016). They typically have both qualitative and quantitative components and are often combined with participatory approaches involving local and regional stakeholders (IPBES, 2016). Another advantage of explanatory scenarios is that they also allow for greater flexibility in the construction of storylines (which encourages greater creativity) and can therefore cover a wide range of issues (IPBES, 2016).

All these features make explanatory scenarios the most appropriate tool for our objective, as we combine different components such as literature research, extrapolations of past trends, and local knowledge and scientific input to describe a range of plausible future outcomes with implications for the welfare of hunter and coastal fisher families in Greenlandic communities.

2.1. Scenario Building

We combine three complementary methods to support the development of plausible and relevant future scenarios. These consist of a: 1) review of the scientific literature focusing on observed trends and predictions for each relevant species, 2) evaluating trends in catch or landings and making forecasts for relevant species and locations where data permit, and 3) consulting experts, including both local knowledge holders and scientists (mainly at GINR) responsible for providing scientific advice for each species.

Reviewing the scientific literature, we aimed to evaluate the reliability and condense the evidence using established standards and practices (Sutherland 2022). Evaluating trends in catch and landings we extend these into the future using time series analysis and forecast approaches. Consulting experts, we present the synthesis of the literature and the forecasts in order to "validate" the implied trends and co-develop plausible future scenarios through consultation with the local hunter and fisher organisations and with the scientific experts. Importantly we also facilitated the identification of alternative scenarios of relevance to local stakeholders.

Overall the aim was to develop scenarios that can be translated to quantitative measures of change in catch to facilitate exploration of the welfare implications for the hunter and coastal fisher families in Greenland.

2.2. Literature Review

The literature-based research was carried out using the Systematic Literature Review (SLR) method described by Siddaway et al., 2019. The SLR is an established systematic literature review method and was used to summarize existing knowledge about the observed and predicted abundance of wild animal populations, stocks or subpopulations. We compiled information from the literature on all aspects relevant to the development of catch in the future.

First, we used data from Statistics Greenland to compile a list of species caught by hunters and coastal fishers. We cross-validated this information in workshops in East and West Greenland (see section 2.5) to ensure that we included all relevant species. We then collected information on the trends in abundance or density of these species. Since multiple data collections in Greenland or information on populations are rare, we also included indirect indicators of population health, such as trends in reproduction, body condition, changes in behaviour, range and genetics. We also collect evidence on interactions between native and new species and changes in prey that may affect other target species (e.g. ~ 700,000 tons of fish and >1,500,000 tons of krill consumed annually by arriving boreal cetacean species in South East Greenland (Heide-Jørgensen et al., 2022). We also collected behavioural changes that may affect catch or hunting patterns (e.g. Human-wildlife conflicts with ''land locked'' polar bears increased (Wilken, 2019), and bowhead whales staying longer in Greenlandic waters with a reduction of sea ice concentration (Matthews et al., 2020)).

To ensure comprehensive coverage, we selected a search string with multiple terms to encompass the various terminologies used in relevant publications. We combined the species common and scientific name with search words, such as "Greenland", "climate change", "global warming", "threats" and "hunting". The search string was used in the Web of Science and PubMed in the beginning in July 2021.

We included only peer-reviewed articles and reports produced by experts on the species (i.e. authored multiple peer-reviewed studies). We included reports provided by institutions that are monitoring and advice hunting and fishing activities, such as the North Atlantic Fisheries Organization (NAFO), the International Council for the Exploration of the Seas (ICES), the International Whaling Commission (IWC) for large whales; the North Atlantic Marine Mammal Commission (NAMMCO) for pinnipeds and cetaceans; the Canada/Greenland Joint Commission for the Conservation of Narwhal and Beluga (JCNB) for narwhals and belugas in West Greenland and the Canada-Greenland Joint Commission on Polar Bear for polar bears in Baffin Bay and Kane Basin, the Polar Bear Specialist Group of the International Union for the Conservation of Nature (PBSG) and the Council for International Trade of Endangered Species (CITES) controls the trade of endangered species.

Publications were excluded if they did not focus on the topic, were reviews with no primary data or were older than 25 years.

We encountered several problems during the literature study, including a lack of published information about many species (e.g. seals), sub-populations or stocks, and contradictory information. We adopted methods for literate research from the Evidence-Based Conservation Initiative (Sutherland 2022) to systematically and standardized collect and evaluate evidence. Evidence is here defined as 'relevant information used to assess one or more assumptions related to a question of interest' and includes published studies as well as reports, observations, citizen science and local knowledge (Salafsky et al., 2022; Sutherland, 2022).

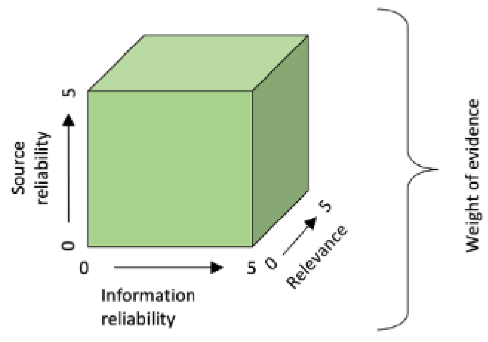


Figure 2.2 Assessing the weight of evidence according to information reliability, source reliability, and relevance (ISR). (Source: (Christie et al., 2022))

Evaluating evidence requires considering three crucial components: 1) the rigour of the information, 2) the trust in the reliability and objectivity of the source, and 3) the relevance to the question under consideration (Sutherland, 2022). One way to visualize the weighing of evidence is to consider each piece of evidence as a cuboid (Figure 2.2).

The three axes of the cuboid are Information reliability (I): i.e. "how much the information contained within a piece of evidence can be trusted, such as the rigour of the experimental design, or whether the statement is supported by information, such as photographs" (Sutherland, 2022).

Source reliability (S): i.e. "how much trust can be placed in the source of the evidence, such as whether it is considered authoritative, honest, competent, and does not suffer from a conflict of interest, or bias" (Sutherland, 2022). Relevance (R): i.e. "how closely the context in which the evidence was derived applies to the assumption being considered, such as whether it relates to a similar problem, action and situation" (Sutherland, 2022).

We adopted Sutherland's (2022) framework to weigh evidence on the three axes using our own definitions presented in Table 2.1. We assume that the most important factor for the catch is whether the target species is present and in what abundance. This factor ultimately affects the absolute number of animals (or kg of fish) that can be caught, although moderated by existing restrictions, including quotas. We focused on gathering evidence on the following questions 1) "how have populations changed?" 2) "how will populations change by 2030?" and 3) "how will populations change by 2050?

Information on current trends, densities, status, reproduction, future trends and future displacement from the area were considered 'highly relevant' evidence for our question on population change. This is followed by 'very relevant evidence', which includes any indirect indicators of population health or conditions that affect abundance. For example, poor body condition is often associated with lower reproductive rates (Laidre et al., 2020a). We classified information as 'relevant' if it could have an effect on population abundances, such as through changes in health, range or behaviour. We considered information older than ten years to be 'not very relevant'. "Not relevant' was reserved for information unlikely to affect population abundance directly or indirectly. "Information reliability" was assessed by the quality of the source. High-quality sources such as peer-reviewed studies and expert committee reports were included where available. However, limited access to certain information was sometimes mentioned, as Greenland is a rugged terrain for research. Such limitations can also lead to very small sample sizes (less than 10). We adjusted our assessment accordingly where such information was mentioned (see Table 2.1). In most cases, source reliability (S) was "high", as we mostly used evidence produced by known experts in certain fields. We made an effort to collect evidence from local and regional sources whenever possible, while evidence obtained from global or generic sources was identified as such.

Table 2.1. Table showing the definitions of Information reliability, Source reliability, and Relevance as defined by Sutherland, 2022. Columns with own definitions describe our rating system for weighing information.

Information reliability (I)		**Own definitions**	**Source reliability (S)**		**Own definitions**	**Relevance (R)**		**Own definitions**
Very reliable approach	**5**	Peer review, suitable methods, sample size, accuracy	Considerable trust	**5**	Peer review, expert reports (we mainly considered reports and studies which included an expert)	Extremely relevant	**5**	Current trends of abundances, densities, and reproduction, status Predictions and scenarios on future trends,
Moderately reliable approach	**4**	Not tested assumptions based on expertise	Moderate trust	**4**		Very relevant	**4**	Indirect indicators for population health, e.g., reproductions, body condition (which often connects to reproduction)
Weakly reliable approach	**3**	Described minor difficulties in accessing information, small sample size	Some trust	**3**		Relevant	**3**	Changes in range/ habitat use that affect body condition or reproduction
No knowledge about the approach	**2**		No knowledge about source	**2**		Somewhat relevant	**2**	Changes in range/habitat use with unknown effects
Some concerns over the approach	**1**	Described major uncertainties in accessing reliable information	Some concerns over reliability	**1**		Not very relevant	**1**	Trends, body conditions, status, older than 10 yrs (longer than one generation)
Considerable concerns over the approach	**0**		Serious concerns over reliability	**0**		No relevance	**0**	Changes with no relevance to trends or reproduction

As proposed by Sutherland, 2022, we weighed each piece of evidence by multiplying the three ISR axes up to a maximum weight of 125. We then used the descriptions of the strength of evidence for a single piece of evidence by Sutherland (Table 2.2).

Table 2.2. Conversion of weights of single pieces of evidence (from multiplying three axes) into descriptions of evidence strengths.

Weight	**Description of evidence strength**
0–1	Unconvincing piece of evidence
2–8	Weak piece of evidence
9–27	Fair piece of evidence
28–64	Reasonable piece of evidence
65–125	Strong piece of evidence

We assigned a direction to all effects, reflecting if reflecting a positive or negative outcome for population trends (Table 2.3)

Table 2.3. The assumed effect on population trends.

Direction of the effect	Direction categories	Number
Negative	**-**	**-1**
Stable	**+/-**	**0**
Positive	**+**	**1**
Unknown		

We assigned, if possible, a change or trend size category with five values to provide an estimate of the magnitude of the change. We accessed this category by scanning the text for words that give hints on the scale of change (strong, severe, e.g.). If there were multiple strands of evidence, we combined the evidence by the categories of the direction of the effect, meaning compiled evidence of a decline, an increase, or stable populations (if possible, we repeated this also for the strength of the effect). The cumulative evidence score is the sum of the weights of each category of evidence (Table 2.4).

Table 2.4. Assignment of change or trend sizes.

Strength of the effect	Effect size categories	Number
Large negative	**---**	**-3**
medium negative	**--**	**-2**
Small negative	**-**	**-1**
Stable	**+/-**	**0**
Medium positive	**+**	**1**
Small positive	**++**	**2**
Large positive	**+++**	**3**
Unknown		

Adding the weights of all evidence blocks together provides the cumulative weight of evidence. We followed Sutherland (2022) to convert the combined evidence into statements of the strength of evidence. Sutherland suggests that evidence can be scored up to a maximum of 125 (5 x 5 x 5) (Table 2.5). Sutherland 2022 proposes that strong evidence requires at least one study using suitable methods with large sample size and high accuracy and/or considerable trust in source reliability and/or extreme relevance (a cumulative evidence score between 101-250) while overwhelming evidence would necessitate more than two similar high-quality studies (2 x 125=250).

Table 2.5. Converting the combined evidence into statements of the strength of evidence.

Cumulative evidence score	Evidence category
>250	Overwhelming evidence
101–250	Strong evidence
51–100	Moderate evidence
11–50	Weak evidence
1–10	Negligible evidence

All evidence was collected in an evidence capture sheet in Excel, including source, finding, I, S, R-ratings, area, population, species, species group, and associated variable of change (Supplemental 1). Results are presented in bar plots, showing the cumulative evidence per category (e.g. decline, stable, increase). We also provide a written synopsis for each species using statements modified from Sutherland et al. 2022 (Table 2.6).

Table. 2..6. Converting the combined scores and strength of trends into statements about evidence for trends.

Cumulative evidence score	Evidence category	Considerable decline	Moderate decline	Minor decline	No effect	Minor increase	Moderate increase	Considerable increase
>250	Overwhelming evidence	Overwhelming evidence of considerable decline	Overwhelming evidence of moderate decline	Overwhelming evidence of minor decline	Overwhelming evidence of no effect	Overwhelming evidence of minor increase	Overwhelming evidence of moderate decline	Overwhelming evidence of considerable decline
101–250	Strong evidence	Strong evidence of considerable decline	Strong evidence of moderate decline	Strong evidence of minor decline	Strong evidence of no effect	Strong evidence of minor increase	Strong evidence of moderate decline	Strong evidence of considerable decline
51–100	Moderate evidence	Moderate evidence of considerable decline	Moderate evidence of moderate decline	Moderate evidence of minor decline	Moderate evidence of no effect	Moderate evidence of minor increase	Moderate evidence of moderate decline	Moderate evidence of considerable decline
11–50	Weak evidence	Weak evidence of considerable decline	Weak evidence of moderate decline	Weak evidence of minor decline	Weak evidence of no effect	Weak evidence of minor increase	Weak evidence of moderate decline	Weak evidence of considerable decline
1–10	Negligible evidence	Negligible evidence of considerable decline	Negligible evidence of moderate decline	Negligible evidence of minor decline	Negligible evidence of no effect	Negligible evidence of minor increase	Negligible evidence of moderate decline	Negligible evidence of considerable decline

We will further cross-validate our ratings and results of this literature review with experts (see section 2.4).

2.3. Forecasts

Data on catch and trade by all individuals with a hunting license, whether occupational ("fanger" in Danish) or part-time hunter ("fritidsjæger" in Danish), but excluding larger offshore vessels, were obtained for the period 2012-2020 from Statistics Greenland through a research associateship. The data also include information about the location of residence and family association, defined as all individuals residing at the same address, as well as the age, education and income of all family members. Trade data include species sold, units, amount and price obtained.

As far as data permitted, we aimed to develop forecasts for each population targeted by hunters and fishers in Greenland. For species that occur in distinct populations, we combine catch or trade data from relevant adjacent districts considering geographical features and the distribution of human settlements into one sample and forecast. However, this report only includes East Greenland differentiating between Ittoqortoormiit and Tasilaq districts and Upernavik and Ilulissat districts in Northwest Greenland.

We take departure in catch data rather than species monitoring data arguing that catch reflects access incorporating both climate change and management regulation impacts as well as the costs of hunting and fishing, and because many populations are not monitored. We use the average monthly catch per registered hunting license to incorporate differences in the number of active hunters across time. For species without quotas, we do not differentiate between occupational and part-time hunters. For trade data, we make forecasts based on the average traded volume per trader. For species where the catch is restricted by quota (e.g. walrus, polar bear, narwhal, beluga, large whales, halibut, cod), we instead make graphs illustrating the catch in relation to the quota where feasible. This approach was chosen due to a lack of better effort indicators and because our ultimate goal is to obtain a measure of the catch of each species at the individual hunter/fisher level for further welfare analysis.

We use R (version 4.3.0) to produce forecasts of catch (mammals and birds) and trade (fish and crustaceans) until 2030. Due to the large number of species and locations, we used the auto.arima function in the forecast package to automate the process. Hence, minimal effort was exerted in terms of determining the most optimal model aside from the procedures incorporated in the auto.arima function. However, an initial exploration of ACF and PACF, decomposition and various difference plots were conducted to assess the need for specifying the seasonal or trend components as a starting point for the auto.arima function. In addition, various transformations were tested to accommodate that the values are averages of counts of often small numbers.

We acknowledge that forecasts this far into the future based on the relatively short time series are highly unreliable (i.e. have large confidence intervals). In addition, the models were, in some cases, unable to accommodate the trends, seasonality, cycles or structural breaks in the data, particularly where the catch was sporadic. Where data was insufficient to conduct a time series analysis, we only made graphs showing the temporal distribution of catch across the available data period. However, in other cases, we made a forecast despite the model's poor performance only to facilitate discussion of the likely future development of the catch.

In all cases, we highlight that our objective is not to make predictions but rather to make material to facilitate discussion and guide the development of future scenarios for 2030 and beyond. To this end, we also calculated the average total annual catch per average individual across the period 2012-2020, for 2020 and the forecasted catch for 2030 and the percentage change in 2030 relative to these measures.

2.4. Expert Consultation

Expert opinions are used extensively to guide conservation planning, particularly when data are scarce (Cook et al., 2014; IPBES, 2016). Expert-based scenarios use expert opinion, knowledge or judgment to inform the various aspects of constructing scenarios (IPBES, 2016). An expert is considered an individual with expertise or experience within a particular dimension through training, study, or involvement in practice (IPBES, 2016). Such individuals can include scientists and local or indigenous knowledge holders (Tengö et al., 2012). Despite experts' often impressive knowledge within their domain, evidence suggests that they do not necessarily significantly outperform non-experts when making judgments and forecasts in unpredictable environments (Sutherland, 2022). The explanation is that also experts are susceptible to cognitive biases (Sutherland, 2022). However, a closer look reveals that the problem is not necessarily the use of experts but instead their inappropriate use (Sutherland, 2022). Understanding the reasons behind experts' potential errors (such as biases and heuristics) and implementing structured methods that enable experts to render their best judgments amidst uncertainty can improve the assessments made by experts (Sutherland, 2022). We, therefore, followed Sutherland’s (2022) guidelines for working with experts, including groups.

2.5. Local Knowledge Input

We conducted workshops with representatives of local hunters and fishers organisations (mainly KNAPK) in selected locations in Greenland. Locations were selected based on the weight of different activities (i.e. hunting vs fishing) and large species with quotas vs smaller species with limited regulation. Here we only report on the results of workshops in East and Northwest Greenland.

We chose a participatory approach to scenario development to enhance the relevance of developed scenarios and to include alternatives to climate change scenarios. Participatory approaches are ideal when dialogue among local stakeholders is critical to successful assessment outcomes and when local and indigenous expertise can supplement scientific knowledge (Flynn et al., 2018; IPBES, 2016; Mallampalli et al., 2016). Usually, this involves a larger group of stakeholders through workshops or other formal meetings to share ideas and ultimately develop scenarios based on their collective knowledge. Moreover, this format can provide a platform for views to be aired, broadened perspectives, and a greater understanding of the policy issue under consideration can be achieved (Flynn et al., 2018; IPBES, 2016; Mallampalli et al., 2016). In this case, obtaining alternative views on population abundance and trends that often differ considerably from scientific results was critical. However, it was also essential to develop alternative scenarios that included a broad range of options to improve local welfare by identifying the critical infrastructure necessary for the industry to develop or change management regulations that often are at odds with local realities.

2.6. Selection of Sites for Workshops

We choose Ittoqqortoormiit and Tasiilaq in East Greenland and Qaanaaq and Upernavik in Avernnata and Qaasuitsup municipalities in Northwest Greenland, respectively, to conduct workshops in April and May 2023. These locations stand out due to their heavy reliance on marine mammal harvesting for food security, culture, and local economy (Straneo et al., 2022). However, due to weather conditions, it was not possible to travel to Qaanaaq in the available time. We therefore rescheduled and conducted a workshop in Ilulissat, which is characterized as more dominated by commercial fishing instead. Further, locations in the future may include Nanortalik and Assiat in South Greenland and Qeqertarsuaq on Disko Island. As far as possible within the scope of the budget, people from smaller settlements are invited to participate in the workshops.

Hunting polar bear and narwhal hunting is still very common in Ittoqqortoormiit, whereas commercial fishing is absent due to the lack of a trading facility for anything other than seal skin and the community is characterized as very isolated and small (345 people in 2020) (Laidre et al., 2018b). Tasiilaq is considerably larger (2000 individuals), and the district also includes five smaller settlements, one of which has a fish processing facility (Kuummiut). Ittoqqortoormiit and Tasiilaq differ in that Tasiilaq already underwent a regime shift in 2003 caused by the disappearance of summer sea ice, the warming of the ocean and an influx of Atlantic waters (Heide-Jørgensen et al., 2022). This was demonstrated, among other things, by a fundamental shift in fish communities towards boreal species (Emblemsvåg et al., 2022a), a collapse in narwhale stocks, and an increased occurrence of boreal whale species (Heide-Jørgensen et al., 2022).

Climate change is expected to impact traditional sustenance activities negatively in Northwest Greenland, including marine mammal hunting, winter ice fishing for Greenland halibut, and sea-bird harvesting (Straneo et al., 2022). This is due to factors such as decreasing access to ice-associated activities and species due to a reduction in sea ice cover, shifts in zooplankton assemblages (Møller and Nielsen, 2020), the replacement of Arctic cod by forage fish of boreal origin like capelin and sand lance, among others (Straneo et al., 2022). Upernavik (1.124 people in the town and a further 1.677 people in the nine settlements) differs from Qaanaaq further north by the significance of particularly the halibut fishery with several processing factories. Ilulissat (4.533 people plus an additional 500 people in the four adjacent settlements) town with an actual harbour, fish processing plants and is the center of tourism for the isfjord (approximately 20.000 tourists per year).

Increased commercial fishing for arriving boreal fish species could enhance employment and the economy in these regions (NAFO, 2023; Straneo et al., 2022). For instance, while fishing processing plants are currently located in West Greenland, there is now a growing interest in establishing a new processing industry in Tasiilaq, situated in East Greenland (Straneo et al., 2022). These observed and expected changes due to climate change, coupled with a traditional way of life based on hunting and fishing, make these locations ideal candidates for exploring the future of these regions.

2.7. Scientific Input

This part of the data collection has not yet been conducted and will be included in future report versions. Scientists with expertise on different species will be solicited from GINR and elsewhere. We will contact, if available, three experts per species or species group (e.g., seals, arctic birds). We will include multiple experts because combining the judgments of multiple experts can yield better aggregated judgements (Sutherland, 2022). Means are usually recommended if the judgements are normally distributed, while medians better reflect skewed data distributions (Sutherland, 2022).

Interview guides will be sent to the experts before interviews, and the interviews will be conducted through a Zoom session. During interviews, a three-point interval elicitation method (Speirs-Bridge et al., 2010) will be used. Dividing the question into several steps increases the likelihood that respondents will think about different types of evidence and be less biased (Soll and Klayman, 2004). For example, instead of asking for a range of values, it is more effective to ask for three points: “what is the highest plausible number of individuals”, “what is the lowest plausible number of animals”, and “what is your best estimate of the number of animals?” (Sutherland, 2022). This way, too precise answers or too narrow and exaggerated intervals can be avoided. Tests show that it is better to ask for the intervals first. Otherwise, the respondent may become too fixated on the best estimate and produce too narrow (inflated) boundaries around it (Soll and Klayman, 2004). Lastly, people tend to use a constant interval width over a wide range of confidence levels, leading to a high degree of overconfidence at 90% intervals (Teigen and Jørgensen, 2005). Therefore, better results are obtained by allowing experts to assign their own confidence level to their interval (Sutherland, 2022). Moreover, experts will be asked if they agree to an anonymous review of their judgments by other experts, following the Delphi technique (Linstone and Turoff, 1976).

Before interviews, the experts will be provided with the results of our literature research and the time-series plots and forecasts (if available). They will be asked to evaluate the literature research and estimate changes in abundance until 2030 and 2050, potential changes in range, or if the protection status and thus quota will change and potential interactions between native and new species.

2.8. Ethical Considerations

This study strictly follows the ethical guidelines developed by the FutureArcticLives project (Nielsen et al., 2019). The guidelines include obtaining free prior informed consent, involving and consulting relevant local stakeholders concerning the interpretation of results and developing recommendations and disseminating final output to relevant decision-makers at the Greenlandic and international level with the explicit objective of ensuring the long-term sustainable use of resources while improving the welfare of hunter and coastal fisher in Greenland.

3. Hooded seals (*Cystophora cristata*)

Hooded seals	
Cystophora cristata	
Klapmyds	
Natsersuaq	

Hooded seals (*Cystophora cristata*) have large home ranges and dive to depths of 1652 m (Ugarte et al., 2020). Two or three stocks inhabit the North Atlantic Ocean. Whelping occurs on the drift ice east of Newfoundland, in the Gulf of St. Lawrence (the Northwest Atlantic stocks), the Davis Strait between Greenland and the east coast of Greenland (Øigård et al., 2014). The stock in Greenland has now stabilized at a low level, and Hooded seals are therefore listed as "Vulnerable" in both the global and the Greenland Red List (Ugarte et al., 2020).

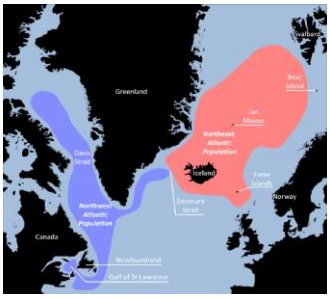


Figure 3.1. Populations of hooded seals (Nammco)

3.1. Climate Change

As ice-associated species (Moore and Huntington, 2008), thin sea ice in the breeding sites poses a risk (Kovacs and Lydersen, 2008). Hooded seals are therefore considered most sensitive to climate change (Laidre et al., 2008). Since 2000, the frequency of light ice years in the Northwest Atlantic whelping areas has increased, resulting in a shorter ice season (Stenson et al., 2016). The decrease in ice cover, particularly the thick multi-year ice required for successful breeding by hooded seals, has significantly declined over the past few decades, and ice can negatively impact hooded seal populations in several ways (Kovacs et al., 2011). Seal pups rely on ice cover for several weeks for weaning and as a resting platform while they learn to forage, and a reduction in the availability or quality of ice for whelping and moulting (Kovacs et al., 2011), Climate change and predation may be inhibiting the recovery of the Greenland Sea stock, which continues to decline despite a cessation in hunting (Øigård et al., 2014). Pups require ice cover for a few weeks for weaning and as a resting platform as they learn to forage for themselves. Prematurely entering the water can lead to interrupted nursing, starvation, and cold stress, reducing their chances of survival, and reduced ice cover can increase vulnerability to predation by killer whales and polar bears (Øigård et al., 2014). There is also some evidence of a reduction in the pregnancy rate among Northwest Atlantic hooded seals, which could also be due to stresses induced by climate change (Frie et al., 2012).

3.2. Hunting

There is no longer commercial sealing, and the average annual catches (2012–17) are 1.700 seals (almost exclusively from the West Atlantic population) (NAMMCO, 2018a; Ugarte et al., 2020b). In Tasiilaq, catches of hooded seal declined precipitously after 1995 and were much reduced in the 2000s (Heide-Jørgensen et al., 2022).

3.3. Status and Population Trends

West Greenland:

Region/ population	Abundance	Status, change	Trend (Short term)	Category of change	Description: Physiological, behavioural change	Climate variable & direction	Hunting
Northwest Atlantic population (Greenland and Canada)	**2005: 593,500 (SE=67,200, 95% CI=465,600-728,300** (Hammill and Stenson, 2006)	**Reduced** (Hammill and Stenson, 2006)	**Increasing** (Hammill and Stenson, 2006)		**Signs of reduced reproductive rates since the 1990s in spite of a modest increase in population abundance** (Frie et al., 2012)		

East Greenland:

Region/ population	Abundance	Status, change	Trend (Short term)	Category of change	Description: Physiological, behavioural change	Climate variable & direction	Hunting
Greenland Sea	**2013: 84,020 (95% CI 68,060–99,980)** (Øigård et al., 2014)	**Reduced, only approximately 7% of the 1946 level** (Øigård et al., 2014)	**Stable** (Øigård et al., 2014)		**Pub production did not change significantly, ow pup production numbers** (Øigård et al., 2014)		

3.4. Synopsis

Hooded seals are considered most sensitive to climate change. We found moderate evidence for a decline and strong evidence for a stable stock in the Greenland Sea. We found moderate evidence for a decline and strong evidence for an increase in the Northwest Atlantic stock.

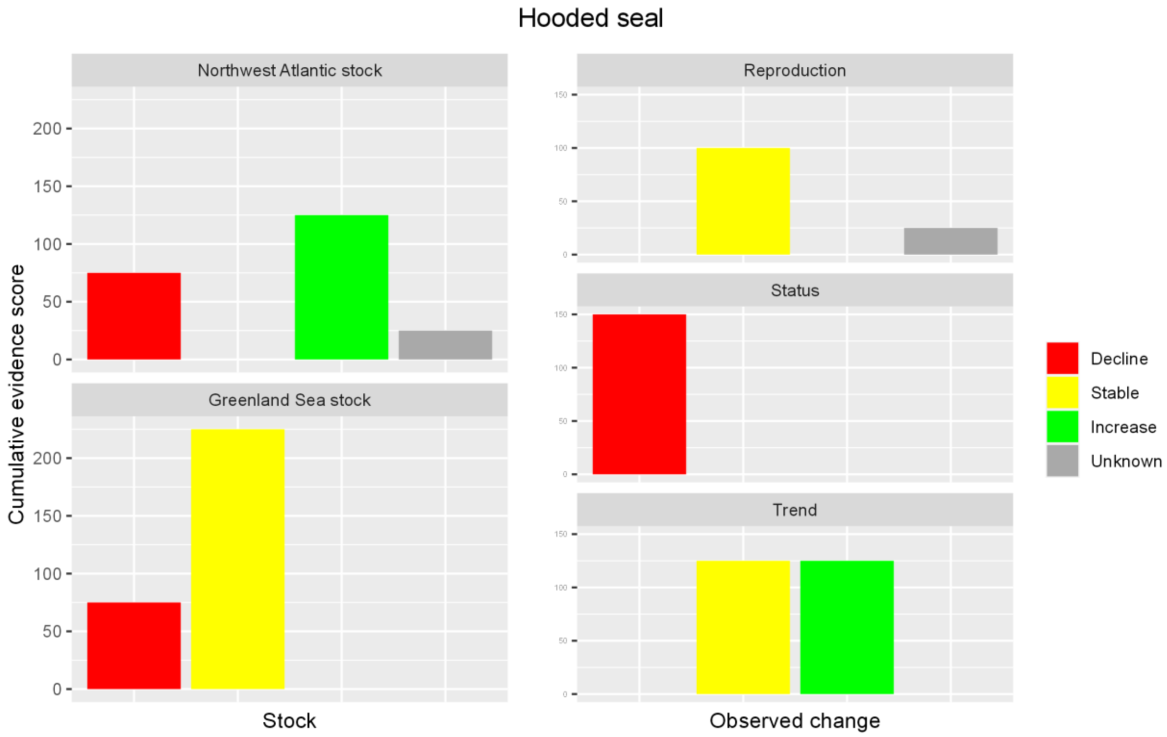


Figure 3.2. Cumulative evidence scores per population and aspect of change.

3.5. Catch and Forecast

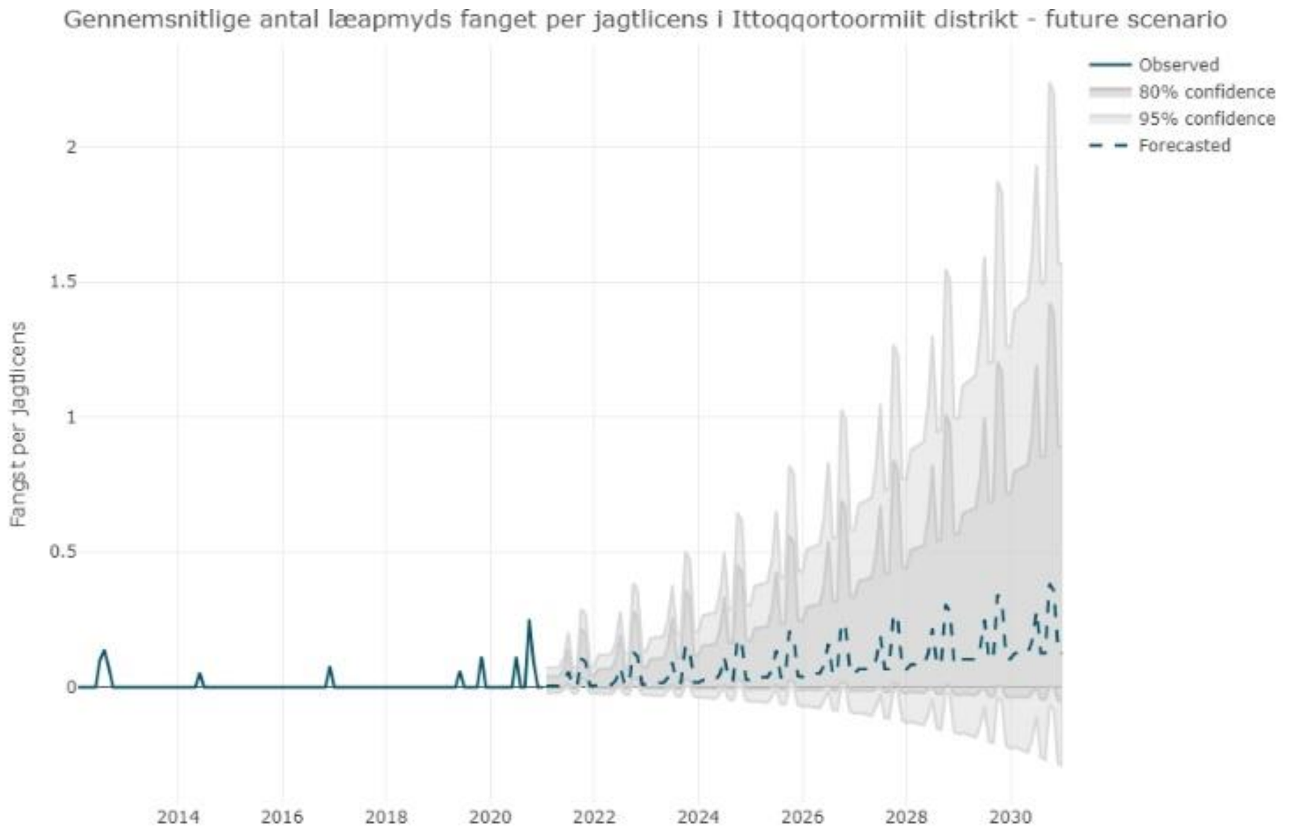


Figure 3.3. Average catch per hunter and forecast for Hooded seal in Ittoqqortoormiit district.

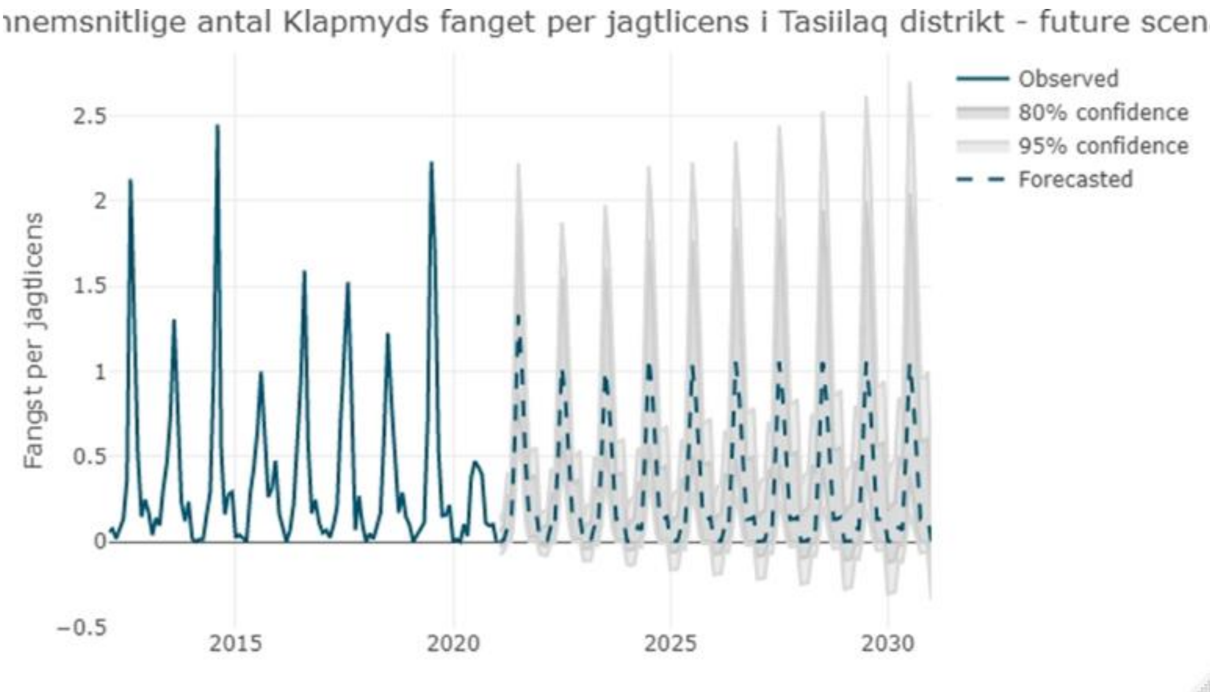


Figure 3.4. Average catch per hunter and forecast for Hooded seal in Tasiilaq district.

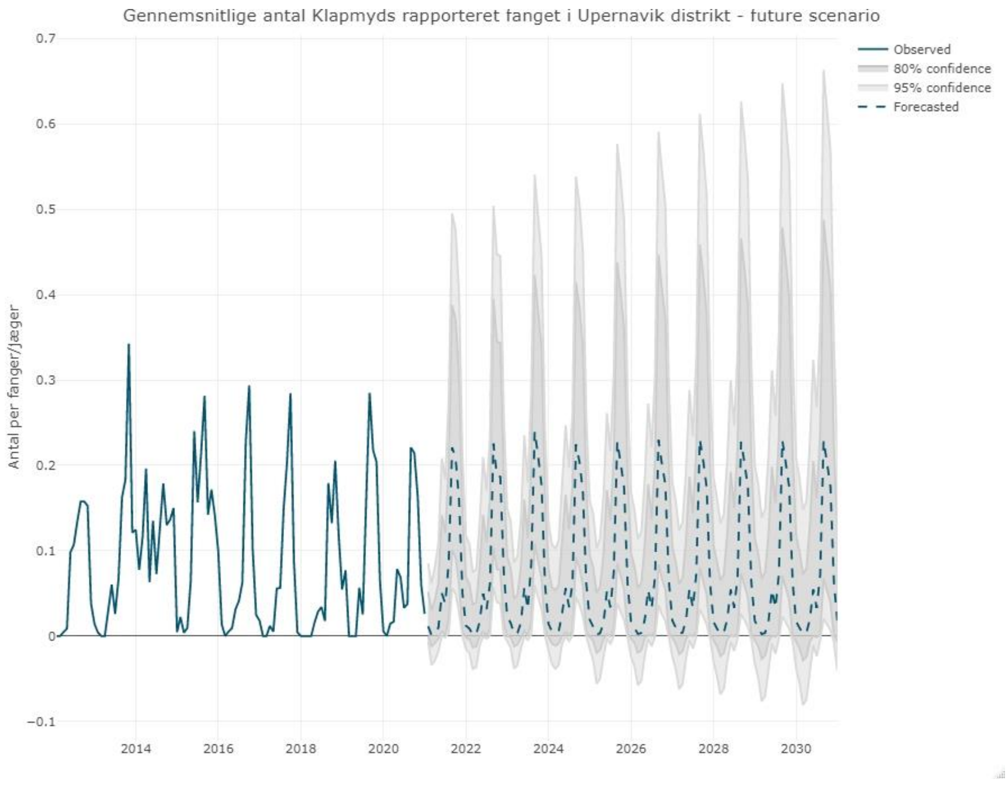


Figure 3.5. Average catch per hunter and forecast for Hooded seal in Upernavik district.

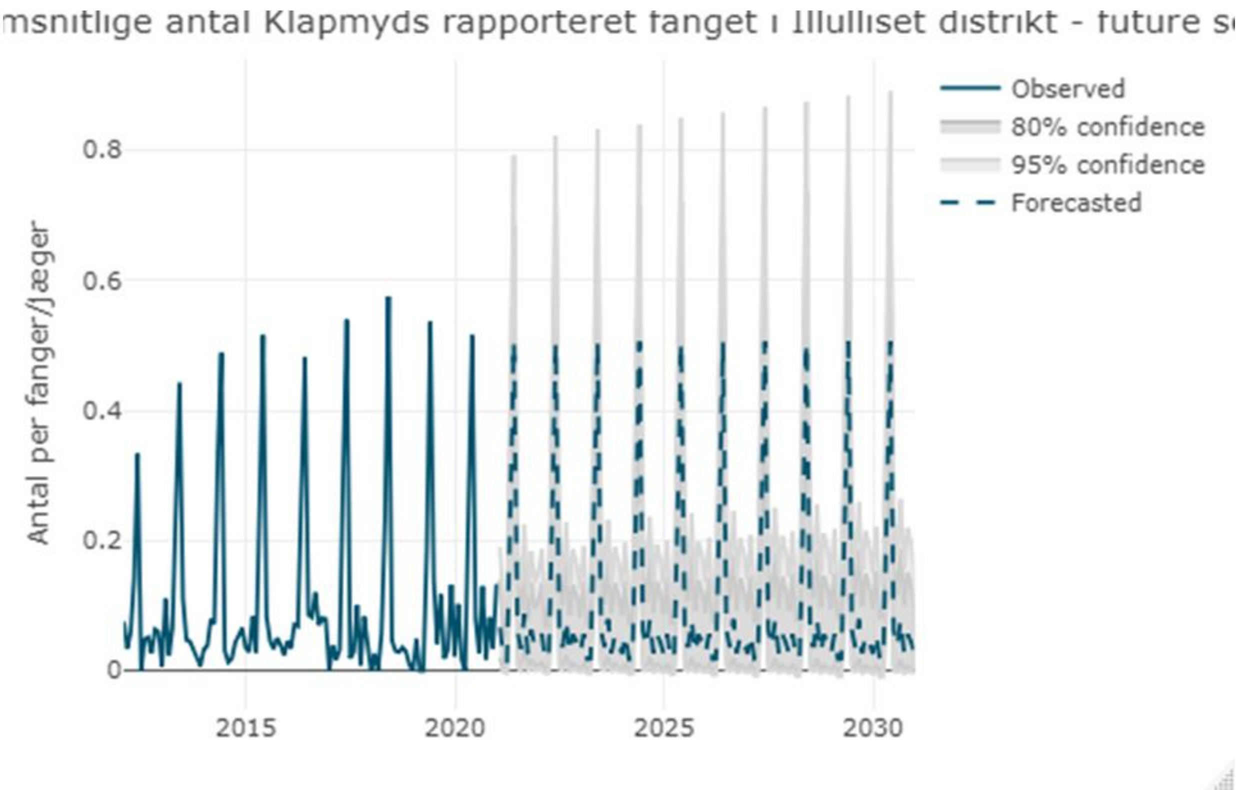


Figure 3.6. Average catch per hunter and forecast for Hooded seal in Ilulisset district.

The forecasts are not reliable and particularly the data from Ittoqoortormiit appears insufficient to produce a forecast and the model takes its que from the increase in the later part of the period. Nevertheless, the material was used as a basis for discussion.

Tabel 3.1. Average annual catch of Klapmyds per hunter in the period 2012-2020, in 2020 and 2030 (forecasted) and the percentage change in 2030 relative to 2012-2020 and 2020.

District	2012-2020	2020	2030	Δ 2012-2020	Δ 2020
Ittoqoortoormiit	0,118	0,452	2,201	1764%	387%
Tasiilaq	4,58	2,14	3,44	-25%	60%
Upernavik	1,05	0,93	0,88	-16%	-5%
Ilulissat	1,23	1,38	1,17	-4%	-15%

3.6. Workshops with Hunter and Fishers Organizations

Scenario	Ittoqortoormiit	Tasiilaq	Upernavik	Ilulissat
Trend scenario	Catch is expected to continue increasing – tied to the arrival of killer whales	Increasingly difficult to access with declining sea ice and declining use mainly as dog food	Fluctuating numbers and declining use as skins can no longer be sold	Less accessible. Catch is determined by the market.
Alternative scenario	NA	NA	NA	NA

3.7. Interviews with Scientific Experts

-will follow-

3.8. Preliminary Future Scenarios

Scenario	Ittoqortoormiit	Tasiilaq	Upernavik	Ilulissat
Stock and catch trend scenario	+20% compared to 2012-20	-20% compared to 2012-20	-10% compared to 2012-20	Stable compared to 2012-20
Underreporting adjustment scenario				
Alternative actions scenario				

4. Harp seals (*Pagophilus groenlandicus*)

Harp seals	
Pagophilus groenlandicus	
Grønlandssæl	
Aataaq	

Adult harp seals often swim in large groups when foraging during summer and fall (NAMMCO, 2016). They forage in most of the Greenland waters that are not ice-covered, from offshore open water to deep inside fjords and close to glaciers (NAMMCO, 2016).

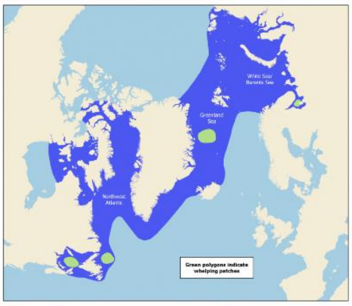


Figure 4.1. Distribution of harp seals (NAMMCO)

The North West Atlantic population is one of the largest populations worldwide (NAMMCO, 2016). The population in the Greenland Sea is the smallest of the three harp seal populations (ICES, 2019a). A large proportion migrates into the Barents Sea during summer and autumn, then return to spend the winter off South-East Greenland in the Denmark Strait (Stenson et al., 2020).

Harp seals have large populations and increasing or stable population trends in the Northwest Atlantic population, in the Greenland Sea, and in South East Greenland.

In Greenland, recording of the catch of harp seals differentiates between the two different life stages, blue-sided (blåsider) being the young seals with grey, spotted back and light grey belly and black-sided (sortsider) being the adult seals characterized by a dark head and a horseshoe-shaped colouration on the back.

4.1. Climate Change

Because the harp seal is dependent on sea ice for pupping, moulting and resting, they will be particularly affected by any changes that might occur in their sea ice habitats. Harp seals are considered an ice-associated species (Moore and Huntington, 2008) and moderately sensitive to climate change (Laidre et al., 2008). Site fidelity and thinner ice on breeding sites might pose a severe risk (Kovacs and Lydersen, 2008). In Newfoundland, Canada, high abortion rates were associated with low capelin abundance and ice cover (Stenson et al., 2016). The three populations of harp seals in the North Atlantic (White Sea/Barents Sea, Greenland Sea, and Northwest Atlantic) are experiencing varying degrees and types of environmental change affecting abundance, body condition and reproduction (Stenson et al., 2020). The loss of sea ice during, or shortly after, pupping has directly impacted the mortality of young harp seals in the Northwest Atlantic (Hammill et al., 2015; Stenson et al., 2003). Pup mortality was extremely high in years with reduced ice coverage or thickness. The increased mortality can be attributed to several factors, such as interrupted nursing, starvation, cold stress, and the risk of being crushed by shifting ice floes. These risks arise when seal pups are forced into the water prematurely due to ice's rapid melting and break-up (Bajzak et al., 2011; Hammill and Stenson, 2014; Johnston et al., 2012).

There has been a decline in sea ice extent and coverage, particularly in the Northwest Atlantic stock's southern wintering and pupping area (Johnston et al., 2012). A study examined the relationship between sea ice cover and the North Atlantic Oscillation (NAO) index values in the Gulf of St. Lawrence and the stranding rates of dead harp seals between 1992 to 2010 (Johnston et al., 2012). The findings indicated negative associations between both ice cover and NAO conditions with seal mortality. This implies that lighter ice cover and lower NAO values are linked to higher mortality rates. Furthermore, a retrospective cross-correlation analysis covering the period from 1978 to 2011 suggested that NAO-related changes in sea ice might have played a role in the decline of seals on the east coast of Canada between 1950 and 1972, as well as their subsequent recovery from 1973 to 2000 (Johnston et al., 2012).

Harp seals prefer the thickest ice stages available. However, since 2000, the frequency of light ice years (measured primarily as ice cover) in the Gulf of St. Lawrence has increased, and the duration of the ice season decreased (Bajzak et al., 2011). Four of the past seven years being among the lowest ice cover ever recorded (Stenson et al., 2016). Also, for the Greenland Sea stock, the extent and concentration of sea ice available to the pupping areas declined and has shifted westwards closer to the Greenland coast (ICES, 2019b). This might make harp seals more vulnerable to predation from polar bears and killer whales occupying coastal waters (Stenson et al., 2020).

4.2. Interactions

Harp seals are replacing ringed seals. Northward retraction of ringed seals may have resulted from changes in sea ice habitat and the availability of their preferred prey species (Laidre et al., 2008). Reproduction success is related to the abundance of prey, here capelin (Stenson et al., 2016).

4.3. Hunting

Overharvest significantly reduced the North Atlantic harp seal stocks in the 19th century, but regulations of catch since the 1970s have allowed a strong recovery (Hammill et al., 2015). In West Greenland, harvests of harp seals have increased 100-fold for adults (sortsider) and tenfold for juveniles (blåsider) in the past 20 years. In the 1980s, only some hundred adults and less than 2,000 young animals were taken. Catch has increased to more than 20,000 of each age group annually from 1995 to 2005 (Rosing-Asvid 2008). Harp seals are increasingly available in the area, and ice conditions permit increased access to the seals (Kovacs et al., 2011). The subsistence catch of harp seals is important in most parts of Greenland. The average annual reported catches in Greenland during 2012–17 were around 59,000 seals (http://nammco.no) (Ugarte et al., 2020). Ringed and harp seals are by far the most important in numbers caught, and both of these species provide the inhabitants with a fundamental source of food and income. Seal meat is a staple food for humans and sledge dogs, while skins are purchased with government subsidies by the state-owned tannery (Great Greenland), providing income in areas with otherwise limited opportunities for paid employment. During the open-water season, all seals are shot from skiffs (Boertmann and Mosbech, 2017).

4.4. Status and Population Trends

West Greenland:

Region/ population	Abundance	Status, change	Trend (Short term)	Category of change	Description: Physiological, behavioural change	Climate variable & direction	Hunting
Northwest Atlantic population (Greenland and Canada)	**2017: 7.6 million (95% CI 6.6 8.8 million)** (Hammill et al., 2021; Stenson et al., 2020)	**Not Reduced** (Hammill et al., 2015)	Appears to be increasing since 2014 (Stenson et al., 2020).	**Reproduction**	Decline in productivity (Hammill et al., 2014)		

East Greenland:

Region/ population	Abundance	Status, change	Trend (Short term)	Category of change	Description: Physiological, behavioural change	Climate variable & direction	Hunting
Greenland Sea	**2019:** 426,808 animals (95% CI: 313,005 – 540,612) (ICES, 2019b)	**Not Reduced** (ICES, 2019b)	**Increasing** (ICES, 2019b)		A significant drop in pup production has been documented from 2007 to 2018. This was from 110,530 pups estimated in 2007, to 89,590 in 2012 and down to 54,181 pups in 2018 (ICES, 2019b)		

4.5. Synopsis

Harp seals are considered moderately sensitive to climate change. For the Greenland Sea, we found moderate evidence of a decline and a stable stock and strong evidence of an increasing stock of Harp seals. The evidence regarding the Atlantic population shows moderate evidence for a decline and strong evidence for an increase. The generic evidence is strong for a decline.

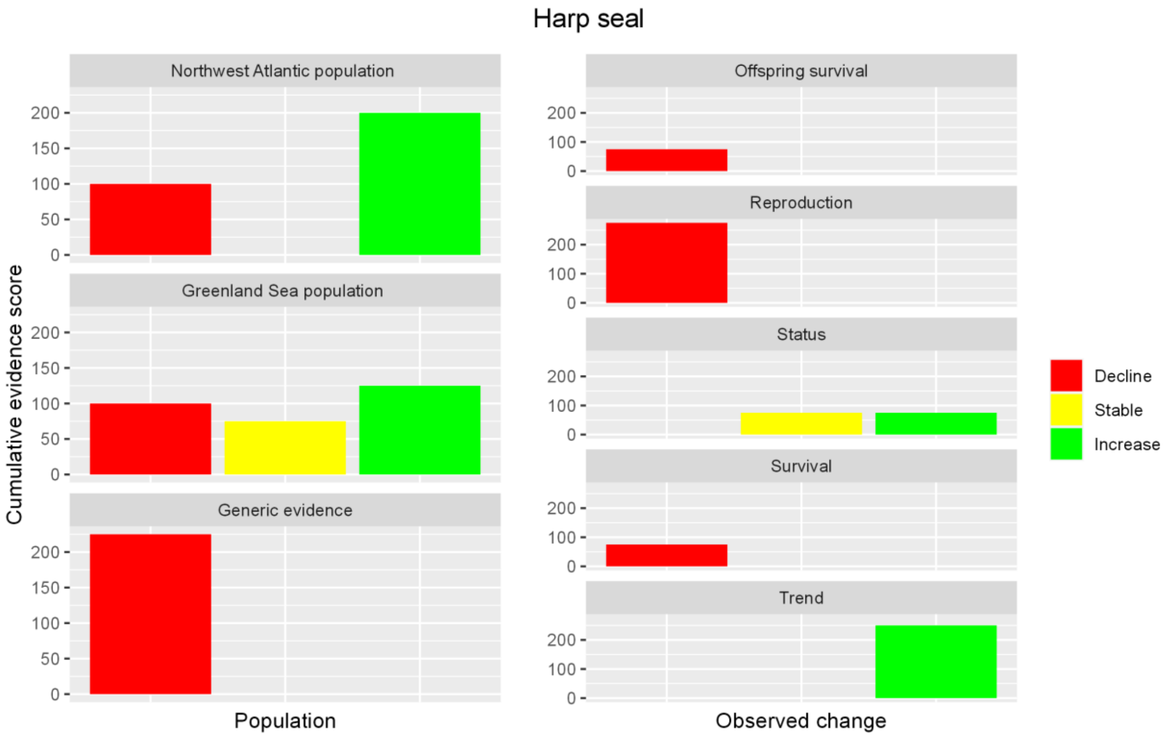


Figure 4.2. Cumulative evidence scores per population and aspect of change.

4.6. Catch and Forecast

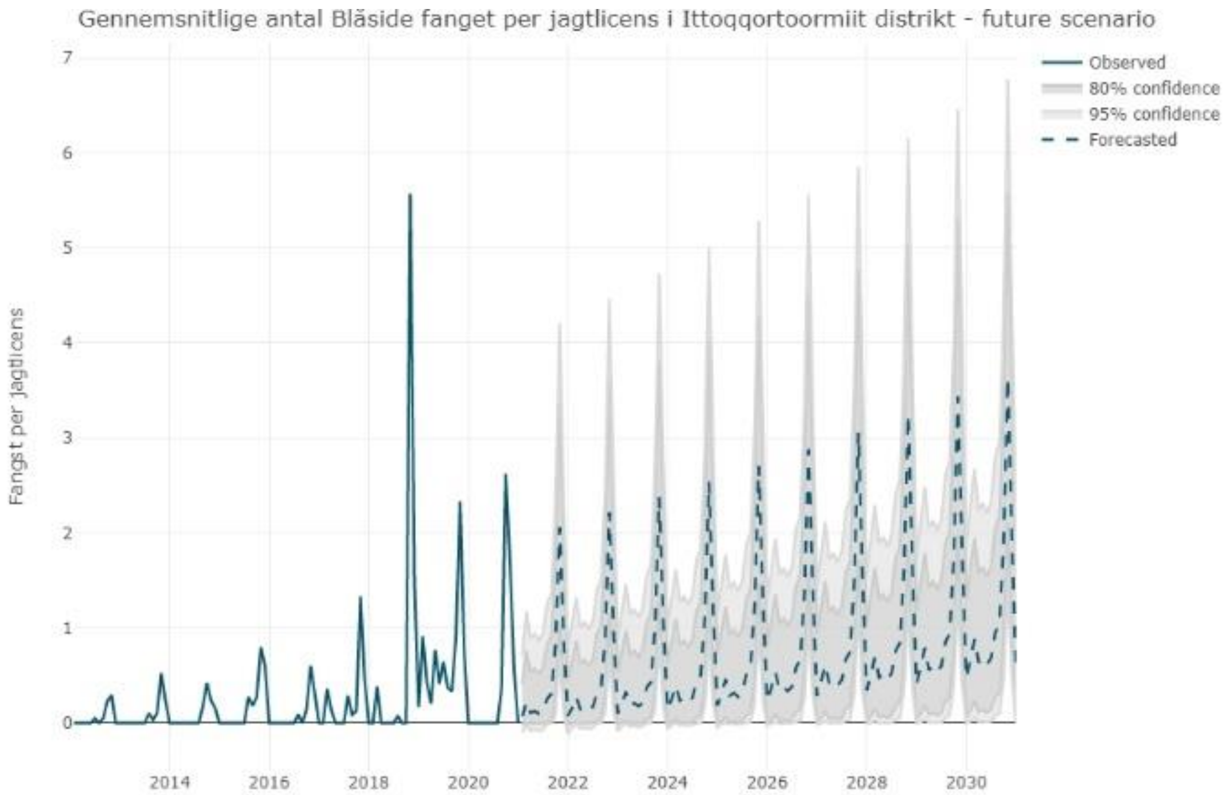


Figure 4.3. Average catch per hunter and forecast for young Harp seal (Blåside) in Ittoqortoormiit district.

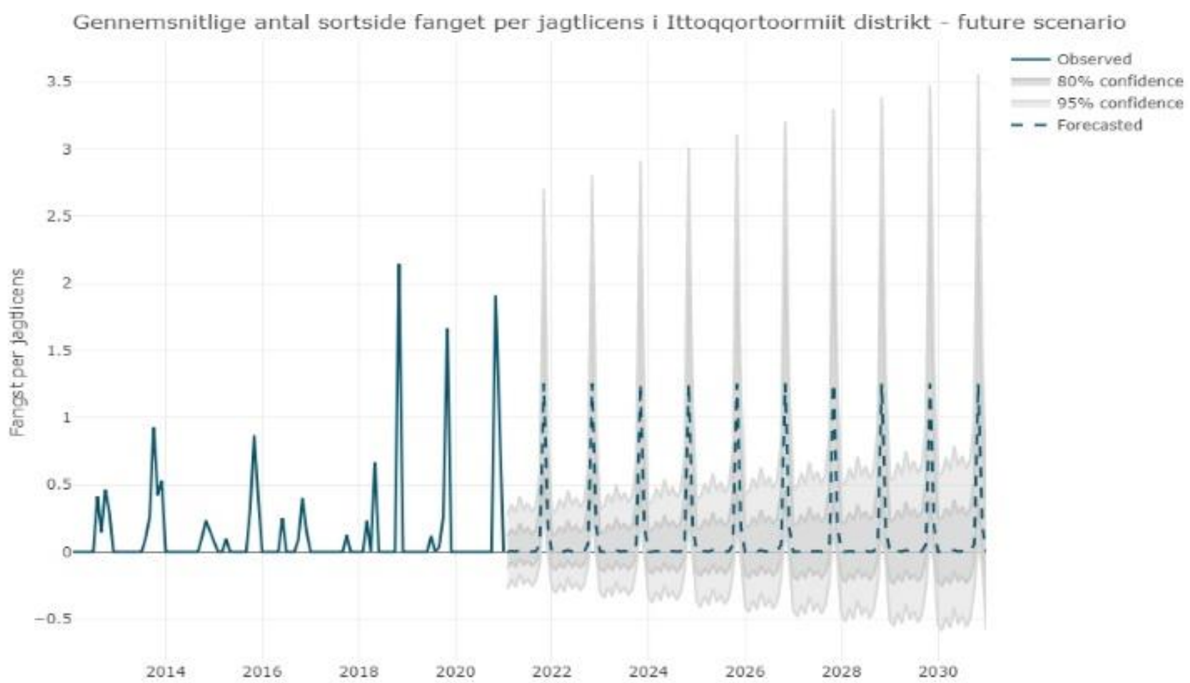


Figure 4.4. Average catch per hunter and forecast for adult Harp seal (Sortside) in Ittoqortoormiit district.

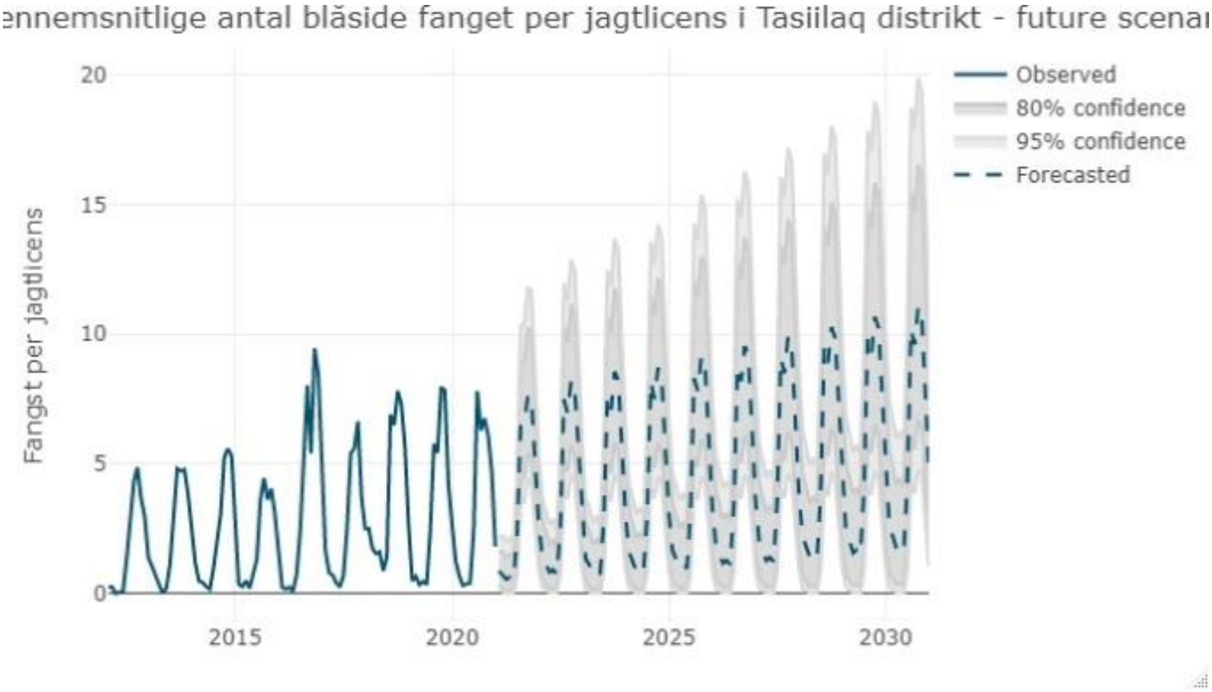


Figure 4.5. Average catch per hunter and forecast for young Harp seal (Blåside) in Tasiilaq district.

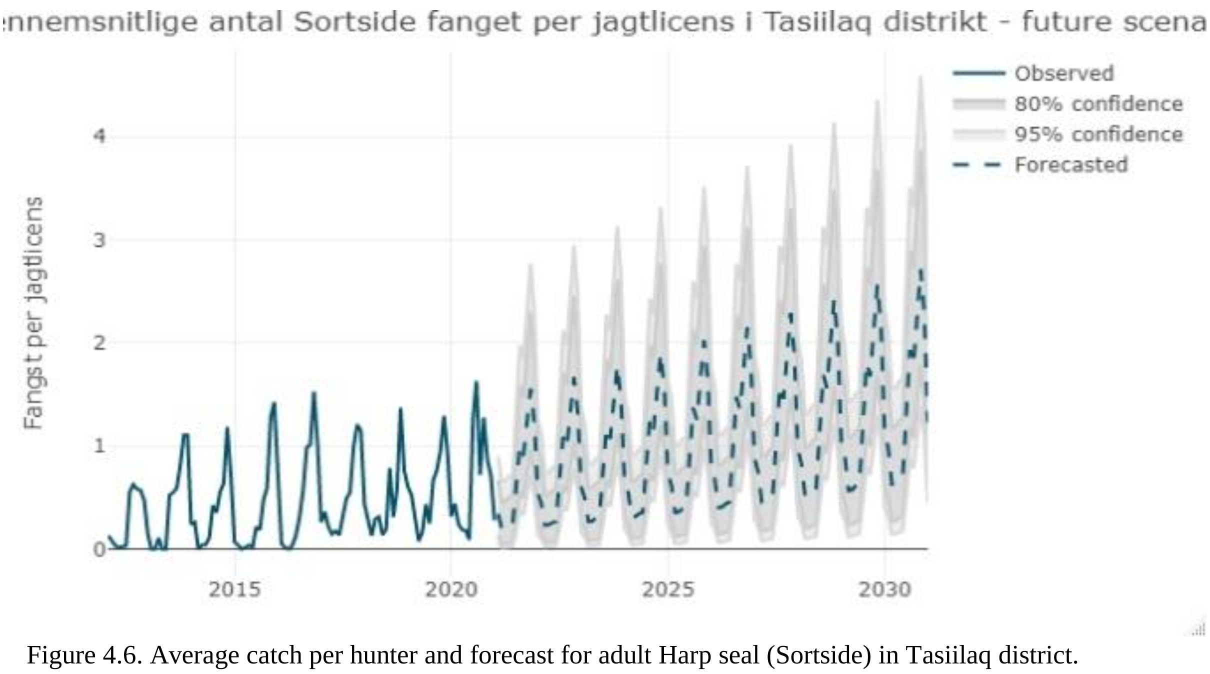


Figure 4.6. Average catch per hunter and forecast for adult Harp seal (Sortside) in Tasiilaq district.

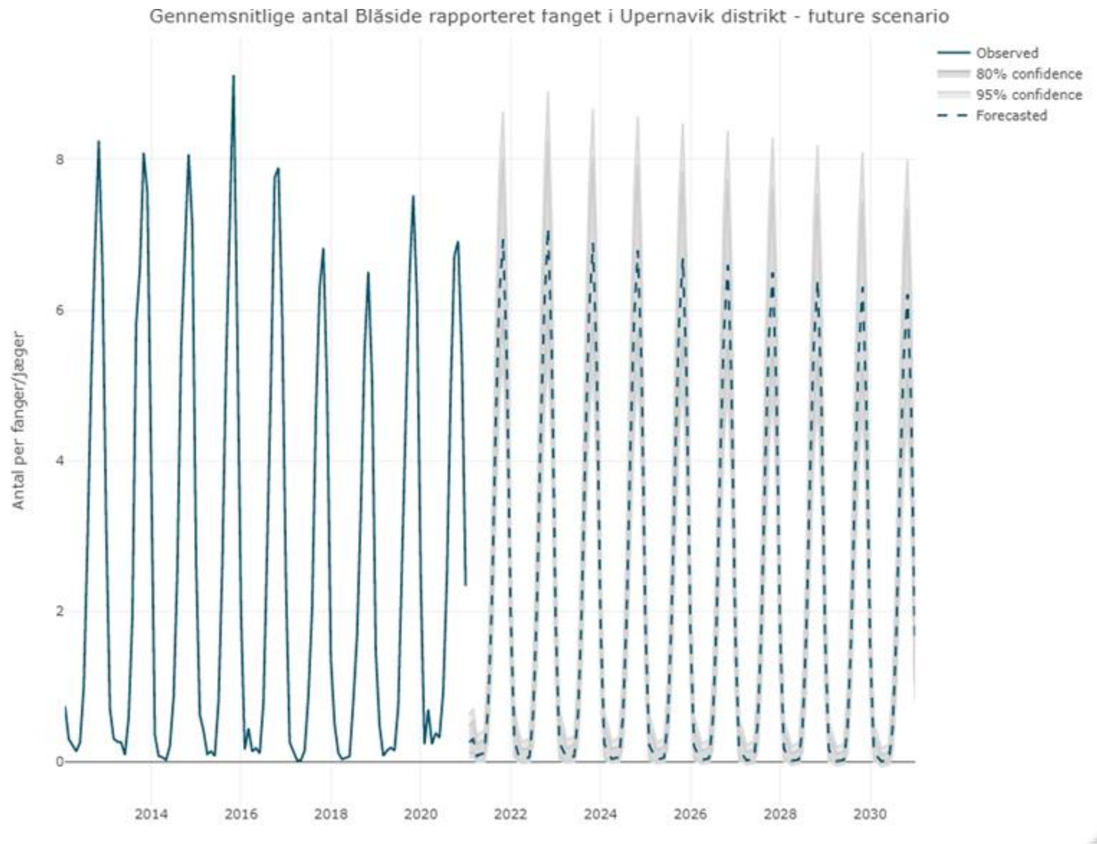


Figure 4.7. Average catch per hunter and forecast for young Harp seal (Blåside) in Upernavik district.

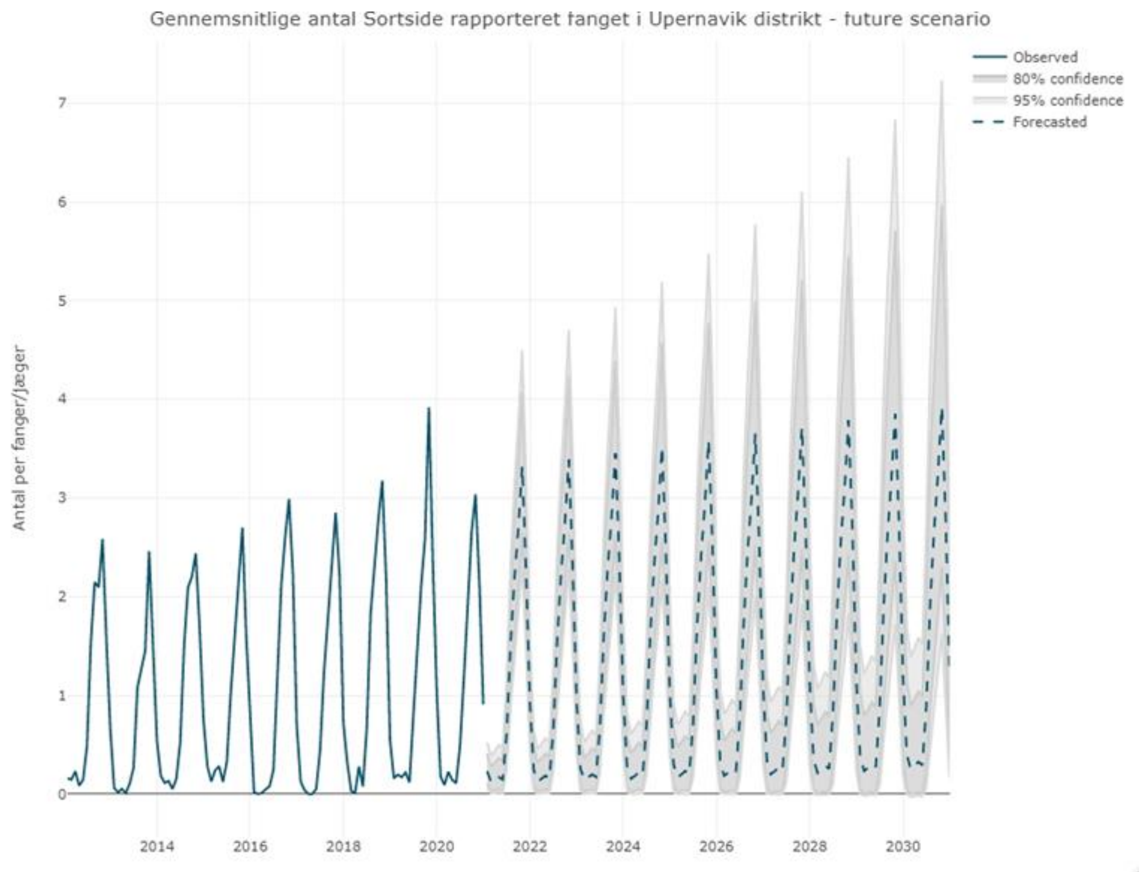


Figure 4.8. Average catch per hunter and forecast for adult Harp seal (Sortside) in Upernavik district.

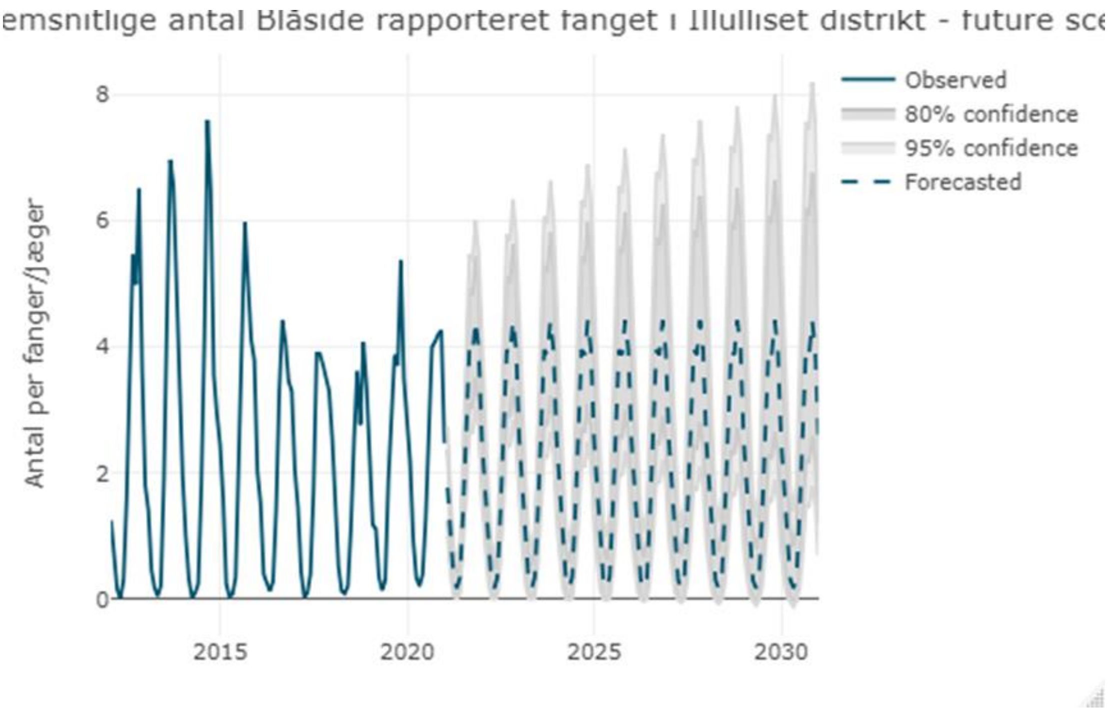


Figure 4.9. Average catch per hunter and forecast for young Harp seal (Blåside) in Ilulisset district.

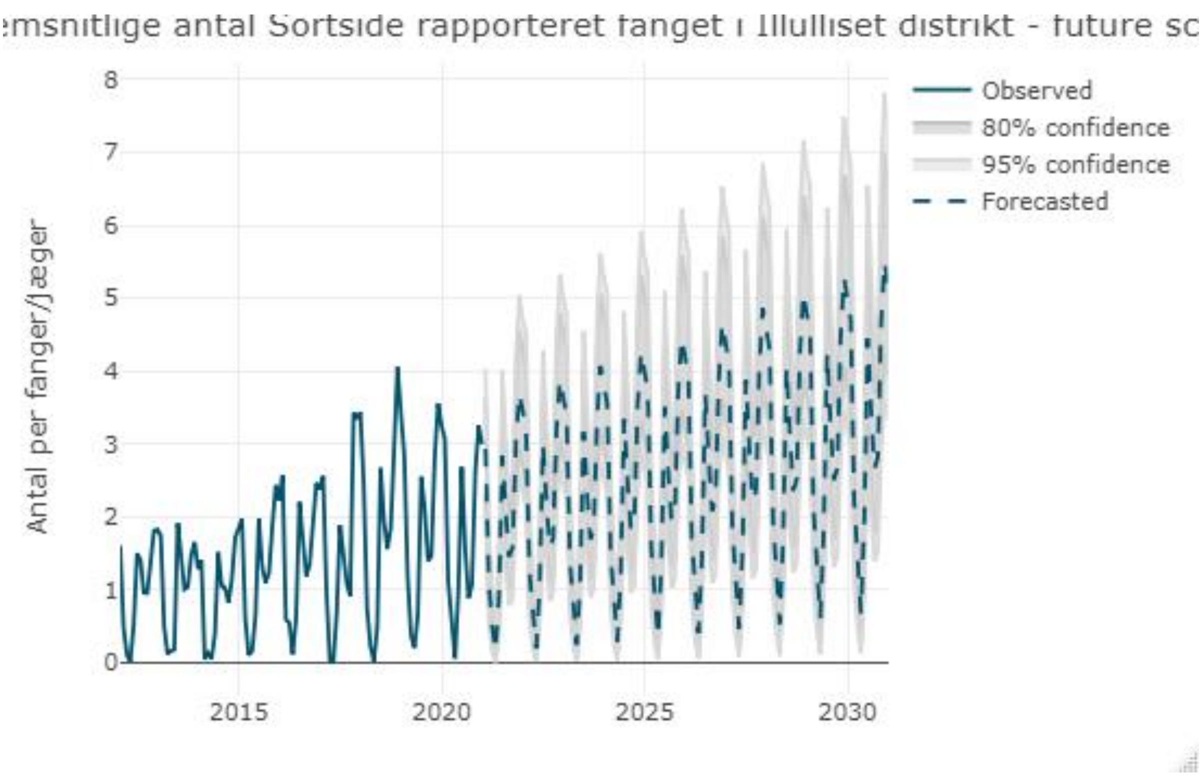


Figure 4.10. Average catch per hunter and forecast for adult Harp seal (Sortside) in Ilulisset district.

The forecasts are not reliable, and particularly the data from Ittoqoortormiit appears insufficient to produce a forecast. Nevertheless, the material was used as a basis for discussion.

Table 4.1. Average annual catch of young Harp seal (Blåsider) per hunter in the period 2012-2020, in 2020 and 2030 (forecasted) and the percentage change in 2030 relative to 2012-2020 and 2020.

District	2012-2020	2020	2030	Δ 2012-2020	Δ 2020
Ittoqoortoormiit	3,30	5,28	14,18	330%	168%
Tasiilaq	33,43	38,91	68,31	104%	76%
Upernavik	32,07	31,51	23,88	-26%	-24%
Ilulissat	27,63	26,84	26,30	-5%	-2%

Table 4.2. Average annual catch of adult Harp seal (Sortsider) per hunter in the period 2012-2020, in 2020 and 2030 (forecasted) and the percentage change in 2030 relative to 2012-2020 and 2020.

District	2012-2020	2020	2030	Δ 2012-2020	Δ 2020
Ittoqoortoormiit	1,65	2,91	1,53	-7%	-47%
Tasiilaq	5,58	7,91	17,18	208%	117%
Upernavik	12,25	13,09	18,19	49%	39%
Ilulissat	17,25	21,00	39,62	130%	89%

4.7. Workshops with Hunters and Fishers Organisations

Young harp seals (Blåsider)

Scenario	Ittoqortoormiit	Tasiilaq	Upernavik	Ilulissat
Trend scenario	Increasing numbers and period present repeating a 1970-80 maximum cycle period	Now overwinter but in scattered and small groups increasing fuel costs. Increasingly dangerous to pursue in the ice (storisen)	Selling skin is less profitable than fishing and therefore expects declining catch of 25%	Trade options restricted/closed. Expects stable catch for subsistence purposes
Alternative scenario	Establishment of processing and trade facilities would increase catch substantially	Estimates that part-time hunters catch 100 each many of which are not reported	NA	NA

Adult harp seals (Sortsider)

Scenario	Ittoqortoormiit	Tasiilaq	Upernavik	Ilulissat
Trend scenario	Many seals but not purchased by GG. Expects declining or stable catch.	Increasing catch due to longer ice free period	Skin and meat is no longer used. Therefore expects 10% decline in catch (contrary to observed trend)	Increasing catch until skin trade facility closed in 2019.
Alternative scenario	NA	NA	NA	NA

4.8. Interviews with Scientific Experts

-will follow-

4.9. Preliminary Future Scenarios

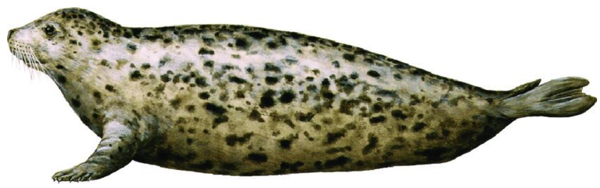
Young harp seals (Blåsider)

Scenario	Ittoqortoormiit	Tasiilaq	Upernavik	Ilulissat
Stock and catch trend scenario	+20 compared to 2012-20	+10% compared to 2012-20	-25% compared to 2012-20	Stable compared to 2012-20
Underreporting adjustment scenario		Check numbers reported by part-time hunters and adjust to 100 stk		
Alternative actions scenario	+30% compared to 2012-20			

Adult harp seals (Sortsider)

Scenario	Ittoqortoormiit	Tasiilaq	Upernavik	Ilulissat
Stock and catch trend scenario	-10% compared to 2012-20	+20% compared to 2012-20	-10% compared to 2012-20 +10% compared to 2012-20	Stable compared to 2020
Underreporting adjustment scenario				
Alternative actions scenario				

5. Harbour seals (*Phoca vitulina*)

Harbour seals	
Phoca vitulina	
Spættet sæl	
Qasigiaq	

Distributed along the sections of the Greenlandic coast with sub-arctic marine environments (south of 67°N on the east coast and south of 75°N on the west coast) (Greenland Institute of Natural Resources, 2021). Although probably never numerous, harbour seals were once spread over much of the West Greenland coast (Ugarte et al., 2020a). Due to excessive hunting and perhaps interactions with fisheries, harbour seals disappeared or became extremely rare throughout most of their former range (Ugarte et al., 2020a). Harbor seals are now only regularly observed at three breeding/molting locations, but observations of individual seals and small groups of seals far from these localities indicate that other small remnant populations still exist (Ugarte et al., 2020a). Harbor seals are listed as of Least Concern in the global Red List, but are Critically Endangered in the Greenland Red List (Ugarte et al., 2020a).

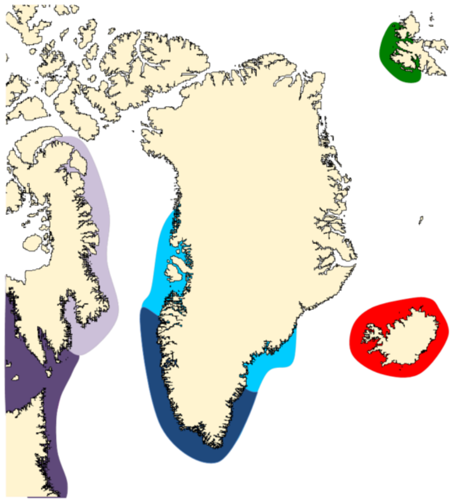


Figure 5.1 Populations of harbour seals (Greenland Institute for Natural Resources)

5.1. Climate Change

Harbour seals do not depend on ice for breeding (Kovacs and Lydersen, 2008). Predictions concerning climate change are challenging due to precipitous declines in northern populations and a northward range expansion (Kovacs and Lydersen, 2008). There is an expected novel occupation of Arctic latitudes and longer residence times (Moore and Huntington, 2008). In recent years predation by polar bears on harbour seals has been documented in Svalbard ((NAMMCO, 2016), Lydersen pers. comm.).

The harbour seal population on Svalbard is temperate, not ice-affiliated, and is not a true Arctic species. Harbour seals avoided heavy ice concentrations (> 50%) but did occupy areas with substantial amounts of drifting ice (5 to 25%) (Blanchet et al., 2014). During the winter/early spring, seals exhibited changes in diving behaviour, including deeper dives (averaging ~150m), longer durations (~480sec), fewer dives (~250 dives/day), and a higher proportion of time spent in pelagic areas compared to the fall (Blanchet et al., 2015). This might relate to an influx of warm saline water with Atlantic Water at depths of approximately 100m, likely bringing Atlantic fish species closer to shore and within the seals' foraging depth-range (Blanchet et al., 2015). It is anticipated that they might have a competitive advantage over local arctic species under warmer conditions and the predicted increase in Atlantic Water influx (Blanchet et al., 2014, 2015).

5.2. Hunting

Hunting is likely the main reason for the former declines (Ugarte et al., 2020). The hunt was unregulated until 1960, when adult harbour seals were given legal protection throughout Greenland between 1st May and 30th September (Anon. 1960). Protection of young animals and newborns or any quota or upper limit on the catch has never been implemented (Ugarte et al., 2020). Therefore, catch statistics trends should reflect relative abundance changes (Rosving-Asvid, 2010). The skin from harbour seals was traditionally used in the women's national costume and, therefore especially coveted. Hunting of this species has been banned in Greenland since 2010 (Ugarte et al., 2020).

5.3. Status and Trends of Populations

South Greenland:

Region/ population	Abundance	Status, change	Trend (Short term)	Category of change	Description: Physiological, behavioural change	Climate variable & direction	Hunting
South Greenland	Unknown (ICES, 2019b)	Reduced (ICES, 2019b)	Increasing (ICES, 2019b)				

West Greenland:

Region/ population	Abundance	Status, change	Trend (Short term)	Category of change	Description: Physiological, behavioural change	Climate variable & direction	Hunting
WestGreenl and	Unknown (ICES, 2019b)	Reduced (ICES, 2019b)	Stable (ICES, 2019b)				

East Greenland:

Region/ population	Abundance	Status, change	Trend (Short term)	Category of change	Description: Physiological, behavioural change	Climate variable & direction	Hunting
East Greenland	Unknown (ICES, 2019b)	Reduced (ICES, 2019b)	Unknown (ICES, 2019b)				

5.4. Synopsis

The literature review pointed out moderate evidence for a decline of the East Greenland population of Harbour seal. For the South Greenland population, we found moderate evidence for a decline and negligible evidence for an increase. For West Greenland, we found moderate evidence for a decline and strong evidence for a stable population.

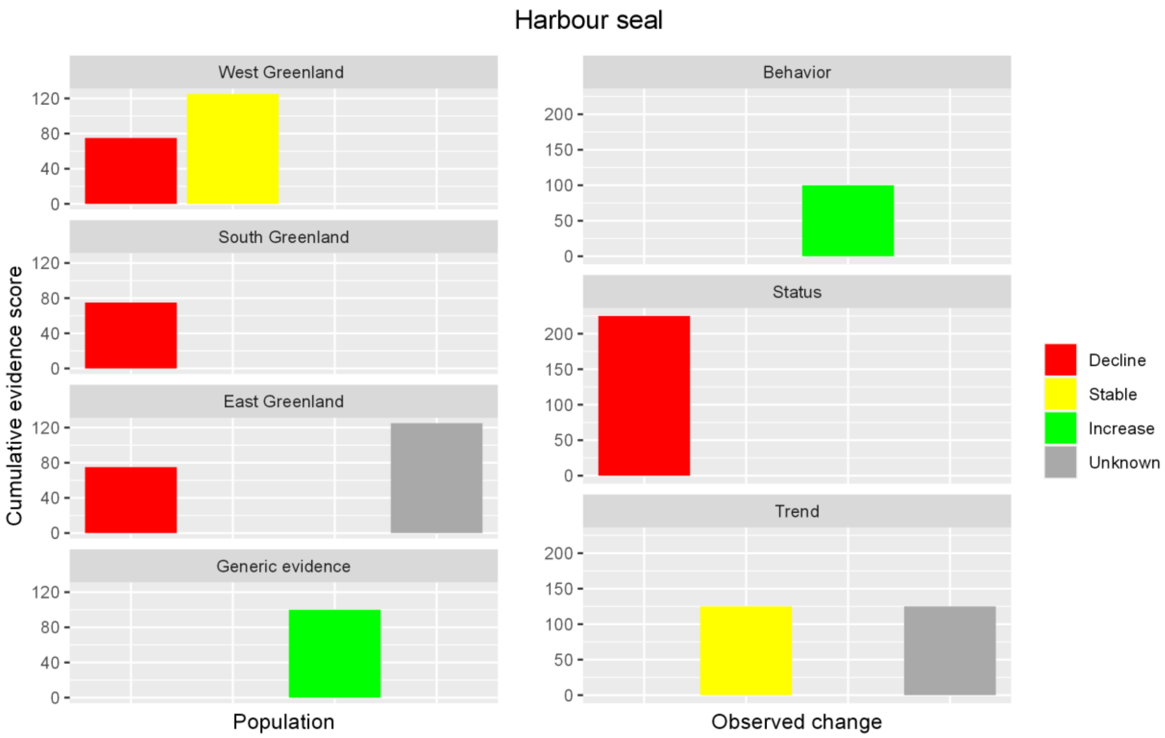


Figure 5.2 Cumulative evidence scores per population and aspect of change.

5.5. Catch and Forecast

The species is protected, and very few catches were recorded. And these may be erroneous.

5.6. Workshops with Hunter and Fishers Orgnisations

-not discussed-

5.7. Interviews with Scientific Experts

-will follow-

5.8. Preliminary Future Scenarios

Scenario	Ittoqortoormiit	Tasiilaq	Upernavik	Ilulissat
Stock and catch trend scenario	-10% compared to 2012-20	+20% compared to 2012-20	-10% compared to 2012-20 +10% compared to 2012-20	Stable compared to 2020

Underreporting adjustment scenario				
Alternative actions scenario				

6. Ringed seals (*Phoca hispida*)

<table>
<tr><td>Ringed seals</td><td rowspan="4"></td></tr>
<tr><td>Phoca hispida</td></tr>
<tr><td>Netside</td></tr>
<tr><td>Natseq</td></tr>
</table>

Ringed seals (*Phoca hispida*) is the only northern seal that can maintain breathing holes in thick sea ice (over 2 m in thickness) and therefore thrive in areas where even other ice-associated seals cannot reside (NAMMCO, 2016).

Table 6.1. World map providing approximate representation of the ringed seal's range

6.1. Climate Change

Ringed seals are the most ice-obligate species (Moore & Huntington 2008) and likely the most vulnerable of the high-arctic pinnipeds (NAMMCO, 2016). Another review assessed them as least sensitive to climate change (Laidre et al., 2008). Their reliance on sea ice as a resting and breeding platform, as well as their need for snow cover as protection from cold and predators, are crucial factors contributing to their dependence on these elements for successful resting, whelping, nursing, and moulting (NAMMCO, 2016). Land-breeding would expose the ringed seals' small neonates to much higher predation rates and collapsing lairs during rain (Kovacs and Lydersen, 2008). There are expected declines in recruitment and body condition (Moore & Huntington 2008). Ringed seals spent less time resident and exhibited more travelling behaviour during the ice-free period in higher latitudes with a shorter ice-free season and more inter-annual variability in sea ice phenology than at lower latitudes (Yurkowski et al., 2016). A decrease in ice cover size and duration would directly reduce the available habitat for ringed seals. This reduction in ice cover could lead to negative consequences such as poor condition of seal pups and higher pup mortality due to the early destruction of their birth lairs. In the southern Baltic Sea, a period of almost ice-free winters from 1989 to 1995 resulted in significantly high pup mortalities (Härkönen et al., 1998). By using a coupled Model Intercomparison, it was estimated that the area with snow depths above 20 cm — a threshold needed for ringed seals to build snow caves — will decline by 70% by the end of the century (Hezel et al., 2012). Snow depths on flat ice of 20–32 cm are necessary to protect young ringed seals from predation and hypothermia (Ferguson et al., 2005). Data on ringed seals killed by Inuit hunters from western Hudson Bay (1991-1992, 1999-2001) showed that decreased snow depth, particularly below 32 cm, corresponded with a significant decrease in ringed seal recruitment as indicated by pups born and surviving to adults that were later harvested a (Ferguson et al., 2005). The examination of two large-scale movement tactics in ringed seals during their non-breeding, post-moulting period in Svalbard showed that some seals used offshore areas containing 40–80% ice coverage, while other individuals spread along the coasts, concentrating their time near glacier fronts (Freitas et al., 2008a). This flexibility could increase population viability (Freitas et al., 2008a). A statistical Cox proportional hazards (CPH) model in combination with a model for ringed seal blubber mass gain during summer showed here that migrations to offshore ice edges were predicted to become energetically unprofitable for ringed seals if the sea ice retreats further than 600–700 km from Svalbard (Freitas et al., 2008b). Aerial surveys were conducted during late May and early June 1996-99 in the central Beaufort Sea of Alaska showed that highest densities occurred at depths between 5 and 35 m and in relatively flat ice and near the fast ice edge, declining both shoreward and seaward of that edge (Frost et al., 2004). During warmer years, ringed seal pups face may increased vulnerability to predation by polar bears (Ferguson et al., 2005; Hammill and Smith, 1991). In addition to the direct impacts on their habitat, climate change presents risks to ringed seals through various indirect changes. These include shifts in the distribution of prey species, heightened competition from boreal species, increased predation rates from polar bears, arctic foxes, and killer whales, elevated risks of diseases and parasites, greater exposure to pollution due to increased human activity and development in previously inaccessible ice-covered areas (Kelly et al., 2010; Kovacs et al., 2011).

6.2. Hunting

Ringed seals are important for the subsistence economy of Greenlanders in some regions. The average annual reported catches during 2012–17 were 56.000 seals (Ugarte et al., 2020). Ringed seal and harp seal are by far the most important in terms of numbers caught, and both of these species provide the inhabitants with a fundamental source of food and income. Seal meat is a staple food for both humans and sledge dogs, while skins are purchased with government subsidies by the state-owned tannery, Great Greenland, providing a much-needed income in areas with otherwise limited opportunities for paid employment (Ugarte et al., 2020). During the open-water season, all seals are shot from skiffs (Boertmann and Mosbech, 2017). Ringed seals are also caught with nets, especially during the dark winter months. In addition, ringed seals are shot while sunning on the sea ice during their moulting period, from April to June (Boertmann and Mosbech, 2017).

6.3. Status Population Trends

Predicting population trends is difficult since ringed seals can only be surveyed during their annual molt (Krafft et al., 2006).

West Greenland

Region/ population	Abundance	Status, change	Trend (Short term)	Category of change	Description: Physiological, behavioural change	Climate variable & direction	Hunting
Baffin Bay	**1990: 1,200,000** (Kingsley, 1998)	Unknown (Ugarte et al., 2020a)	Unknown (Ugarte et al., 2020a)				

East Greenland:

Region/ population	Abundance	Status, change	Trend (Short term)	Category of change	Description: Physiological, behavioural change	Climate variable & direction	Hunting
East Greenland	Unknown (Ugarte et al., 2020a)	Unknown (Ugarte et al., 2020a)	Unknown (Ugarte et al., 2020a)				

6.4. Synopsis

Ringed seas are ice-obligate and conisderd most sensitive to climate change. Most population trends or status of Ringed seal remain unknown. We found strong generic evidence for a decline in populations in Greenland.

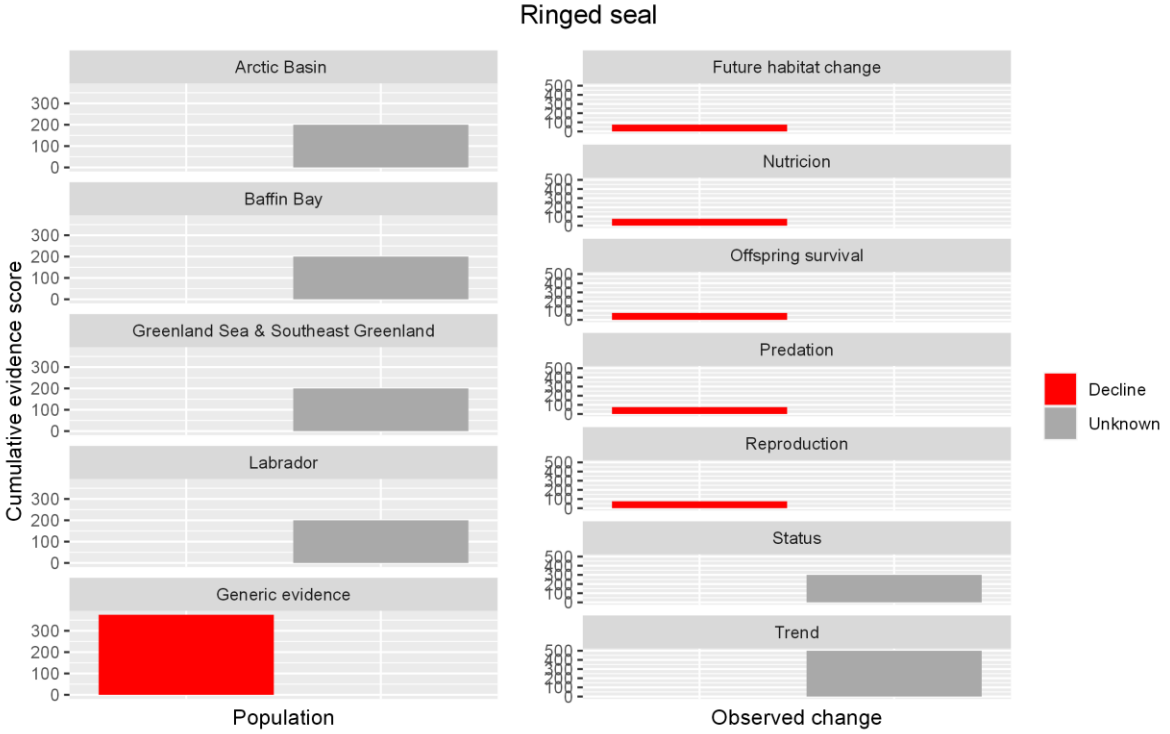


Figure 6.2. Cumulative evidence scores per population and aspect of change.

6.5. Catch and Forecast

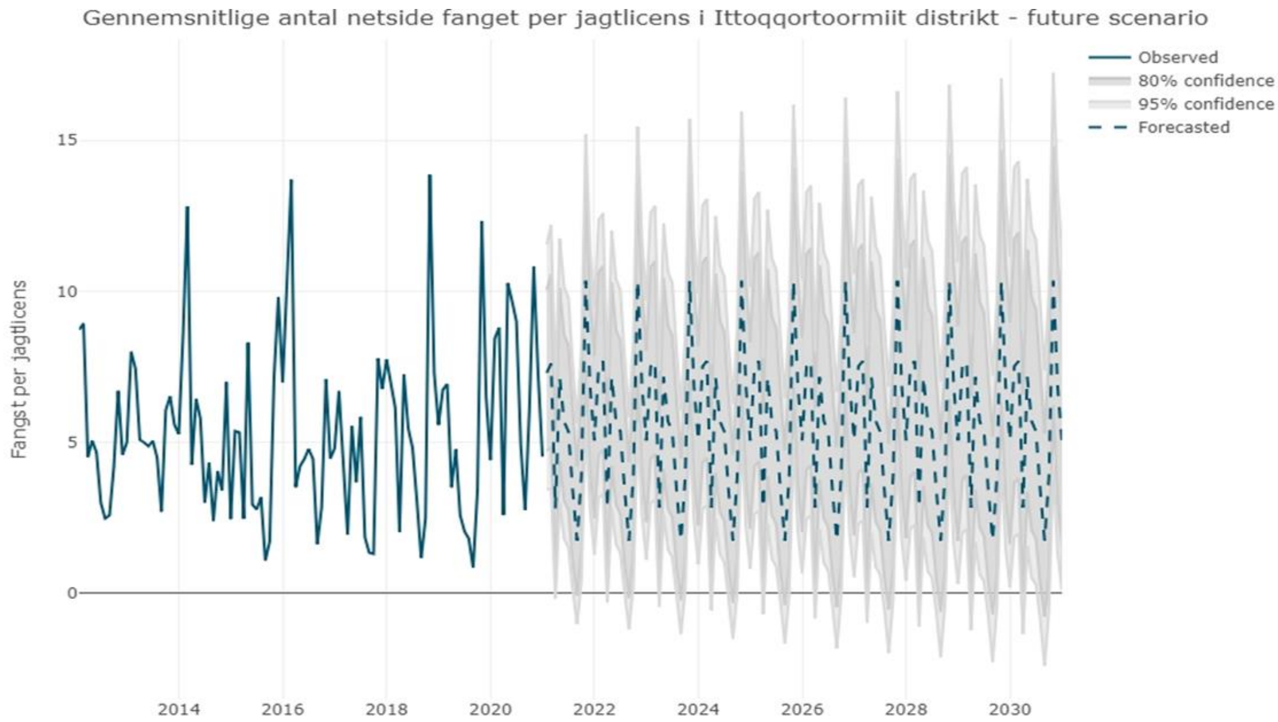


Figure 6.3. Average catch per hunter and forecast for Ringed seal in Ittoqortoormiit district.

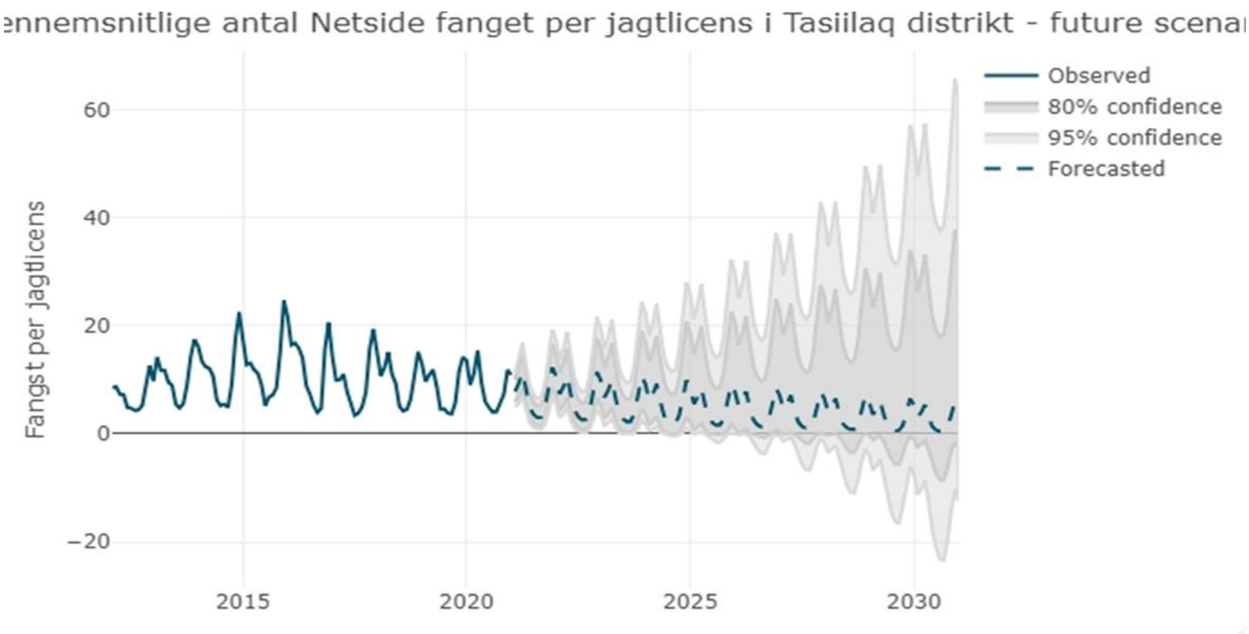


Figure 6.4. Average catch per hunter and forecast for Ringed seal in Tasiilaq district.

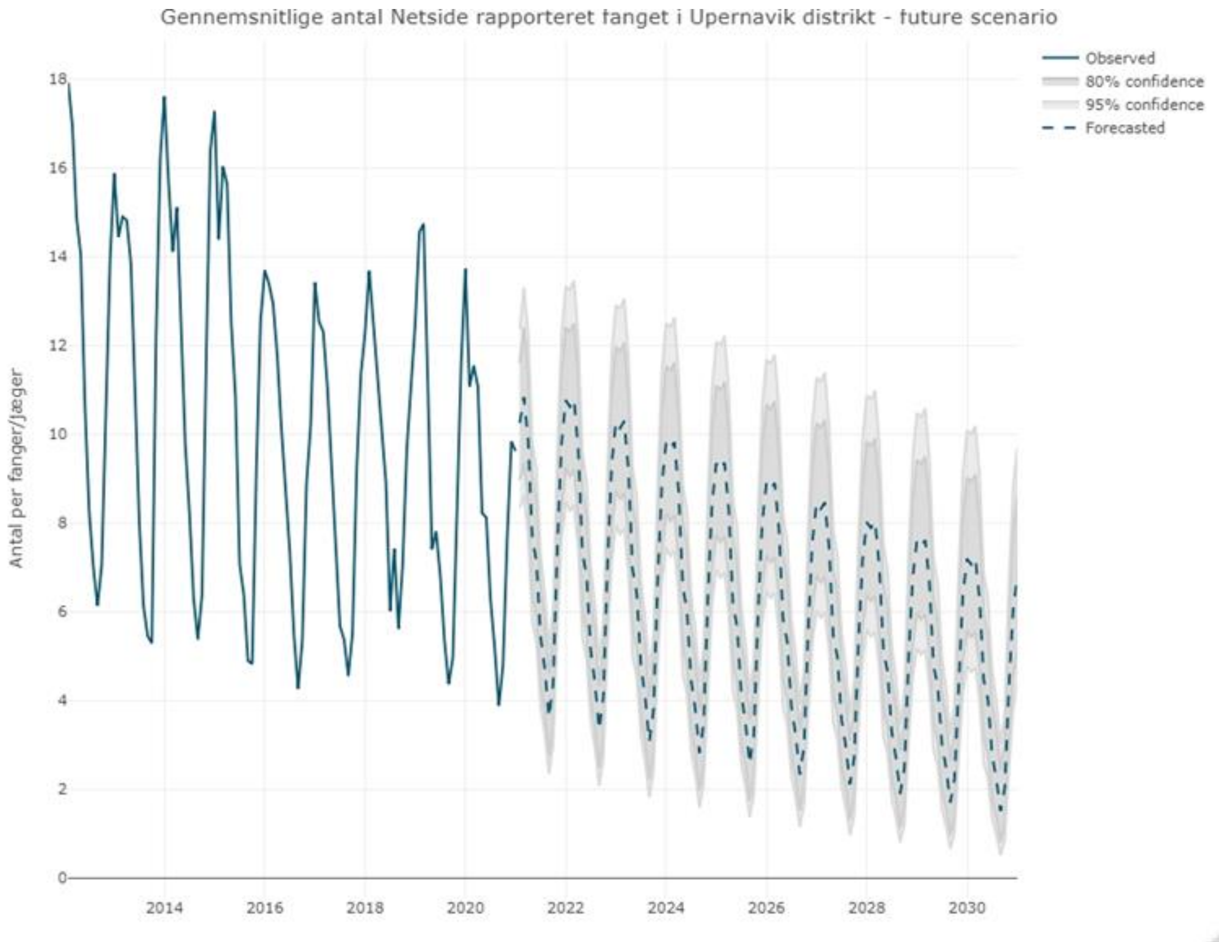


Figure 6.5. Average catch per hunter and forecast for Ringed seal in Upernavik district.

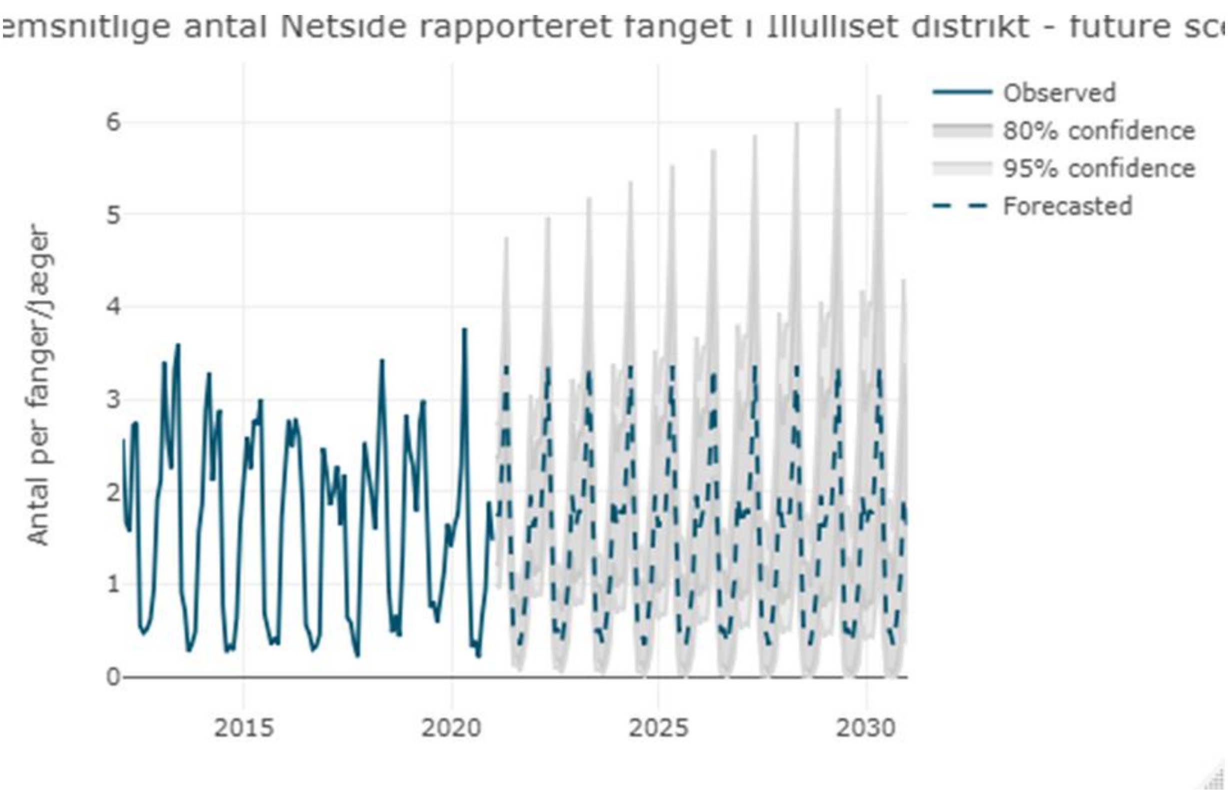


Figure 6.6. Average catch per hunter and forecast for Ringed seal in Ilulissat district.

The forecasts are not reliable. Nevertheless, the material was used as a basis for discussion.

Table 6.1. Average annual catch of Ringed seal per hunter in the period 2012-2020, in 2020 and 2030 (forecasted) and the percentage change in 2030 relative to 2012-2020 and 2020.

District	2012-2020	2020	2030	Δ 2012-2020	Δ 2020
Ittoqoortoormiit	64,06	85,22	67,60	6%	-21%
Tasiilaq	119,86	100,04	33,78	-72%	-66%
Upernavik	121,26	97,29	54,57	-55%	-44%
Ilulissat	19,33	16,93	17,76	-8%	5%

6.6. Workshops with Hunter and Fishers Orgnisations

Scenario	Ittoqortoormiit	Tasiilaq	Upernavik	Ilulissat
Trend scenario	Food preferences are shifting to other species. Expects slight decrease	Declining due to overharvesting.	Catch limited by factory capacity, Would otherwise be increasing	Catch using nets is being reviewed by younger generation
Alternative scenario	Increase if better production facilities	Part-time hunters banned from catching, and only 3-4 nets allowed	Marketing of dried meat and improved trading facilities	NA

6.7. Interviews with Scientific Experts

-will follow-

6.8. Preliminary Future Scenarios

Scenario	Ittoqortoormiit	Tasiilaq	Upernavik	Ilulissat
Stock and catch trend scenario	-5% compared to average over the period 2012-20	-40% compared to average over the period 2012-20	Stable at average catch in the period 2012-2020	+5% compared to average over the period 2012-20
Underreporting adjustment scenario				
Alternative actions scenario		0 catch by part time hunters and catch reduced by 20% compared to average over 2012-20 by occupational hunters	+10% increase compared to the average in the period 2012-2020	

7. Bearded seals (*Erignathus barbatus*)

Bearded seals	
Erignathus barbatus	
Remmesæl	
Ussuk	

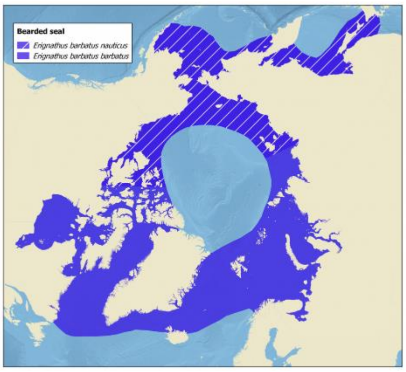


Figure 7.1. Distribution of Brearded seals

Occur throughout the Arctic in a patchy, low-density distribution (ICES, 2019b). Not enough is known to be able to delineate distinct stocks or breeding populations (NAMMCO, 2016).

7.1. Climate Change

Bearded seals are considered as least sensitive to climate change (Laidre et al., 2008). As an ice-obligate species (Moore & Huntington 2008), climate change will likely negatively impact recruitment and body condition (Moore and Huntington, 2008). However, this species seems flexible in adapting to a warmer Arctic with less ice (Kovacs and Lydersen, 2008). Bearded seals rely heavily on sea ice throughout the year. They specifically need stable ice pans during late spring for raising their pups and undergoing moulting and summer ice for resting (NAMMCO, 2016).

Additionally, the availability of suitable ice is crucial during the pupping and nursing periods, as it should be located over shallow waters with a rich benthic community, which ensures food supply (Kovacs et al., 2011). Bearded seals will lose critical pupping and nursing habitat if suitable ice floes are not available (Hindell et al. 2012, Kovacs et al. 2011), which could result in a lowering of the carrying capacity of their habitat (Laidre et al. 2015). Bayesian isotopic mixing models indicated that diet varied considerably among years with most fast-ice (2005), where seals had the greatest proportion of pelagic fish and lowest benthic invertebrate content, and during the year with the least ice (2006), the seals ate more benthic invertebrates and less pelagic fish (Hindell et al., 2012). This suggests that they adapt to changing conditions by feeding offshore in years with greater ice cover and using fjords when ice-cover is lower, giving them access to different types of prey (Hindell et al., 2012). In the vicinity of Svalbard, bearded seals have been observed utilizing sections of calved glacier ice as resting platforms, potentially as a response to the reduction of sea ice (Lydersen et al., 2014). The reduction of ice cover in May increased the display behaviour of male individuals, and roaming males were not detected when the ice cover exceeded 60%, while territorial males were present across all ice conditions (Van Parijs et al., 2004). Yearly variations in ice cover could therefore affect the long-term mating success of individuals (Van Parijs et al., 2004). In the western Beaufort, the call activity of bearded seals increased with the formation of pack ice during the winter, reaching its peak in the spring, which aligned with the mating season and preceded the breakup of the sea ice

(MacIntyre et al., 2013). The timing of peak call activity corresponded to the changes in the timing of seasonal sea ice formation and retreat observed between two consecutive years (MacIntyre et al., 2013). In southern Baffin Bay and Davis Strait, calling occurred between November and late June with most intense calling during the mating season. The number of detections were affected by depth and distance to shore, and the Greenland shelf (< 300 m) appeared to be the preferred habitat during the mating season (Boye et al., 2020). These results suggest that bearded seals may retreat with the receding sea ice to Canada during summer or possibly spend the summer along the West Greenland coast (Boye et al., 2020). However, an absence of existing baseline data for bearded seals presents challenges in monitoring and assessing the impact of climate change on their populations, both in the present and future (NAMMCO, 2016).

7.2. Hunting

The average annual reported catches during 2012–17 in Greenland were 1200 seals (NAMMCO, 2016).

7.3. Status and Population Trends

West Greenland

Region/ population	Abundance	Status, change	Trend (Short term)	Category of change	Description: Physiological, behavioural change	Climate variable & direction	Hunting
Eastern Canada and West Greenland	Unknown (Ugarte et al., 2020a)	Unknown (Ugarte et al., 2020a)	Unknown (Ugarte et al., 2020a)				

East Greenland:

Region/ population	Abundance	Status, change	Trend (Short term)	Category of change	Description: Physiological, behavioural change	Climate variable & direction	Hunting
East Greenland	Unknown (Ugarte et al., 2020a)	Unknown (Ugarte et al., 2020a)	Unknown (Ugarte et al., 2020a)				

7.4. Synopsis

Bearded seals are considered ice-obligate but exhibit some flexibility. We found weak evidence for a decline in the Eastern Canada/West Greenland population and weak generic evidence that populations are or will decline. Most population trends are unknown.

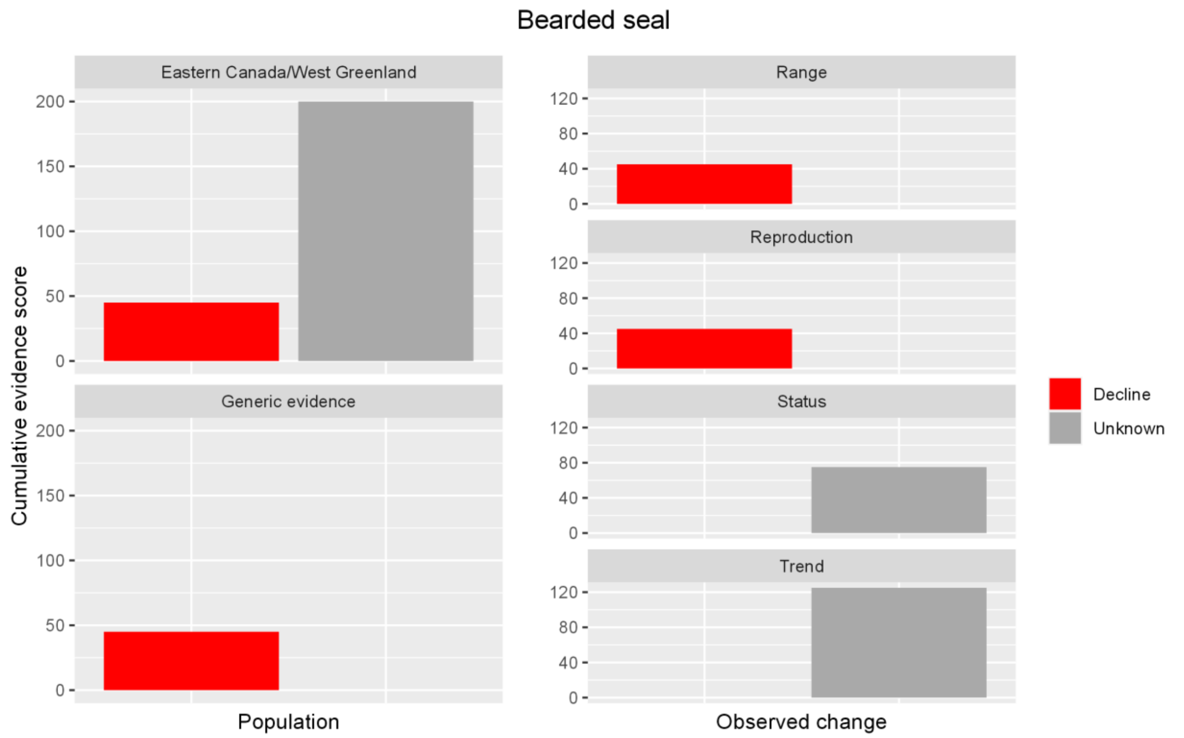


Figure 7.1 Cumulative evidence scores per population and aspect of change.

7.5. Catch and Forecast

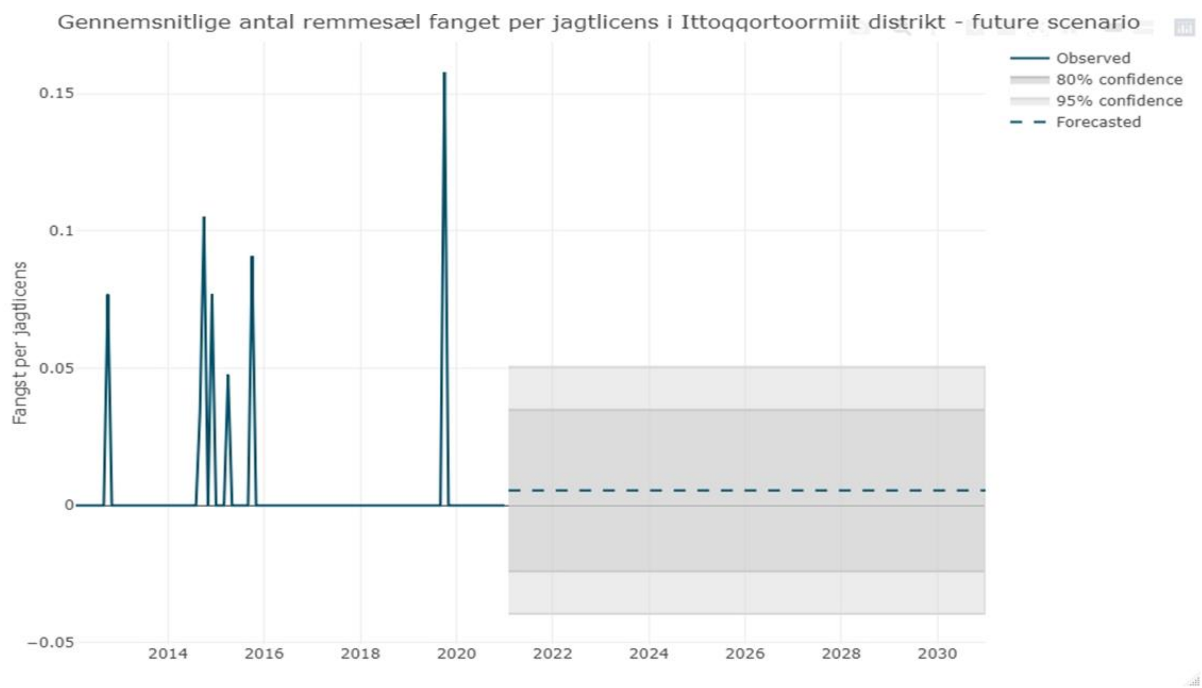


Figure 7.3. Average catch per hunter and forecast for Bearded seal in Ittoqortoormiit district.

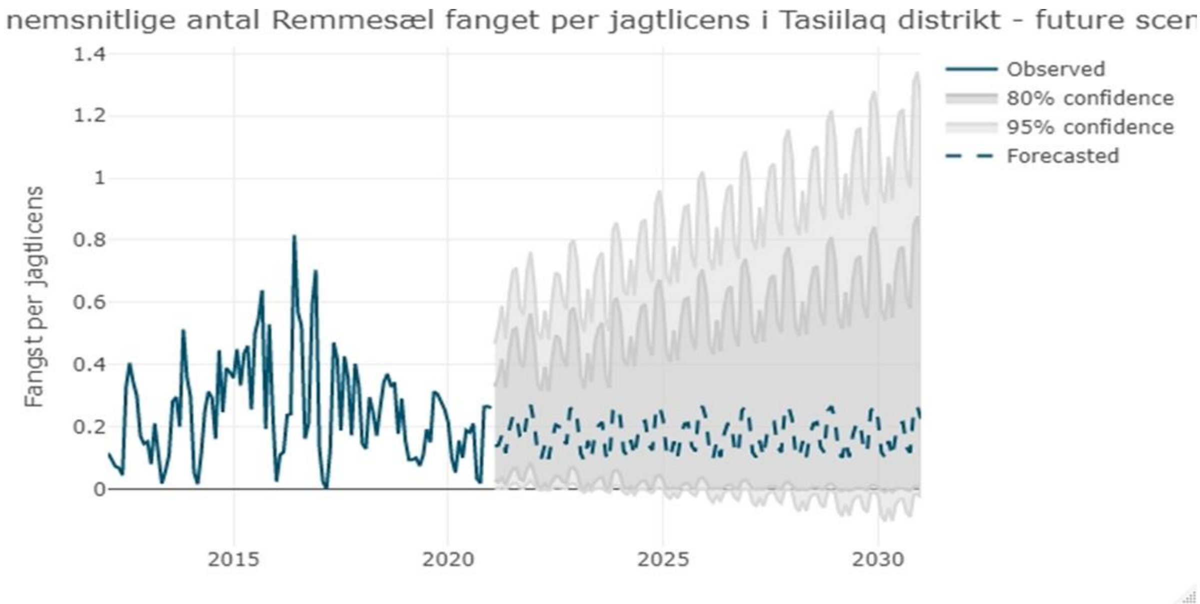


Figure 7.4. Average catch per hunter and forecast for Bearded seal in Tasiilaq district.

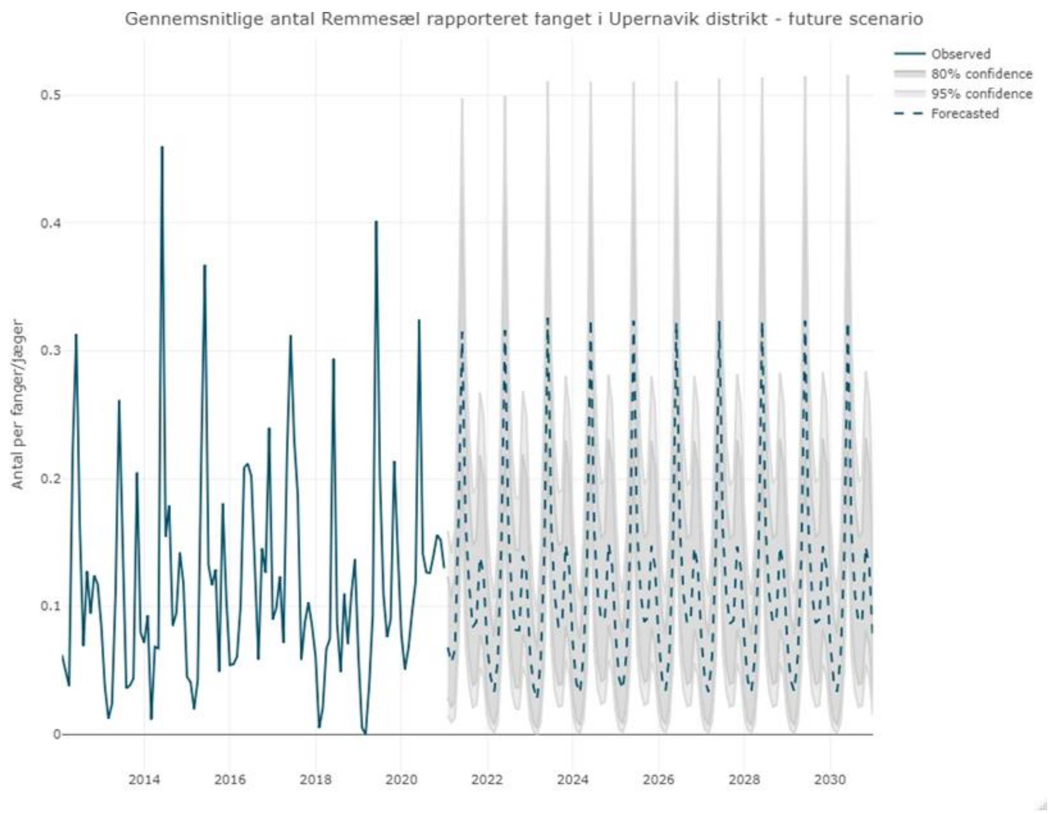


Figure 7.5. Average catch per hunter and forecast for Bearded seal in Upernavik district.

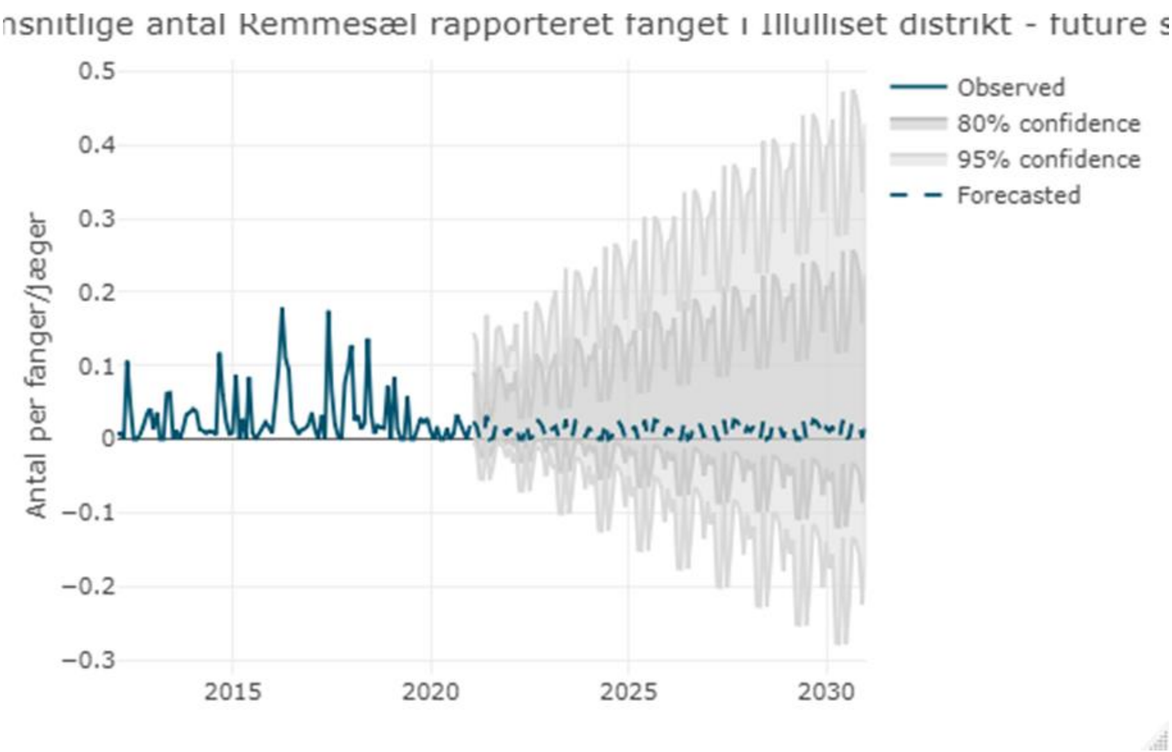


Figure 7.6. Average catch per hunter and forecast for Bearded seal in Ilulissat district.

The forecasts are not reliable, and particularly the data from Ittoqoortormiit appears insufficient to produce a forecast. Nevertheless, the material was used as a basis for discussion.

Table 7.1. Average annual catch of Bearded seal per hunter in the period 2012-2020, in 2020 and 2030 (forecasted) and the percentage change in 2030 relative to 2012-2020 and 2020.

District	2012-2020	2020	2030	Δ 2012-2020	Δ 2020
Ittoqoortoormiit	1,37	1,43	1,19	-13%	-17%
Tasiilaq	3,00	1,83	2,07	-31%	13%
Upernavik	1,44	1,63	1,40	-3%	-14%
Ilulissat	0,36	0,13	0,14	-60%	12%

7.6. Workshops with Hunter and Fishers Orgnisations

Scenario	Ittoqortoormiit	Tasiilaq	Upernavik	Ilulissat
Trend scenario	Only used for dog food and as the number of dogs is declining catch is also expected to decline	No longer used for rope and skin cannot be traded after 2015. Therefore, agree with the scenario	Use for soles declining. Expects stable catch compared to average over the period 2012-20	Declining use mainly for whips. Expects stable catch relative to 2020 level
Alternative scenario	NA	NA	NA	NA

7.7. Interviews with Scientific Experts

-will follow-

7.8. Preliminary Future Scenarios

Scenario	Ittoqortoormiit	Tasiilaq	Upernavik	Ilulissat
Stock and catch trend scenario	-10% compared to the average over the period 2012-20	-30% compared to the average over the period 2012-20	Stable compared to average over the period 2012-20	Stable compared to 2020 catch
Underreporting adjustment scenario				
Alternative actions scenario				

8. Polar bears (*Ursus maritimus*)

Polar bears	
Ursus maritimus	
Isbjørn	
Nanok	

Polar bears are ice-dependent (Moore and Huntington, 2008) and, therefore, among the species most sensitive to climate change (Laidre et al., 2018a). Polar bears depend on sea ice for all aspects of their life, including travel, breeding, and foraging for ice seals (Ugarte et al., 2020). Sea ice conditions are the most influential determinant of population outcomes (Atwood et al., 2016a; Laidre et al., 2008). In the areas without summer sea ice, polar bears either fast on land, spend the summer on multiyear sea ice, or near glaciers where limited opportunities for feeding on seals resting on glacial ice may arise (Ugarte et al., 2020).

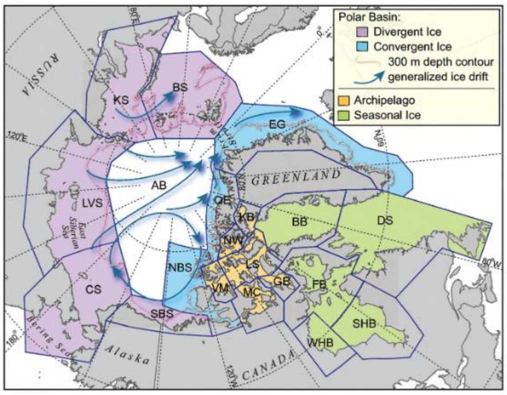


Figure 8.1. Map of the four polar bear ecoregions. Dark blue lines represent seasonal ice motion patterns. The blue area is the polar basin convergent ecoregion, green is the seasonal ice ecoregion, yellow is the archipelago ecoregion and purple is the polar basin divergent ecoregion (from (Atwood et al., 2016a).

8.1. Populations

The Polar bear range includes four polar bear ecoregions defined by grouping recognized subpopulations that share seasonal ice motion patterns and distribution as depicted in Figure 8.1 (Amstrup et al., 2008). The polar basin convergent ecoregion (PBCE) (blue) includes East Greenland (EG), Queen Elizabeth Islands* (QE), and Northern Beaufort Sea (NBS). The seasonal ice ecoregion (SIE) (green) includes southern Hudson Bay (SHB), western Hudson Bay (WHB), Foxe Basin (FB), Davis Strait (DS), and Baffin Bay (BB). The archipelago ecoregion (AE) (yellow) includes the Gulf of Boothia (GB), M'Clintock Channel (MC), Lancaster Sound (LS), Viscount-Melville Sound (VM), Norwegian Bay (NW), and Kane Basin (KB). Finally, the polar basin divergent ecoregion (PBDE) (purple) includes the Southern Beaufort Sea (SBS), Chukchi Sea (CS), Laptev Sea (LVS), Kara Sea (KS), and the Barents Sea (BS). Recently, an isolated population of polar bears from southeastern Greenland was discovered (living south of 64°N) (Laidre et al., 2022). This population inhabitat the terminal end of a glacier using the resources from this glacial-freshwater mélange and is therefore much less dependent on sea ice (Laidre et al., 2022). Here, we focus on the subpopulations considered fully or partly Greenlandic, namely the subpopulation in Baffin Bay (BB), Davis Strait (DS), the Kane Basin (KB), the Artic Basin (AB) and East Greenland (EG) (Ugarte et al., 2020a). These populations are managed by the

Greenlandic authorities and for Davis Streat, Baffin Bay and Kane Basin by Canadian and Greenlandic authorities (IUCN/PBSG, 2021; SWG, 2016; Ugarte et al., 2020a). The Greenland Institute of Natural Recourses (GINR) and the Canada-Greenland Joint Commission on Polar Bear advise the Greenlandic government on polar bear management (Ugarte et al., 2020a).

8.2. Behavioral Changes

The disappearance of summer offshore sea ice leads to longer durations on land (Laidre et al., 2020b) and declines in monthly movement rates (Laidre et al., 2018a). There are increased observations near-shore (Wiig et al., 2008) and summer use of coastal habitats by polar bears (Atwood et al., 2016b; Laidre et al., 2020b). Adult female polar bears in the Baffin Bay subpopulation now spend an additional 30 d on land (90 d in total) in the 2000s compared to the 1990s (Laidre et al., 2020b). A positive relationship was found between the distance from shore to the ice edge and the number of bears observed on the coast (Laidre et al., 2008). In the southern Beaufort Sea, intense storm events with sustained high wind speeds were shown to trigger seasonal movements of polar bears towards land, especially when the sea ice habitat was suboptimal (Kellner et al., 2023). Migration towards land may be beneficial in the short-term. However, in the long-term, it could be an ecological trap due to insufficient resources and greater exposure to terrestrial risks (conflicts with humans, competition with brown bears (Ursus arctos), new pathogens) (Atwood et al., 2016b; Kellner et al., 2023). In Baffin Bay, the maternity denning duration decreased and dens moved to greater elevations and slopes, likely due to less presence of snowdrifts in lower regions (Escajeda et al., 2018). Fewer maternity dens of polar bears have been recorded in the multiyear ice than onshore, and the proportion of females denning offshore might decrease with the retreating pack ice in summer (Laidre et al., 2008). Thin snow layers may not allow for den construction, and heavy rain might cause the den to collapse, leading to increased mortality of females and cubs (Wiig et al., 2008). Moreover, bears have a high risk of drowning while swimming in the open water between the coast and offshore pack ice (Laidre et al., 2008). The newly discovered population in southeast Greenland might be more resistant to climate change due to its behavioural adaptations to ice-free sea environments by using marine-terminating glaciers as hunting platforms (Laidre et al., 2022).

8.3. Physiological Changes

From the late 1980s to the 1990s, a steady decline in body condition, fecundity, and survival of cubs was documented (Moore and Huntington, 2008; Wiig et al., 2008). Particularly earlier sea ice breakup is connected to the poorer condition of the bears and lower survival of bears <4 years and >20 years of age (Laidre et al., 2008; Regehr et al., 2016). The bears have a shorter time to feed on the ice at the most crucial time of the year (Laidre et al., 2008). Moreover, the number of dens is strongly negatively correlated to the date of sea ice arrival, and the proportion of dens on the pack ice decreased from about 62% in 1985–1994 to 37% in 1998–2004 (Wiig et al., 2008). In 2004, the average breakup date was already three weeks earlier than 30 years ago (Wiig et al., 2008). Survival, reproduction, and body condition will likely decrease in parallel with the availability of sea ice, and longer ice-free periods will lead to smaller and fewer litters (Laidre et al., 2020b). Females may be below the minimum required mass for successful reproduction within the next 20–30 years (Laidre et al., 2008). In Baffin Bay, two-cub litters, previously the norm, could largely disappear within 35 yrs (Laidre et al., 2020b). Moreover, a cyclic variation in body size of adult male and female polar bears between 1990 and 2002 correlated with the Arctic Oscillation that is currently under change (Laidre et al. 2008). Additionally, future sea-ice loss is expected to fragment polar bear subpopulations, increase isolation, alter gene flow, and disrupt population boundaries (Laidre et al., 2018a). In two decades (1995–2016), polar bears from the Svalbard Archipelago, Norway, lost 3–10% of genetic diversity, accompanied by a nearly 200% increase in genetic differentiation across regions (Maduna et al., 2021).

8.4. Interactions with other species

Throughout most of its range, the diet primarily consists of ringed (*Pusa hispida*) and bearded seals (*Erignathus barbatus*). In the Davis Strait, polar bear survival is related to harp seal (*Pagophilus groenlandicus*) abundance (Peacock et al., 2013). Local populations might be able to compensate for some of the loss of ringed seals (cf. section 4.1.1) by using other food sources (Wiig et al. 2008). An increase in feeding on bowhead whale carcasses, walruses, and bearded seals has been recorded (Wiig et al., 2008). Scavenging of subsistence-harvested bowhead whales (*Balaena mysticetus*) appears to be an essential food source during extended periods on shore, influencing the spatial distribution of bears (Atwood et al., 2016b). In addition, hunters in south-east Greenland reported that polar bears eat eider ducklings from the nest and eggs, land plants such as plants, grasses, flowers, berries and kelp, and recently also the bones of seals (Laidre et al., 2018b). Intraspecific predation and cannibalism occur and may reflect nutritional stress related to longer ice-free seasons (Amstrup et al., 2006).

8.5. Hunting

Polar bears are hunted primarily for their meat, but also the fur is used to make traditional clothing, and some skins, skulls, and claws are sold in Greenland (Ugarte et al., 2020a). CITES non-detrimental findings ban the export of polar bear products because of over-exploitation (Born and Ugarte, 2007). Quotas for 2014 and 2015 were of six polar bears per year for the Kane Basin subpopulation (Qaanaaq north of Savissivik) and 67 polar bears per year for the Baffin Bay subpopulation (Boertmann and Mosbech, 2017). The quota for the Baffin Bay subpopulation is divided so that hunters can take 18 polar bears from Savissivik, 37 by hunters from Upernavik, and 12 bears are to be shared by hunters from Uummannaq and settlements south of the assessment area (Boertmann and Mosbech, 2017). In the short-term, access to hunting polar bears might increase. In Ittoqqortoormiit, for example, the distance travelled during polar bear hunting trips has decreased dramatically (Laidre et al., 2018b). Polar bears stay on land and near settlements for extended periods, and the number of ''land locked'' polar bears killed in self-defence has increased (Wiig et al. 2008). In the southern Beaufort Sea population, the number of bears killed annually for safety reasons increased from approximately three in the early 1990s to 10 between 1998 and 2004 as bears have spent more time on land along the coast (Laidre 2008). Also, in Greenland, human-bear conflicts increased due to sea ice loss and the introduction of hunting quotas in 2005 (Laidre et al., 2018b; Ugarte et al., 2020a). In Tasiilaq and Ittoqqortoormiit hunters noted that more polar bears were coming into their communities compared to 10–15 years ago (81% of Tasiilaq hunters and 78% of Ittoqqortoormiit hunters) and pointed to the introduction of quotas and loss of sea ice as potential reasons (Laidre et al., 2018b). Polar bears approaching towns and settlements are killed to protect human lives and property. Of the 143 polar bears hunted annually during 2017–19 in Greenland, seven were killed annually in selfdefense (Wilken, 2019). Moreover, in northeast Greenland (i.e., 698 N to 768 N), the fraction of polar bears shot from a boat (as opposed to spring sled trips) increased from 5% in 1983–1991 to 30% in 1994–1999 (Sandell and Sandell, 1996; Wiig et al., 2008b). However, hunters in Tasiilaq and Ittoqqortoormiit mentioned that reaching their previous hunting areas is harder because the ice has either receded or has become too thin to travel (Laidre et al., 2018b). Nevertheless, quotas for most populations are rarely reached. The mean harvest over five years in Baffin Bay was 142.4 (5.0% of the population), while official quotas were higher (160 (Canada (C):80+Greenlad (GL):80)) (IUCN/PBSG, 2021). In Kane Basin, the five year average was 9.0 (2.5%), while quotoas were higher with 11 (C:5+GL:6) through 2017, and 14 (C:5+GL:9) in 2018. In Davis Strait, the potential remove (5 yrs mean) consists of the QuotaCanada + 76 (NU:61+NL:12+GL:3), however, only 67.6 (3.1%) were hunted: (5 yrs mean) (IUCN/PBSG, 2021). In East Greenland, the potential removal is 65.0, while 68.0 were removed within 5 years (% unknown). For the Artcic Basin, nor the number of removals nor potential removals are known (IUCN/PBSG, 2021).

8.6. Predicted Trends

There is high uncertainty in predictions about long-term polar bear population trends (ref). The mean global population size of polar bears is expected to decline due to a reduction in ice cover by more than 30% over the next three generations (35–41 years) (Regehr et al., 2016) and during the next 35–50 years due to decreased sea ice and earlier spring breakup (from 2005) (Wiig et al., 2008). An expert assessment predicts that the global range will decrease by about 33% by 2050, relative to 2007. Polar bears will likely disappear from the current southern range and retreat to high latitude areas such as the coast of northern Greenland (Wiig et al. 2008) and the Arctic Basin (IUCN/PBSG, 2021) and adjacent interisland channels of Arctic archipelagos with suitable ice conditions, that may serve as climate refugia (Laidre et al., 2008). One exception may be the South East population. This newly discovered population occupies marine-terminating glaciers in areas with sea-ice conditions similar to those projected for the High Arctic in the late 21st century, with an annual ice-free period >100 days longer than the assessed fasting threshold for the species (Laidre et al., 2022). The Arctic Basin, especially the parts close to North Greenland and the Canadian Archipelago, is expected to be the last refuge for polar bears across the Arctic (Ugarte et al., 2020). The current thick multiyear ice at the Arctic Basin will likely melt and transition to seasonal ice, suitable habitat for seals and polar bears (Ugarte et al., 2020),

However, improved sea ice habitat could reduce the likelihood of polar bear population status in a given ecoregion reaching a state of decline or severe decline by ≈50% (Atwood et al., 2016a). Rapid and forceful emissions mitigation can reduce the probability of any regional population experiencing significant drops by up to 25% (Atwood et al. 2016). Since polar bears are relatively adaptable and can switch opportunistically to alternative prey, it is challenging to predict how well they might cope as a species in the future (Wiig et al., 2008).

8.7. Status and Trends of Sub-populations

Buffin Bay (BB):

Abundance	Status, change (≥2 generations)	Trend (Short term~1 generation)	Category of change	Description: Physiological, behavioural change	Climate variable & direction	Hunting
2013: 2,826 polar bears	Not Reduced (SWG, 2016;	Unknown (IUCN/PBSG, 2021; Laidre et al.,	Reproduction	Females are by 53% less likely to have two cubs ((1991–1997) and (2009–2015) (Laidre et al., 2020b)	Later spring sea ice transition (+), longer ice-free seasons in	Potential removable (5 year mean): 160

(2,059–3,593) (SWG, 2016)	Ugarte et al., 2020a)	2020b; Ugarte et al., 2020a)			the previous year (-)	(Canada:80+ Greenland:80) Hunted (5 year mean): 142.4 (5.0% of subpopulation) (IUCN/PBSG, 2021)
			Future trends/ Reproduction	Two-cub litters, previously the norm, could largely disappear within three polar bear generations (~ 35 yr) (Laidre et al., 2020b)	Later spring sea ice transition (+), longer ice-free seasons in the previous year (-)	
			Habitat use	30+ days more on land (1990-2000), more fasting on land (Laidre et al., 2020b)	Later spring sea ice breakup +, later fall sea ice formation +	
			Range	Shift northward during the on-ice seasons (2.6° shift in winter, 1.1° shift in spring) (Laidre et al., 2018a)	Loss of sea ice	
			Range	Summer range size declined by 70% (1991 to 2015) (Laidre et al., 2018a)	Loss of sea ice	
			Genetics	Functionally isolated (Laidre et al., 2018a)	Loss of sea ice	
			Behaviour	Increased swimming (Laidre et al., 2020b, p. 20, 2018a)	Loss of sea ice	
			Reproduction	Changes in dents location and timing (1991-1997 and 2009-2015) (Escajeda et al., 2018)	Changed snow and sea ice conditions	
			Reproduction	Denning duration decreased by 27 days by a mean of 194.1 days to 167.1 days (1991-1997 and 2009-2015) (Escajeda et al., 2018)	Changed snow and sea ice conditions	
			Body condition	Body conditions declined (Laidre et al., 2020b; SWG, 2016)	Sea ice availability in the current and previous year (+)	
			Habitat use	Significant declines in monthly movement rates (one half to one third from 1990-2000) (Laidre et al., 2018c)	Disappearance of summer offshore sea ice	
			Habitat use	Closer to land in all months, except at the end of spring breakup (Laidre et al., 2018c)	Disappearance of summer offshore sea ice	

Since the 2010s, physiological and behavioural changes due to reduced sea ice and longer open water have been observed in this subpopulation. The disappearance of summer offshore sea ice in the 2000s resulted in significant declines in monthly movement rates (one-half to one-third from 1990-2000) (Laidre et al., 2018c). From 1991 to 2015, the subpopulation range size declined by 70% in summer and shifted northward during the on-ice seasons (2.6° shift in median winter latitude, 1.1° shift in median spring latitude) (Laidre et al., 2018a). Moreover, with more time fasting on land during the open water season, the body condition declined with sea ice availability (Laidre et al., 2020b), and maternity dens built on higher ground, reduced cub recruitment with the early sea-ice breakup and shorter maternity denning periods were documented (Escajeda et al., 2018; SWG, 2016; Ugarte et al., 2020a). Satellite telemetry analyses comparing movements of adult females in the 1990s to 2000s indicate reduced seasonal ranges (Laidre et al., 2018a), increased isolation, 30+ days more on land on Baffin Island in summer, and increased swimming (Escajeda et al., 2018; IUCN/PBSG, 2021; Laidre et al., 2020b; SWG, 2016). Reduced sea ice availability was associated with longer times on land, reduced body condition, and reproductive success in BB polar bears (Laidre et al., 2020b). The rate of sea ice loss in Buffin Bay is comparatively high, at 19.3 % per cent per decade (IUCN/PBSG, 2021). Change in the date of spring sea-ice retreat/change in date of fall sea-ice advance is -6.4 / +4.4 days per decade (IUCN/PBSG, 2021).

<u>Kane Basin (KB):</u>

Abundance	**Status, change (≥2 generations)**	**Trend (Short term~1 generation)**	**Category of change**	**Description: Physiological, behavioural change**	**Climate variable & direction**	**Hunting**

2014: 357 (95% CI = 221–493) (SWG, 2016)	Data deficient (IUCN/PBSG, 2021)	Likely increased (1997 to 2014) SWG, 2016)	Range	Sub-population summer range doubled between the 1990s and the 2000s (SWG, 2016)	(+) multi-year ice is transitioning to annual ice	the five-year average was 9.0 (2.5%), while quotas were higher with 11 (C:5+GL:6) through 2017 and 14 (C:5+GL:9) in 2018.
			Reproduction	Reproductive metrics for KB were comparable between the 1990s and 2010s sampling period (SWG, 2016)		
			Body condition	Body condition in KB appeared to have slightly improved between sampling periods (SWG, 2016)	Likely because the multi-year ice is transitioning to annual ice which is more productive, and the hunting pressure by humans is lower than before SWG, 2016)	
			Population trends	Overall, the available data on abundance together with information on movements, body condition, and reproduction, suggest that the KB subpopulation has increased in size (IUCN/PBSG, 2021).		

The Kane Basin population occupies a small area with multiyear ice in the far north, between North Greenland and Ellesmere Island, including the North Water Polynya (Ugarte et al., 2020). Populations in West Greenland in the Kane Basin (KB) are considered at high risk (11 of 13) (Hamilton and Derocher, 2019). Nevertheless, available data on the abundance, movements, body condition and reproduction suggests that the KB subpopulation is stable or increasing in the short term (IUCN/PBSG, 2021; Ugarte et al., 2020), likely, because the multiyear ice is transitioning to annual ice, which is more productive, and human hunting pressure is lower than before (IUCN/PBSG, 2021; SWG, 2016). Sea ice decline in the Kane Basin is -10.3 % per decade, lower than for many other populations (IUCN/PBSG, 2021). Change in the date of spring sea-ice retreat/change in date of fall sea-ice advance is -6.6 / +5.2 days per decade (IUCN/PBSG, 2021).

Davis Strait (DS):

Abundance	**Status, change (≥2 generations)**	**Trend (Short term~1 generation)**	**Category of change**	**Description: Physiological, behavioural change**	**Climate variable & direction**	**Hunting**
2007: 2158 (95% CI = 1833–2542) (Peacock et al., 2013)	Data deficient (IUCN/PBSG, 2021)	Data deficient (IUCN/PBSG, 2021)	Reproduction	Lowered reproductive rates and declines in body condition of polar bears in DS (Peacock et al., 2013)	Likely a result of habitat changes and changes in polar bear density	Quota: QC + 76 (NU:61+NL:12+GL: 3) Hunted: 67.6 (3.1%)
			Population trends	Polar bear survival in DS varied with time and geography (i.e., northern vs. southern DS). Survival rate related to Harp seal abundance (Peacock et al., 2013)	Related to reductions in sea-ice habitat and increases of harp seal numbers (IUCN/PBSG, 2021)	
			Population trends	Less bears moving into Davis Strait in winter and Lancaster Sound in summer (Laidre et al., 2018a).		
			Body condition	Body condition has declined (Rode et al., 2012)	Annual changes in ice habitat	
			Reproduction	Litter rate in Davis Strait low compared to western Hudson Bay and Baffin	Greater densities or worsening ice conditions (Peacock et al., 2013)	

				Bay (Peacock et al., 2013)		

The Davis Strait polar bears spend the summers in Canada, and only a tiny part of their range is in Greenland during the winter when the sea ice forms (Ugarte et al., 2020a). Observations suggest that fewer bears have been moving into Davis Strait in winter and Lancaster Sound in summer since 2000 (Laidre et al., 2018a). Bear survival and reproduction in the southern Davis Strait was greater than in the north and was associated with a concurrent dramatic increase in breeding harp seals (Pagophilus groenlandicus) (Peacock et al., 2013). Davis Strait polar bears were in 2007 characterised by low recruitment rates, average adult survival rates and high population densities in an environment with high prey densities but deteriorating and variable ice conditions (Peacock et al., 2013). With a reduction in the extent of sea ice due to climate change, the proportion of polar bears from this subpopulation wintering in Greenland is becoming smaller (Ugarte et al., 2020). Changes in summer sea ice area are -18.6 % per decade, and changes in the date of spring sea-ice retreat/change in date of fall sea-ice advance are -5.2/+6.2 days per decade (IUCN/PBSG, 2021).

East Greenland (EG):

Abundance	**Status, change (≥2 generations)**	**Trend (Short term~1 generation)**	**Category of change**	**Description: Physiological, behavioural change**	**Climate variable & direction**	**Hunting**
2019: 991 (501–1469) (model estimates) (Hamilton and Derocher, 2019)	Data deficient (IUCN/PBSG, 2021)	Data deficient (IUCN/PBSG, 2021)				Quota: 65.0 Hunted: 68.0 (N/A)
Unknown (IUCN/PBSG, 2021)			Habitat use	Shifts in polar bear habitat use: Adult females used areas with significantly lower sea-ice concentrations during winter (10–15% lower), are located closer to open water in all seasons and spent ~ two months longer in areas with <60% sea-ice concentration (1990s -2000) (Laidre et al., 2015)	Multi-decadal loss of sea ice	
			Reproduction	Timing of maternity denning did not significantly differ between 1990s -2000s (Laidre et al., 2015)		
			Behaviour	Distance traveled during polar bear hunting trips has decreased in Tasiilaq and Ittoqqortoormiit. Hunters noted that more polar bears are coming into their communities compared to 10–15 years (Laidre et al., 2018b)	Likely introduction of quotas and loss of sea ice (Laidre et al., 2018b)	
			Body condition	Ittoqqortoormiit and Tasiilaq: Hunters did not report major changes in polar bear body condition (Laidre et al., 2018b)		
			Body condition	Greenland polar bears may be negatively affected by relatively high body burden of organic pollutants (Dietz et al., 2013; Lunn and Derocher, 2006)		
			Threat	Highly vulnerable subpopulation (Vulnerability index 11 out of 13) (Hamilton and Derocher, 2019).	Concidering subpopulation densities, latitude, continental shelf habitat, prey diversity, sea ice extent, length of the ice-free season	
			Genetics	Recently described genetically distinct and functionally isolated group of polar bears in Southeast Greenland (south of 64°N, hereafter Southeast Greenland). Since ~200 years isolated (95%: 189 to 264 years (Laidre et al., 2022)		

			Behaviour	Southeast Greenland subpopulation is adapted to sea ice-free environments and uses year-round hunting platform in the form of freshwater glacial mélange (Laidre et al., 2022)		
			Reproduction	Birth rates in Southeast Greenland were low compared with Northeast Greenland and most other polar bear subpopulations (Laidre et al., 2022)		
			Hunting	Uncommon for polar bear hunters to go to Southeast Greenland today (Laidre et al., 2022)		

Considering subpopulation densities and ecological parameters, including latitude, continental shelf habitat, prey diversity, sea ice extent and the length of the ice-free season, the populations in EG is considered as high vulnerable (Vulnerability index 11 out of 13) (Hamilton and Derocher, 2019). EG polar bears occupy areas with reduced sea ice habitat leading to changes in habitat use (Laidre et al., 2018a). However, there is high uncertainty, as little is known about the EG populations (Ugarte et al., 2020). Increased mortality and lower reproductive success are expected in East Greenland, the Barents Sea, and the Kara Sea (Wiig et al., 2008). The newly discovered population in southeast Greenland seem to be more adapted to sea ice-free environments (Laidre et al., 2022). Changes in summer sea ice area are -7.5 % per decade, and change in date of spring sea-ice retreat / change in date of fall sea-ice advance are +7.6 /-7.7 days per decade (IUCN/PBSG, 2021).

Arctic Basin (AB):

Abundance	**Status, change (≥2 generations)**	**Trend (Short term~1 generation)**	**Physiological, behavioural change**	**Climate variable & direction**	**Hunting**
Unknown (IUCN/PBSG, 2021)	Data deficient (IUCN/PBSG, 2021)	Data deficient (IUCN/PBSG, 2021)			

Historically, polar bears have occurred at low densities here. The waters here are deep, cold, stratified, and less biologically productive and, formerly at least, extensively covered by multiyear ice (IUCN/PBSG, 2021). Polar bears from several subpopulations are known to have travelled through the area, but the total numbers of bears that occupy the AB region seasonally or year-round is unknown (IUCN/PBSG, 2021; Ugarte et al., 2020a). As climate warming continues, an influx into this region is expected (IUCN/PBSG, 2021). It is anticipated that areas, especially the parts close to North Greenland and the Canadian Archipelago, where some ice remains over the continental shelf may become important as a refuge (IUCN/PBSG, 2021). The thick multiyear ice will melt and transition to seasonal ice, which is good habitat for seals and polar bears (Ugarte et al., 2020a). However, a large part of the AB region is over the deepest waters of the Arctic Ocean, and biological productivity will likely remain low (IUCN/PBSG, 2021). The Artic Basin might be the last refuge for polar bears across the Arctic when the southern parts of their current habitat disappear (Ugarte et al., 2020a). Changes in summer sea ice area are -7.5% per decade, and change in date of spring sea-ice retreat/change in date of fall sea-ice advance are -9.6/+14.6 days per decade (IUCN/PBSG, 2021).

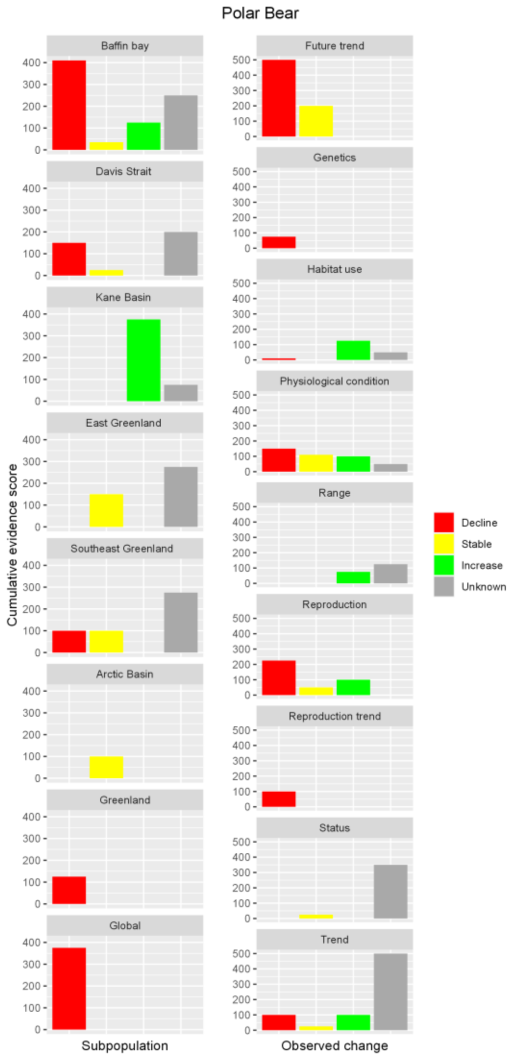


Figure 8.2. Cumulative evidence per subpopulation and aspects in which change is observed or expected.

8.8. Synopsis

Polar bears are considered most climate-sensitive. For the Baffin Bay Polar Bear subpopulation, we found overwhelming evidence that the population is declining, but also strong evidence that the subpopulation will increase and weak evidence that they will remain stable. We found strong evidence for a declining subpopulation in Davis Strait, weak evidence for a stable subpopulation, and overwhelming evidence for an increase. For the Kane basin subpopulation, we found overwhelming evidence for an increase of the subpopulation. In East Greenland, there is strong evidence for a stable subpopulation. For the Southeastern population, we found moderate evidence that populations will remain stable. On the global level, there is overwhelming evidence that this species will decline. In the literature, there is overwhelming evidence that especially trends of most populations are unknown.

8.9. Catch and Forecast

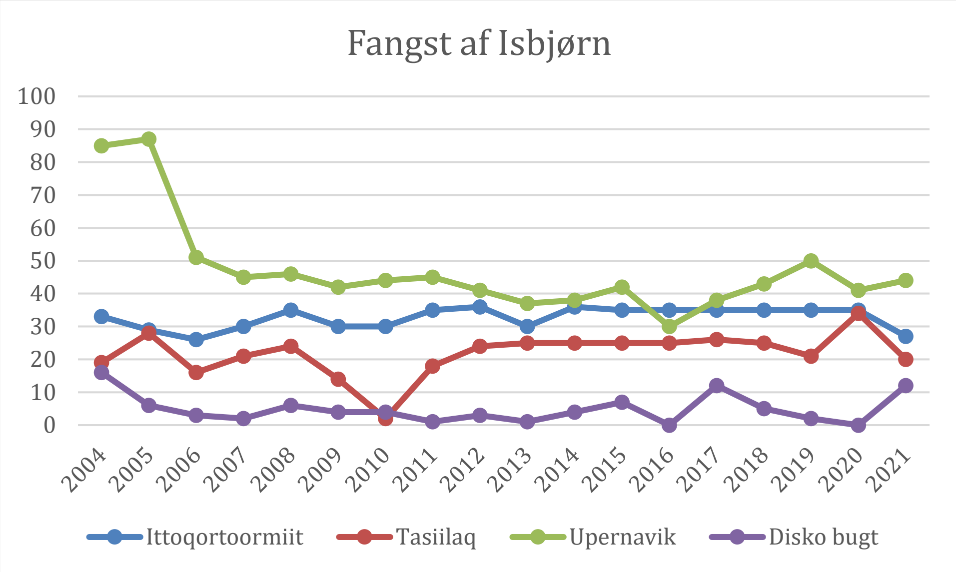


Figure 8.3. Total catch of polar bears in Ittoqortoormiit, Tasiilaq, and Upernavik districts and for Disko bay districts combined.

Due to errors in the data supplied by Statistics Greenland, data on total catch per district was obtained instead, and no forecasts were made.

8.10. Workshops with Hunter and Fishers Orgnisations

Scenario	Ittoqortoormiit	Tasiilaq	Upernavik	Ilulissat
Trend scenario	Catch determined by quotas. Disagrees with biological recommendations. See more bears after the prohibition on shooting females with cubs	Catch determined by quotas. Disagrees with biological recommendations	Catch determined by quotas. Disagrees with biological recommendations. See more bears after the prohibition on females with cubs	Catch determined by quotas. Disagrees with biological recommendations. The ice determines whether the quota is caught here or in Ummannaq
Alternative scenario	Wants quota of 7 per occupational hunter or 45 bears. Wants prohibition on skin export revoked	Wants prohibition on skin export revoked	Wants prohibition on skin export revoked	NA

8.11. Interviews with Scientific Experts

-will follow-

8.12. Preliminary Future Scenarios

Scenario	Ittoqortoormiit	Tasiilaq	Upernavik	Ilulissat
Stock and catch trend scenario	Increase catch to 5 bears per occupational hunter			Stable compared to average over the period 2012-2020
Underreporting adjustment scenario				
Alternative actions scenario	Increase price of skin t0 15-20.000 kr	Increase price of skin t0 15-18.000 kr	Increase price of skin t0 18-25.000 kr	

9. Narwhals (*Monodon monoceros*)

Narwhals	
Monodon monoceros	
Narhval	
Qilalugaq qernertaq	

In summer, narwhals now occupy most of northern Baffin Bay in the West and a tight coastal strip along Greenland in the East (Chambault et al., 2022). Population numbers for narwhals have been reduced in both the West (particularly in Melville Bay) and throughout their range in the East, where the situation for the species is already dire (Chambault et al., 2022). Narwhals can dive to more than 1700 m to feed on Greenland halibut, although they can also find their prey, including squid, shrimp and fish at depths of 200–600 m (Watt et al., 2015). Narwhals spend summers in fjords with glacier fronts. They have a high degree of site fidelity and return to the same areas every summer (Heide-Jørgensen et al., 2015). During winter, when the fjords freeze, narwhals migrate to offshore areas with high concentrations of sea ice. Narwhals from several summer stocks in Arctic Canada and Northwest Greenland mix during winter in areas with high concentrations of sea ice of Baffin Bay, Davis Strait and West Greenland (Heide-Jørgensen et al., 2013b). Narwhals can live to be 100 years old and, together with humans, are one of the few species in which females live a considerable part of their life after menopause (Ugarte et al., 2020).

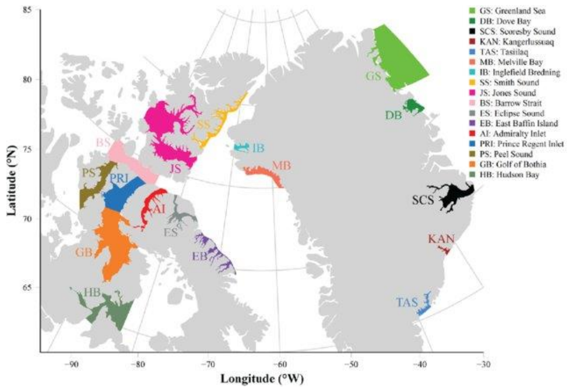


Figure 9.1. Map of 17 narwhal summer grounds in Canada and Greenland. The extent of the summer grounds reflects the summer distribution of whales as delimited by abundance surveys (Chambault et al., 2020).

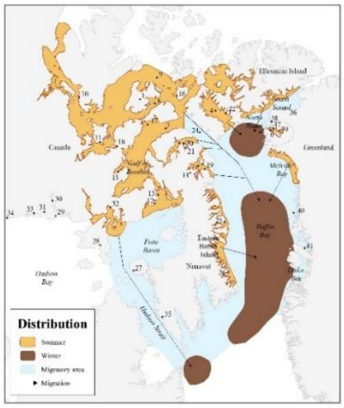


Figure 9.2. Summer (light brown) and winter (dark brown) distribution of Narwhales (NAMMCO 2016)

9.1. Climate Change

Narwhals (*Monodon monoceros*) are one of the most sensitive species of Arctic marine mammals to climate change (5) due to their reliance on sea ice, restricted niche, limited range, specialized diet, and complex population structure (Chambault et al., 2022; Laidre et al., 2008). Narwhals have a narrow temperature niche of preferred temperatures of 0.7 °C, avoiding water masses with temperatures above 2°C and < 0.5°C (Chambault et al., 2020). Therefore, they will become under pressure to abandon their traditional habitats due to ocean warming (Chambault et al., 2020; Heide-Jørgensen et al., 2022). The small population in Melville Bay in Northwest Greenland is decreasing due to unsustainable hunting, warming temperatures and disturbance from increased boat traffic (NAMMCO, 2016; Ugarte et al., 2020). The southeastern narwhal stocks around Tasiilaq already collapsed, starting in 2004, which could be a combination of excessive hunting pressure and habitat changes due to increasing sea temperatures (Heide-Jørgensen et al., 2022). Southeast Greenland is affected by a regime shift that is warming temperatures in coastal areas and the East Greenland coast with reduced transport of polar pack-ice (Chambault et al., 2020). When leaving the fjord systems and travelling to their wintering grounds, the narwhals will be affected by increasing sea temperatures and reduced transport of sea ice along East Greenland (Chambault et al., 2020). Only areas dominated by the East Greenland Current that transports drift- ice from the Fram Strait seem to be suitable habitat for narwhals and areas with influx of dense and warm Atlantic water masses seem unsuitable, (Chambault et al., 2022). It still remains open, if the stocks from Mideast and Southeast of Greenland manage to migrate further north, or will go locally extinct due to a lack of physiological flexibility to adjust swimming and diving behaviors in response to shifts in habitat and prey resources (Chambault et al., 2020; Williams et al., 2011). Moreover, more frequent sea ice entrapments are observed in Northwest Greenland (Laidre et al., 2012). Additionally, the arrival of new predators, such as killer whales in areas now lacking seasonal sea ice are increasing predation pressure (e.g. >1000 narwhal during the open-water season in eastern Canadian Arctic) (Lefort et al., 2020) and depletion of potential prey species (Heide-Jørgensen et al., 2022). It is estimated that the new cetacean species in South East Greenland are responsible for an annual predation level of 700,000 tons of fish and >1.500.000 tons of krill species mainly consumed by fin whales (Heide-Jørgensen et al., 2022).

9.2. Scenarios until 2100

Newest scenarios are available for a most optimistic (ssp126) and a worst-case (ssp585) emission scenario until 2100 using satellite tracking data from a 28-year-long period and taking only SST, mixed layer depth (MLD), sea surface height (SSH), and sea surface salinity (SSS) into account (Chambault et al., 2022). Except for narwhals in the East, these show a notable habitat loss in summer by 2100, with the most pronounced loss under scenario ssp585 (Fig. C, D) (Chambault et al., 2022). In summer, narwhals in the East are expected to gain habitat area between 85% (±67.0, ssp126) and 105% (±114.0, ssp585). Narwhals are expected to lose a significant portion of their current winter habitat by 2100 in the West, especially under scenario ssp585. In the East, they are expected to experience a complete loss of their offshore wintering habitat (Fig A/B). Projected habitat decline for narwhals for winter varies between −10% (±23.6, ssp126, narwhals West) and −63% (±41.9, ssp585, narwhals East). Moreover, the range will shift further northwards by projected 37±44 km (narwhals West in winter ssp126). Narwhal distributions north of the current range might be feasible, given that narwhals are deep divers that might be able to feed on mesopelagic prey in deeper waters of the Arctic Ocean. Traditional migration patterns for some stocks, strong site fidelity, and their natural tendency to at least seasonally affiliate with sea ice might however limit their adaptability to such new habitats (Chambault et al., 2022). In contrast to summer, most current wintering habitats are projected to disappear for narwhals in the East (Chambault et al., 2022).

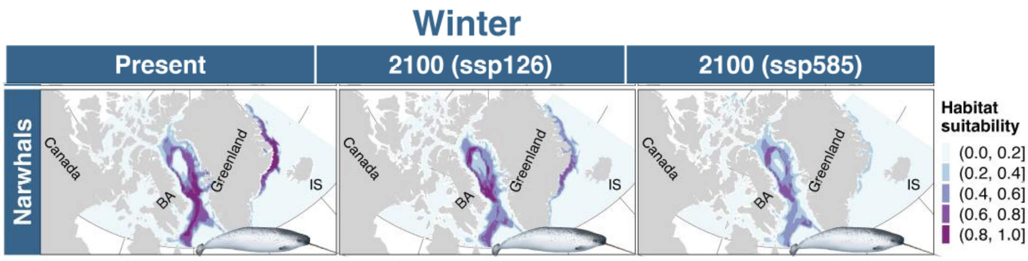


Figure 9.3. Maps of habitat suitability for bowhead whales and narwhals for the present and for 2100 in winter (December to March) for both scenarios (ssp126 and ssp585). (Chambault et al., 2022).

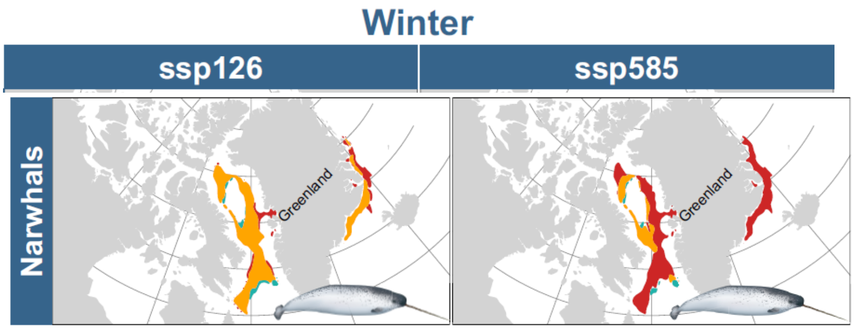


Figure 9.4. Changes in projected winter core habitats (probabilities >0.5) by the year 2100 for bowhead whales and narwhals for both scenarios. Red areas are projected losses by 2100, orange areas are expected to remain unchanged, and green areas are projected to increase in habitat.

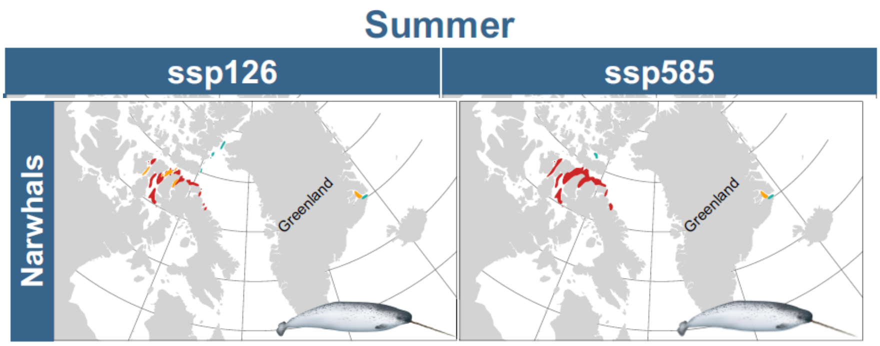


Figure 9.5. Changes in projected summer core habitats (probabilities >0.5) by the year 2100 for the three Arctic whale species for both scenarios. Red areas are projected losses by 2100, orange areas are expected to remain unchanged, and green areas are projected increase in habitat.

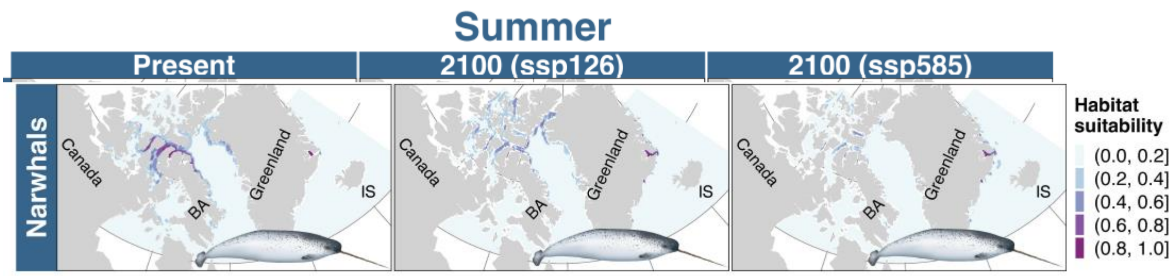


Figure 9.6. Predictive maps of habitat suitability for belugas, bowhead whales and narwhals for the present and 2100 in summer (August to September) for both scenarios (ssp126 and ssp585). “BA” corresponds to Baffin Island, “IS” to Iceland, and “SVB” to Svalbard.

9.3. Hunting

A yearly average of 445 narwhals were reported caught in Greenland in 2016–18 (http://nammco.no) (Ugarte et al., 2020). Catch statistics are available in: Garde et al., (2017). Richard (2008) assumes that half of the animals wounded and escaped later die from their injuries. Reported landed catches are multiplied by a struck and loss factor of 1.28 ± 0.15 (NAMMCO, 2018b). The hunt for narwhals is important for both subsistence and the cultural identity of people in Northwest Greenland. Inglefield Inlet and Melville Bay are the most important hunting areas, where hunters still take narwhals using traditional kayaks (Boertmann and Mosbech, 2017). Kayaks are preferred because narwhals are particularly shy and show high site fidelity to their summer grounds. Hunters can sneak close to the narwhals with minimal disturbance by using the nearly silent kayaks. The narwhal hunters express concern about their resources, especially concerning climate change and industrial activities, including seismic surveys (Boertmann and Mosbech, 2017). In Uummannaq and southern Upernavik, narwhals are caught during the southward migration to their wintering grounds from October to January and during the northward migration back to the summering grounds from March to July. In southern Upernavik, narwhals are shot from the ice edge or chased by skiffs (NAMMCO in press) (Boertmann and Mosbech, 2017). Most of the whales in Uummannaq are caught in November and December before the sea ice consolidates. Narwhals are spotted from land and chased with skiffs or caught with nets from the shoreline (Boertmann and Mosbech, 2017; NAMMCO, 2016). The primary products from the narwhal hunt are meat and mattak, while tusks are used for carving or sold internally in Greenland (Ugarte et al., 2020a). The export of narwhal products was banned in 2006 when the CITES Scientific Authority could not document that narwhal catches in Greenland was sustainable. The export ban is still valid despite documentation in 2009 that catches are sustainable (Boertmann and Mosbech, 2017; Heide-Jørgensen and Ugarte, 2009).

9.4. Trends and Stock Status

West Greenland

Areas	Abundance	Status, change (≥2 generations)	Trend (Short term~1 generation)	Category of change	Description: Physiological, behavioural change	Climate variable & direction	Hunting
W-Greenland winter aggregation (Eastern Baffin bay, summer in Melville Bay)	2012: 18,583 narwhals (95% CI: 7,308–47,254) (NAMMCO, 2016).	Reduced (Ugarte et al., 2020a)	Stable (Ugarte et al., 2020a)	Migration	Fluctuating, probably because of annual variations in ice conditions and variations in the timing of seasonal migrations (NAMMCO, 2016). Likely mix of summer stocks from Inglefield Brednin, Melville Bay, and Canada (NAMMCO, 2016).	Ice conditions	
The North Water/ northern Baffin Bay (winter aggregation area)	2014: 3059, 95 % CI 1760–5316) (Heide-Jørgensen et al., 2016)	Unknown (NAMMCO, 2016)	Unknown (NAMMCO, 2016)		Migration unclear, but likely some narwhals from Inglefield Bredning stock		
Smith Sound (summer stock)	2013: 17,010 (CV=0.68) (Doniol-Valcroze et al., 2020)	Not Reduced (NAMMCO/JCNB, 2015)	Unknown (Ugarte et al., 2020)	Habitat use	Highest abundance: 0.7 °C Sea Surface Temperature (Chambault et al., 2020)	SST	

Inglefield Bredning (summer stock)	2019: 2,874 animals (CV=0.28) (Hansen et al., *unpublished*; NAMMCO-JCNB, 2022) (NAMMCO, 2016)	Reduced (Ugarte et al., 2020a)	Stable (NAMMCO, 2016)		Stable, Small-medium sized stock with low removals, general habitat concerns related to climate change, future development (Hobbs et al., 2019) (NAMMCO, 2018b)		Allowable take is 98 individuals per year (2015-2020) (NAMMCO, 2018b)
Melville Bay (summer stock)	4,755 animals (CV=0.77) (Hansen et al., *unpublished*) (NAMMCO, 2016)	Reduced (NAMMCO/JCNB, 2015)	Stable (insignificant increase) (NAMMCO, 2016)				Allowable take is 84 individuals per year (2015-2020) (NAMMCO 2018)

<u>East Greenland:</u>

Narwhales occur along the coast from 64°N to 72°N, with concentrations around Scoresby Sound, Tasiilaq, and Kangerlussuaq (three "management units").

Areas	**Abundance**	**Status, change (≥2 generations)**	**Trend (Short term~1 generation)**	**Category of change**	**Description: Physiological, behavioural change**	**Climate variable & direction**	**Hunting**
"Scoresby Sund management stock"	2016: 433 (0.04) (NAMMCO-North Atlantic Marine Mammal Commission, 2019)	Reduced (Hansen and Heide-Jørgensen, 2019)	Decreasing (Hansen and Heide-Jørgensen, 2019)				
"Kangerlussuaq management stock"	2016: 269 (0.06) (NAMMCO-North Atlantic Marine Mammal Commission, 2019)	Reduced (Hansen and Heide-Jørgensen, 2019)	Decreasing (Hansen and Heide-Jørgensen, 2019)				
"Tasiilaq management stock	2008: 206 (0.07) (NAMMCO-North Atlantic Marine Mammal Commission, 2019)	Reduced (Hansen and Heide-Jørgensen, 2019)	Decreasing (Hansen and Heide-Jørgensen, 2019) Collapse of narwhal stocks (Heide-Jørgensen et al., 2022)	Habitat use	The fjord systems where narwhals are found in summer, are affected by the increase in sea temperature from inflow of warm Atlantic water (Dietz et al., 1994; Heide-Jørgensen et al., 2022) Only areas dominated by the East Greenland Current (EGC) that transports drift- ice from the Fram Strait seem to be suitable habitat for narwhals and areas with influx of dense and warm Atlantic water masses seem unsuitable (Chambault et al., 2022) The recent collapse of narwhal stocks could be a combination of excessive hunting pressure and habitat changes (Heide-Jørgensen et al., 2022)	SST, Atlantification, East Greenland Current (EGC)	Catches declined significantly after 2004
"Dove bay" summer component"	2018: 700 in 2018, corrected: 1,395 (R. Hansen et al., 2019)						National park, not hunting grounds, although narwhals from this area may be supplying the hunt in regions

							further south (NAMMCO, 2016)

9.5. Synopsis

Narwhals are considerd most sensitive to climate-change. We found strong evidence on a decline and a stable Inglefield Narwhale stock. For the Melville Bay stock, we found moderate evidence of a decline and strong evidence of a stable stock. For the North water winter aggregation, we found moderate evidence of a decline stock and strong evidence that much is unknown. For the West Greenland winter aggregation, we also found overwhelming evidence of a decline. We found overwhelming evidence for a decline in the Scoresby Sund management unit stock, but also moderate evidence of an increase. We found overwhelming evidence of a decline in the Kangerlussuaq management unit stock, and moderate evidence of an increase. For the Tasiilaq management unit stock, there was overwhelming evidence of a decline. There was moderate evidence for a stable stock in Dove bay, and literature is pointing out that trends are unkown.

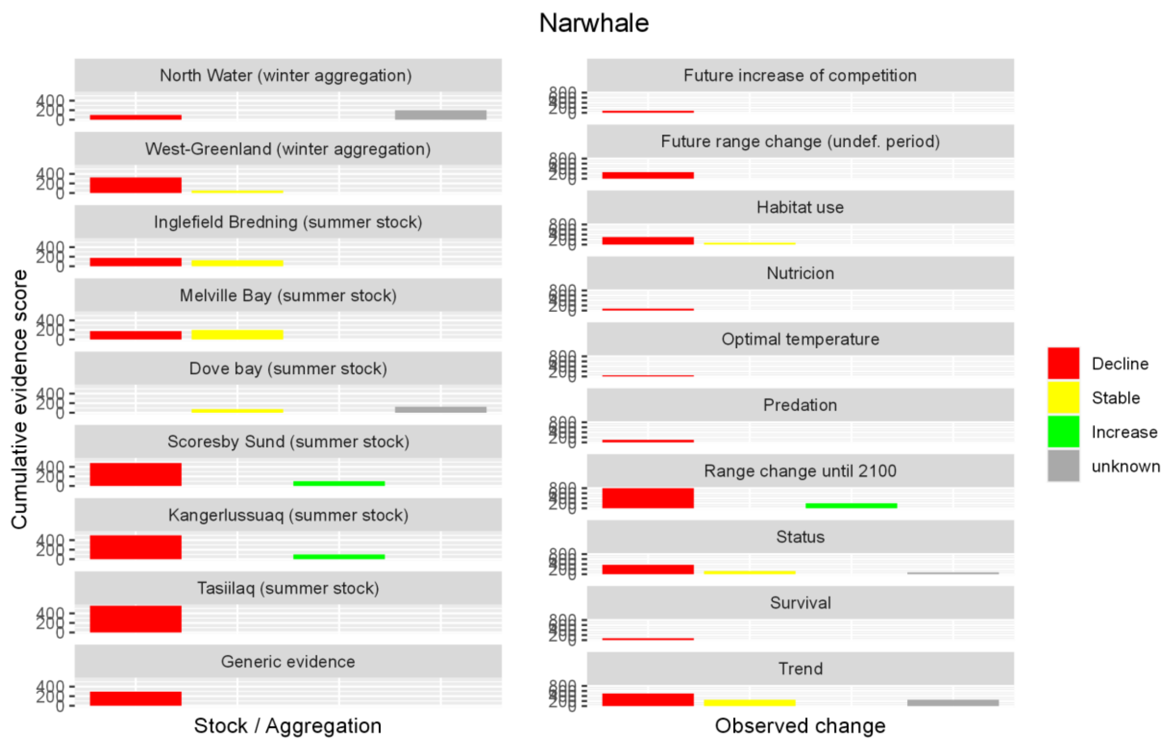


Figure 9.7. Cumulative evidence per stock/aggregation and aspects in which change is observed or expected

9.6. Catch and Forecast

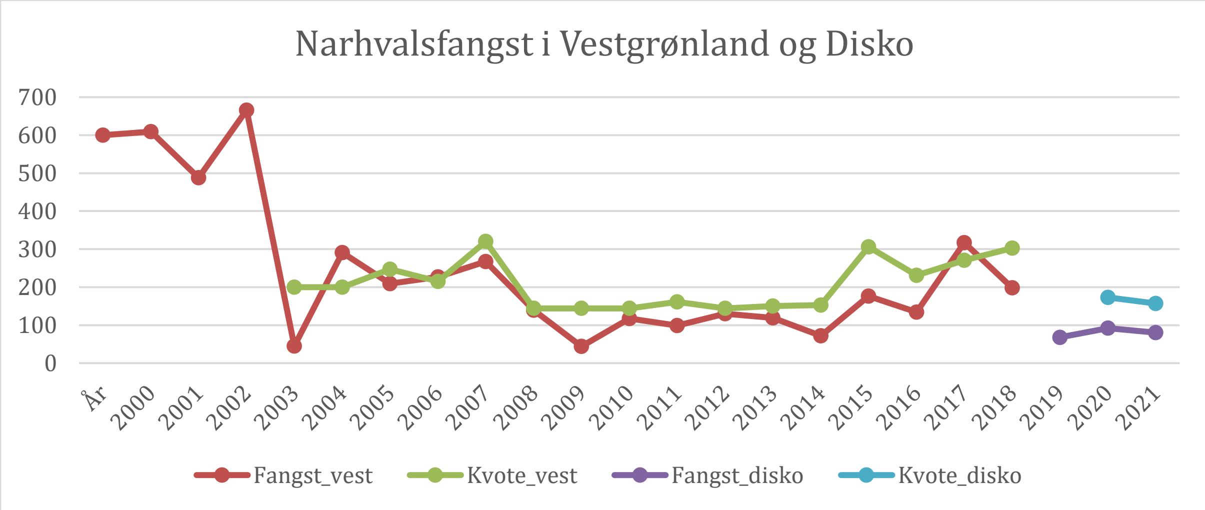


Figure 9.8. Catch statistics accumulated and quotas for narhvals in West Greenland and the Disco Bay.

Due to errors in the data supplied by Statistics Greenland, data on total catch was obtained instead from NAMMCO on the management unit (no data available for East Greenland), and no forecasts were made.

9.7. Workshops with Hunter and Fishers Orgnisations

Scenario	Ittoqortoormiit	Tasiilaq	Upernavik	Ilulissat
Trend scenario	Catch determined by quota that has been gradually reduced. Expects the quota to be reduced to 10. Disagrees with biological recommendations and management units	Disagrees with biological advice. Sees many whales although killer whales and increasing small whale catch disturb the pods. Has requested quota of 50-100 over existing quota of 7-15	Catch determined by quota. Sees many more now compared to 1970'ies. Thinks that there should be one quota of 150 for all of the west coast.	Sees more whales now migrating earlier together with belugas. Thinks that they could catch 30-40 but that there should be one quota for all of the west coast
Alternative scenario	NA	NA	NA	NA

9.8. Interviews with Scientific Experts

-will follow-

9.9. Preliminary Future Scenarios

Scenario	Ittoqortoormiit	Tasiilaq	Upernavik	Ilulissat
Stock and catch trend scenario	Catch halved compared to	Catch multiplied by	150 quota distributed	150 quota distributed

	average over the period 2012-2020 (may fail to consider gradual reduction of quota)	3 compared to average over period 2012-20	between occupational hunters in relevant districts	between occupational hunters in relevant districts
Underreporting adjustment scenario				
Alternative actions scenario				

10. Walruses (*Odobenus rosmarus*)

Walruses	
Odobenus rosmarus	
Hvalros	
Aaveq	

Walruses (*Odobenus rosmarus*) are considered moderately sensitive to climate change (Laidre et al., 2008). Historically, they occurred also in areas with only seasonal or no predictable sea ice, and their current distribution might be the result of human hunting rather than climatic conditions (Kovacs and Lydersen, 2008).

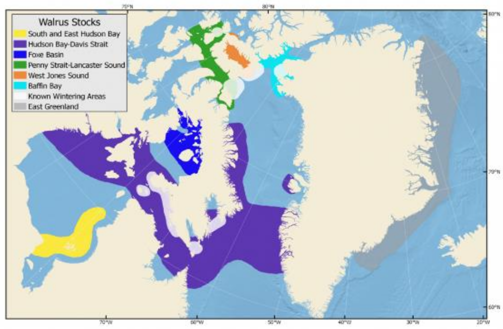


Figure 10.1.. Range of walruses of the different population (NAMMCO)

10.1. Climate Change

Reduced seasonal ice cover over the continental shelf can impact walrus recruitment, reproduction and body condition (Moore and Huntington, 2008; Kovacs et al., 2011; Laidre et al., 2008). Walruses use terrestrial haul outs in summer and autumn but give birth and mate on sea ice and use it seasonally to reach bivalve beds too far from shore (Kovacs et al., 2011). In doing so, they rely on shallow water (≤100 m) with suitable bottom substrate to support high bivalve abundances. However, there are reduced amounts of ice over the continental shelf and waters offshore are too deep for finding food (Kovacs et al., 2011). Moreover, predation through polar bears might increase (Laidre et al., 2008). However, all populations use the marginal ice zone as a platform to move over foraging areas too far from land-based haul-out sites to be considered energetically viable foraging areas (Kovacs et al., 2011). Use of the two seasonally distinct haul-out habitats, at least by portions of the population, results in a significant expansion of feeding distribution, which in turn allows for a greater overall abundance of walrus and might result in greater flexibility to adapt to climate change (Kovacs et al., 2011). They also show flexibility in feeding habits, shifting their diet toward eating more seals and fewer benthic invertebrates (Kovacs et al., 2011). Nevertheless, walruses depend on rich benthic communities of bivalves, fed in part by benthic-pelagic coupling permitting vertical flux from ice-algae and marginal ice zone algal blooms (Kovacs et al., 2011). Climate change's effects disturb the benthic–pelagic coupling process, resulting in declines in epibenthic biomass (Huntington et al., 2020).

10.2. Hunting

Greenlandic hunters reported taking an average of 157 walruses per year in 2016–18 (NAMMCO, 2016). Nowadays, the Greenlandic subsistence hunt is sustainable. However, in the period 2013–15, catches in Baffin Bay were higher than the scientific advice from NAMMCO, which led to a self-imposed ban on the export of walrus products in July 2016. This ban had not been lifted until now. Past hunting has resulted in walrus being rare in East Greenland, south of the national park, where they no longer use terrestrial haul-outs, and current catches consist of stragglers from the north (Ugarte et al., 2020). Today, walruses in West Greenland haul out almost exclusively on sea ice, and their former haul-out sites on land have been abandoned for at least 50 years (Boertmann and Mosbech, 2017).

10.3. Status and Population Trends

West Greenland

Areas	Abundance	Status, change (≥2 generations)	Trend (Short term~1 generation)	Category of change	Description: Physiological, behavioural change	Climate variable & direction	Hunting
Baffin Bay "Winter component in Greenland"	2014: 2544 (95% CI 1513–4279) (Heide-Jørgensen et al., 2016)	Reduced (Heide-Jørgensen et al., 2016)	Increasing (Heide-Jørgensen et al., 2016)		Declined by 40% from the 1960s to 2005 (NAMMCO, 2016)		
West Greenland winter aggregation	2012: 1408 (95% CI 922–2150)	Reduced (Heide-Jørgensen et al., 2013)	Increasing (Heide-Jørgensen et al., 2013)				

East Greenland

Areas	Abundance	Status, change (≥2 generations)	Trend (Short term~1 generation)	Category of change	Description: Physiologica, behavioural change	Climate variable & direction	Hunting
East Greenland (Northeast Water/ Northeast pop.)	2017: 279 (226–345) (NAMMCO, 2018a)		Stable or slightly increasing (NAMMCO, 2016)				
South East Greenland	No resident population in South East Greenland, but stragglers from Northeast Greenland are transported passively on drifting ice southwards						

10.4. Synopsis

Walrus are considered flexible to climate change. We found moderate evidence that the Baffin Bay winter aggregation will decline and strong evidence for an increase. For the West Greenland winter aggregation, we found weak evidence for a decline as well as weak evidence for an increase. For the Northeast Greenland stock, we found moderate evidence for an increase but also evidence that developments are unknown.

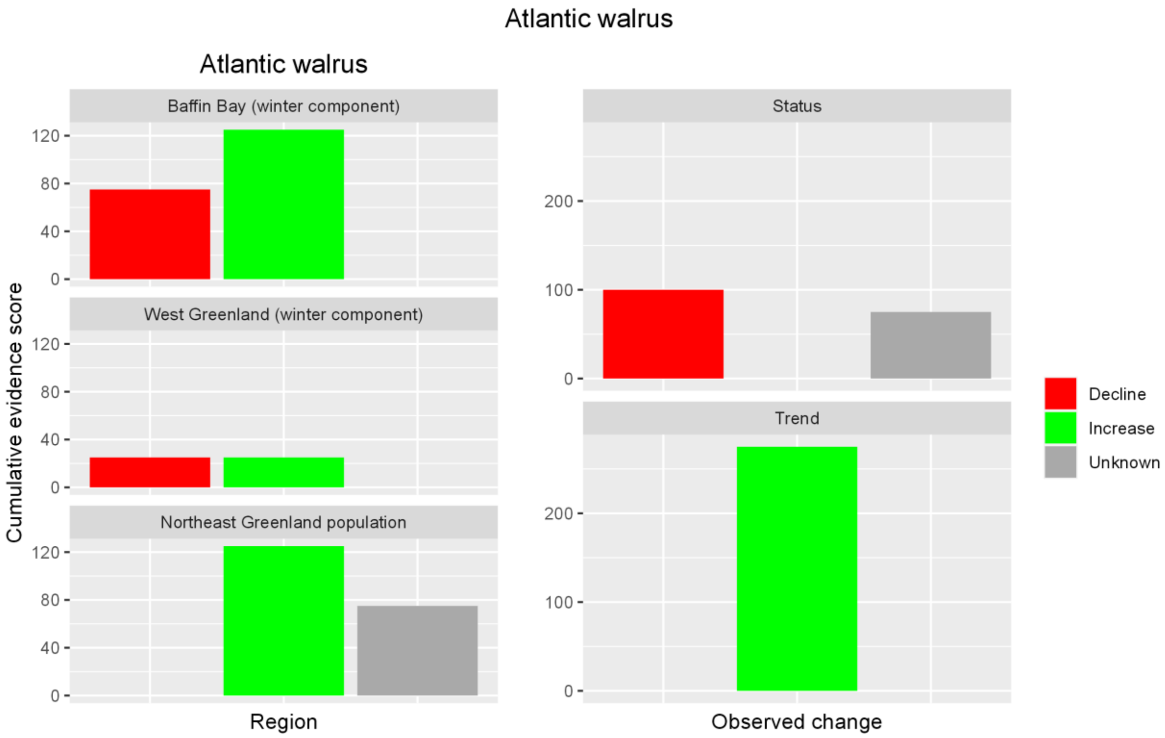


Figure 10.2. Cumulative evidence per region and aspects in which change is observed or expected.

10.5. Catch and Forecast

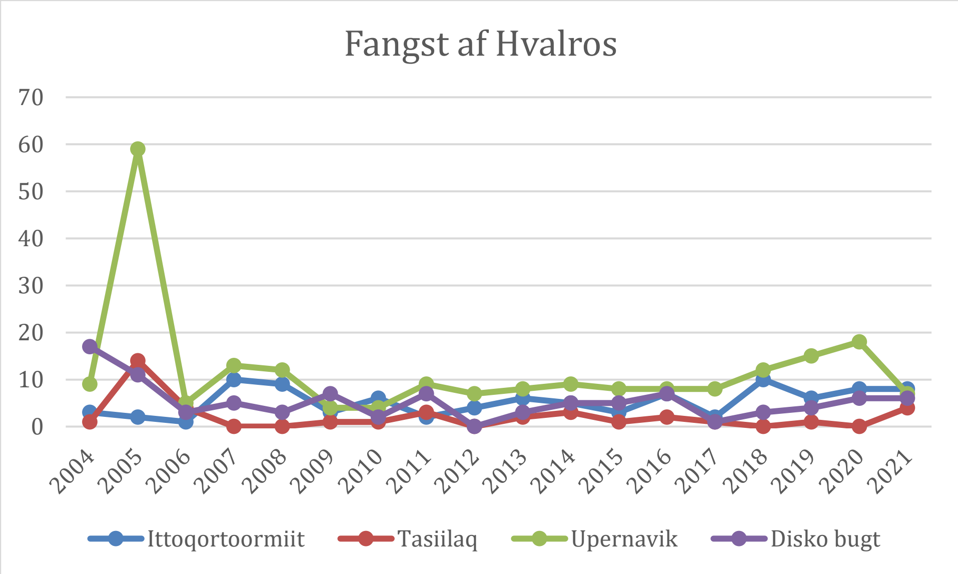


Figure 10.3. Total catch of walrus in Ittoqortoormiit, Tasiilaq and Upernavik districts and in the Disco Bay districts combined.

Due to errors in the data supplied by Statistics Greenland, data on total catch was obtained instead from NAMMCO on the management unit (no data available for East Greenland), and no forecasts were made.

10.6. Workshops with Hunter and Fishers Orgnisations

Scenario	Ittoqortoormiit	Tasiilaq	Upernavik	Ilulissat
Trend scenario	Hunting season was recently removed, and a quota was introduced. Expects increasing catch to reach the full quota of 30 individuals	Rarely seen. No expected catch	Starting to return after being absent. West Greenland quota has increased from 69 to 109 individuals. Expects increasing catch	Limited effort by a few individuals targeting walrus for carving and meat
Alternative scenario	NA	NA	NA	NA

10.7. Interviews with Scientific Experts

-will follow-

10.8. Preliminary Future Scenarios

Scenario	Ittoqortoormiit	Tasiilaq	Upernavik	Ilulissat
Stock and catch trend scenario	Increase catch to 3 individuals per hunter	0%	+10 compared to largest catch	-5% compared to average over

			over the period 2012-20	the period 2012-20
Underreporting adjustment scenario				
Alternative actions scenario				

11. Beluga whale (*Delphinapterus leucas*)

Beluga whale	
Delphinapterus leucas	
Hvidhval	
Qilalugaq Qaqortaq	

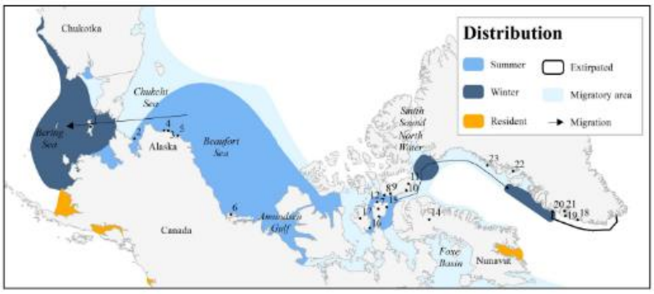


Figure 11.1. Distribution of Beluga (NAMMCO)

Beluga whales (*Delphinapterus leucas*) are considered moderately sensitive to climate change (Laidre et al., 2008a), and hunting seems to be the main factor for declining populations (Alvarez-Flores and Heide-Jørgensen, 2004). They show flexibility regarding food and habitat choices, choices and ability to deal with non-invasive interactions with humans and climate change (Kovacs and Lydersen, 2008). Belugas can accommodate widely varying sea-ice conditions and can mediate habitat change (less SIC) despite their sea-ice associations (O'Corry-Crowe et al., 2016). Their current summer distribution, consisting of two main aggregations, is located north and south of Baffin Island (Chambault et al., 2022). Spend October/November- April in West Greenland and the summer in the Canadian high Arctic around Somerset Island (Heide-Jørgensen et al., 2003). One segment of the beluga aggregation near Somerset Island moves to West Greenland in the winter (Heide-Jørgensen et al., 2003). The rest winters in the North Water region in northern Baffin Bay (Heide-Jørgensen et al., 2016b).

11.1. Climate Change

The distribution of belugas in West Greenland might shift further northward (Heide-Jørgensen et al., 2010). Potential response to near-future climate change may be a population-specific combination of site fidelity and spatial flexibility, interacting with local or regional factors, such as prey availability, predation, and anthropogenic activities (O'Corry-Crowe et al., 2016). Future decline of beluga populations is therefore expected (O'Corry-Crowe et al., 2016). Additionally, there is an alteration in migration and occupation of new feeding areas (Moore and Huntington, 2008). Substantial variations in sea-ice conditions contrasted with a highly consistent pattern of migration and residency by several populations, indicating that belugas can accommodate widely varying sea-ice conditions to perpetuate philopatry to coastal migration destinations (O'Corry-Crowe et al., 2016). Anomalous migration and residency events coincided with anomalous ice years and in one case, with an increase in killer whale (Orcinus orca) sightings and reported predation on beluga whales (O'Corry-Crowe et al., 2016). Continued reductions in sea ice may result in increased predation (O'Corry-Crowe et al., 2016).

11.2. Scenarios until 2100

Projections of suitable available habitat for the year 2100 estimate a 39% decline and a northward shift of 4.9°N relative to the present (O'Corry-Crowe et al., 2016). Scenarios by (Chambault et al., 2022) project a loss of habitat associated with a northern migration by 2100 under scenario ssp126 (best case emission scenario), while under ssp585 (worst case), a complete loss of habitat is expected for this species. The models project an average decline between −71% (SD, ±17.5, ssp126) and −88% (±23.6, ssp585) in available habitat for belugas. Belugas now have a broad north-south range, but they are divided into small local populations that exhibit high site fidelity, which makes them vulnerable to environmental change. Most beluga populations in the North Atlantic region are now small, including the one in southeast Baffin Island tracked in this study. Climate change is already thought to be a factor that is limiting the recovery of these populations from previous overexploitation, and because belugas show strong site fidelity to summering grounds, they will likely not move, despite the expected habitat deterioration (Chambault et al., 2022).

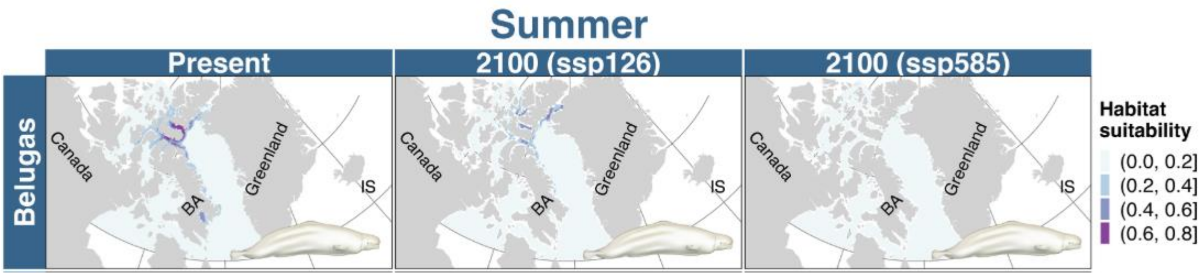


Figure 11.2. Predictive maps of habitat suitability for belugas, bowhead whales and narwhals for the present and for 2100 in summer (August to September) for both scenarios (ssp126 and ssp585). "BA" corresponds to Baffin Island, "IS" to Iceland, and "SVB" to Svalbard. Cetacean illustrations by Uko Gorter.

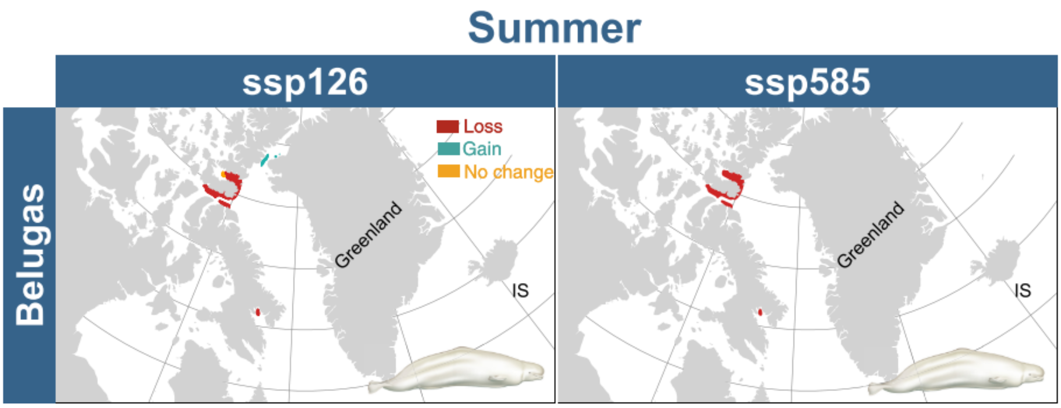


Figure 11.3. Changes in projected summer core habitats (probabilities >0.5) by 2100 for the three Arctic whale species for both scenarios. Red areas are projected losses by 2100, orange areas are expected to remain unchanged, and green areas are projected increases in habitat. Not enough data were available to model belugas in winter.

11.3. Status and Population Trends

West Greenland:

Areas	Abundance	Status, change (≥2 generations)	Trend (Short term~1 generation)	Category of change	Description: physiological,behavioral change	Climate variable & direction	Hunting
West Greenland (winter-Somerset Island stock)	**2012: 9,072 whales (95% CI: 4,895 to 16,815**	Reduced	Stable				
North Water Polynya (winter) (area around Qaanaaq, separated to a stock in a 2020)	**2014: 2324 (95% CI 1786–2820)**	Reduced (NAMMCO, 2016)	Unknown (NAMMCO, 2018b)				

East Greenland:

Areas	Abundance	Status, change (≥2 generations)	Trend (Short term~1 generation)	Category of change	Description: physiological,behavioral change	Climate variable & direction	Hunting
Southwest Greenland winter		Extinct (ca. 1930) (NAMMCO/ JCNB, 2015; Ugarte et al., 2020)	Driven to extinction by unsustainable hunting (Heide-Jørgensen, 1994).				

11.4. Synopsis

Belugas are considered less sensitive to climate change. We found moderate evidence of a decline and strong evidence of a stable aggregation of Beluga whales in winter in the North Water Polynya. For the West Greenland winter aggregation, we found moderate evidence of a decline and strong evidence of stable abundance. For the West Greenland summer stock, we found strong evidence of a decline. Also from the generic evidence, there is strong evidence of a decline, especially for future changes in range.

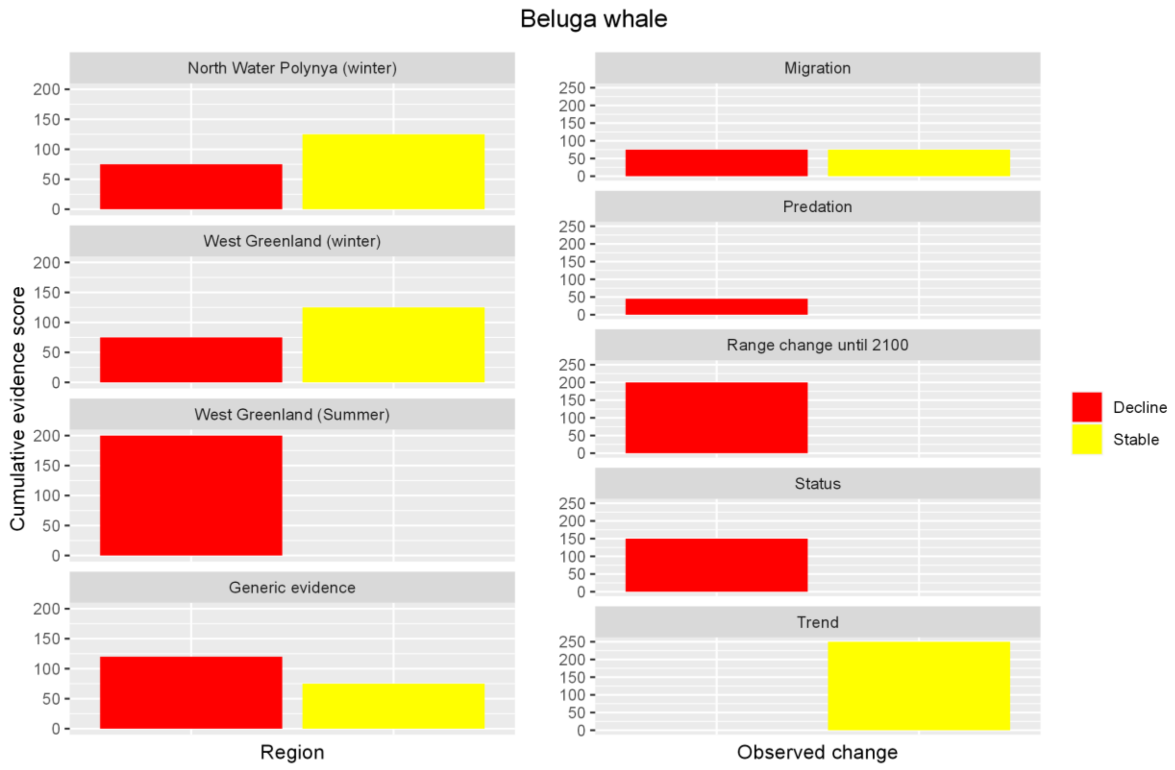


Figure 11.4. Cumulative evidence per stocks and aspects in which change is observed or expected.

11.5. Catch and Forecast

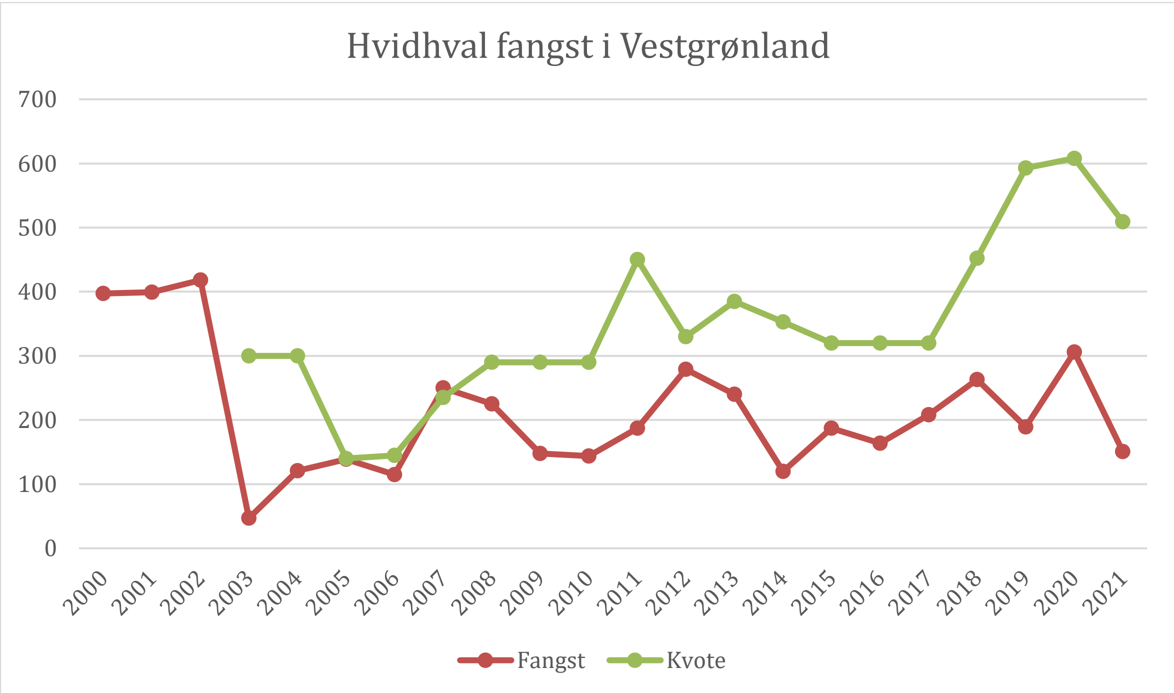


Figure 11.5. Catch and quota of Beluga in West Greenland.

Due to errors in the data supplied by Statistics Greenland, data on total catch was obtained instead from NAMMCO on the management unit (no data available for East Greenland), and no forecasts were made.

11.6. Workshops with Hunter and Fishers Orgnisations

Scenario	Ittoqortoormiit	Tasiilaq	Upernavik	Ilulissat
Trend scenario	Have recently received a technical quota of 15 until 2027 and have already caught 5. Wants unlimited catch	Have recently received a technical quota of 15 until 2027. Suggest larger quota	Sees more whales after regulations were introduced. But the catch is declining due to harsh weather in the open season.	Increased due to regulations but has become a limited resource that everyone wants to catch. Content with quota
Alternative scenario	Remove the trade ban to the west coast	Remove the trade ban to the west coast	NA	NA

11.7. Interviews with Scientific Experts

-will follow-

11.8. Preliminary Future Scenarios

Scenario	Ittoqortoormiit	Tasiilaq	Upernavik	Ilulissat
Stock and catch trend scenario	5 caught per year distributed between all occupational hunters	5 caught per year distributed between all occupational hunters	-10% compared to average over 2012-20 period	Stable compared to average over 2012-20 period
Underreporting adjustment scenario				
Alternative actions scenario	Price increase based on national trade	Price increase based on national trade		

12. Bowhead whale (*Balaena mysticetus*)

Bowhead whale	
Balaena mysticetus	
Grønlandshval	
Arfivik	

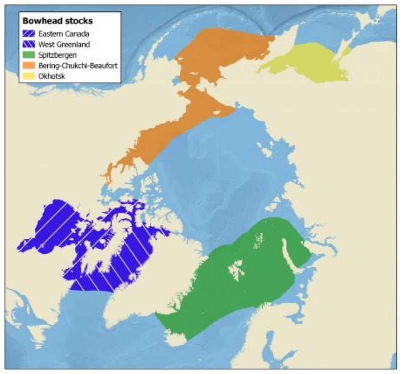


Figure12.1. Range of Bowhead whales stocks (NAMMCO)

Bowhead whales are found largely in coastal areas in the West and in areas with pack ice (>200 km) north of Svalbard eastward to Franz Joseph Land (Chambault et al., 2022). Bowhead whales live in close association with sea ice and migrate to the high Arctic in summer and move southward in winter with the ice edge (NAMMCO, 2016).

12.1. Climate Change

Bowhead whales are moderately sensitive to climate change and show positive demographic changes during sea ice reduction (Laidre et al., 2008). There was a consistent growth of the western Arctic bowhead population at an annual rate of 3.4% for the period 1978–2001 (George et al., 2015). Moreover, there has been an increase in abundance and bowhead whale body condition and a positive correlation with summer sea ice loss over the last 2.5 decades in the Pacific Arctic (George et al., 2015). Also, the condition of bowheads landed by Alaskan Inuits between 1982 and 1999 was higher when average sea ice concentrations in summer feeding areas were lower, presumably due to local increases in primary production due to reduced sea ice cover (Laidre et al., 2008). Aggregations of whales have been found at higher latitudes during spring and summer, likely in response to sea-ice retreat and increasing sea temperature (SST) (Chambault et al., 2018). For East Greenland, no estimates are available.

The effects of climate change on bowhead whales are two-fold. Bowhead whales may face extensive habitat loss since whales target a narrow range of SSTs from −0.5 to 2 °C, and Sea surface temperature should be below 2°C (Chambault et al., 2018). Nevertheless, the Sea ice appears to act more like a barrier restricting access to foraging areas (Chambault et al., 2018), and the increased secondary trophic production due to sea ice loss might have positive effects on bowhead whales (George et al., 2015, 2004; Laidre et al., 2008).

Anticipated effects of climate change include migration alteration and occupation of new feeding areas (Moore and Huntington, 2008). However, the bowhead whale's dependence on lipid-rich species of Calanus and euphausiids for their food makes it likely that changes in sea-ice conditions will significantly impact the bowhead whale foraging (Kovacs and Lydersen, 2008). Their low reproductive potential, their vulnerability to predation in more open water, their likely sensitivity to increased development (boat strikes etc. make them a species of concern with regard to climate change and it is difficult to predict whether this species could adjust to ice-free waters (Kovacs and Lydersen, 2008).

12.2. Scenarios until 2100

Scenarios by made Chambault et al. (2022) project a northerly shift of key habitats in summer between the present and 2100, simultaneous with a significant contraction in habitat for both sides, with the most marked habitat loss suggested under scenario ssp585 (worst case emission scenario) (Fig. 12.2). In winter, their models project a northwestward expansion of bowhead whales' habitat in the West into the Canadian Arctic Archipelago. In the East, bowheads will lose most of their current habitat under the ssp585 scenario, while ssp126 projects some new habitat becoming available further north.

The models project an average decline in habitat between −28% (±53.7) and −68% (±15.3) for bowhead whales. In winter, projected habitats are expected, on average, to increase for bowhead whales at least in the West. In the East, little change is predicted, and the direction of change varies under the two climate scenarios. Expected habitat gain for bowheads in winter ranged between 7% (±36.8, ssp126, bowheads East) and 80% (±135, ssp585, bowheads West). For bowhead whales, only the East side, under scenario ssp585, shows an average loss of habitat by 2100 (−9 ± 48.0%). A northward shift was projected in both summer and winter habitats for all three Arctic endemic species (475 ± 261 km for bowheads West in summer, ssp126).

Bowhead whales are now mainly found in coastal areas in the West and areas with pack ice (>200 km) north of Svalbard eastward to Franz Joseph Land, well north of their historical range. Few sightings occur around Svalbard, where bowheads were abundant during the Little Ice Age (1300 to 1860) before the near extirpation of the Spitsbergen stock by commercial whaling. Loss of sea ice in the Canadian Arctic Archipelago due to rising temperatures will allow bowhead whales to remain year-round in small refugial areas. Historically, these areas were used intensively by bowhead whale hunters from the Thule culture during a warm period some 1000 years ago. In East Greenland, bowhead whales are already found further north than their historical range (Kovacs et al., 2020). However, there is a limit to how far north they can move without losing contact with important pelagic zooplankton prey resources that benefit from upwelling along (Chambault et al., 2022).

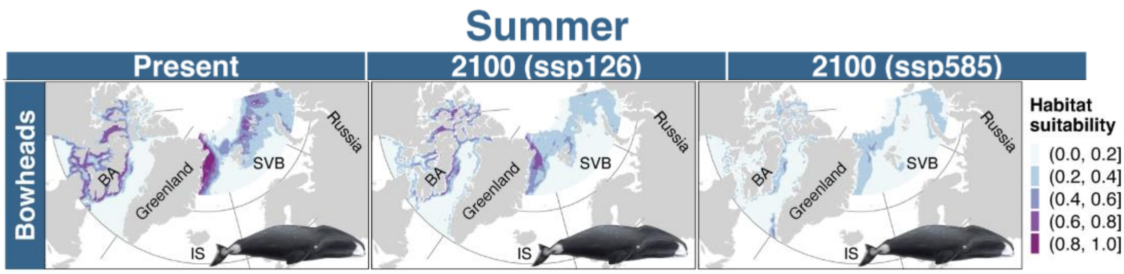


Figure 12.2. Predictive maps of habitat suitability for belugas, bowhead whales and narwhals for the present and for 2100 in summer (August to September) for both scenarios (ssp126 and ssp585). "BA" corresponds to Baffin Island, "IS" to Iceland, and "SVB" to Svalbard.

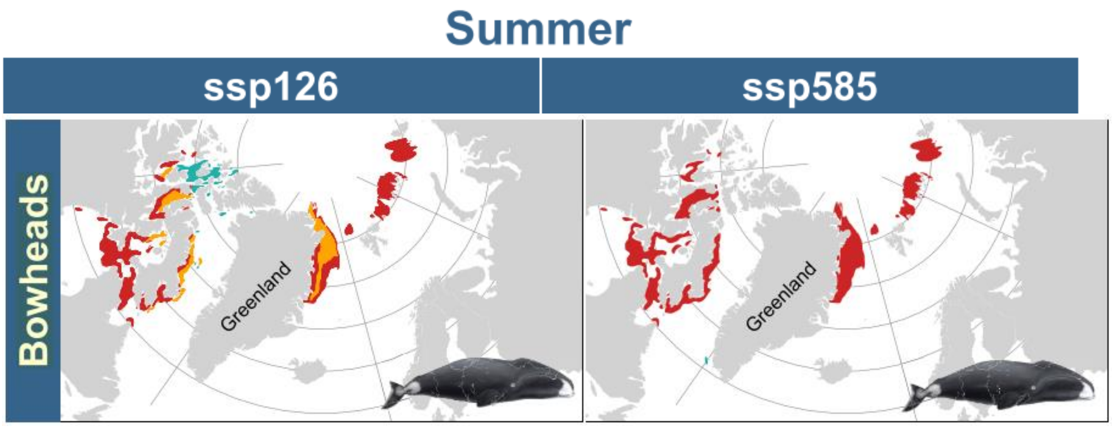


Figure 12.3. Changes in projected summer core habitats (probabilities >0.5) by 2100 for the three Arctic whale species for both scenarios. Red areas are projected losses by 2100, orange areas are expected to remain unchanged, and green areas are projected increase in habitat.

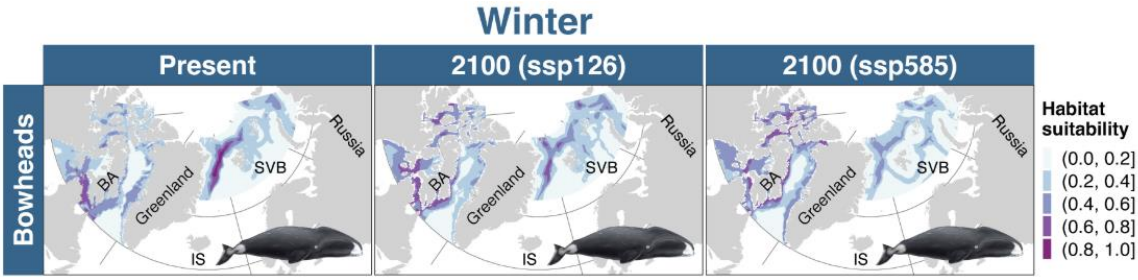


Figure 12.4. Predictive maps of habitat suitability for bowhead whales and narwhals for the present and 2100 in winter (December to March) for both scenarios (ssp126 and ssp585). Not enough data were available to model belugas in winter.

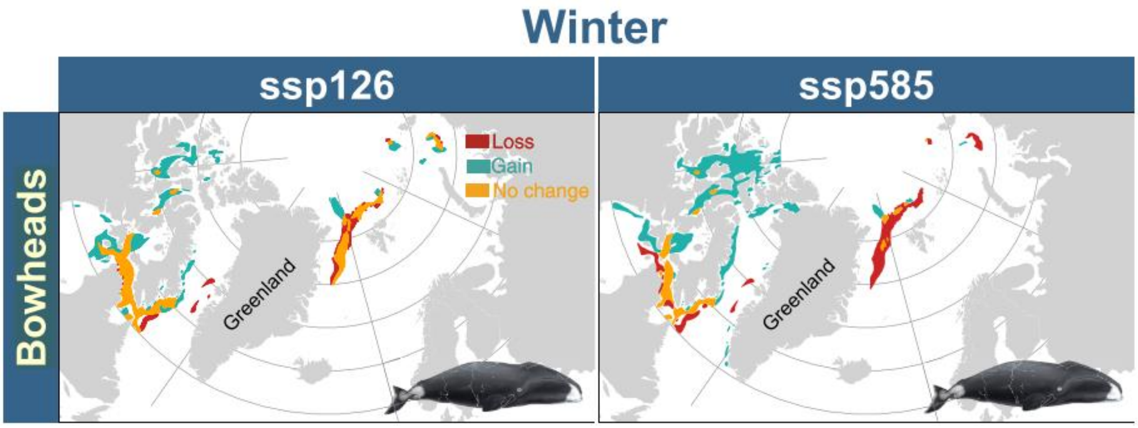


Figure 12.5. Changes in projected winter core habitats (probabilities >0.5) by 2100 for bowhead whales and narwhals for both scenarios. Not enough data were available to model belugas in winter. Red areas are projected losses by 2100, orange areas are expected to remain unchanged, and green areas are projected to increase in habitat.

12.3. Hunting

Bowhead whales may reach ages of more than 200 years (NAMMCO, 2016). During the 18th and 19th centuries, bowhead whales in East Greenland faced near extinction as they were extensively hunted (Ugarte et al., 2020). Similarly, in the 19th and 20th centuries, the bowhead whale population in West Greenland suffered severe depletion due to extensive hunting. (Ugarte et al., 2020). In 1932, the League of Nations implemented global protection measures for bowhead whales. At that time, these whales were believed to be extinct in East Greenland and were considered rare in West Greenland. The bowhead whale population in West Greenland experienced a remarkable resurgence after the 1990s. This recovery was so significant that the International Whaling Commission (IWC), in 2009, granted Greenland a quota of two whales per year for subsistence whaling. However, between 2016 and 2019, no bowhead whales were captured in Greenland (Ugarte et al., 2020).

12.4. Status and Population Trends

West Greenland:

Areas	Abundance	Status, change (≥2 generations)	Trend (Short term~1 generation)	Category of change	Description: physiological,behavioral change	Climate variable & direction	Hunting
Eastern Canada-West Greenland (EC–WG)	**2013:** 6,446 (CV 26%)(Doniol -Valcroze et al., 2015)	Reduced (Rekdal et al., 2015)	Increased significantly (NAMMCO, 2016)		**Until 2100, northerly shift of key habitats in summer (to 475 ± 261 km (West in summer)**(Chambault et al., 2022) **Until 2100, significant contraction in habitat for both sides** (Chambault et al., 2022)		

East Greenland

Areas	Abundance	Status, change (≥2 generations)	Trend (Short term~1 generation)	Category of change	Description: physiological,behavioral change	Climate variable & direction	Hunting
The Svalbard-Barents Sea stock (or the Spitsbergen stock)	2017: 318 (95% CI 110–956) (Hansen et al., 2018)	Reduced (Hansen et al., 2018)	Increasing (NAMMCO, 2016)		**Until 2100, northerly shift of key habitats in summer (to 475 ± 261 km (West in summer)**(Chambault et al., 2022) **Until 2100, significant contraction in habitat for both sides** (Chambault et al., 2022)		

12.5. Synopsis

Bowhead whales are considered moderately sensitive to climate change. We found strong evidence for a decline and an increase in the Eastern Canada-West Greenland stock. For the Svalbard-Barents Sea stock, we found overwhelming evidence of a decline but also strong evidence for an increase. For West Greenland, we found moderate evidence for an increase. The generic evidence showed overwhelming evidence for an increase and moderate evidence for a decrease. The opposing evidence for the stocks is likely due to a mismatch between current increasing trends and projected declining trends in future.

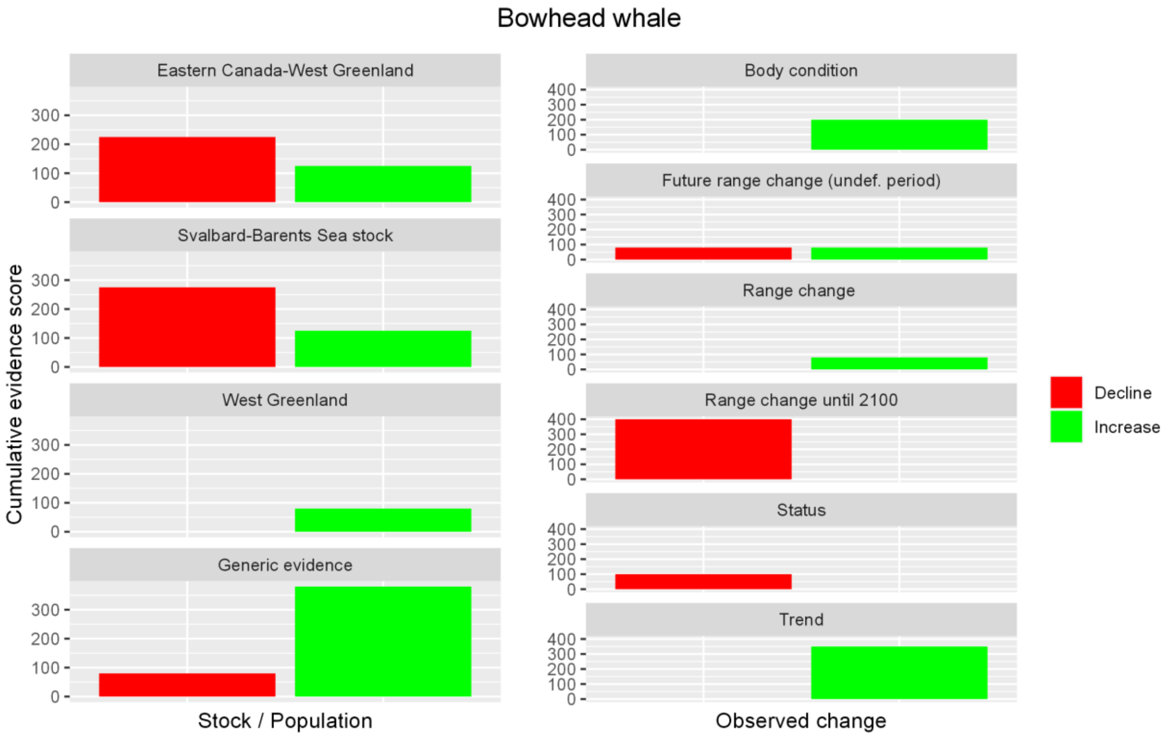


Figure 12.6. Cumulative evidence per stock/population and aspects in which change is observed or expected.

12.6. Catch and Forecast

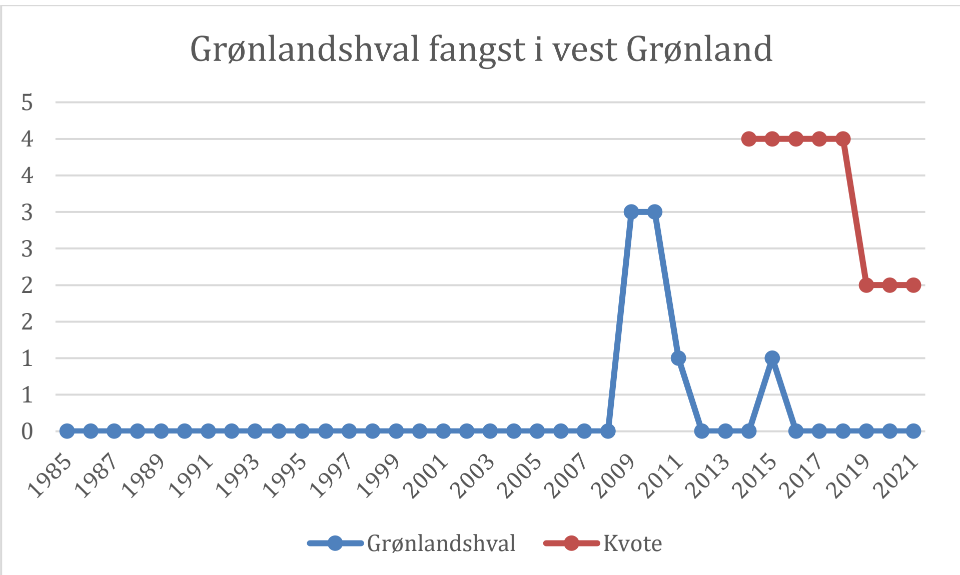


Figure 12.7. Catch and quota for bowhead whale in West Greenland.

Due to errors in the data supplied by Statistics Greenland, data on total catch was obtained instead from IWC on the management unit level (no data available for East Greenland), and no forecasts were made.

12.7. Workshops with Hunter and Fishers Orgnisations

-not discussed-

12.8. Interviews with Scientific Experts

-will follow-

12.9. Preliminary Future scenarios

Scenario	Ittoqortoormiit	Tasiilaq	Upernavik	Ilulissat
Stock and catch trend scenario				
Underreporting adjustment scenario				
Alternative actions scenario				

13. Mink whale (*Balaenoptera acutorostrata*)

Mink whale	
Balaenoptera acutorostrata	
Sildepisker	
Tikaagullik	

Mink whales (*Balaenoptera acutorostrata*) are a seasonally migrant marine mammal species (Moore and Huntington, 2008) and the largest ice-dependent krill predators in the Southern Ocean, distribution and ecology are directly tied to sea ice and foraging on krill (Risch et al., 2019) (Fig. 13.1).

In Southeast Greenland, catches of Mink whales are increasing, pointing towards an increasing population (Heide-Jørgensen et al., 2022).

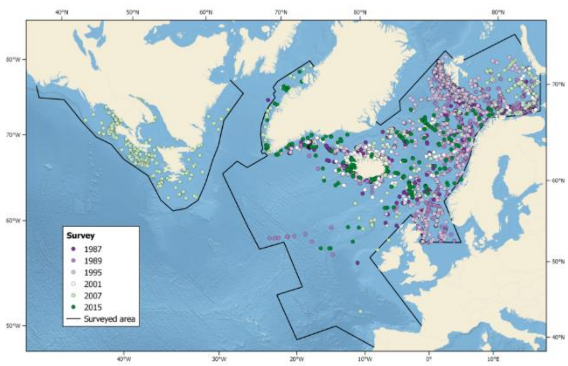


Figure 13.1. Observations from all surveys, 1987 – 2015 (NAMMCO)

13.1. Climate Change

Changes that affect the quantity and quality of their habitat and food availability of krill could be significant and could simultaneously increase competition with other krill predators (humpback whales, crabeater seals, Antarctic fur seals, penguins, seabird, and fish species) (Risch et al., 2019). The main distribution of Antarctic minke whales could shift to regions currently covered by sea ice. In their current distribution, they could face higher predation risk from killer whales in open water (Higdon and Ferguson, 2009) and compete with other predators for limited prey (Risch et al., 2019).

13.2. Hunting

Minke whales are hunted for their meat and mattak, and are chased from skiffs and smaller fishing vessels during summer (Boertmann and Mosbech, 2017). Hunting is regulated by quotas, and a minimum of five skiffs need to work together to be allowed to hunt a minke whale. The first minke whale ever reported from Qaanaaq was caught in 2009. Subsequently, from 2010-2014, one minke whale was caught in Qaanaaq each year in 2011, 2012 and 2013. In the same period, seven minke whales were caught each year in Upernavik, with the exception of 2013, when 21 minke whales were caught. Yearly catches in Uummannaq from 2010-2014 ranged from five to eleven (APNN, unpublished data). Hunting for minke whales may become more common as the climate warms and the range of this species shifts northwards (Boertmann and Mosbech, 2017). Minke whale is the only baleen whale currently hunted in East Greenland, and the low number of catches fluctuates a lot but has also increased significantly in recent years (Heide-Jørgensen et al., 2022).

13.3. Status and Population Trends

West Greenland:

Areas	Abundance	Status, change (≥2 generations)	Trend (Short term~1 generation)	Category of change	Description: physiological,behavioral change	Climate variable & direction	Hunting
West Greenland	2015: 5,095 (2,171-11,961) (Hansen et al., 2018)	**Unknown** (Ugarte et al., 2020a)	Fluctuating (Hansen et al., 2018; Ugarte et al., 2020)				

East Greenland

Areas	Abundance	Status, change	Trend (Short term)	Category of change	Description: physiological,behavioral change	Climate variable & direction	Hunting
East Greenland	2015: 2,762 (1160-6574) (Hansen et al., 2018)	Not reduced (Hansen et al., 2018; Ugarte et al., 2020)	Fluctuating (Hansen et al., 2018; Ugarte et al., 2020)				

13.4. Synopsis

Minke whales may benefit from climate change. We found strong evidence for a decline and moderate evidence for a stable abundance of Mink whales in West Greenland. In East Greenland, we found strong evidence for an increasing abundance.

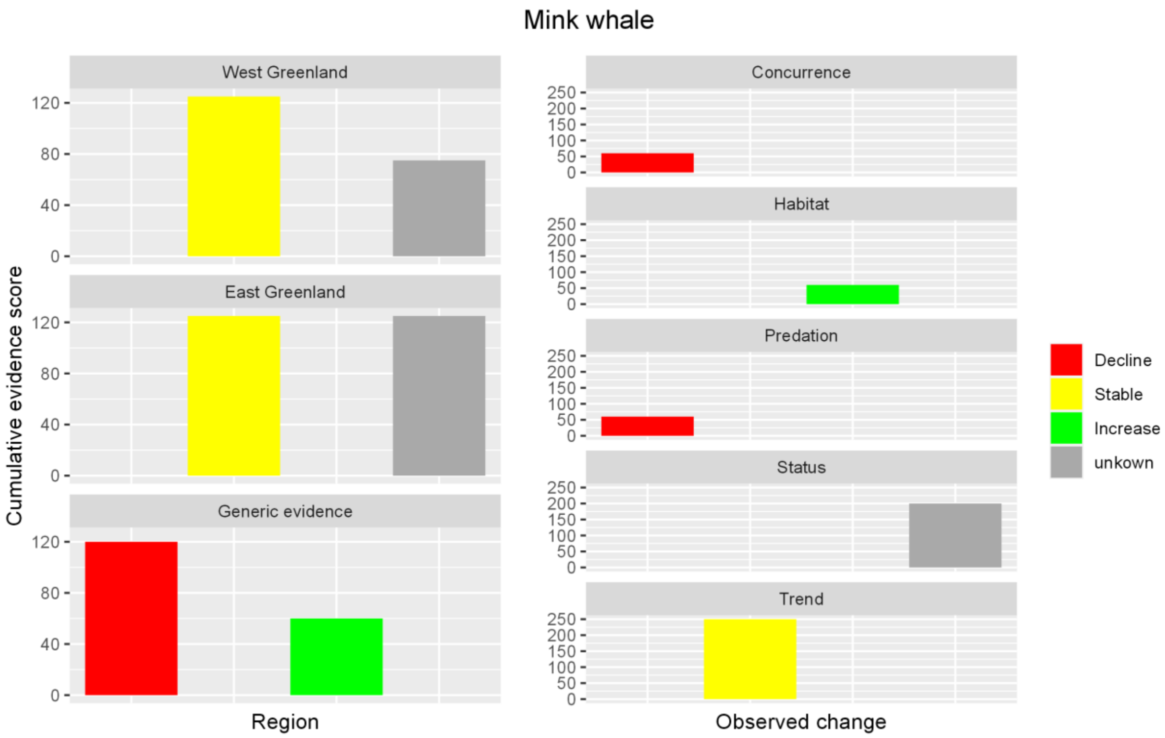


Figure 13.2. Cumulative evidence per region and aspects in which change is observed or expected.

13.5. Catch and Forecast

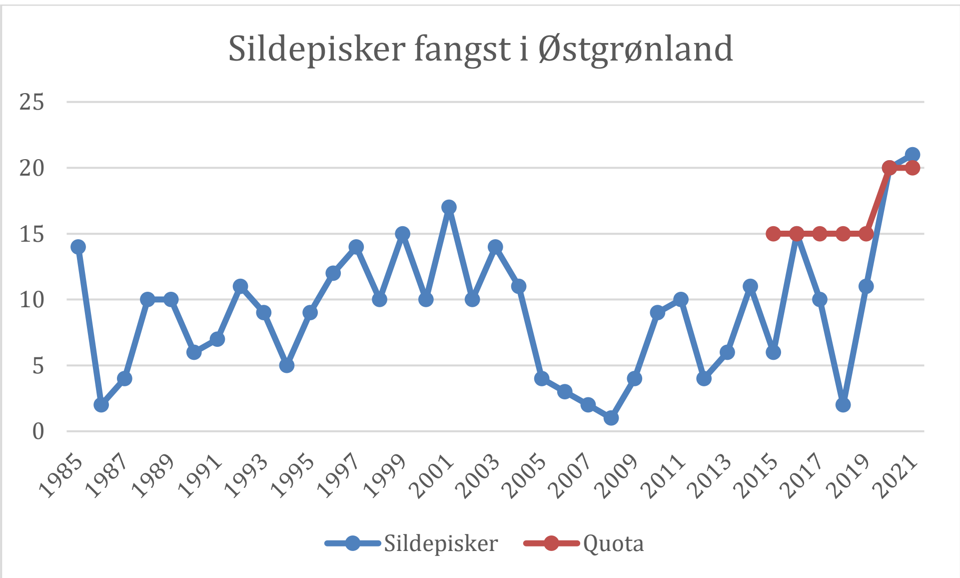


Figure 13.3. Total catch of Minke whale and quotas in East Greenland.

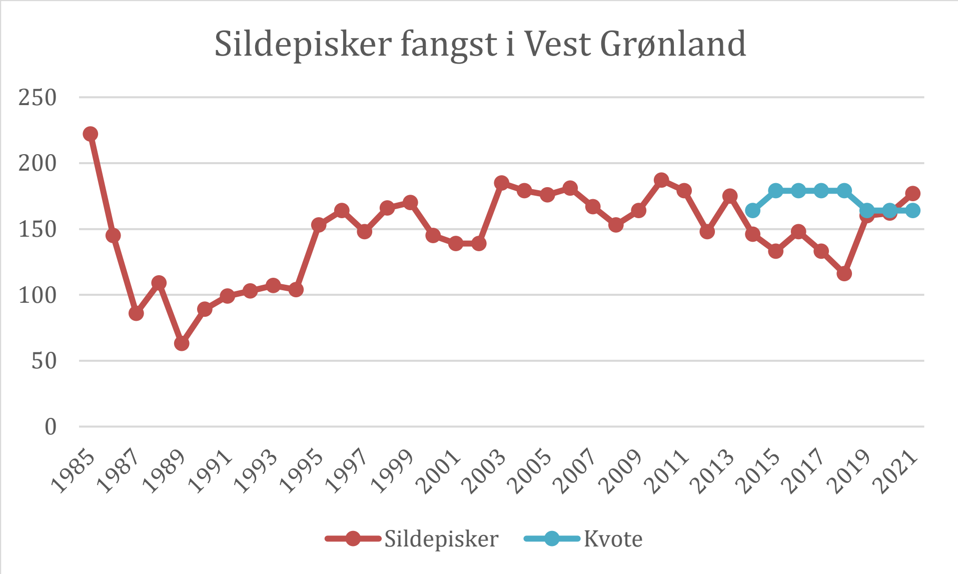


Figure 13.4. Total catch of Minke whale and quotas in West Greenland.

Due to errors in the data supplied by Statistics Greenland, data on total catch was obtained instead from IWC on the management unit level (no data available for East Greenland), and no forecasts were made.

13.6. Workshops with Hunter and Fishers Organizations

Scenario	Ittoqortoormiit	Tasiilaq	Upernavik	Ilulissat
Trend scenario	Do not catch	Catch determined by quota and is always caught	Catch determined by quota and is always caught	Catch reduced after prohibition on using trawlers and larger vessels implemented. Quota of two whales determines catch
Alternative scenario		Remove trade ban (or just allow the 5 kg non-commercial trade) to allow international trade		

13.7. Interviews with Scientific Experts

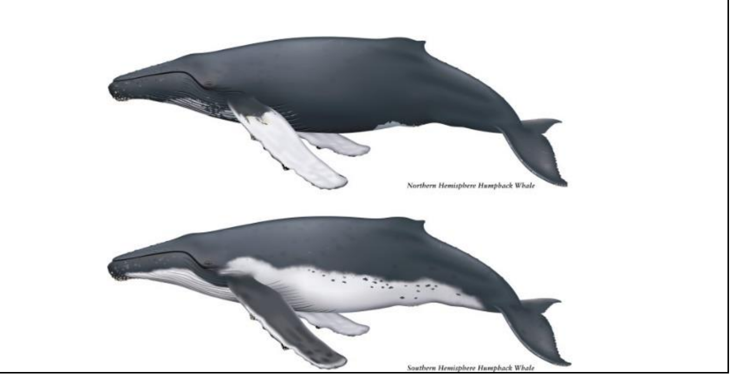
-will follow-

13.8. Preliminary Future Scenarios

Scenario	Ittoqortoormiit	Tasiilaq	Upernavik	Ilulissat
Stock and catch trend scenario				

Underreporting adjustment scenario				
Alternative actions scenario		Adjust the price of meat and mattak upwards (by a yet undetermined amount)		

14. Humpback whales (*Megaptera novaeangliae*)

Humpback whales	
Megaptera novaeangliae	
Pukkelhval	
Qipoqqaq	

The humpback whales (*Megaptera novaeangliae*) make annual migrations (Moore and Huntington, 2008) between winter mating grounds in the Caribbean and summer feeding grounds in the North Atlantic. So far, no summer feeding ground has been identified in East Greenland (Heide-Jørgensen et al., 2022).

14.1. Climate Change

In South East Greenland, the abundance of humpback whales rose from zero in 1900 to 4.223 (95% CI: 1845- 9666) whales, about one-fifth of the current total estimate for the North Atlantic in August 2015 (Hansen et al., 2018).

This higher abundance might be connected to an influx from neighbouring areas driven by an ice-free coastal zone and substantial availability of prey (Hansen et al., 2018; Heide-Jørgensen et al., 2022; Pike et al., 2019). A redistribution of the cold- water species capelin, an important prey of humpback whales in West Greenland and Iceland, in the past two decades from the Iceland Sea north of Iceland toward the East Greenland coast and shelf region (Bárðarson et al., 2021) could explain the increase in humpback whales (Heide-Jørgensen et al., 2022). In the same year, cetacean surveys around Iceland and West Greenland detected substantial declines in the abundance of humpback whales (Hansen et al., 2018; Pike et al., 2019).

14.2. Interactions

Humpback whales are the biggest consumer of fish species among the cetaceans moving into the Arctic, targeting the capelin that have migrated onto the shelf area (Heide-Jørgensen et al. 2022).

14.3. Hunting

Humpback whales are protected in East Greenland.

14.4. Status and Population Trends

West Greenland:

Areas	Abundance	Status, change	Trend (Short term)	Category of change	Description: physiological,behavioral change	Climate variable & direction	Hunting
West Greenland	**2015: 427 (95% CI: 219-831)** (Hansen et al., 2018)	**Not reduced** (Hansen et al., 2018)	**Remarkably decrease** (Hansen et al., 2018)				

East Greenland

Areas	Abundance	Status, change	Trend (Short term)	Category of change	Description: physiological,behavioral change	Climate variable & direction	Hunting
East Greenland	**2015 : 1816 (95% CI: 933-3536)** (Hansen et al., 2018)	**Unknown** (Hansen et al., 2018)	**Remarkably increase** (Hansen et al., 2018)				

14.5. Synopsis

Humpback whales might benefit from climate change. We found strong evidence of a decline and moderate evidence of a stable abundance of Humpback whales in West Greenland. We found strong evidence for an increase in East Greenland. Nevertheless, much is listed as unknown in the literature about the development in the region.

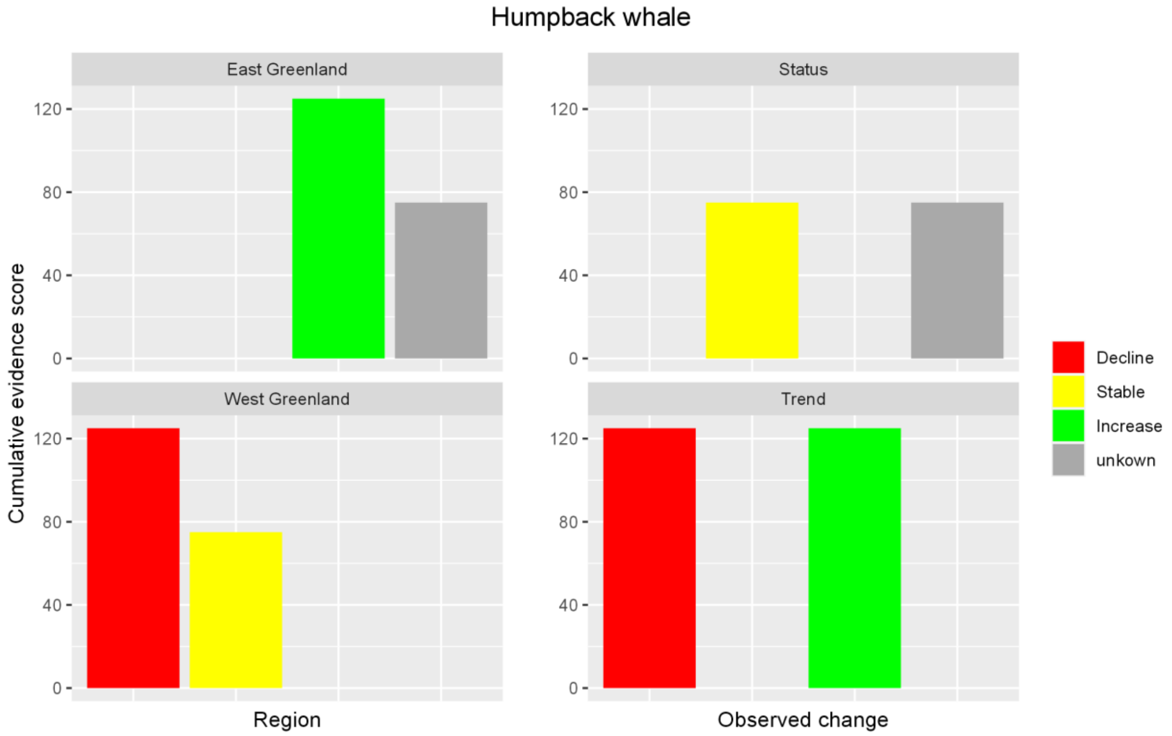


Figure 14.1 Cumulative evidence per region and aspects in which change is observed or expected.

14.6. Catch and Forecast

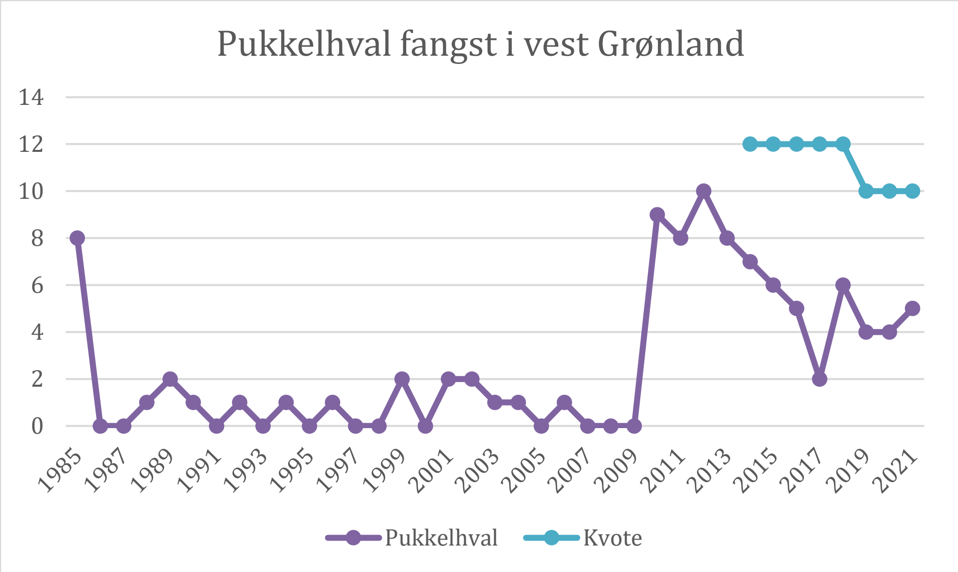


Figure 14.2. Catch of Humpback whale in West Greenland.

Due to errors in the data supplied by Statistics Greenland, data on total catch was obtained instead from IWC on the management unit level (no data available for East Greenland), and no forecasts were made.

14.7. Workshops with Hunter and Fishers Organizations

-not discussed-

14.8. Interviews with Scientific Experts

-will follow-

14.9. Preliminary Future Scenarios

Scenario	Ittoqortoormiit	Tasiilaq	Upernavik	Ilulissat
Stock and catch trend scenario				
Underreporting adjustment scenario				
Alternative actions scenario				

15. Fin whales (*Balaenoptera physalus*)

Fin whales	
Balaenoptera physalus	
Finhval	
Tikaagulliusaaq	

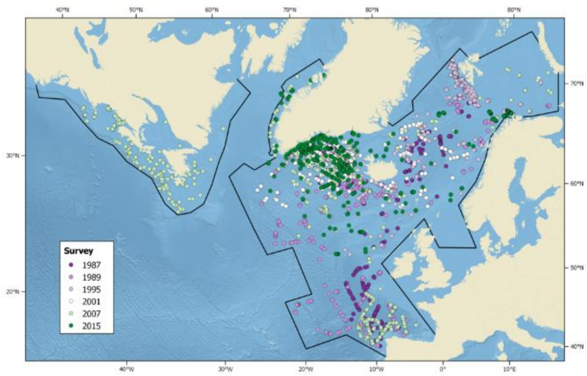


Figure 15.1. Sightings from all surveys, 1987 – 2015 (NAMMCO)

Fin whales (*Balaenoptera physalus*) migrate to lower latitudes in winter for breeding and to high latitudes in summer as feeding grounds. Fin whales are the second-largest living animal; the oldest specimen captured in Iceland was 94 years old (NAMMCO, 2016).

In South East Greenland, a region with little or no historical evidence of fin whales, an unexpectedly large number of fin whales were found in the coastal waters of East Greenland (6.440 fin whales) in 2015 (Hansen et al., 2018). The warming of the Irminger Sea in recent decades has likely improved conditions for zooplankton species, making the area attractive for foraging fin whales (Heide-Jørgensen et al., 2022). In general, habitat conditions for cetaceans may continue to improve due to increased pelagic productivity in coastal areas and further expansion due to new ice-free access (Heide-Jørgensen et al., 2022).

15.1. Interactions

About >1,500,000 tons of krill species are mainly consumed by fin whales that expand their range and residence time towards South East Greenland (Heide-Jørgensen et al., 2022).

15.2. Hunting

The annual catches since 2000 have been in Greenland between 5 and 13 whales.

15.3. Status and Population Trends

West Greenland:

Areas	Abundance	Status, change (≥2 generations)	Trend (Short term)	Category of change	Description: physiological,behavioral change	Climate variable & direction	Hunting
West Greenland	2015: 9190 (95% CI 3635–23,234) (R. Hansen et al., 2019)	Unknown (R. Hansen et al., 2019)	Unknown (R. Hansen et al., 2019)				

East Greenland

Areas	Abundance	Status, change	Trend (Short term)	Category of change	Description: physiological,behavioral change	Climate variable & direction	Hunting
East Greenland	**2015: 258 (95% CI 50–1354)** (R. Hansen et al., 2019)	Unknown (R. Hansen et al., 2019)	Unknown (R. Hansen et al., 2019)				

15.4. Synopsis

Fin whales may benefit from climate change. We found overwhelming evidence in the literature that there is a lack of information on the abundance of Fin whales in Greenland.

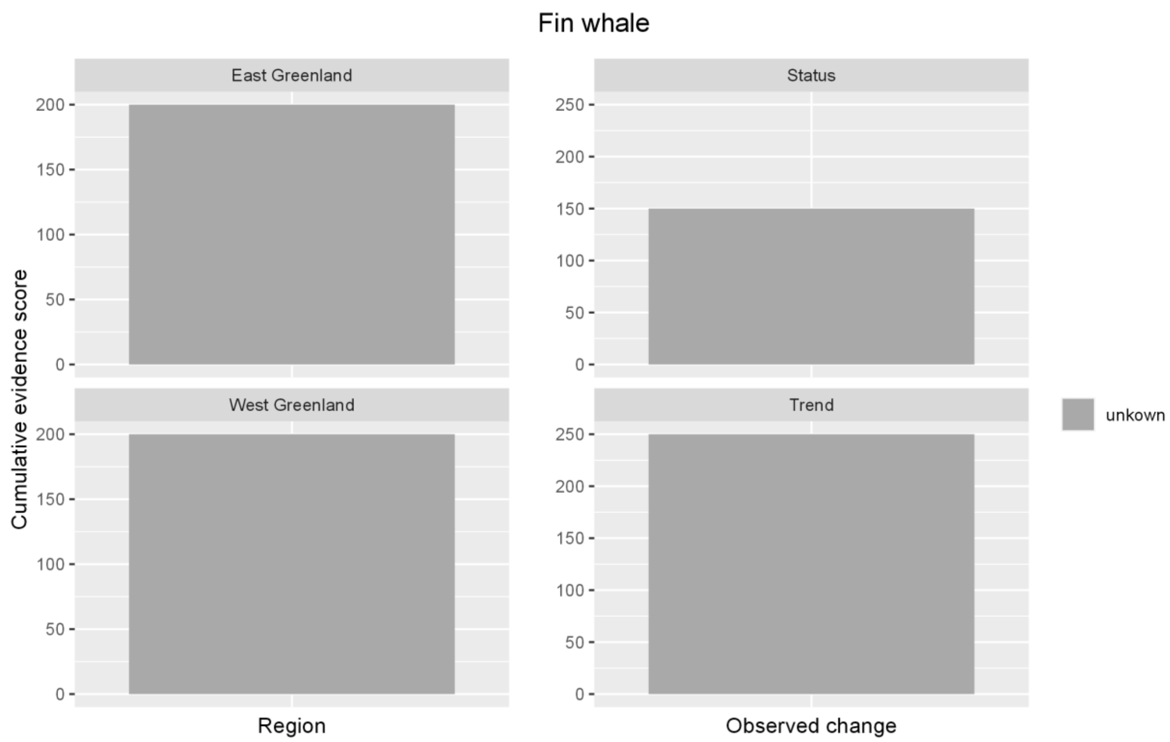


Figure 15.2. Cumulative evidence per region and aspects in which change is observed or expected.

15.5. Catch and Forecast

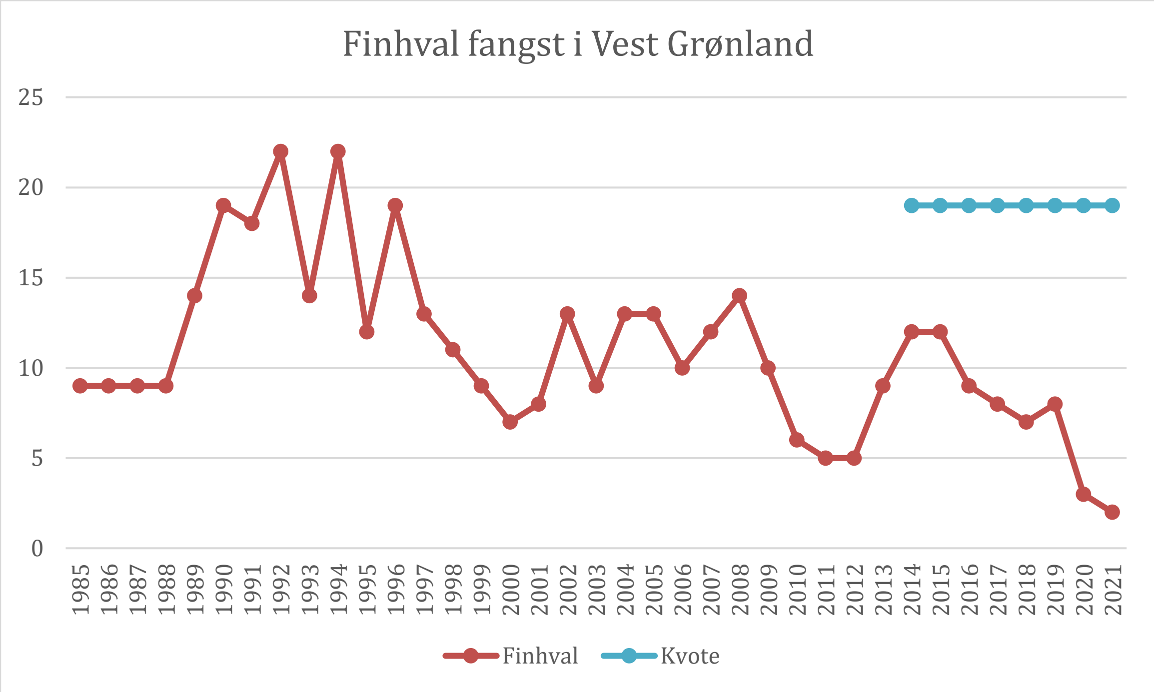


Figure 15.3. Total catch of Fin whales and quotas in West Greenland.

15.6. Workshops with Hunter and Fishers Organizations

-not discussed-

15.7. Interviews with Scientific Experts

-will follow-

15.8. Preliminary Future Scenarios

Scenario	Ittoqortoormiit	Tasiilaq	Upernavik	Ilulissat
Stock and catch trend scenario				
Underreporting adjustment scenario				
Alternative actions scenario				

16. Harbour porpoise (*Phocoena phocoena*)

Harbour porpoise	
Phocoena phocoena	
Marsvin	
Niisa	

Population trends are unknown for Harbour porpoises. However, with the general warming on the banks of West Greenland, they showed longer residence times and increased Atlantic cod consumption resulting in improved body condition in the form of larger fat deposits in 2009 compared to 1995 (Heide-Jørgensen et al., 2011).

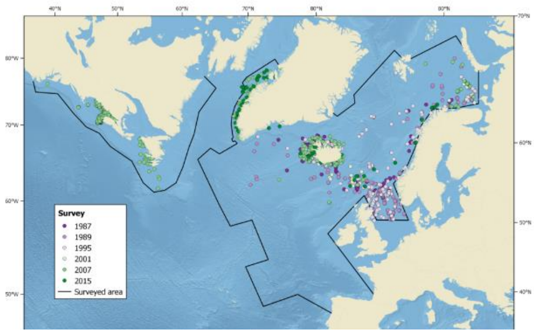


Figure 16.1. Sightings from all surveys, 1987 – 2015 (NAMMCO)

After a sharp decline, Atlantic cod returned to West Greenland in 2005, likely due to an increase in sea temperature on the banks. Reduced sea ice conditions allow for extended residence times at the Greenland banks, where the porpoises can prey intensively on the abundant cod resources (Heide-Jørgensen et al., 2011). However, there might be increased competition with other dolphin species also moving northward due to climate change (Kovacs and Lydersen, 2008).

16.1. Hunting

The average yearly catch in 2015–17 was 2.275, according to hunter's reports (http://nammco.no). There are no quotas or catch limits.

16.2. Status and Population Trends

West Greenland:

Areas	Abundance	Status, change (≥2 generations)	Trend (Short term~1 generation)	Category of change	Description: physiological,behavioral change	Climate variable & direction	Hunting
West Greenland:	83,321 (95% CI 4377–160,047) (Hansen et al., 2018)	Unknown (Hansen et al., 2018)	Unknown (Hansen et al., 2018)				

East Greenland

Areas	Abundance	Status, change (≥2 generations)	Trend (Short term~1 generation)	Category of change	Description: physiological,behavioral change	Climate variable & direction	Hunting
East Greenland	1642 (95% CI 318–8464) (Hansen et al., 2018)	Unknown (Hansen et al., 2018)	Unknown (Hansen et al., 2018)				

16.3. Synopsis

Harbour porpoise may benefit from climate change. There is strong evidence of an increase of Habour porpoise in West Greenland. In East Greenland, trends are unknown. There is weak evidence of a decline, due to concurrence with other boreal species.

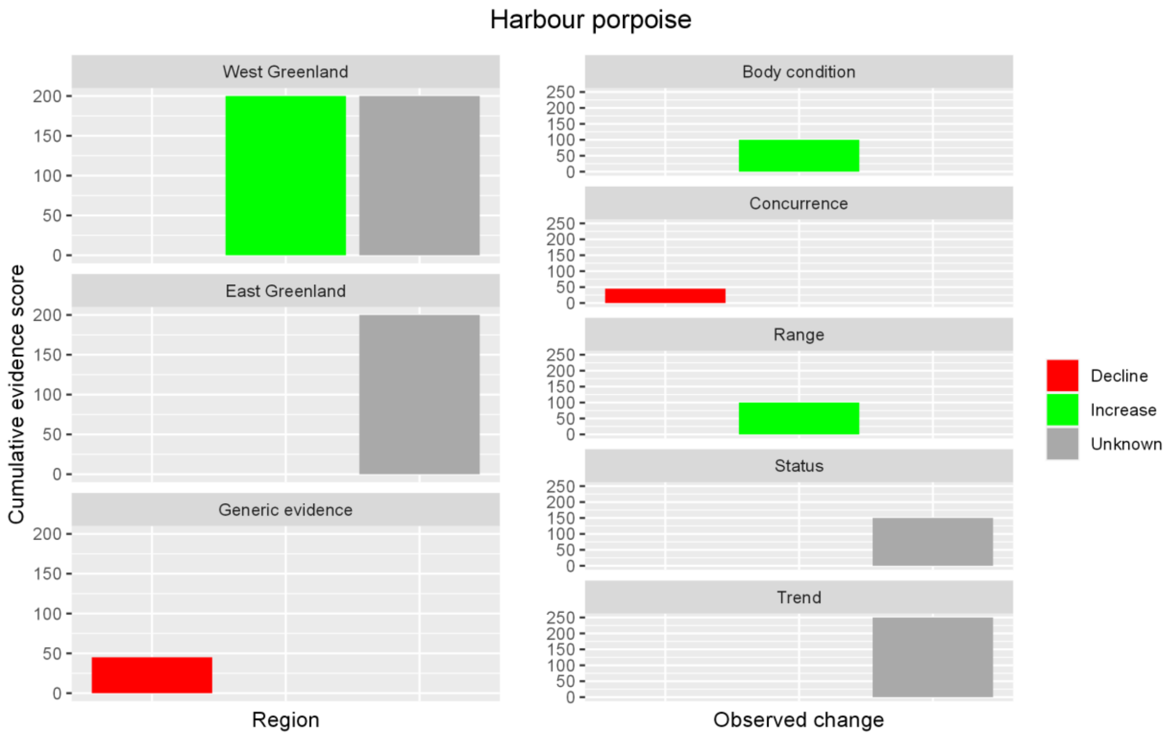


Figure 16.2. Cumulative evidence per region and aspects in which change is observed or expected.

16.4. Catch and Forecast

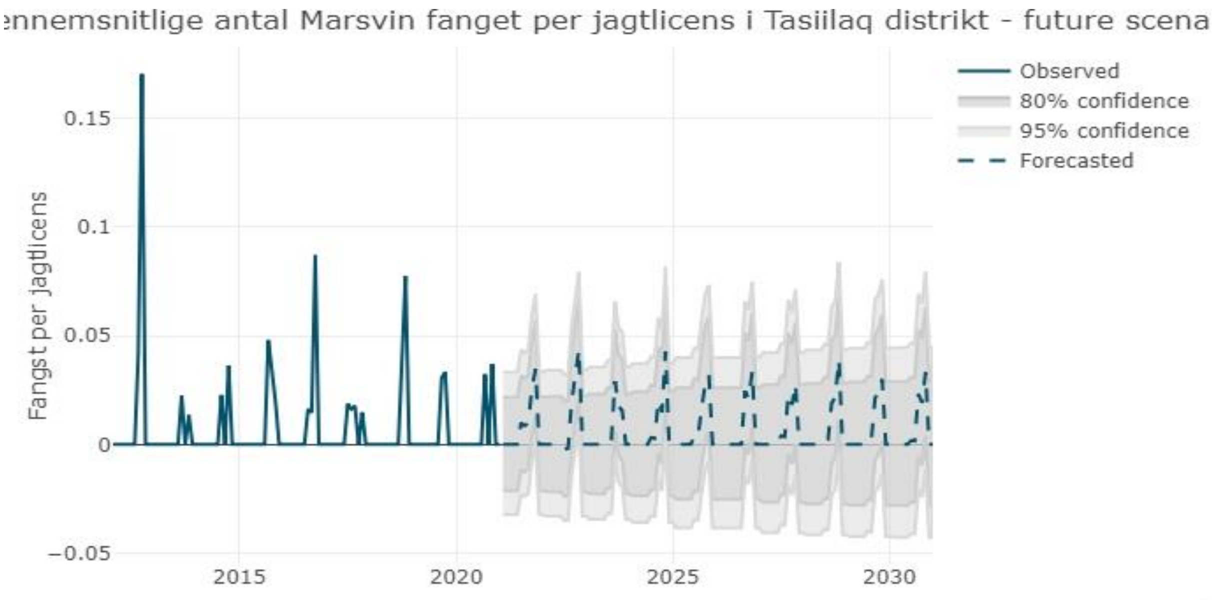


Figure 16.3. Average catch per hunter and forecast for Harbour porpoise in Tasiilaq district.

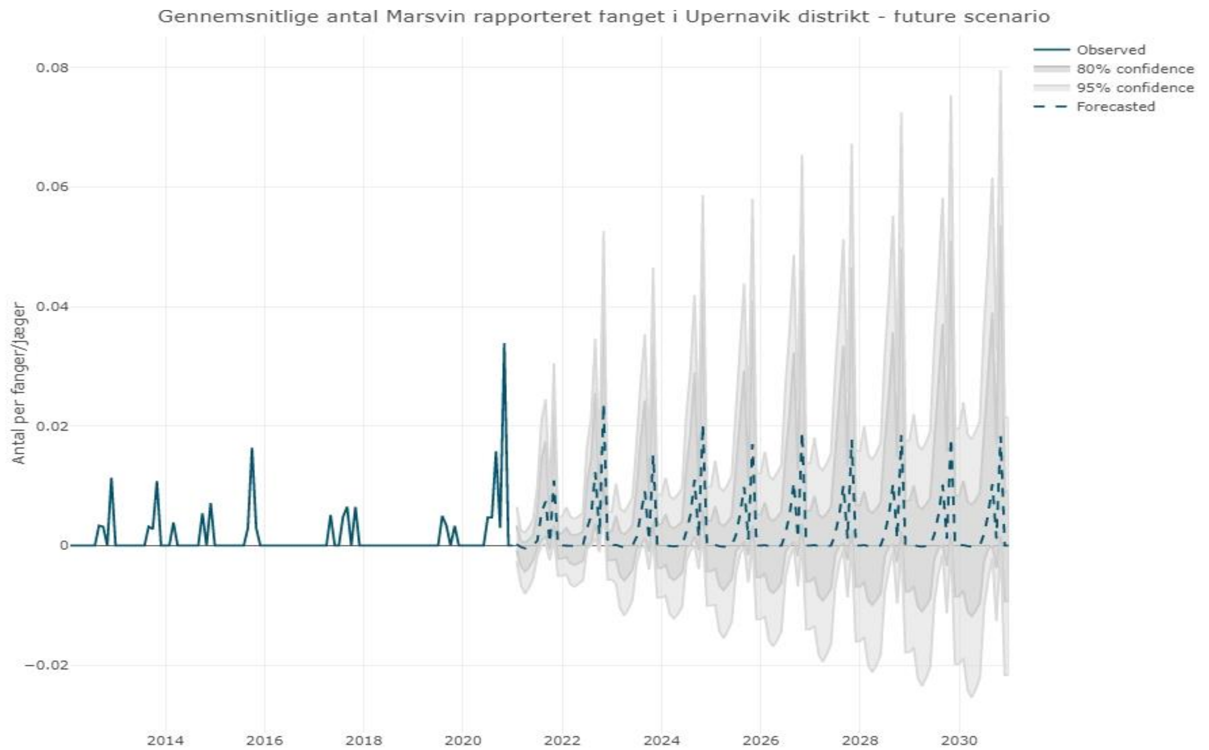


Figure 16.4. Average catch per hunter and forecast for Harbour porpoise in Upernavik district.

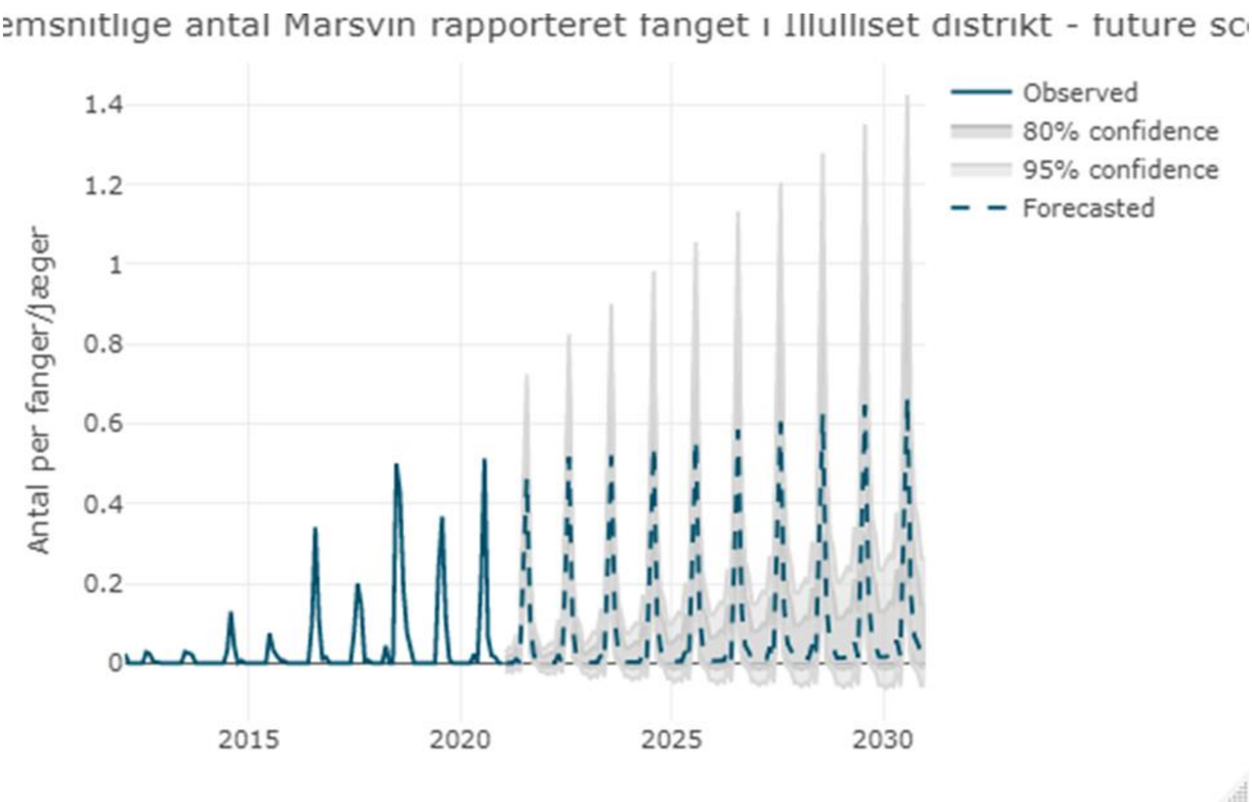


Figure 16.5. Average catch per hunter and forecast for Harbour porpoise in Ilulissat district.

The forecasts are not reliable, and particularly the data from Tasiilaq and Upernavik appears insufficient to produce a forecast. Nevertheless, the material was used as a basis for discussion.

Table 16.3. Average annual catch of Marsvin per hunter in the period 2012-2020, in 2020 and 2030 (forecasted) and the percentage change in 2030 relative to 2012-2020 and 2020.

District	2012-2020	2020	2030	Δ 2012-2020	Δ 2020
Ittoqoortoormiit					
Tasiilaq	0,10	0,07	0,08	-19	12%
Upernavik	0,02	0,06	0,04	96%	-40%
Ilulissat	0,48	0,82	1,47	207%	79%

16.5. Workshops with Hunter and Fishers Organizations

Scenario	Ittoqortoormiit	Tasiilaq	Upernavik	Ilulissat
Trend scenario	Not caught	More animals are seen. Expects an increased catch of 10% towards 2030 (contrary to the model)	Has become common in the area. Thinks that catch will increase.	Increasing catch and agrees that it will continue to increase
Alternative scenario	NA	NA	NA	NA

not discussed-

16.6. Interviews with Scientific Experts

-will follow-

16.7. Preliminary Future Scenarios

Scenario	Ittoqortoormiit	Tasiilaq	Upernavik	Ilulissat
Stock and catch trend scenario		+10% compared to average over the period 2012-20	+20% compared to 2012-20 average	+40% compared to 2012-20 average
Underreporting adjustment scenario				
Alternative actions scenario				

17. Killer whales (*Orcinus orca*)

Killer whales	
Orcinus orca	
Spækhugger	
Aarluk	

Killer whales respond to reduced Arctic ice cover by moving further north and have been seen more frequently since the 1920s in Southern Greenland, but even in the Canadian subarctic waters (Heide-Jørgensen et al., 2022; Laidre et al., 2006). Killer whales are assumed to have access to a spatiotemporally greater open-water season, extend their distribution farther north, and remain in Arctic waters longer due to climate change (Lefort et al., 2020).

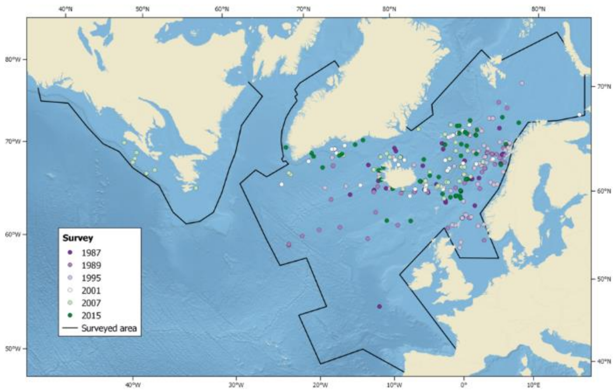


Figure 17.1. Sightings from all surveys, 1987 – 2015 (NAMMCO.

17.1. Interactions

Killer whales, as apex predators, are increasing predation pressure on resident species. In the Canadian Arctic, it was estimated that they could consume 1.290 ±214 narwhals during their residency in Arctic waters (Lefort et al., 2020). Bowhead whales (*Balaena mysticetus*) show predator avoidance and are moving from the open sea into heavy sea ice and shallow water in the presence of killer whales, coupled with greatly reduced activity and likely at the expense of foraging (Matthews et al., 2020). This behaviour has long been recognized by the Inuit, who call it "aarlirijuk" ("fear of killer whales") (Matthews et al., 2020). Moreover, pressure on fish stocks such as mackerel or bluefin tuna might increase as a result of killer whale presence (Heide-Jørgensen et al., 2022). Using data from a concurrently tracked predator (killer whales) and prey (narwhal) revealed that the presence of killer whales significantly changes the behaviour and distribution of narwhal (Breed et al., 2017).

17.2. Climate Change

Likely due to climate change-related sea-ice declines, range expansions and increase in sightings th of killer whale sightings have been documented in the eastern Canadian Arctic (Lefort et al., 2020). Sea ice restricting killer whales Arctic distribution by inhibiting their movement (Higdon and Ferguson, 2009). Around 50 years ago, the Hudson Strait experienced an opening, which facilitated the initial sudden appearance of killer whales, followed by a gradual expansion of their distribution throughout the entire Hudson Bay region (Higdon and Ferguson, 2009). Over time, there has been an exponential increase in the number of killer whale sightings, and they are now regularly reported in the Hudson Bay region during the summer season (Higdon and Ferguson, 2009). Ten out of 19 populations have either a moderate or high risk of extinction in the future due to PCB pollution (Desforges et al., 2018).

17.3. Hunting

Average annual reported catches in Greenland were 12 killer whales in 2015–17 (http:// nammco.no). Generally, catches are increasing. In South East Greenland, Tasiilaq, catches of killer whales rose from three recorded catches during 1942– 1984 to at least 77 killer whales between 2003– 2018 (Heide-Jørgensen et al., 2022).

17.4. Status and Population Trends

All populations:

Areas	Abundance	Status, change (≥2 generations)	Trend (Short term~1 generation)	Category of change	Description: physiological,behavioral change	Climate variable & direction	Hunting
All regions	Unknown (Ugarte et al., 2020b)	Unknown (Ugarte et al., 2020b)	Unknown (Ugarte et al., 2020b)				

17.5. Synopsis

Killer whales may benefit from climate change but are vulnerable to pollution. We found strong evidence for an increase in killer whale abundance in Greenland, although trend and status are unknown. This is mainly related to an expanding range of this species.

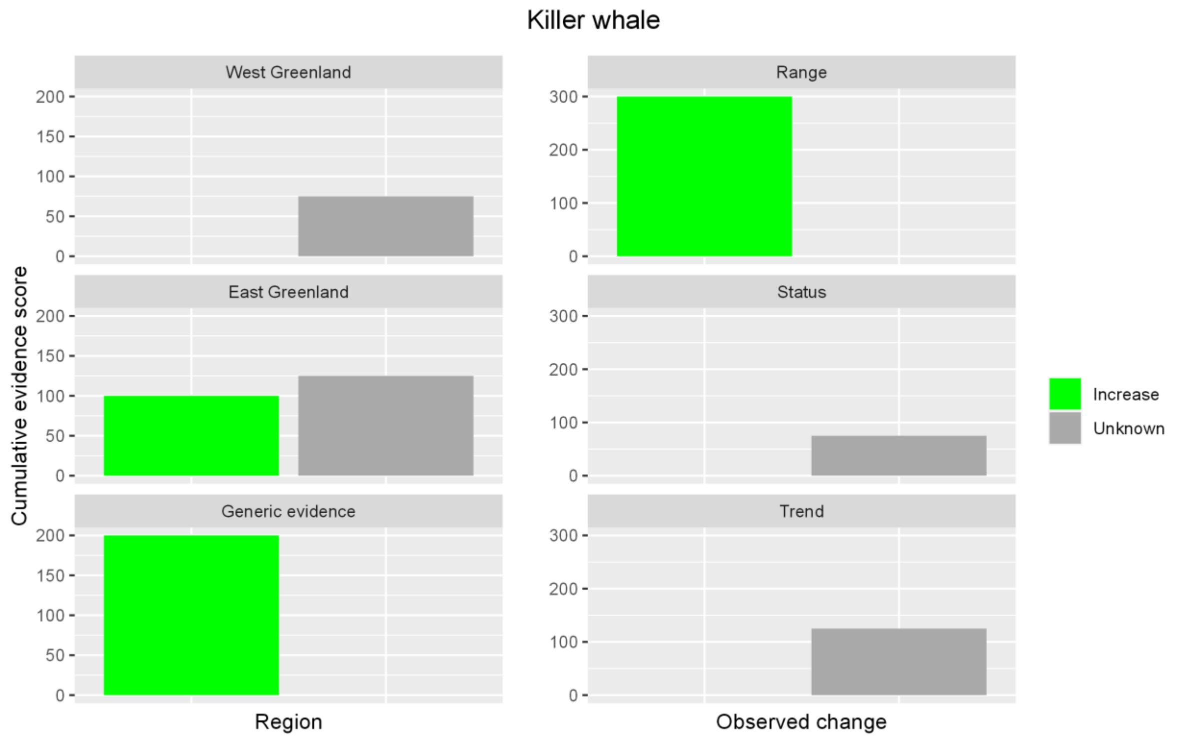


Figure 17.2. Cumulative evidence per region and aspects in which change is observed or expected.

17.6. Catch and Forecast

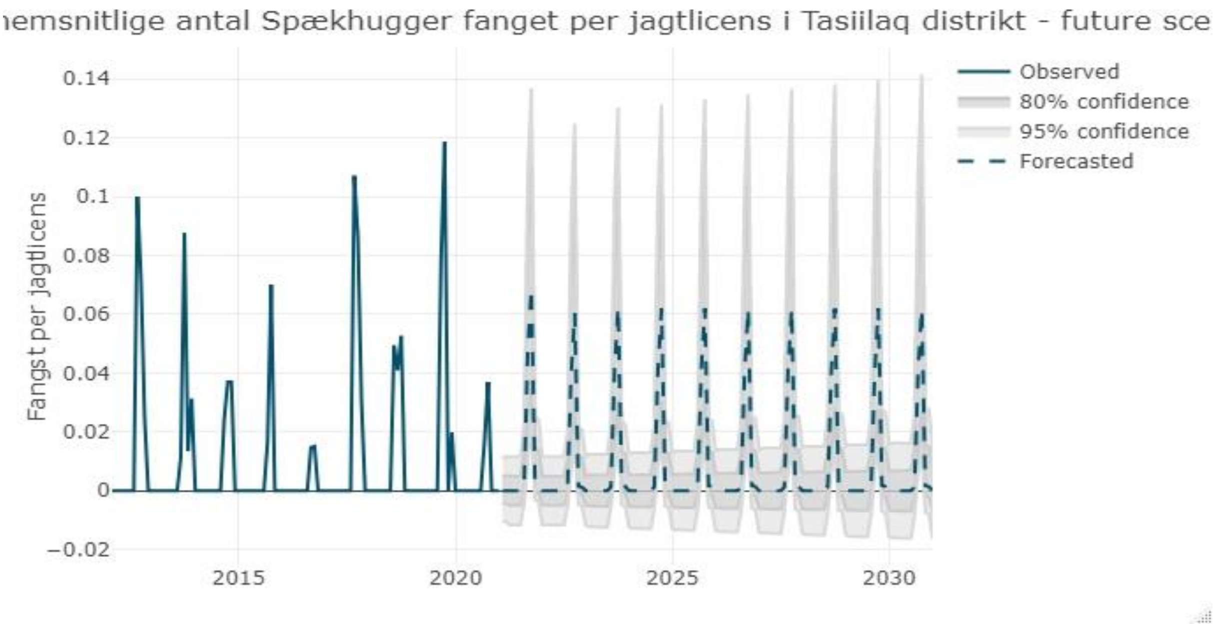


Figure 17.3. Average catch per hunter and forecast for adult Killer whales in Tasiilaq district.

Catch is very infrequent in Upernavik and Ilulissat. The forecasts are not reliable, and the data from Tasiilaq appears insufficient to produce a forecast. Nevertheless, the material was used as a basis for discussion.

Table 17.1. Average annual catch of Killer whale per hunter in the period 2012-2020, in 2020 and 2030 (forecasted) and the percentage change in 2030 relative to 2012-2020 and 2020.

District	2012-2020	2020	2030	Δ 2012-2020	Δ 2020
Ittoqoortoormiit					
Tasiilaq	0,13	0,05	0,11	-19%	100%
Upernavik					
Ilulissat					

17.7. Workshops with Hunter and Fishers Organizations

Scenario	Ittoqortoormiit	Tasiilaq	Upernavik	Ilulissat
Trend scenario	Seen more frequently and expects that the catch will increase. Has caught 6-7 since 2021	Increasingly regular catch (small numbers). Wants regulation hunt.	Stable numbers seen. No catch	Rarely seen
Alternative scenario	NA	NA	NA	NA

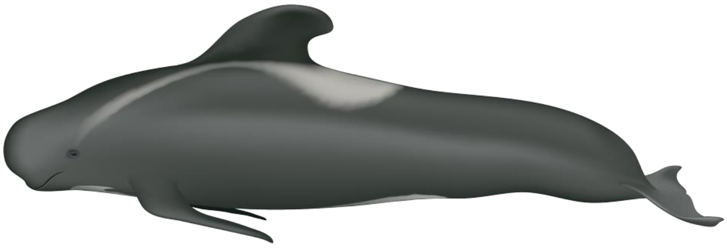
17.8. Interviews with Scientific Experts

-will follow-

17.9. Preliminary Future Scenarios

Scenario	Ittoqortoormiit	Tasiilaq	Upernavik	Ilulissat
Stock and catch trend scenario	Add ½ to all occupational hunters	+5% compared to 2012-20 average		
Underreporting adjustment scenario				
Alternative actions scenario				

18. Long-finned pilot whale (*Globicephala melas*)

Long-finned pilot whale	
Globicephala melas	
Grindehval	
Niisarnaq	

Before 2000, there was little evidence of the presence of pilot whales in Tasiilaq and South East Greenland (Heide-Jørgensen et al., 2022). Today, they show regularly, and catches are increasing (Heide-Jørgensen et al., 2022; Ugarte et al., 2020). They will likely expand their ranges northwards with regular occurrence in more places (Heide-Jørgensen et al., 2022).

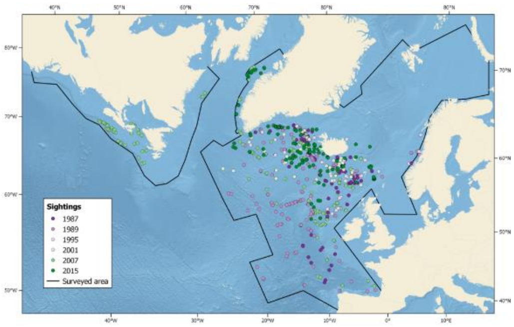


Figure 18.1. Sightings from all surveys, 1987 – 2015 (NAMMCO)

18.1. Climate Change

No literature was found. Like many beaked whales, this species is likely to be vulnerable to loud anthropogenic sounds, such as those generated by navy sonar and seismic exploration and behavioural responses are expected to result in a change in dive pattern (Sivle et al., 2012).

18.2. Hunting

Average reported yearly catches in Greenland in 2015–17 were 289 pilot whales (http://nammco.no). In general, catches are increasing. In South East Greenland, the first catches of pilot whales were taken in 2001, but the catch level remained low (<50 per year). From 2017 on, catches increased rapidly and reached a maximum of 178 in 2019 (Heide-Jørgensen et al., 2022). The high catch levels reached after 2010 are unprecedented for this area (Heide-Jørgensen et al., 2022).

18.3. Status and Population Trends

West Greenland

Areas	**Abundance**	**Status, change (≥2 generations)**	**Trend (Short term~1 generation)**	**Category of change**	**Description: physiological,behavioral change**	**Climate variable & direction**	**Hunting**

West Greenland	2015: 9190 (95% CI 3635–23,234) (Hansen et al., 2018)	Unknown (Hansen et al., 2018)	Unknown (Hansen et al., 2018)				

East Greenland

Areas	**Abundance**	**Status, change (≥2 generations)**	**Trend (Short term~1 generation)**	**Category of change**	**Description: physiological,behavioral change**	**Climate variable & direction**	**Hunting**
East Greenland	2015: 258 (95% CI 50–1354) (Hansen et al., 2018)	Unknown (Hansen et al., 2018)	Unknown (Hansen et al., 2018)				

18.4. Synopsis

There is overwhelming evidence in the literature that little is known about the Long-finned pilot whale in Greenland.

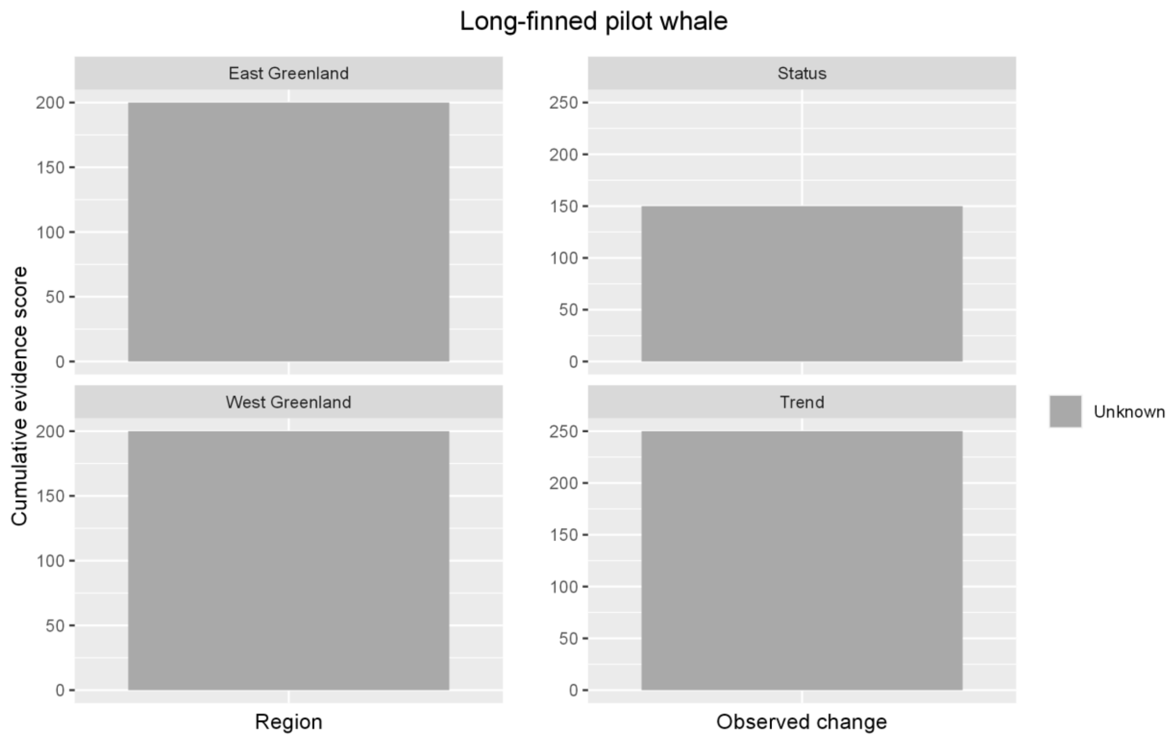


Figure 18.2 Cumulative evidence per region and aspects in which change is observed or expected.

18.5. Catch and Forecast

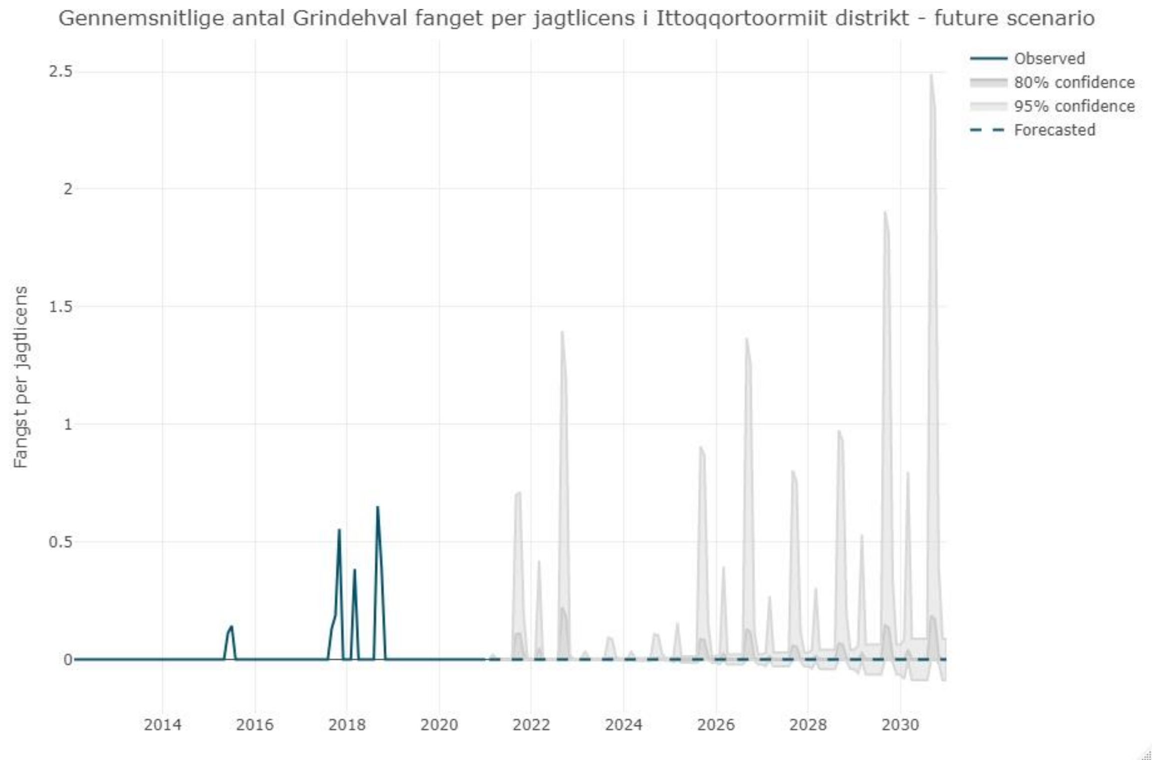


Figure 18.3. Average catch per hunter and forecast for Long-finned pilot whale in Ittoqortoormiit district.

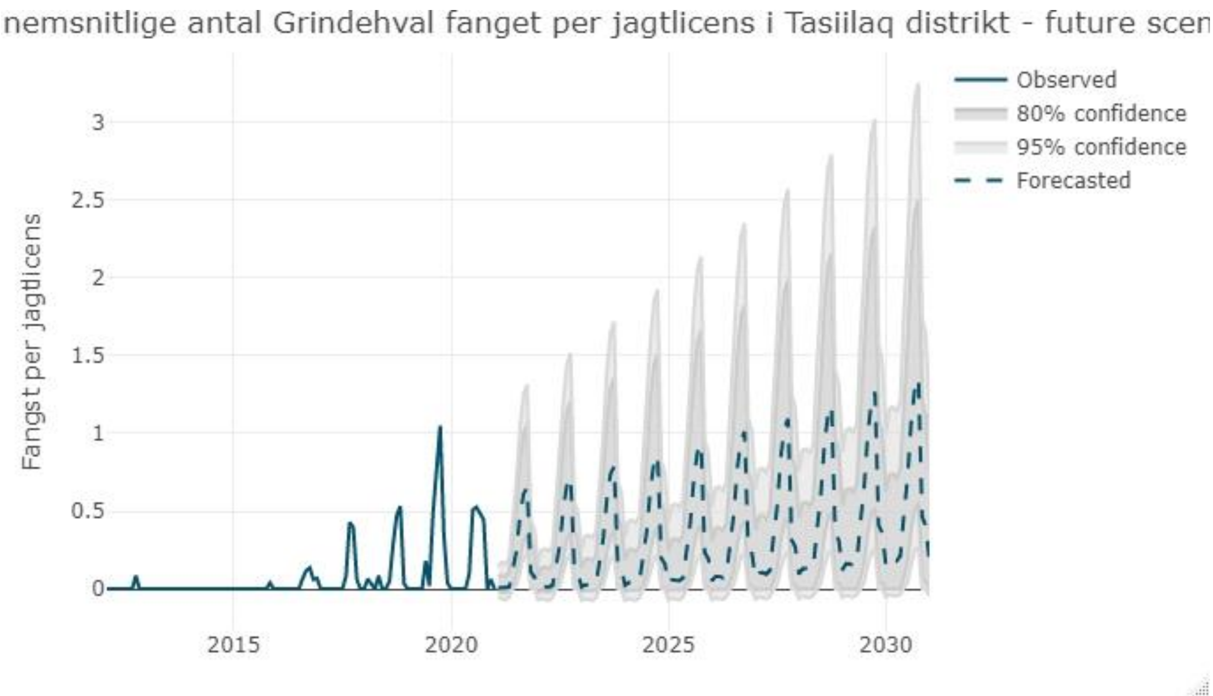


Figure 18.4. Average catch per hunter and forecast for Long-finned pilot whale in Tasiilaq district.

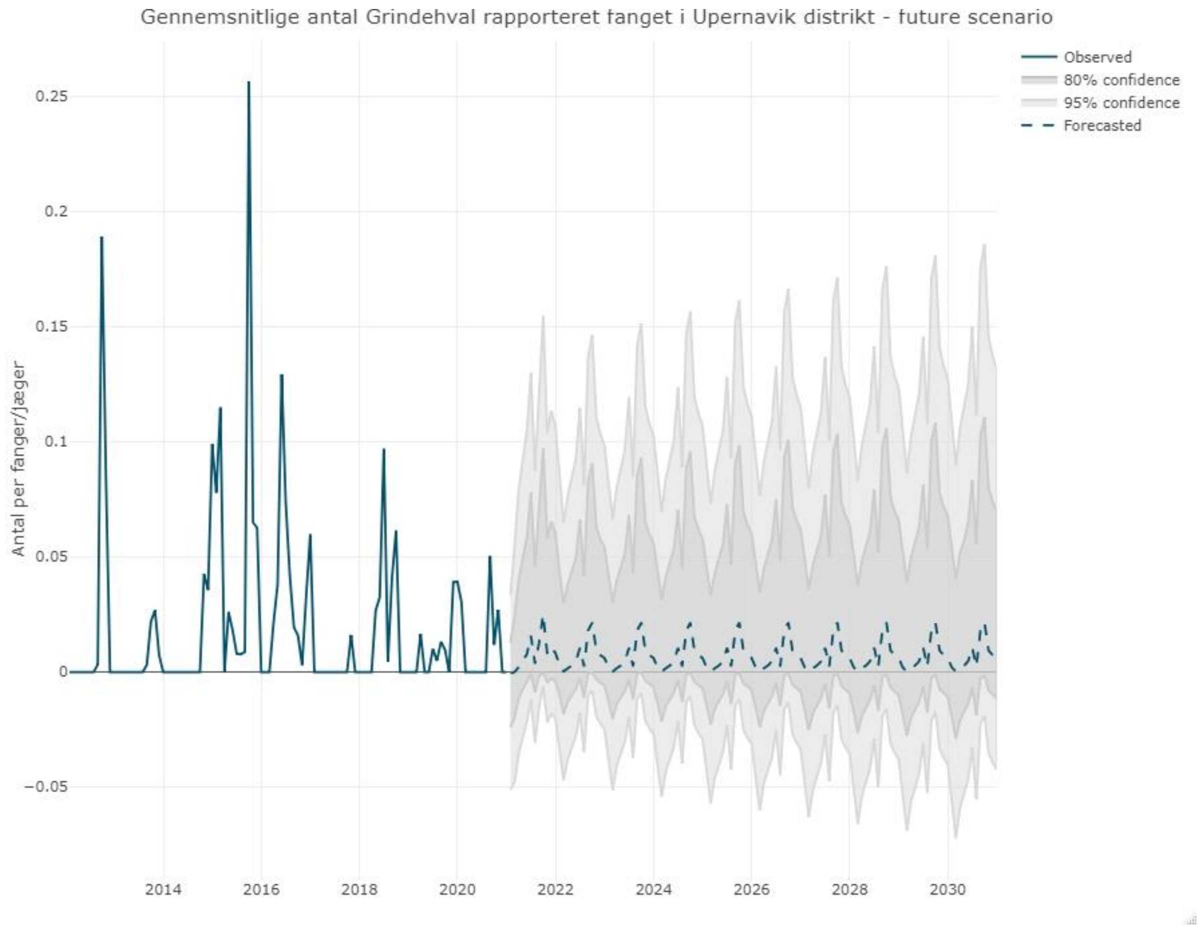


Figure 18.5. Average catch per hunter and forecast for Long-finned pilot whale in Upernavik district..

Data were insufficient to develop forecasts for Ilulissat. The forecasts are not reliable, and particularly the data from Ittoqoortormiit appears insufficient to produce a forecast. Nevertheless, the material was used as a basis for discussion.

Table 18.1. Average annual catch of Long-finned pilot whale per hunter in the period 2012-2020, in 2020 and 2030 (forecasted) and the percentage change in 2030 relative to 2012-2020 and 2020.

District	2012-2020	2020	2030	Δ 2012-2020	Δ 2020
Ittoqoortoormiit	0,28	0,00	0,00	-100%	NA
Tasiilaq	0,91	2,13	6,77	644%	218%
Upernavik	0,24	0,12	0,09	-63%	-27%
Ilulissat	0,15	0,03	0,05	-66%	52%

18.6. Workshops with Hunter and Fishers Organizations

Scenario	Ittoqortoormiit	Tasiilaq	Upernavik	Ilulissat
Trend scenario	Not seen (claim error in data)	Expects a continued increase in the catch	Has had low catch some years with low probability and sporadic observations. But is seeing	Rare and sporadic catch but is seen more frequently

Alternative scenario	NA	NA	NA	NA

18.7. Interviews with Scientific Experts

-will follow-

18.8. Preliminary Future Scenarios

Scenario	Ittoqortoormiit	Tasiilaq	Upernavik	Ilulissat
Stock and catch trend scenario		+30% compared to the 2012-20 average	+5% compared to the 2020 catch	+10% compared to the 2012-20 average
Underreporting adjustment scenario				
Alternative actions scenario				

19. White-beaked dolphin (*Lagenorhynchus albirostris*)

White-beaked dolphin	
Lagenorhynchus albirostris	
Hvidnæse	
Aarluarsuk	

The species has a wide range across the North Atlantic Ocean, with higher densities of dolphins around southwestern Greenland (NAMMCO, 2016). Trends are unknown, but increasing catches are reported in South Greenland (Heide-Jørgensen et al., 2022).

Likely some misidentification and reporting by hunters occur with Atlantic white-sided dolphin (*Lagenorhynchus acutus*).

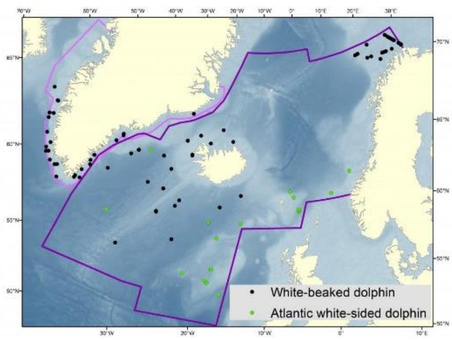


Figure 19.1. Sightings of white-sided and white-beaked dolphins during 2015. (NAMMCO)

19.1. Climate Change

The distribution pattern of white-beaked dolphins is closely tied to water temperature, as they tend to favour cooler waters. Their occurrence significantly decreases when the water temperature exceeds 12-14°C (Tetley and Dolman, 2013). Water temperature has also been identified as a contributing factor to the movement of white-beaked dolphins around the UK, with a northward shift in distribution (Canning et al., 2008) and a decline observed on the west coast of Scotland due to rising water temperatures (MacLeod et al., 2005). The potential consequences of global climate change-induced increases in water temperatures are significant for white-beaked dolphins' distribution and habitat availability, particularly in northwestern Europe. The area of suitable shelf waters for these dolphins may dramatically reduce (MacLeod et al., 2005). This could result in the displacement of white-beaked dolphins by other species, such as the common dolphin, which are more inclined towards warmer waters (MacLeod et al., 2008). Model predictions show that temperature increase severely threatens White-beaked dolphins in UK waters, leading to an 80% reduction in relative occurrence (Lambert et al., 2014). Changing water temperatures could also lead to the redistribution of the dolphin's prey species and the introduction of new diseases or parasites. For instance, sea lampreys have recently been observed on white-beaked dolphins in Icelandic waters for the first time (Bertulli et al., 2012).

19.2. Status and Population Trends

West Greenland

Areas	Abundance	Status, change (≥2 generations)	Trend (Short term~1 generation)	Category of change	Description: physiological,behavioral change	Climate variable & direction	Hunting
West Greenland	2015: 15,261 (95% CI 7084–33,046) (Hansen et al., 2018)	Unknown (Hansen et al., 2018)	Unknown (Hansen et al., 2018)				

East Greenland

Areas	Abundance	Status, change (≥2 generations)	Trend (Short term~1 generation)	Category of change	Description: physiological,behavioral change	Climate variable & direction	Hunting
East Greenland	2015: 11,889 (95% CI 4710–30,008) (Hansen et al., 2018)	Unknown (Hansen et al., 2018)	Unknown (Hansen et al., 2018)				

19.3. Synopsis

White-beaked dolphins may benefit from climate change in Greenland. We found moderate evidence for an increase of the White-beaked dolphin in East Greenland due to an increase in catch. However, population trends are unknown. In West Greenland trends are unknown. We found weak generic evidence of a decline due to habitat changes and novel parasites.

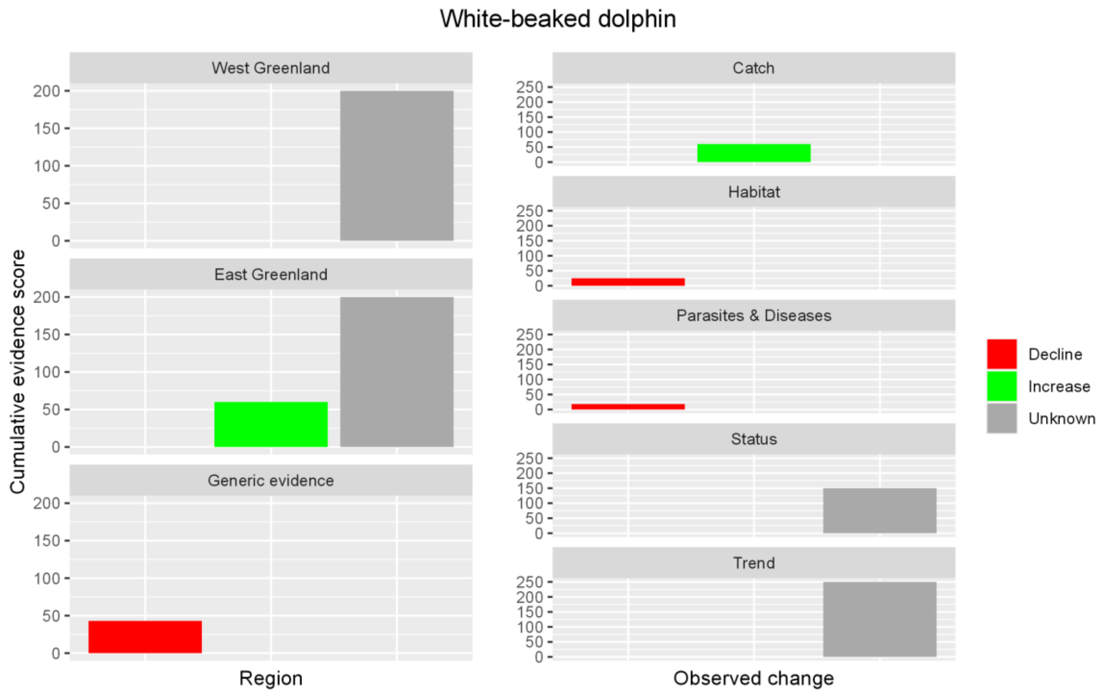


Figure 19.2. Cumulative evidence per region and aspects in which change is observed or expected.

19.4. Catch and Forecast

Scenario	Ittoqortoormiit	Tasiilaq	Upernavik	Ilulissat
Trend scenario	Observed irregularly but not caught			
Alternative scenario	NA			

19.5. Workshops with Hunter and Fishers Organizations

-not discussed-

19.6. Interviews with Scientific Experts

-will follow-

19.7. Preliminary Future Scenarios

Scenario	Ittoqortoormiit	Tasiilaq	Upernavik	Ilulissat
Stock and catch trend scenario				

Underreporting adjustment scenario				
Alternative actions scenario				

20. Atlantic white-sided dolphin (*Lagenorhynchus acutus*)

Atlantic white-sided dolphin	
Lagenorhynchus acutus	
Hvidskæving	
Aarluarsuk	

Atlantic white-sided dolphins are abundant throughout their range, although there are few surveys available to provide population estimates (NAMMCO, 2016) (Fig. 20.1.). Current trends are unknown (Ugarte et al., 2020).

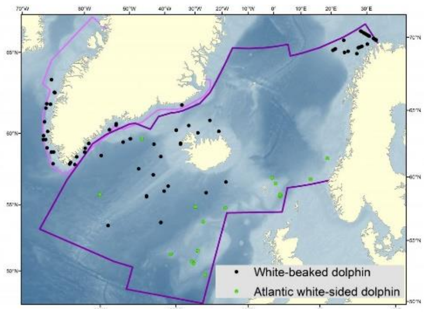


Figure20.1. Sightings of white-sided and white-beaked dolphins during 2015. (NAMMCO).

20.1. Climate Change

No literature found

20.2. Status and Population Trends

West Greenland

Areas	Abundance	Status, change (≥2 generations)	Trend (Short term~1 generation)	Category of change	Description: physiological,behavioral change	Climate variable & direction	Hunting
West Greenland	Unknown populations (Ugarte et al., 2020)	Unknown (Ugarte et al., 2020)	Unknown (Ugarte et al., 2020)				

East Greenland

Areas	Abundance	Status, change (≥2 generations)	Trend (Short term~1 generation)	Category of change	Description: physiological,behavioral change	Climate variable & direction	Hunting
East Greenland	Unknown populations (Ugarte et al., 2020)	Unknown (Ugarte et al., 2020)	Unknown (Ugarte et al., 2020)				

20.3. Synopsis

We found overwhelming evidence that there is a lack of data on trends of the Atlantic white-sided dolphin in Greenland.

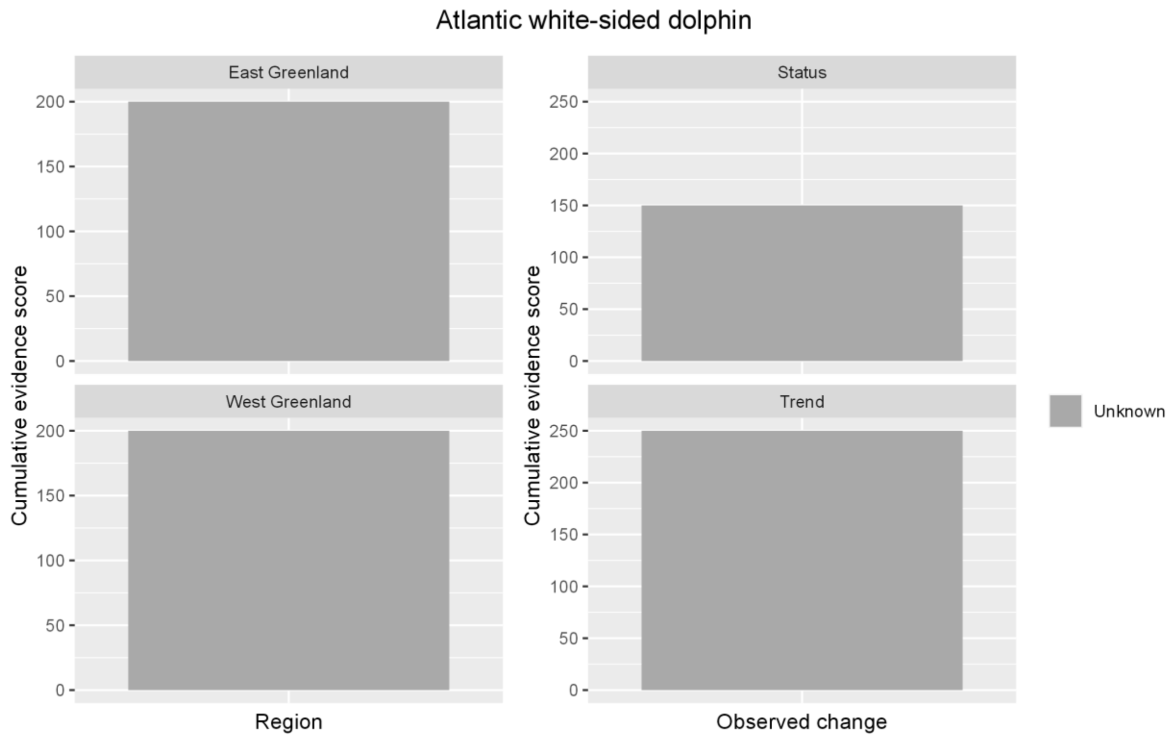


Figure 20.1 Cumulative evidence per region and aspects in which change is observed or expected.

20.4. Catch and Forecast

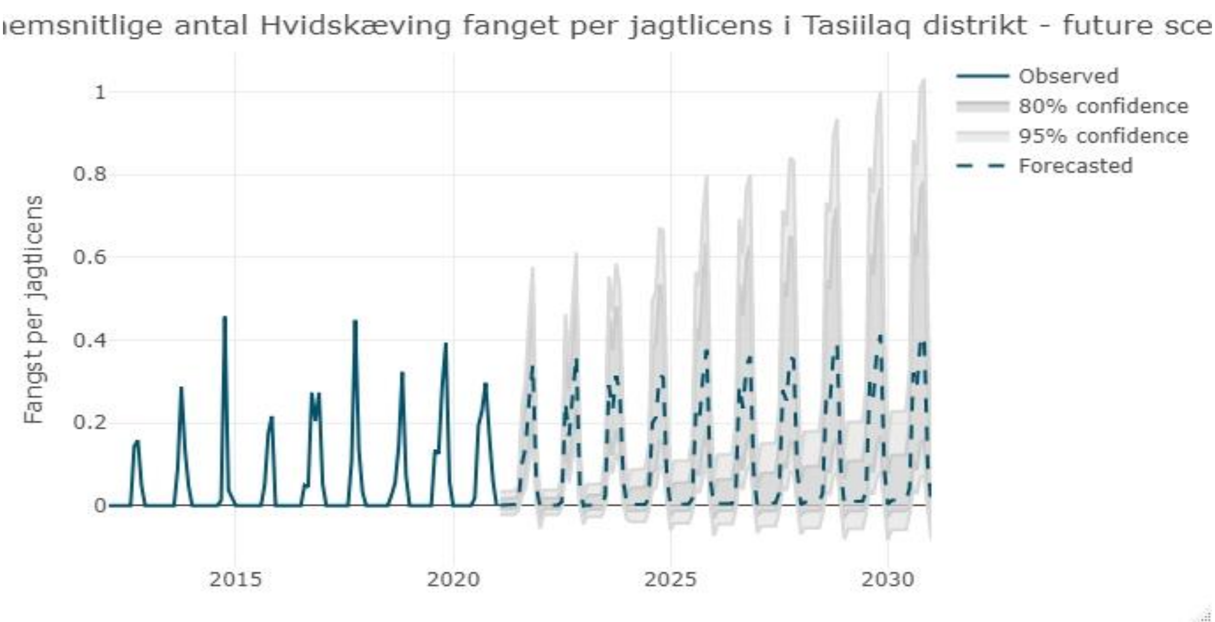


Figure 20.3. Average catch per hunter and forecast for Atlantic white-sided dolphin in Tasiilaq district.

The forecasts are not reliable. Nevertheless, the material was used as a basis for discussion.

Table 20.1. Average annual catch of Atlantic white-sided dolphin per hunter in the period 2012-2020, in 2020 and 2030 (forecasted) and the percentage change in 2030 relative to 2012-2020 and 2020.

District	2012-2020	2020	2030	Δ 2012-2020	Δ 2020
Ittoqoortoormiit					

Tasiilaq	0,68	0,97	1,62	140%	68%
Upernavik					
Ilulissat					

20.5. Workshops with Hunter and Fishers Organizations

Scenario	Ittoqortoormiit	Tasiilaq	Upernavik	Ilulissat
Trend scenario	No observations and no catch	More observations. And agree with the scenario		
Alternative scenario	NA	NA		

20.6. Interviews with Scientific Experts

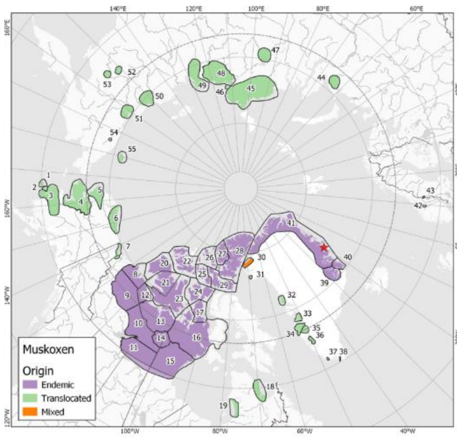
-will follow-

20.7. Preliminary Future Scenarios

Scenario	Ittoqortoormiit	Tasiilaq	Upernavik	Ilulissat
Stock and catch trend scenario		+20% compared with the 2012-20 average		
Underreporting adjustment scenario				
Alternative actions scenario				

21. Muskoxen (*Ovibos moschatus*)

Muskoxen	
Ovibos moschatus	
Moskusokse	
Umimmak	



Greenland has the largest Muskoxen population worldwide. Shifts in temperature and precipitation may influence muskox reproduction and survival and increase anthropogenic stressors, diseases, and changes in food availability (Cuyler et al., 2020).

21.1. Climate Change

The trends for most of the populations in Greenland are unknown, but an increasing trend was observed in Nanortalik, a stable trend in Cape Atholl and a declining trend in Ivittuut (Cuyler et al., 2020). Muskoxen show a wide thermal variability within their endemic habitat (mean summer maximums of 21–27°C to mean winter minimums of - 34°C), and seven muskox populations live in designated Sub Arctic Zone, and two in non-arctic zones (Cuyler et al., 2020). This suggests that the species is adaptable to climatic changes within their environment. However, climate, diseases, and anthropogenic changes are likely the principal drivers of muskox population change, all strongly intertwined and temporally and spatially variable (Cuyler et al., 2020).

A maximum entropy (MaxEnt) algorithm and Schoener's D niche overlap index were used to assess shifts and changes in overlap of species-specific distributions under recent (1979–2013) and future (2061–2080; representative concentration pathways [RCPs] 2.6, 4.5 and 8.5) bioclimatic conditions in the Northeast Greenland National Park (Beest et al., 2021). For muskoxen, the change in probability of occurrence over time was positive in some parts of their distribution range and negative in others, a pattern that also became more pronounced with the severity of the RCP scenarios considered (Beest et al., 2021). Moreover, a northward shift in range was observed (Beest et al., 2021). Spatiotemporal reconstructions of past climatic change and species-specific population ecology concluded that climatic change and human activities in Canada and Greenland probably combined to drive recent population sizes (Canteri et al., 2022). A parameterized full life cycle, individual-based energy budget model for wild muskoxen, using year-round environmental data with detailed ontogenic metabolic physiology, showed that winter food accessibility, summer food availability, and density dependence drive seasonal dynamics of energy storage and life history and population dynamics (Desforges et al., 2021). Winter forage accessibility defined by snow depth, more than summer forage availability impacted calf recruitment and maternal investment (Desforges et al., 2021).

21.2. Status and Population Trends

West Greenland

Areas	Abundance	Status, change (≥2 generations)	Trend (Short term~1 generation)	Category of change	Description: physiological,behavioral change	Climate variable & direction	Hunting
Inglefield Land	2000: 273		Unknown (Cuyler et al., 2020)		Mix translocated and endemic		
Cape Atholl	2017: 212 (Cuyler et al., 2020)		Stable		Translocated		
Sigguk (Svartenhuk)	2002: 193 (Cuyler et al., 2020)		Unknown (Cuyler et al., 2020)		Translocated		
Naternaq	2004: 112 (Cuyler et al., 2020)		Unknown (Cuyler et al., 2020)		Translocated		
Sisimiut	2018: 2622 (Cuyler et al., 2020)		Unknown (Cuyler et al., 2020)		Translocated		
Kangerlussuaq	2018: 20334 (Cuyler et al., 2020)		Unknown (Cuyler et al., 2020)		Translocated		
Nuuk	2016: 14 (Cuyler et al., 2020)		Unknown (Cuyler et al., 2020)		Translocated		
Ivittuut	2017: 812 (Cuyler et al., 2020)		Decreasing (Cuyler et al., 2020)				
Nanortali	2018: 32 (Cuyler et al., 2020)		Increasing (Cuyler et al., 2020)		Translocated		

East Greenland

Areas	Abundance	Status, change (≥2 generations)	Trend (Short term~1 generation)	Category of change	Description: physiological,behavioral change	Climate variable & direction	Hunting
Inner Kangertittivaq Fjord	2004: 562 (Cuyler et al., 2020)		Unknown (Cuyler et al., 2020)		Endemic		
Jameson Land	2000: 1761 (Cuyler et al., 2020)		Unknown (Cuyler et al., 2020)		Endemic		

North East Greenland	1992: 12500 (Cuyler et al., 2020)		Unknown (Cuyler et al., 2020)		Endemic		

21.3. Synopsis

For the Muskoxen Ivittuut population, we found strong evidence of a decline. For Cape Atholl population, evidence was strong for a stable population. For the Northeast Greenland National Park, evidence was strong for a declining and stable population. For the Nanortali population, we found strong evidence of an increase. Most trends of populations are unknown. There is moderate generic evidence for an increase of this species.

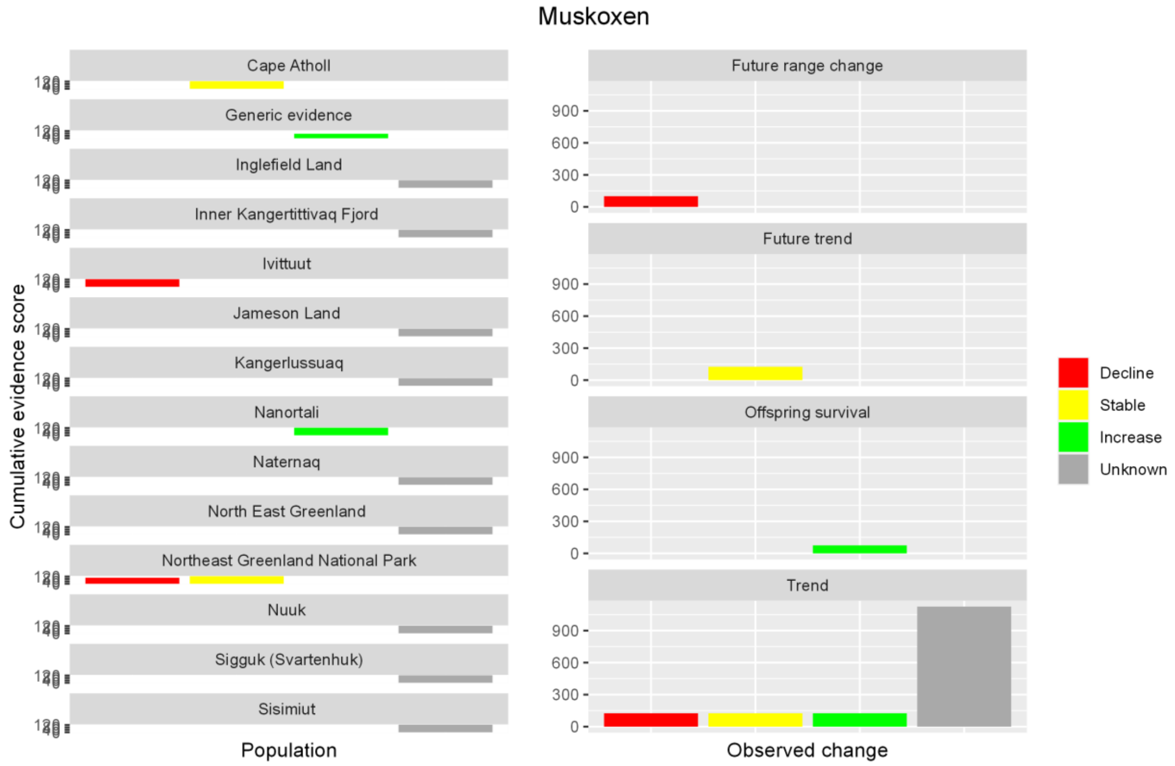


Figure 21.1 Cumulative evidence per population and aspects in which change is observed or expected.

21.4. Catch and Forecast

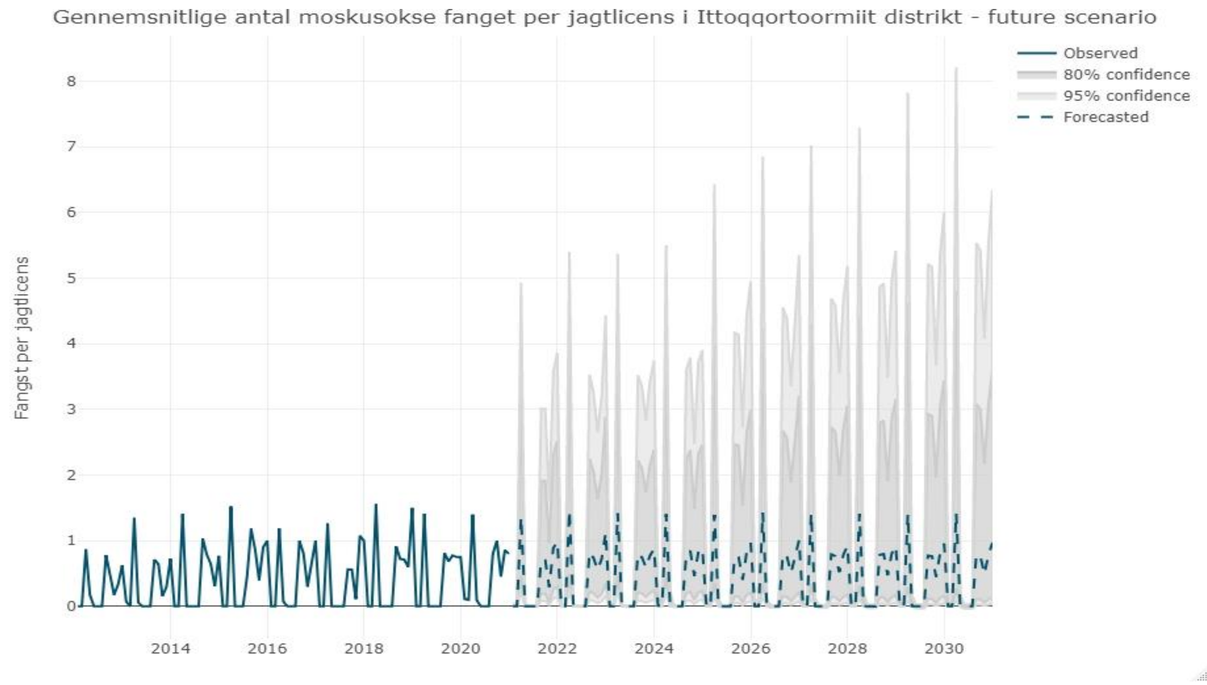


Figure 21.2. Average catch per hunter and forecast for Muskoxen in Itoqqortoormiit district.

Figure 21.3. Average catch per hunter and forecast for Muskoxen in Tasiilaq district.

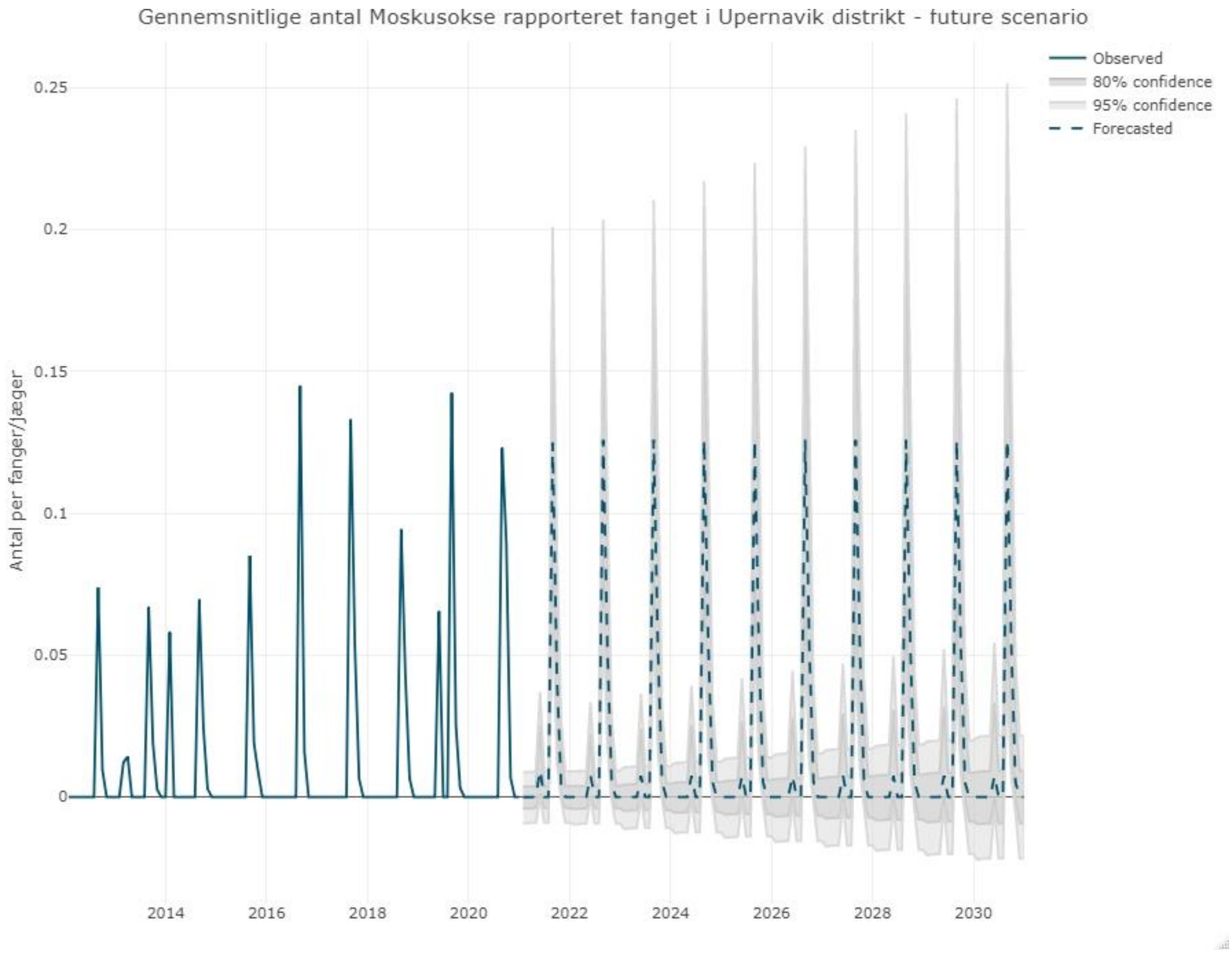


Figure 21.4. Average catch per hunter and forecast for Muskoxen in Upernavik district.

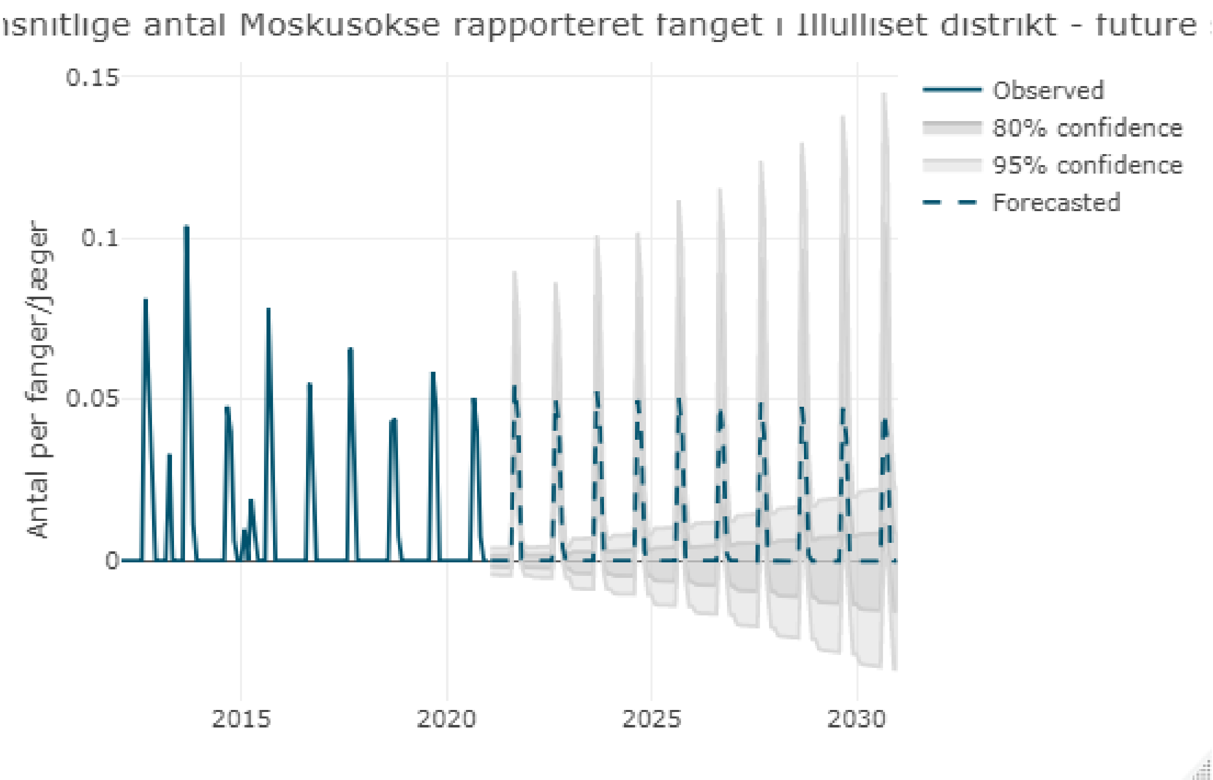


Figure 21.5. Average catch per hunter and forecast for Muskoxen in Ilulissat district.

The forecasts are not reliable, and particularly the data from Tasiilaq appears insufficient to produce a forecast. Nevertheless, the material was used as a basis for discussion.

Table 21.1. Average annual catch of Muskoxen per hunter in the period 2012-2020, in 2020 and 2030 (forecasted) and the percentage change in 2030 relative to 2012-2020 and 2020.

District	2012-2020	2020	2030	Δ 2012-2020	Δ 2020
Ittoqoortoormiit	5,01	5,61	5,22	4%	-7
Tasiilaq	0,01	0,00	0,01	-1%	NA
Upernavik	0,16	0,22	0,19	22%	-12%
Ilulissat	0,12	0,10	0,08	-29%	-14%

21.5. Workshops with Hunter and Fishers Organizations

Scenario	Ittoqortoormiit	Tasiilaq	Upernavik	Ilulissat
Trend scenario	Catch determined by quota.	Not locally available	Catch determined by quotes (75). Becoming more abundant and larger flocks	Catch determined by quota. Is becoming easier to access.
Alternative scenario	Restricted to occupational hunters only. Commercial production of venison and hair			Adjust quota in accordance with meat requirements/population size

21.6. Interviews with Scientific Experts

-will follow-

21.7. Preliminary Future Scenarios

Scenario	Ittoqortoormiit	Tasiilaq	Upernavik	Ilulissat
Stock and catch trend scenario				
Underreporting adjustment scenario				
Alternative actions scenario	Adjust the value (not yet clear – 8-9.000 per animal and 6 times as much for hair)			

22. Reindeer / Caribou (*Rangifer tarandus groenlandicus*)

Reindeer / Caribou	
Rangifer tarandus groenlandicus	
Rensdyr	
Tuttu	

Worldwide, at least 34 out of 43 large herds of reindeer and caribou, monitored in the last decade are declining (Gunn et al., 2009; Vors and Boyce, 2009). In West Greenland, populations seem to increase, while most populations in East Greenland experienced strong declines.

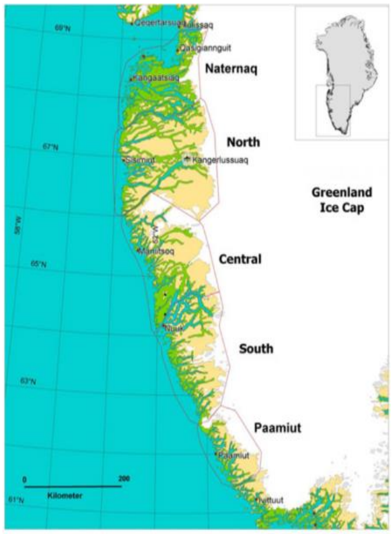


Figure 1. Caribou regions of west Greenland.

22.1. Climate Change

The reasons might be that caribous are not adjusting their migration timing to an earlier spring green-up leading to lower calf production and high calf mortality because females and their offspring miss a high-quality forage (Post and Forchhammer, 2008). Moreover, increased insect harassment due to increases in temperature and precipitation prevents rangifer populations from taking full advantage of summer forage (Vors and Boyce, 2009). Migratory caribou and reindeer may also face increased predation pressure and interspecific competition as shrubs and forests displace the tundra, and the ranges of southern ungulate species are expanding northward (Vors and Boyce, 2009). Moreover, extreme weather events that increase with climate warming have been linked to dramatic declines in some populations (Vors and Boyce, 2009).

Assuming a severe climatic warming scenario, caribou distribution will likely become restricted to high latitudes and possible extirpations in the southernmost regions (Yannic et al., 2014). The Euro-Beringia region is predicted to be less dramatically affected by climate change (60% of the suitable area lost) than North America, probably supporting in the future large populations with higher genetic diversity and, therefore, higher evolutionary potential to adapt to a changing environment (Yannic et al., 2014). For the Svalbard reindeer, 'Rain-on-snow' events led to a short-term decrease in population growth rate in 1999–2010), or respectively in 1991–2010 (Hansen et al., 2011; Hanssen et al., 2013), a decrease in recruitment rate (between 1995–201) (Stien et al., 2012), range displacement (between 1994–1998) (Stien et al., 2010). An increase in winter precipitation increased in Svalbard the overall mortality in reindeer (between 1978–1998 and 1979–1999) (Aanes et al., 2003, 2000; Solberg et al., 2001) and has led to a decrease in recruitment rate (between 1979–1999) (Solberg et al., 2001). An increase in Arctic Oscillation (i.e. milder winter) led to a decrease in the population growth rate between

1978–1999 (Aanes et al., 2002). Increased summer temperature has led to an increase in the population growth rate between 1991–2010 (Hanssen et al., 2013). Ablation in winter increased in population growth rate (between 1979–2007) (Tyler et al., 2008).

A stochastic population model for the Svalbard reindeer population showed that frequent rain-on-snow events reduce extinction risk and stabilize population dynamics due to interactions with age structure and density dependence (Hansen et al., 2019). Frequent rain-on-snow events might suppress vital rates of vulnerable ages at high population densities, resulting in a crash and a new population state with resilient ages and reduced population sensitivity to subsequent icy winters (B. B. Hansen et al., 2019). Increased large-scale climatic variability [measured by the North Atlantic Oscillation (NAO) winter index] in central Norway had a negative effect on calves' body weight and growth rate (Weladji and Holand, 2003).

A review suggests that the response of Rangifer populations to climate change is, and will continue to be, varied in large part to their broad circumpolar distribution (Mallory and Boyce, 2018). While caribou and reindeer could have some resilience to climate change, current global trends in abundance undermine all but the most precautionary outlooks (Mallory and Boyce, 2018).

22.2. Status and Population Trends

West Greenland

Areas	Abundance	Status, change	Trend (Short term~1 generation)	Category of change	Description: physiological,behavioral change	Climate variable & direction	Hunting
West Greenland	1996: 22 000 (Cuyler, 2007)		Steady population growth (1993-1996) (Cuyler, 2007)				After 2003 free/unlimited harvest over an extended hunting season, mainly monopolized by commercial hunters (Witting and Cuyler, 2011).
North: Population: Kangerlussuaq-Sisimiut	2005: 90 464 (70 276 – 113 614) 90% CI's (Cuyler et al., 2005, 2002)						
Central: Population: Akia-Maniitsoq	2005: 35 807 (27 474 – 44 720) 90% CI's (Cuyler et al., 2005, 2002).						
South: Population Ameralik	2006: 9680 (90% CI: 6515 - 13 147) (Witting and Cuyler, 2011).		70% decrease (2001-2006) (Witting and Cuyler, 2011).				Average harvest of 2950 individuals/ from 2000-2006 (Witting and Cuyler, 2011).
South: Qeqertarsuatsiaat)	2006: 5224 (Witting and Cuyler, 2011)		No change (Witting and Cuyler, 2011)				Average harvest of 230 /year from 2000-2006 (in line with replacement yield) (Witting and Cuyler, 2011).
South West Greenland (Qeqertarsuatsiaat, , Ameralik)	2006: 60,469 (Cuyler et al., 2021)		Ameralik: Decline (Witting and Cuyler, 2011)				Average harvest of almost 3200 caribou per year since 2000 (Witting and Cuyler, 2011).

22.3. Synopsis

The literature research revealed a strong evidence for a decline in Reindeer for the South Greenland population in Ameralik and of a stable population in Qeqertarsuatsiaat. For West Greenland, there is negligible evidence of an increase. For many populations, trends are unknown. There is overwhelming generic evidence of a decline of this species in Greenland due to multiple aspects connected to climate change.

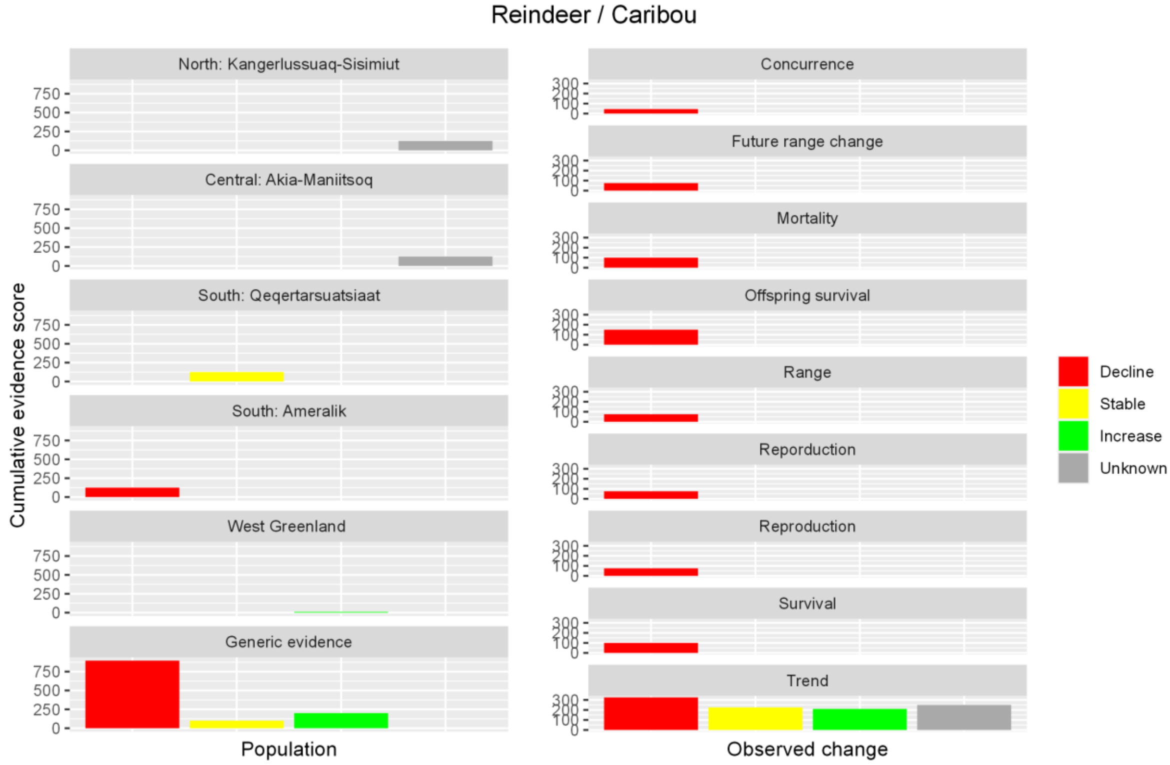


Figure 22.2. Cumulative evidence per population and aspects in which change is observed or expected

22.4. Catch and Forecast

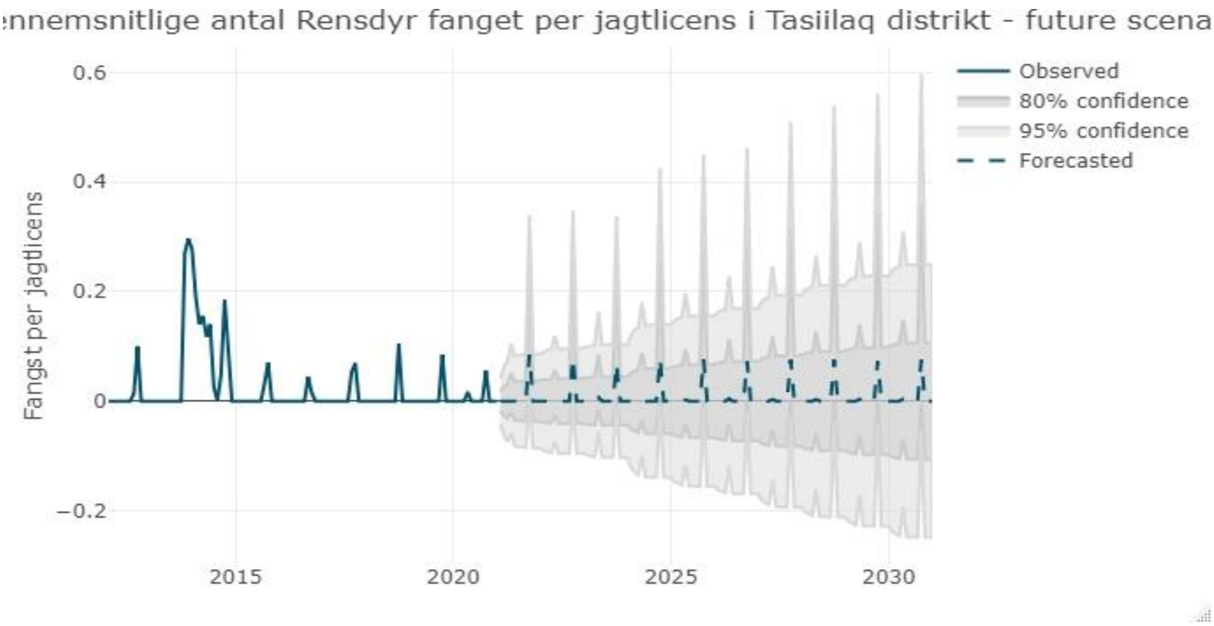


Figure 22.3. Average catch per hunter and forecast for Reindeer in Tasiilaq district.

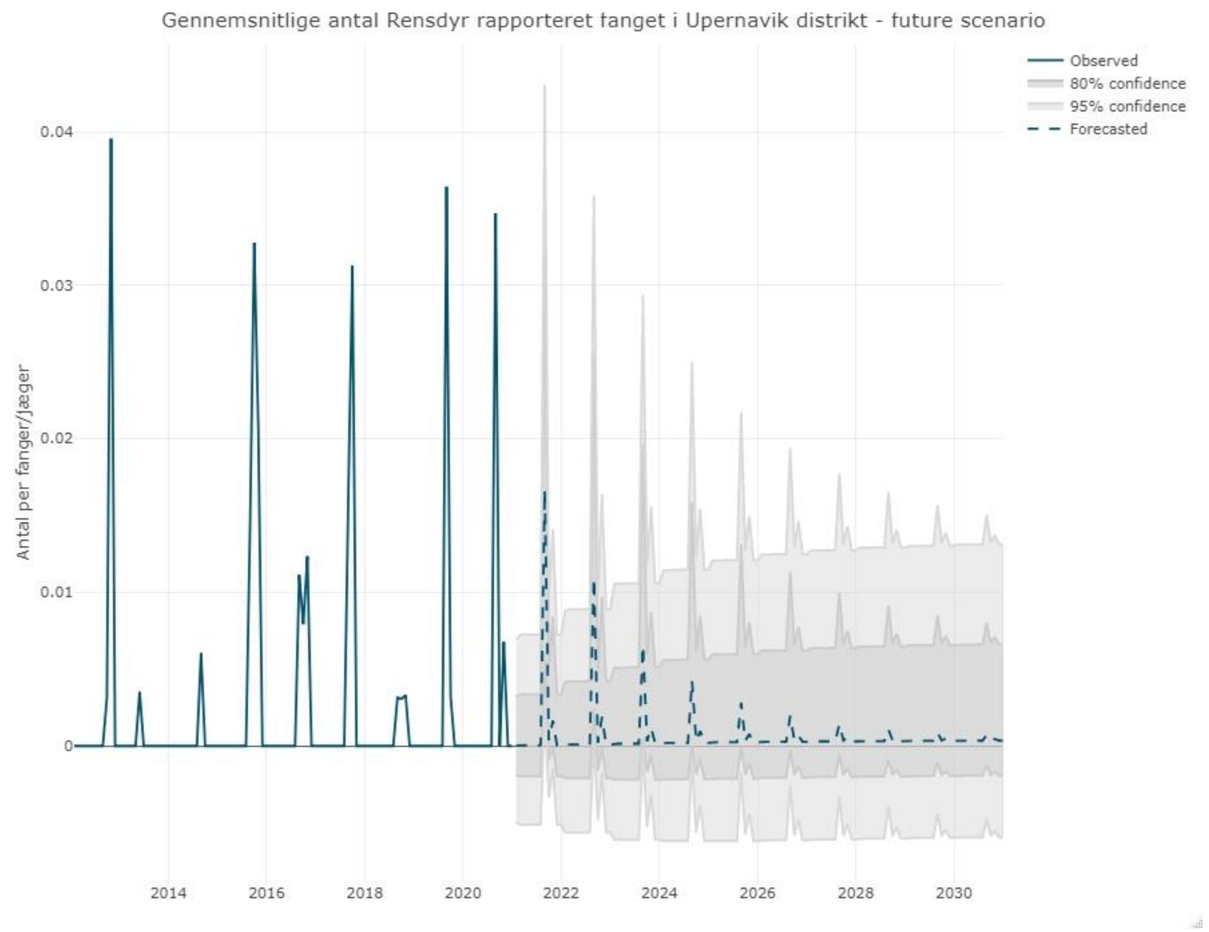


Figure 22.4. Average catch per hunter and forecast for Reindeer in Upernavik district.

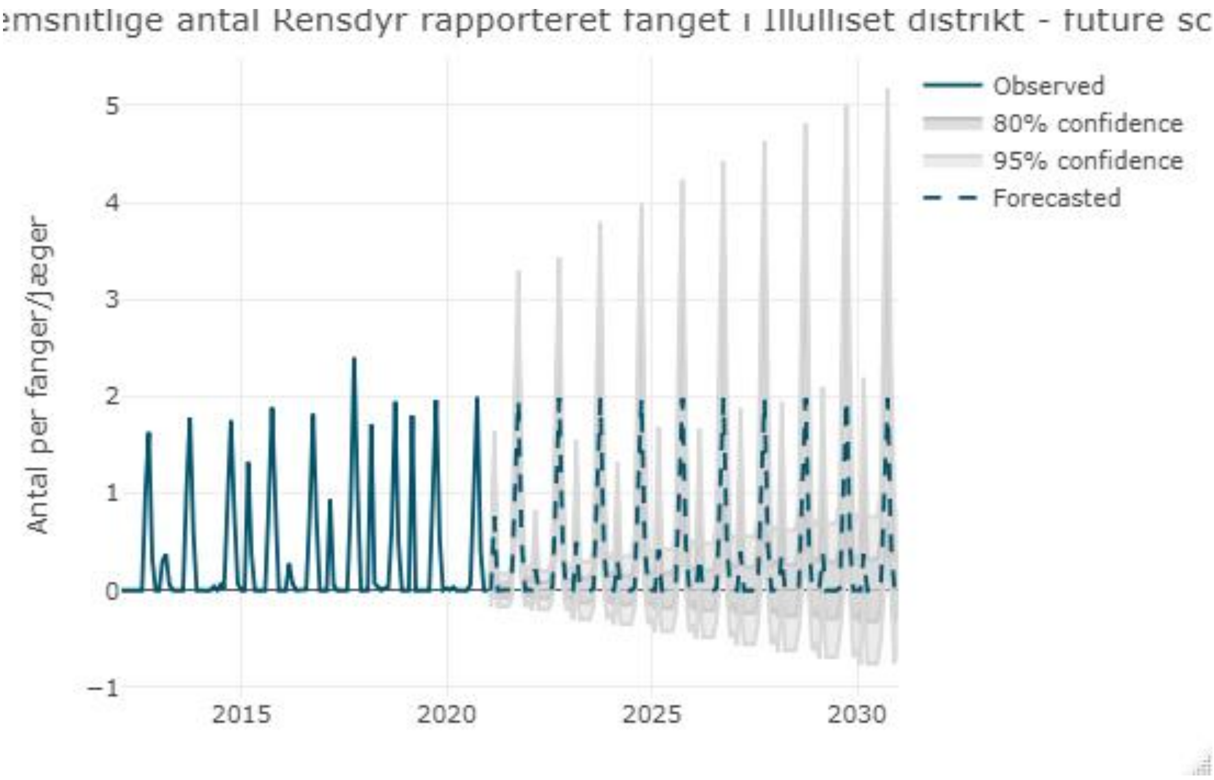


Figure 22.5. Average catch per hunter and forecast for Reindeer in Ilulissat district.

The forecasts are not reliable, and from Ittoqoortormiit, Tasiilaq and Upernavik appear insufficient to produce a forecast. Nevertheless, the material was used as a basis for discussion.

Table 22.1. Average annual catch of Reindeer per hunter in the period 2012-2020, in 2020 and 2030 (forecasted) and the percentage change in 2030 relative to 2012-2020 and 2020.

District	2012-2020	2020	2030	Δ 2012-2020	Δ 2020
Ittoqoortoormiit	0,07	0,00	0,07	0%	NA
Tasiilaq	0,29	0,07	0,08	-73%	9
Upernavik	0,03	0,04	0,00	-85%	-89%
Ilulissat	4,31	3,54	3,86	-11%	9%

22.5. Workshops with Hunter and Fishers Organizations

Scenario	Ittoqortoormiit	Tasiilaq	Upernavik	Ilulissat
Trend scenario	Not available	Not available	Catch determined by quota. Reindeer are seen where there is no registered population or quota	Content with the quota
Alternative scenario	NA	NA	NA	NA

22.6. Interviews with Scientific Experts

-will follow-

22.7. Preliminary Future Scenarios

Scenario	Ittoqortoormiit	Tasiilaq	Upernavik	Ilulissat
Stock and catch trend scenario			+10% compared to 2012-2020 average	
Underreporting adjustment scenario				
Alternative actions scenario				

23. Arctic hare (*Lepus arcticus*)

Arctic hare	
Lepus arcticus	
Snehare	
Ukaleq	

Distributed over the northernmost regions of Greenland, the Canadian Arctic islands and Northern Canada, including Ellesmere Island, and further south in Labrador and Newfoundland. No literature has been found about populations or body conditions.

Figure 23.1. Map over the distribution range

23.1. Climate Change

A maximum entropy (MaxEnt) algorithm and Schoener's D niche overlap index were used to assess shifts and changes in the overlap of species-specific distributions under recent (1979–2013) and future (2061–2080; representative concentration pathways [RCPs] 2.6, 4.5 and 8.5) bioclimatic conditions in the Northeast Greenland National Park (Beest et al., 2021). For Arctic hares, the change in probability of occurrence over time was positive in some parts of their distribution range and negative in others, a pattern that also became more pronounced with the severity of the RCP scenarios considered (Beest et al., 2021). Moreover, a northward shift in range was observed (Beest et al., 2021).

23.2. Status and Population Trends

<u>All populations</u>

Areas	Abundance	Status, change (≥2 generations)	Trend (Short term~1 generation)	Category of change	Description: physiological,behavioral change	Climate variable & direction	Hunting
	unknown	unknown	unknown				

23.3. Synopsis

There is strong evidence for a decline and stable population in the Northeast Greenland National Park. However, trends are unkown for East and West Greenland.

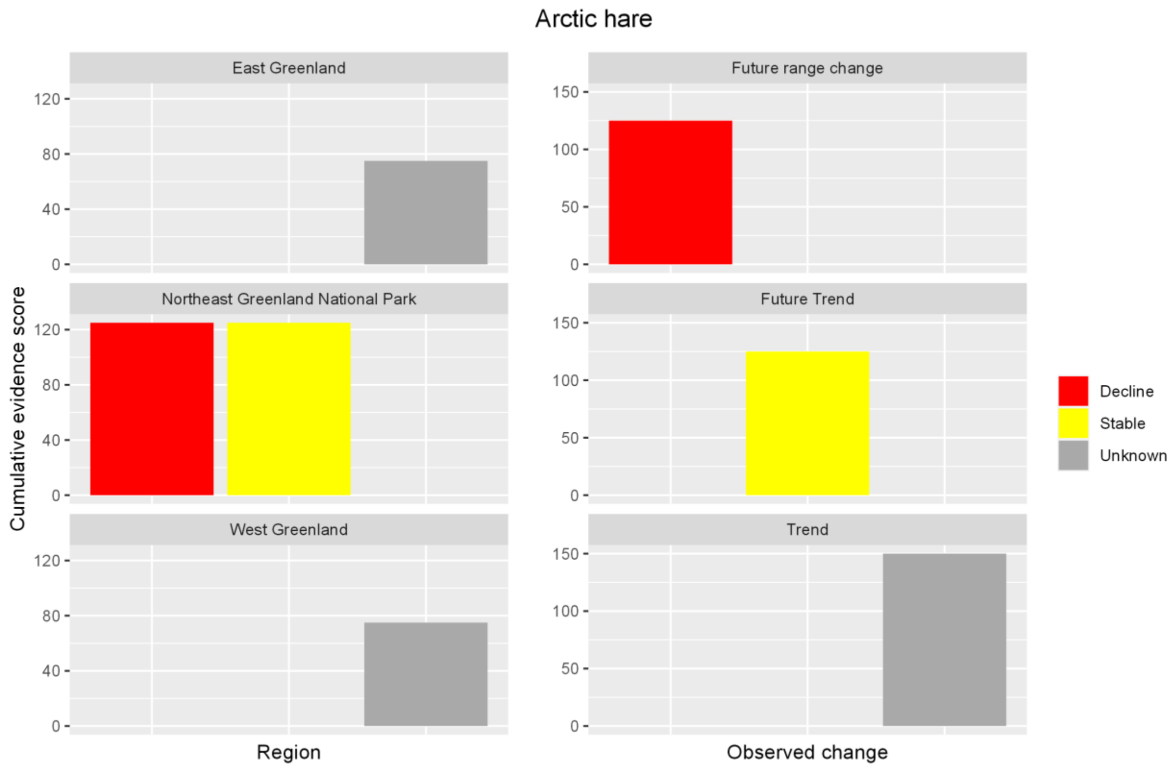


Figure 23.2 Cumulative evidence per region and aspects in which change is observed or expected.

23.4. Catch and Forecast

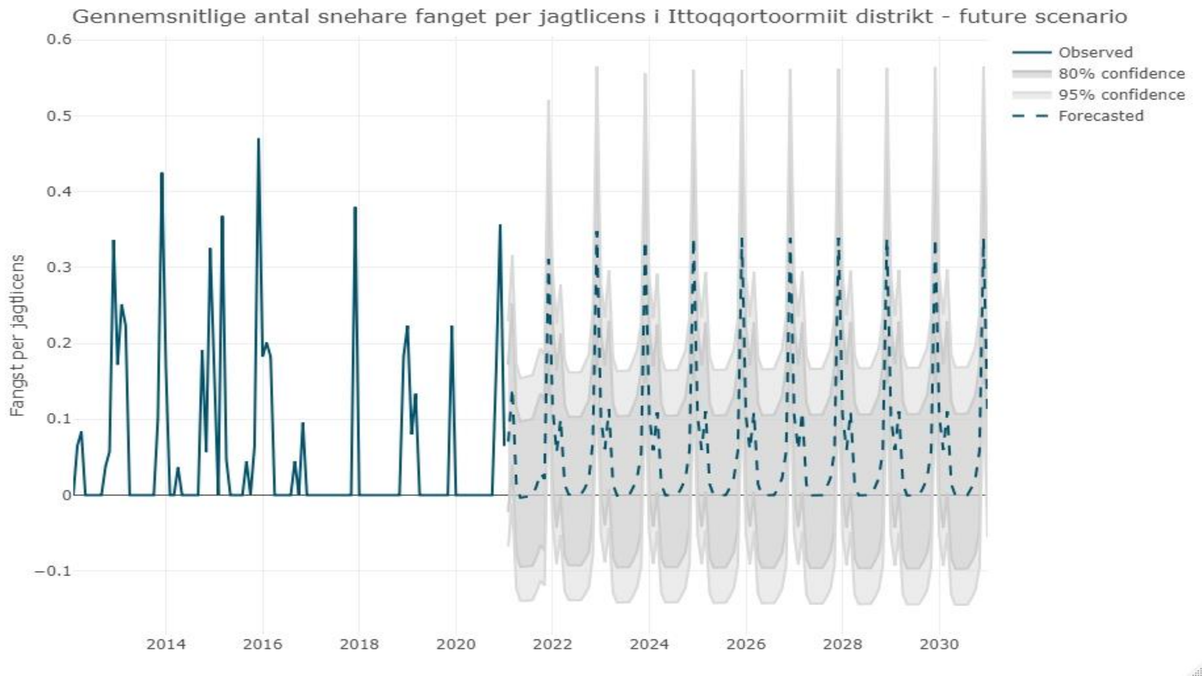


Figure 23.3. Average catch per hunter and forecast for Snowhare in Ittoqortoormiit district.

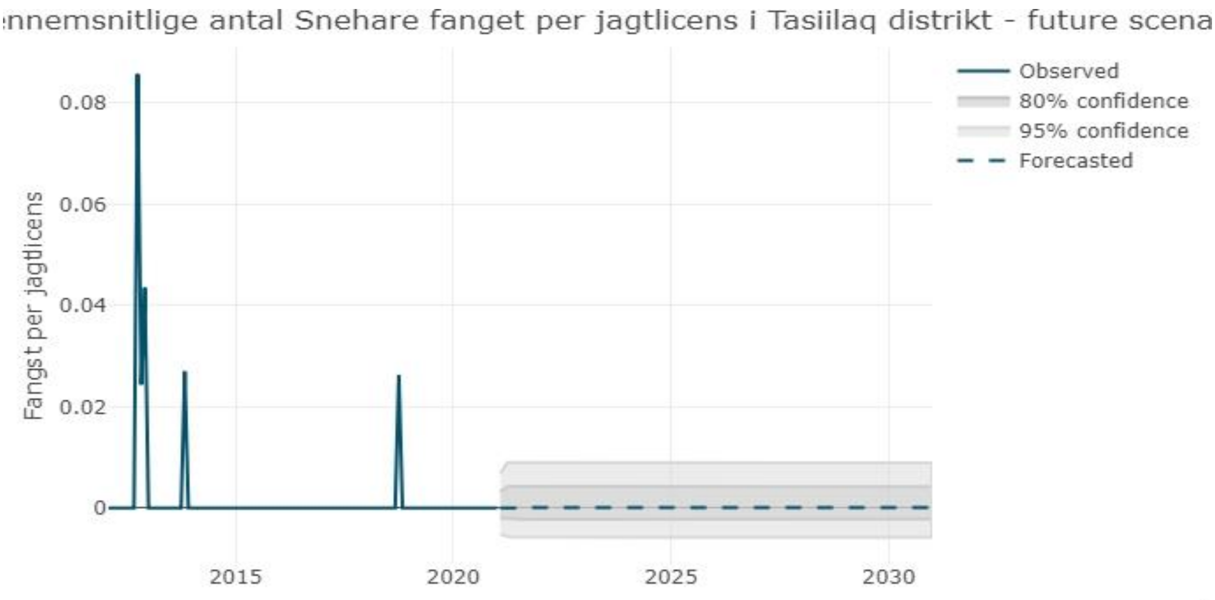


Figure 23.4. Average catch per hunter and forecast for Snowhare in Tasiilaq district.

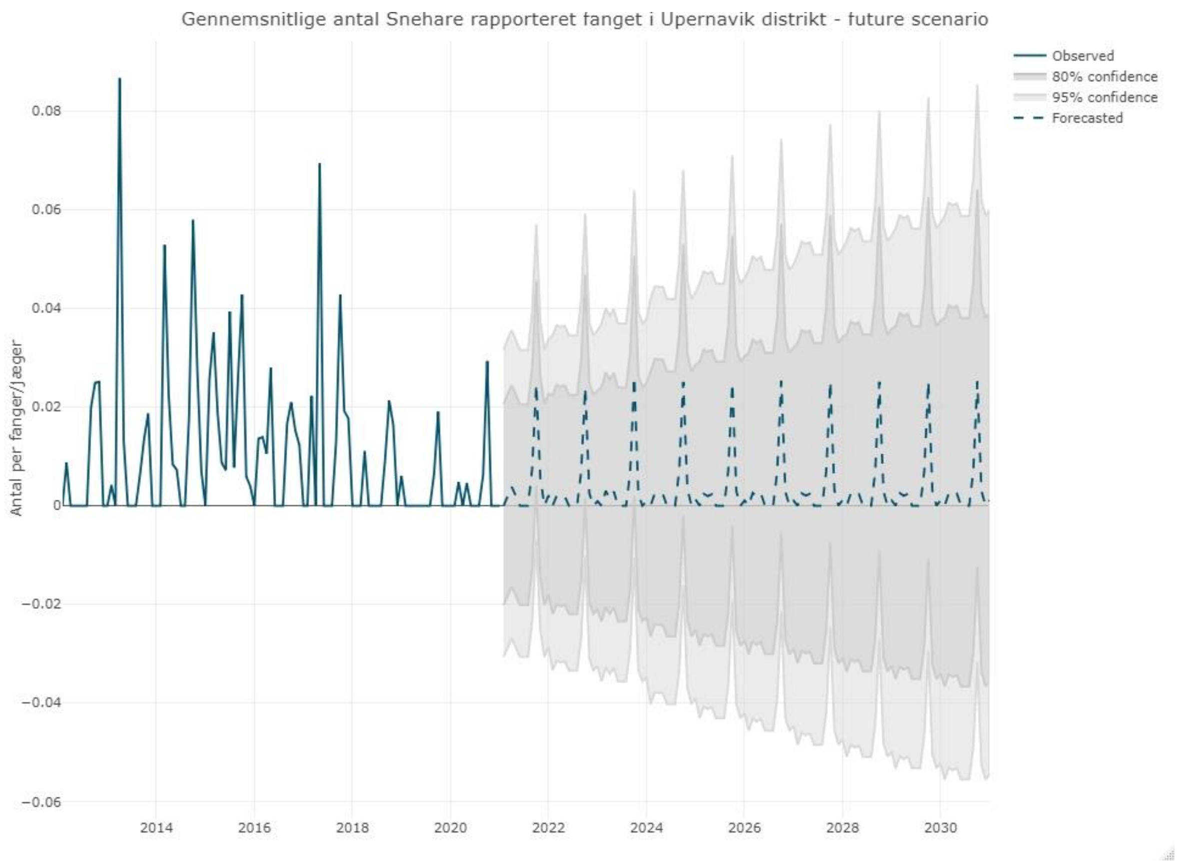


Figure 23.5. Average catch per hunter and forecast for Snowhare in Upernavik district

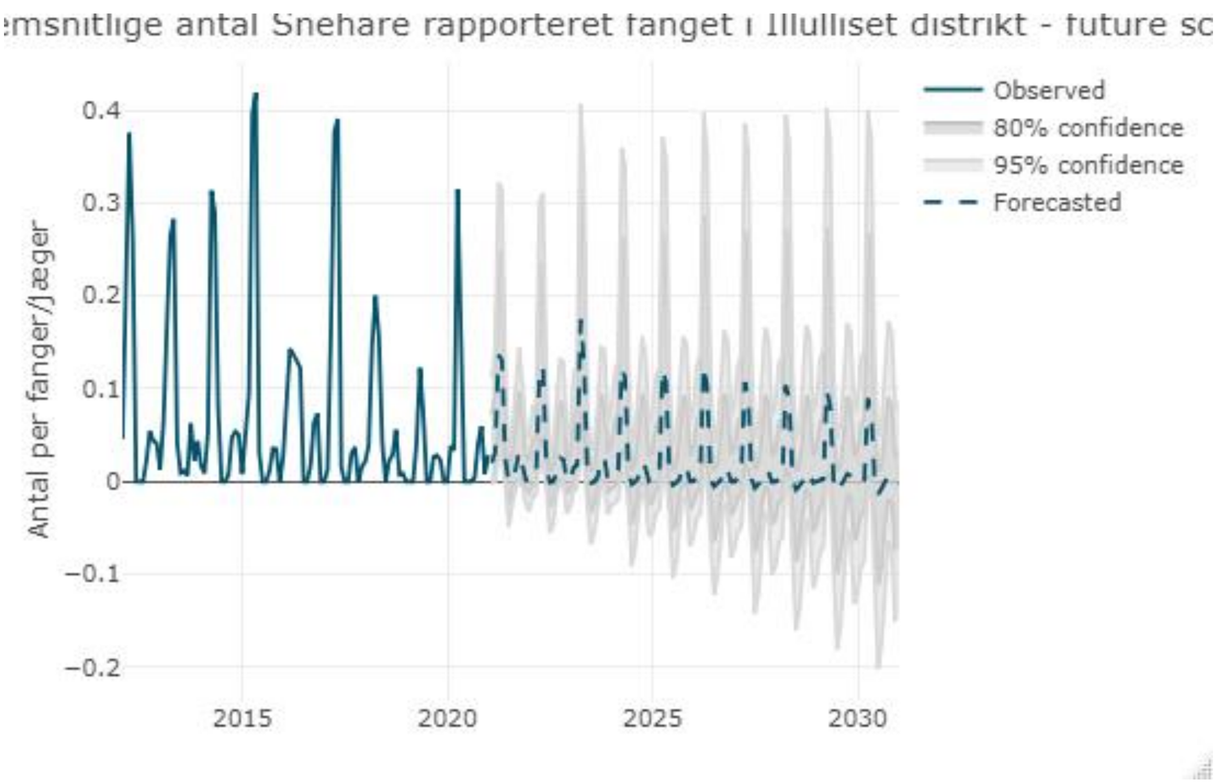


Figure 23.6. Average catch per hunter and forecast for Snowhare in Ilulissat district.

The forecasts are not reliable, and particularly the data from Tasiilaq appears insufficient to produce a forecast. Nevertheless, the material was used as a basis for discussion.

Table 23.1. Average annual catch of Snowhare per hunter in the period 2012-2020, in 2020 and 2030 (forecasted) and the percentage change in 2030 relative to 2012-2020 and 2020.

District	2012-2020	2020	2030	Δ 2012-2020	Δ 2020
Ittoqoortoormiit	0,79	0,68	0,72	-9%	6
Tasiilaq	0,02	0,00	0,00	-96%	NA
Upernavik	0,12	0,05	0,04	-65%	-5%
Ilulissat	0,85	0,70	0,18	-79%	-75%

23.5. Workshops with Hunter and Fishers Organizations

Scenario	Ittoqortoormiit	Tasiilaq	Upernavik	Ilulissat
Trend scenario	No longer targeted because of lack of trade options	Not available	Not available	Only caught while hunting grouse
Alternative scenario	NA	NA	NA	NA

23.6. Interviews with Scientific Experts

-will follow-

23.7. Preliminary Future Scenarios

Scenario	Ittoqortoormiit	Tasiilaq	Upernavik	Ilulissat
Stock and catch trend scenario				
Underreporting adjustment scenario				
Alternative actions scenario				

24. Arctic fox (*Vulpes lagopus*)

Arctic fox	
Vulpes lagopus	
Polarræv	
Terianniaq	

Classified into two different ecotypes, the “lemming fox” and the “coastal fox” (Norén et al., 2011). Lemming foxes inhabit Siberia, Scandinavia, Kola Peninsula, Alaska, Canada and eastern Greenland. It mainly feeds on lemmings and other rodents. The abundance is closely connected to the lemming cycle (Norén et al., 2011). Coastal foxes rely on stable access to food resources like eggs, birds and carcasses and inhabit Iceland, Svalbard and southern, western and northern Greenland (Norén et al., 2011).

Figure 24.1. Map over the Arctic fox distribution range

In West Greenland, the population is considered coastal foxes, predating on birds, eggs, marine resources, ptarmigan, and migratory gees (Norén et al., 2011). The species is considered common with a population larger than 10 000 (2004) (Norén et al., 2011). In East Greenland, the population is considered lemming foxes, predating on rodents, birds, eggs, and marine resources (Norén et al., 2011). The species is common. However, the numbers are unknown (Norén et al., 2011).

24.1. Climate Change

Genetic differentiation of Artic foxes in Iceland and Scandinavia was significantly correlated to the presence of sea ice on a global scale, showing the importance of sea ice for maintaining connectivity between Arctic fox populations (Norén et al., 2011). Climate change will likely increase genetic divergence among populations in the future (Norén et al., 2011). Climate-related changes in the arctic fox’s diet are likely to influence contaminant concentrations in arctic foxes from Svalbard (Andersen et al., 2015). High mortality levels of Svalbard reindeer may influence concentrations of HCB in arctic foxes, and β-HCH concentrations showed a positive association with sea ice cover (Andersen et al., 2015). Moreover, as temperatures are warming, a decrease in reported rabid arctic foxes may be expected (Kim et al., 2014).

A maximum entropy (MaxEnt) algorithm and Schoener's D niche overlap index were used to assess shifts and changes in the overlap of species-specific distributions under recent (1979–2013) and future (2061–2080; representative concentration pathways [RCPs] 2.6, 4.5 and 8.5) bioclimatic conditions in the Northeast Greenland National Park (Beest et al., 2021). The model shows that Artic fox's occurrence might increase with climate change, especially under the

RCPs 8.5 (Beest et al., 2021). Moreover, o northwards shift in range was observed (Beest et al., 2021). In Svalbard, 'Rain-on-snow' events led to a decrease in population growth rate (1-year lagged) in Artci foxes (1997–2011) (Hanssen et al., 2013).

24.2. Status and Population Trends

West Greenland

Areas	Abundance	Status, change	Trend (Short term~1 generation)	Category of change	Description: physiological,behavioral change	Climate variable & direction	Hunting
	2004: >10000 (Norén et al., 2011)		unknown				

East Greenland

Areas	Abundance	Status, change	Trend (Short term~1 generation)	Category of change	Description: physiological,behavioral change	Climate variable & direction	Hunting

24.3. Synopsis

We found strong evidence of a future increase of Arctic Foxes in the Greenland National Park. Nevertheless, most trends are unknown. There is weak generic evidence for a decline due to genetic isolation connected to climate change.

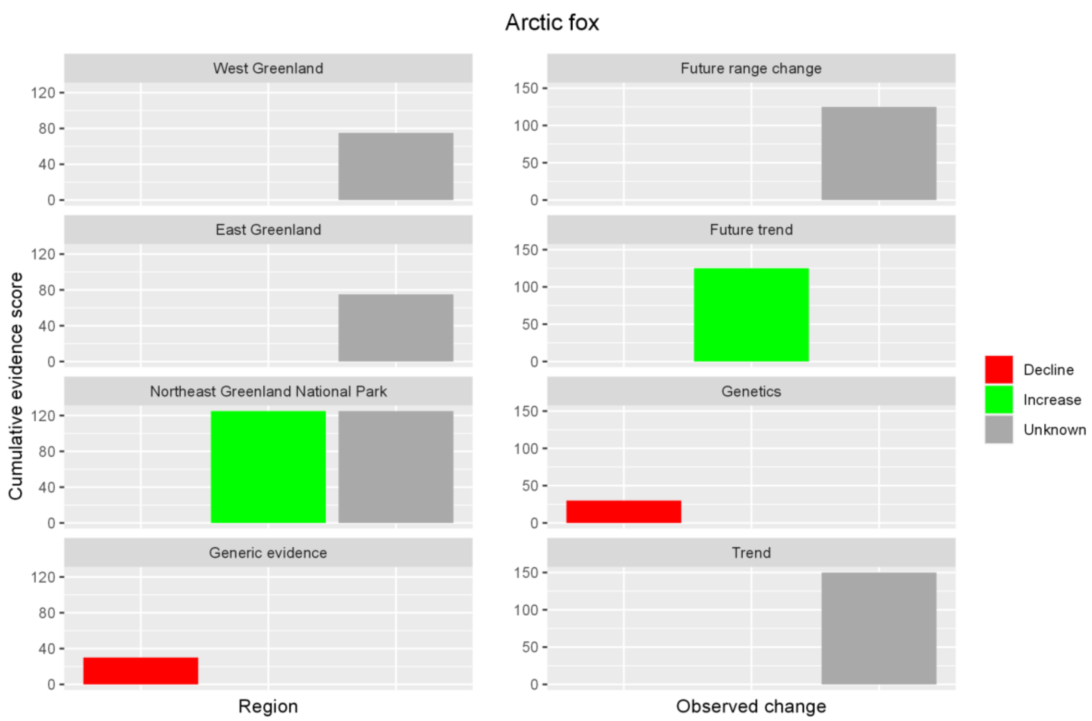


Figure 24.2 Cumulative evidence per region and aspects in which change is observed or expected.

24.4. Catch and Forecast

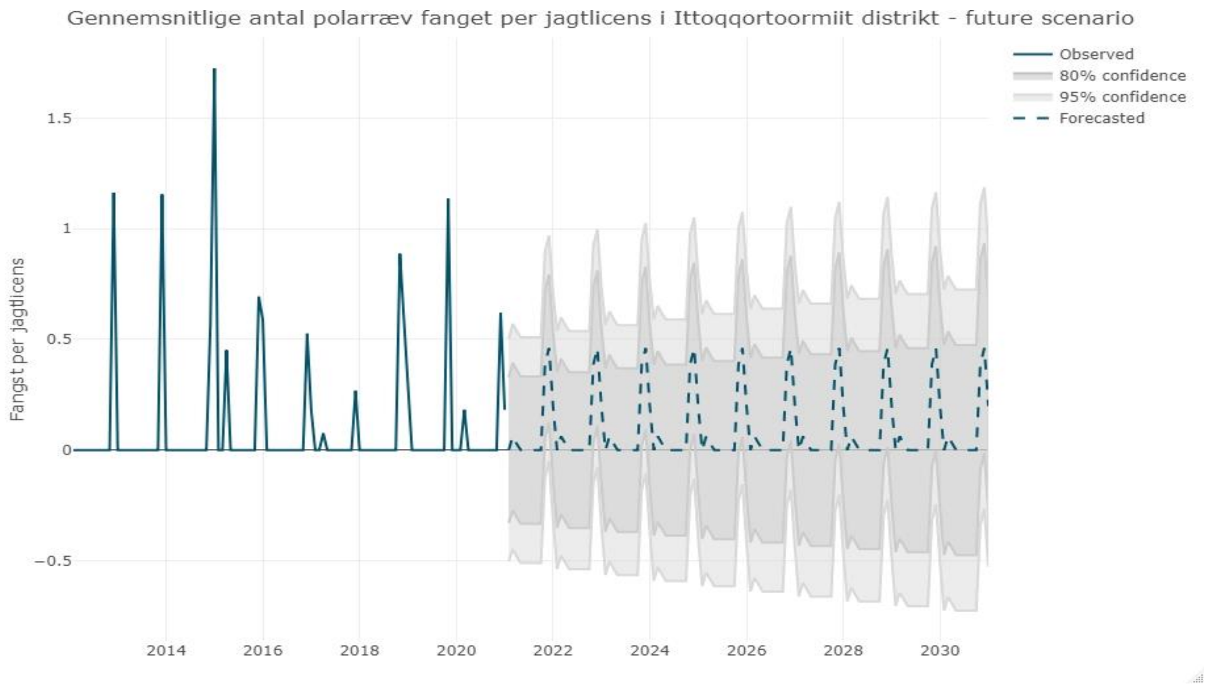


Figure 24.3. Average catch per hunter and forecast for Arctic fox in Ittoqortoormiit district.

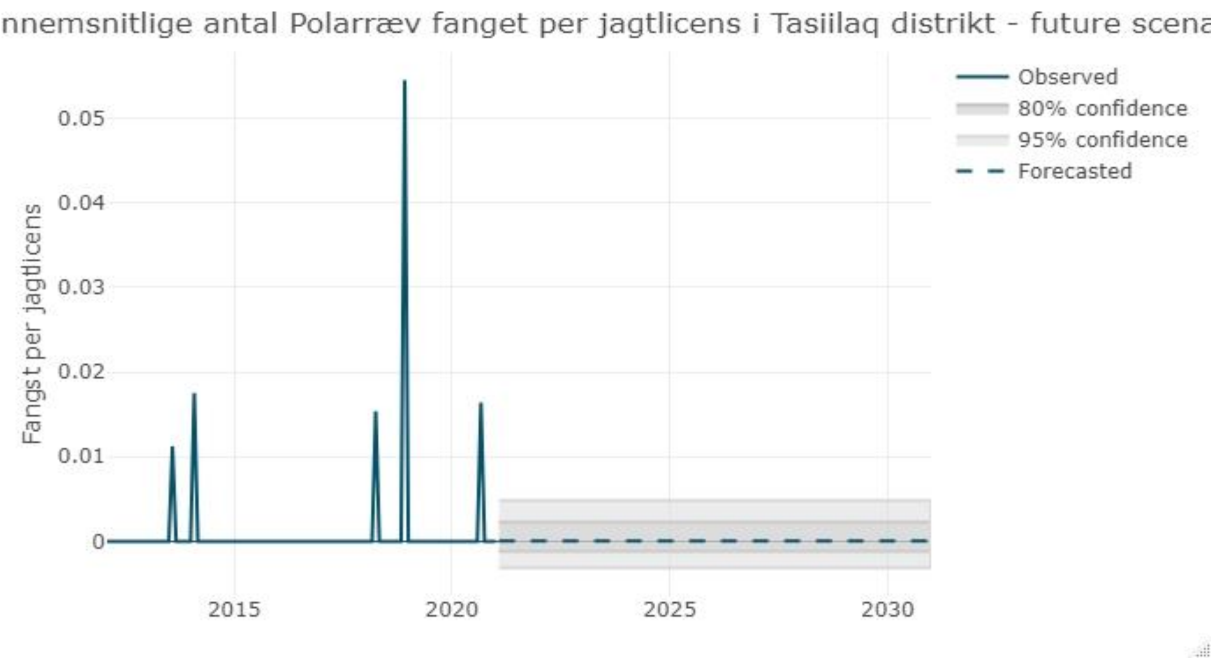


Figure 24.4. Average catch per hunter and forecast for Arctic fox in Tasiilaq district.

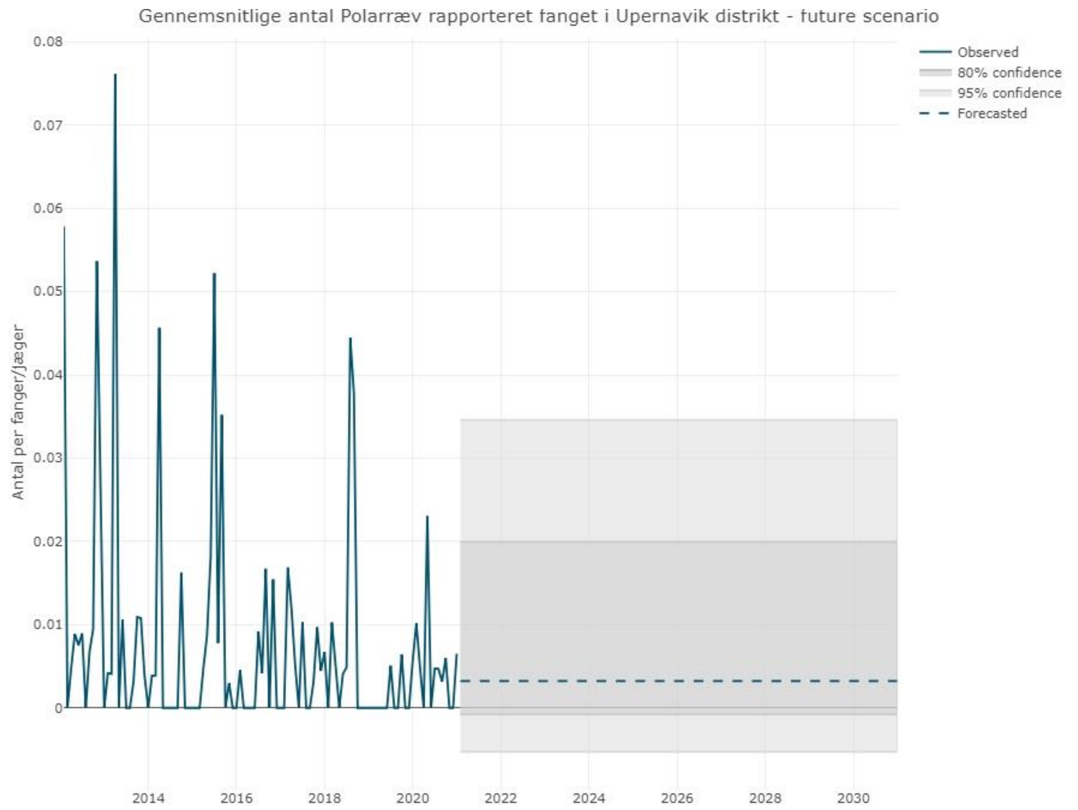


Figure 24.5. Average catch per hunter and forecast for Arctic fox in Upernavik district.

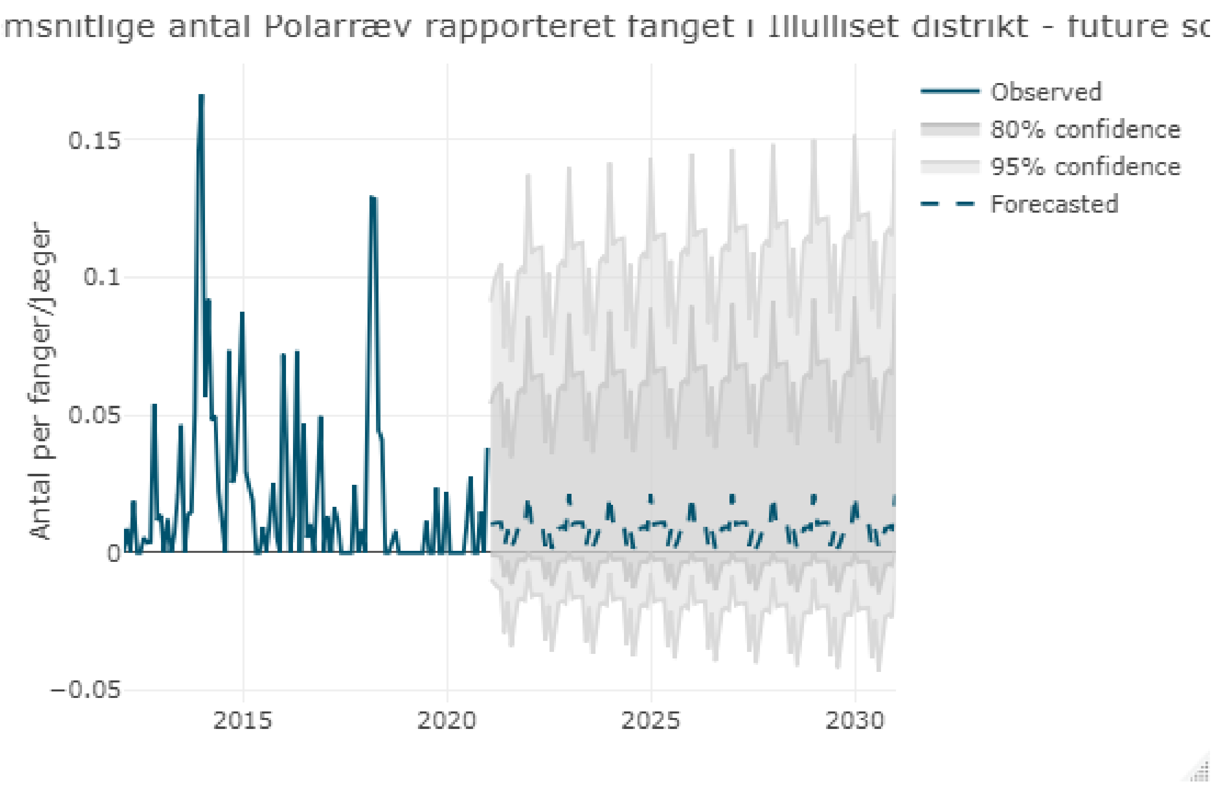


Figure 24.6. Average catch per hunter and forecast for Arctic fox in Ilulissat district.

The forecasts are unreliable, particularly the data from Tasiilaq appears insufficient to produce a forecast, and the model for Upernavik seems unreliable. Nevertheless, the material was used as a basis for discussion.

Table 24.1. Average annual catch of Arctic fox per hunter in the period 2012-2020, in 2020 and 2030 (forecasted) and the percentage change in 2030 relative to 2012-2020 and 2020.

District	2012-2020	2020	2030	Δ 2012-2020	Δ 2020
Ittoqoortoormiit	2,15	1,25	1,14	-47%	-10%
Tasiilaq	0,01	0,02	0,00	-96%	-97%
Upernavik	0,09	0,06	0,00	-99%	-99%
Ilulissat	0,25	0,09	0,11	-57%	17%

24.5. Workshops with Hunter and Fishers Organizations

Scenario	Ittoqortoormiit	Tasiilaq	Upernavik	Ilulissat
Trend scenario	Few people hunt	Not targeted because of lack of trade options	Not targeted except during extermination campaigns	Not targeted except during extermination campaigns
Alternative scenario	Enable trade of skin	NA	NA	NA

24.6. Interviews with Scientific Experts

-will follow-

25.7. Preliminary Future Scenarios

Scenario	Ittoqortoormiit	Tasiilaq	Upernavik	Ilulissat
Stock and catch trend scenario				
Underreporting adjustment scenario				
Alternative actions scenario	Increase value by 200 kr			

25. Greenland Barnacle Goose (*Branta leucopsis*)

Greenland Barnacle Goose	
Branta leucopsis	
Bramgås	
Nerlernarnaq	

The population doubled in Northeast and North Greenland from 1988 to 2009 to about 74.000 individuals (Boertmann et al., 2009). Breeding areas are in East Greenland, and they winter in Scotland and Ireland (Mitchell and Hall, 2020). The number of geese in wintering sites in Britain and Ireland has increased more than six-fold since 1959 (Mitchell and Hall, 2020). Overall, 72.162 Geese in Scotland and Ireland originating from Greenland were counted in 2018 (wintering areas of East Greenland's Breeding sites) (Mitchell and Hall, 2020). The range is shifting northwards.

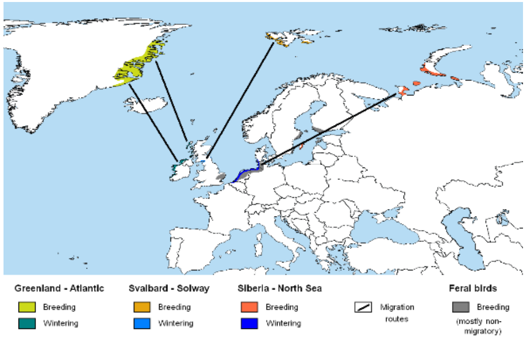


Figure 25.1 Breeding and wintering grounds

25.1. Climate Change

In the breeding grounds of the barnacle goose over the territory of Russia, steady population growth and range expansion is observed (Rozenfeld et al., 2021). Warming has led to a prolonged vegetation period and phytomass growth, which might offer young barnacle geese advantages in the fledging period and adult birds an additional opportunity to accumulate internal reserves before the autumn migration (Rozenfeld et al., 2021). In the spring–staging areas in Norway, the goose population has doubled in size and the number of geese stage in new areas 250 km further north has increased since the mid-1990s due to higher temperatures (Tombre et al., 2019). Recent climate change in Svalbard with earlier onset of spring and warmer summers and thus advanced snow melt and earlier vegetation green-up has positively impacted egg production and hatching success (Layton-Matthews et al., 2020).

These positive effects are counterbalanced by a significant decline in fledging probability due to an increased abundance of the arctic fox, which is the primary predator in the region and has led to a greater threat to the survival of young birds, resulting in lower fledging rates (Layton-Matthews et al., 2020). Additionally, density-dependent effects have been observed throughout the annual cycle. As the total flyway population size steadily increases, negative trends have emerged in overwinter survival and carryover effects on egg production (Layton-Matthews et al., 2020). The higher population density has placed increased pressure on available resources, reducing survival rates during winter and impacting future reproductive success (Layton-Matthews et al., 2020). Overall, the combination of density-dependent processes and direct and indirect effects of climate change across different life history stages has played a role in stabilizing the local population size in Svalbard (Layton-Matthews et al., 2020).

The interplay between these factors has resulted in a complex dynamic where some aspects of the ecosystem are positively influenced by climate change while others are negatively affected (Layton-Matthews et al., 2020). A dynamic state variable model predicted that barnacle geese will experience a significant decline in reproductive success as Arctic amplification intensifies (Lameris et al., 2017). This decline is primarily attributed to mistimed arrival, as geese cannot anticipate the accelerated progression of Arctic spring from their wintering grounds (Lameris et al., 2017). However, when geese can anticipate the swifter advancement of Arctic spring, the model suggests that they will adjust their spring arrival by up to 44 days (Lameris et al., 2017). This adaptation would not imposing any reproductive costs in terms of optimal condition or breeding timing (Lameris et al., 2017). A transient Life-Table Response Experiment ('transient-LTRE') to demographic data from Svalbard barnacle geese shows declines in body condition (1980–2017), which positively affected reproduction and fledgling survival, had negligible consequences for population growth (Layton-Matthews et al., 2021). Instead, population growth rates were largely reproduction-driven, in part through positive responses to rapidly advancing spring phenology (Layton-Matthews et al., 2021).

25.2. Interactions

Polar bears may severely affect the reproductive success of the barnacle goose (*Branta leucopsis*), common eider (*Somateria mollissima*) and glaucous gull (*Larus hyperboreus*) (Prop et al., 2015). Since polar bears are arriving almost 30 days earlier on land during the last ten years, observations on Spitsbergen (Svalbard) and east Greenland showed that nest predation was strongest in years when the polar bears arrived well before hatch, with more than 90% of all nests being predated (Prop et al., 2015).

25.3. Status and Population Trends

East Greenland

Areas	Abundance	Status, change	Trend (Short term~1 generation)	Category of change	Description: physiological,behavioral change	Climate variable & direction	Hunting
	72,162 Geese in Scotland and Ireland (wintering areas of East Greenland's Breeding sites) (Mitchell and Hall, 2020) 74000 in Northeast and North Greenland (Boertmann et al., 2009).	**Expanding**	Increasing (more than six-fold since 1959) (Mitchell and Hall, 2020)				

25.4. Synopsis

The barnacle goose may benefit from climate change in Greenland. We found strong evidence for an increase and moderate evidence for a stable population in East Greenland. There is overwhelming generic evidence for an increase in Greenland.

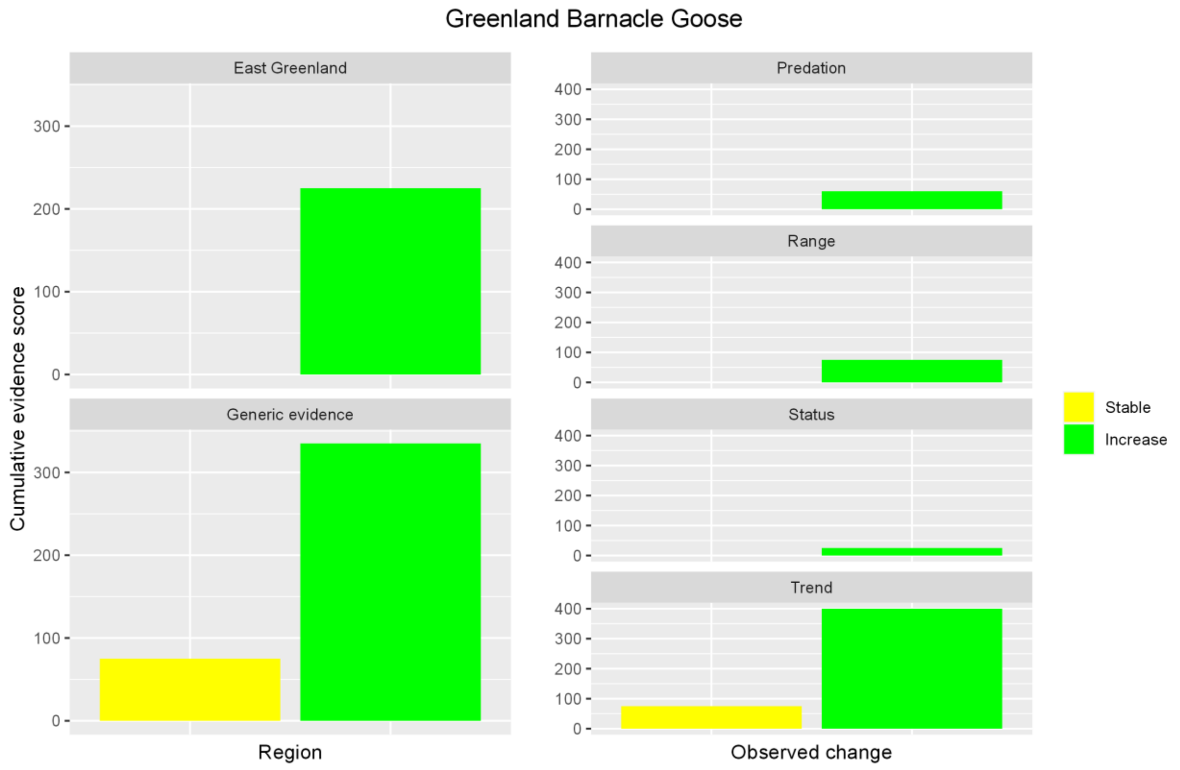


Figure 25.2 Cumulative evidence per region and aspects in which change is observed or expected.

25.5. Catch and Forecast

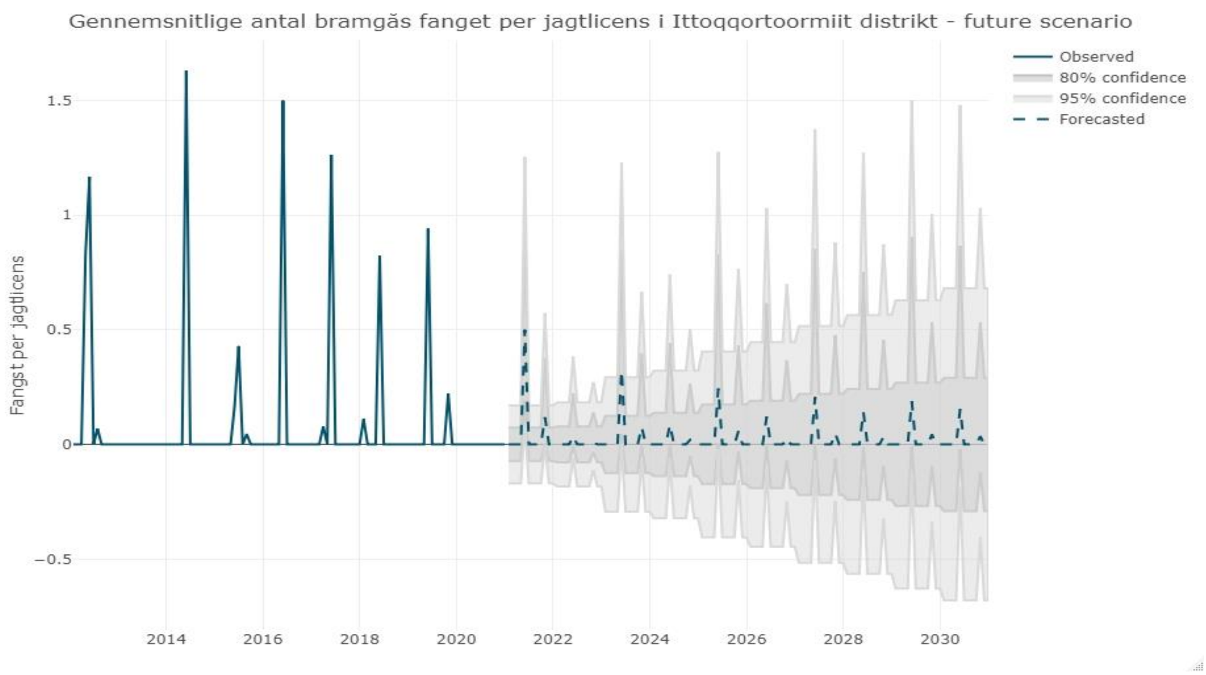


Figure 25.3. Average catch per hunter and forecast for Greenlandic barnacle goose in Ittoqortoormiit district.

The forecast is not reliable. Nevertheless, the material was used as a basis for discussion.

Table 25.1. Average annual catch of Greenlandic barnacle goose per hunter in the period 2012-2020, in 2020 and 2030 (forecasted) and the percentage change in 2030 relative to 2012-2020 and 2020.

District	2012-2020	2020	2030	Δ 2012-2020	Δ 2020
Ittoqoortoormiit	1,03	0,00	0,19	-82%	NA
Tasiilaq					
Upernavik					
Ilulissat					

25.6. Workshops with Hunter and Fishers Organizations

Scenario	Ittoqortoormiit	Tasiilaq	Upernavik	Ilulissat
Trend scenario	Not recorded consistently. Estimated catch 5-7 per occupational hunter and 5 per part time hunter.	More seen (but uncertain identification)	Not hunted/available	More observed but during closed season
Alternative scenario	NA	NA	NA	NA

25.7. Interviews with Scientific Experts

-will follow-

25.8. Preliminary Future Scenarios

Scenario	Ittoqortoormiit	Tasiilaq	Upernavik	Ilulissat
Stock and catch trend scenario				
Underreporting adjustment scenario	Increase to min catch of 5-7 per occupational hunter and 5 per part-time hunter			
Alternative actions scenario				

26. Canada Goose (*Branta canadensis*)

Canada Goose	
Branta canadensis	
Canadagås	
Canadap nerlia	

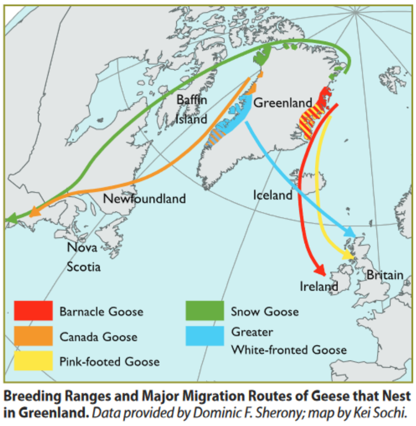


Figure 26.1. Map of migration routes and distribution in Greenland.

Three subspecies of the Canada Goose (*Branta canadensis interior*, *B.c. parvipes* and *B.c. hutchinsii*) have been reported from Greenland, where the species has increased dramatically as a breeding and summering bird in the last 30 years (Fox, 2012). Other populations are breeding in East Greenland and wintering in Ireland and Scotland (Fig. 26.1).

The range is expanding northwards. Previously there were only a few records of this species in NE Greenland. Now single individuals of the subspecies *B.c. hutschinsii* are arriving at Primula Pond in East Greenland (Meltofte and Dinesen, 2009).

In West Greenland, until recently, the only common goose species breeding was the Greenland White-fronted Goose (*Anser albifrons flavirostris*) (Kristiansen and Jarrett, 2001). Since 1980, Canada Geese are increasingly observed and have established themselves successfully, suggesting a population of c. 2.500 breeding pairs in 1998 (Fox, 2012; Kristiansen and Jarrett, 2001). The process of colonizing and expanding the population in Greenland's interior is ongoing (Fox, 2012). Populations are established in West Greenland, spanning from Svartenhuk to a latitude north of 76°N. South of Svartenhuk, significant numbers of birds breed and moult on Nuussuaq, Disko Island, and the land south of Disko Bay, extending at least as far south as Paamiut (at 62°N) (Fox, 2012). An increasing frequency of large Canada Geese has been reported in Northeast Greenland (Fox, 2012). While the current numbers remain relatively small, with flocks consisting of up to six individuals, the presence of mating pairs on multiple occasions suggests that breeding may be observed in the near future (Fox, 2012).

26.1. Climate Change

It appears that conditions are very amenable for Canada Geese breeding in west Greenland, which may explain their dramatic increase from relatively few birds in the late 1980s to over 41.500 in 2007 (Fox et al., 2011). Milder spring conditions, potentially lower predation rate, availability of abundant food and lack of competition for nest sites may explain the rapid expansion of this goose population in west Greenland (Fox et al., 2011). In Great Britain, large population increases in the non-native Branta Canadensis were found, consistent with large positive climate change impacts (Martay et al., 2017). Booming goose (*Chen caerulescens* and *Branta canadensis*) populations are also observed in nest sites in Churchill, Manitoba, Canada, and Beluga River, Alaska, USA (Swift et al., 2017). Though most Subarctic-breeding populations have been relatively stable since the early 2000s, some populations have undergone dramatic variations, such as the Atlantic sub-population (Government of Canada, 2023).

26.2. Status and Population Trends

West Greenland

Areas	**Abundance**	**Status, change**	**Trend (Short term~1 generation)**	**Category of change**	**Description: physiological,behavioral change**	**Climate variable & direction**	**Hunting**
West Greenland	1998: 2500 breeding pairs (Kristiansen and Jarrett, 2001)	**Expanding** (Fox, 2012)	Increasing (Fox, 2012; Fox et al., 2011)				

East Greenland

Areas	**Abundance**	**Status, change**	**Trend (Short term~1 generation)**	**Category of change**	**Description: physiological,behavioral change**	**Climate variable & direction**	**Hunting**
West Greenland	**Few individuals** **2008: Two individuals were observed in Jameson Land** (Boertmann et al., 2009) **2009: One individual, (B. c. hutschinsii) at Primula Pond** (Meltofte and Dinesen, 2009)	**Expanding** (Fox, 2012)	**Increasing** (Fox, 2012)				

26.3. Synopsis

Canadian goose may benefit from climate change in Greenland. We found weak evidence of an increase in East and West Greenland. There is strong generric evidence that populations of this species will remain stable or increase in Greenland.

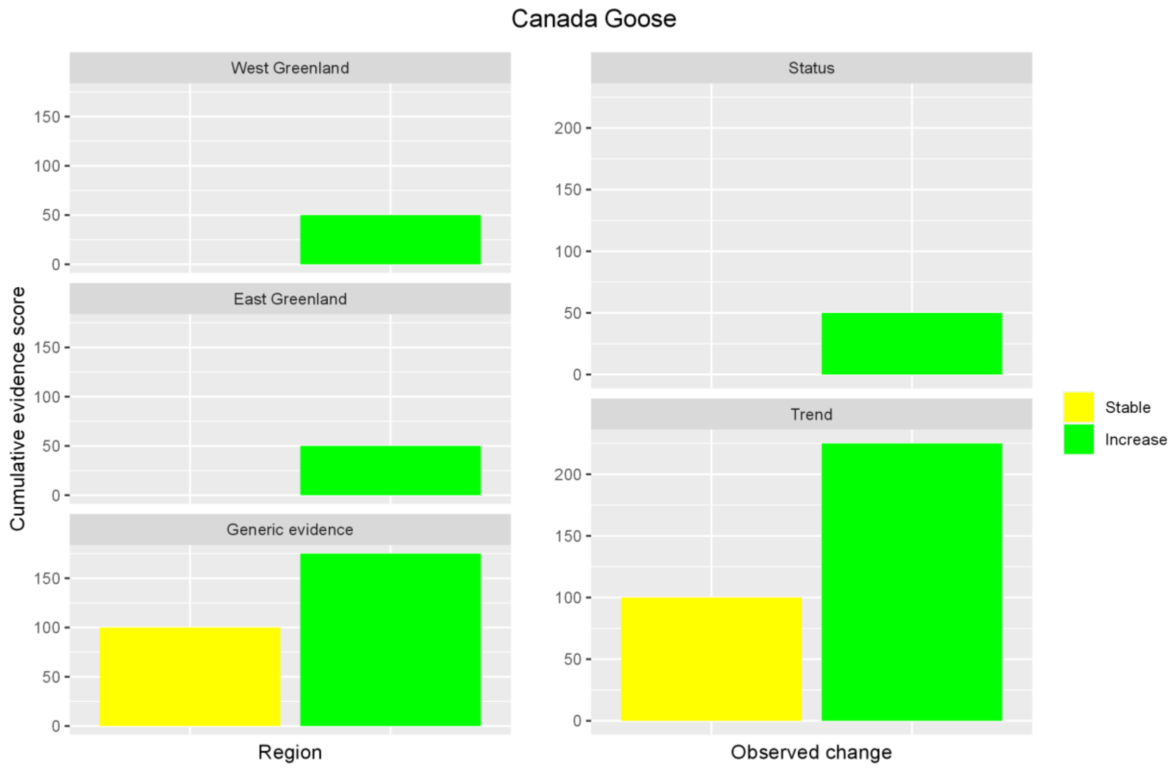


Figure 26.1 Cumulative evidence per region and aspects in which change is observed or expected.

26.4. Catch and Forecast

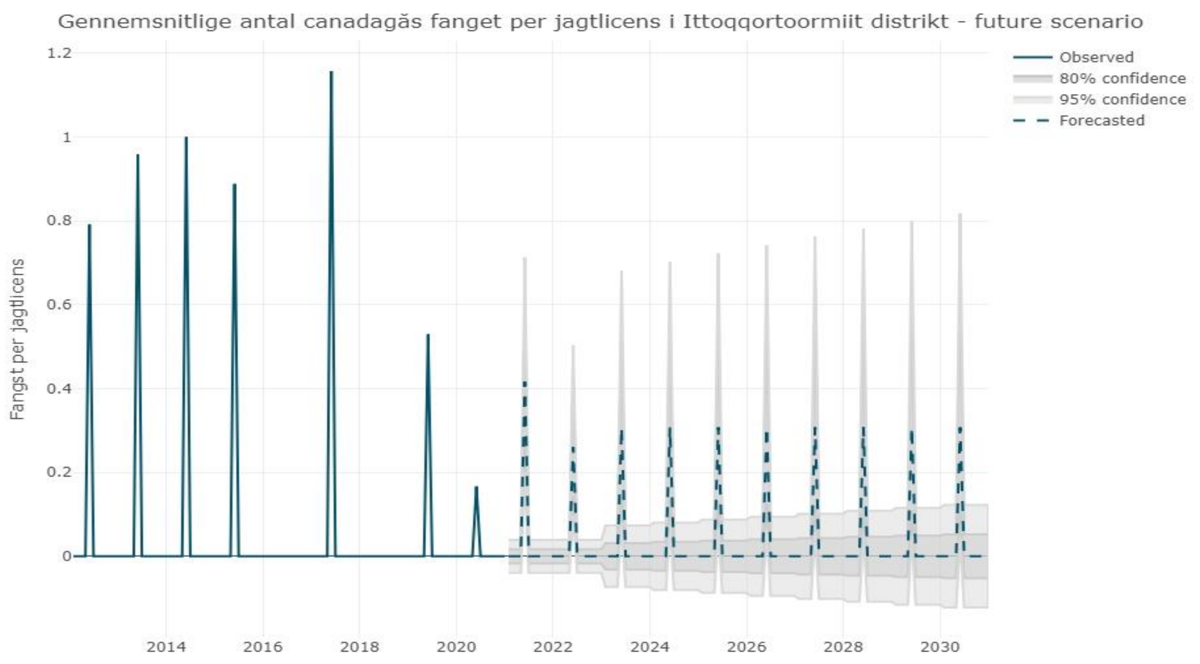


Figure 26.2. Average catch per hunter and forecast for Canada goose in Ittoqortoormiit district.

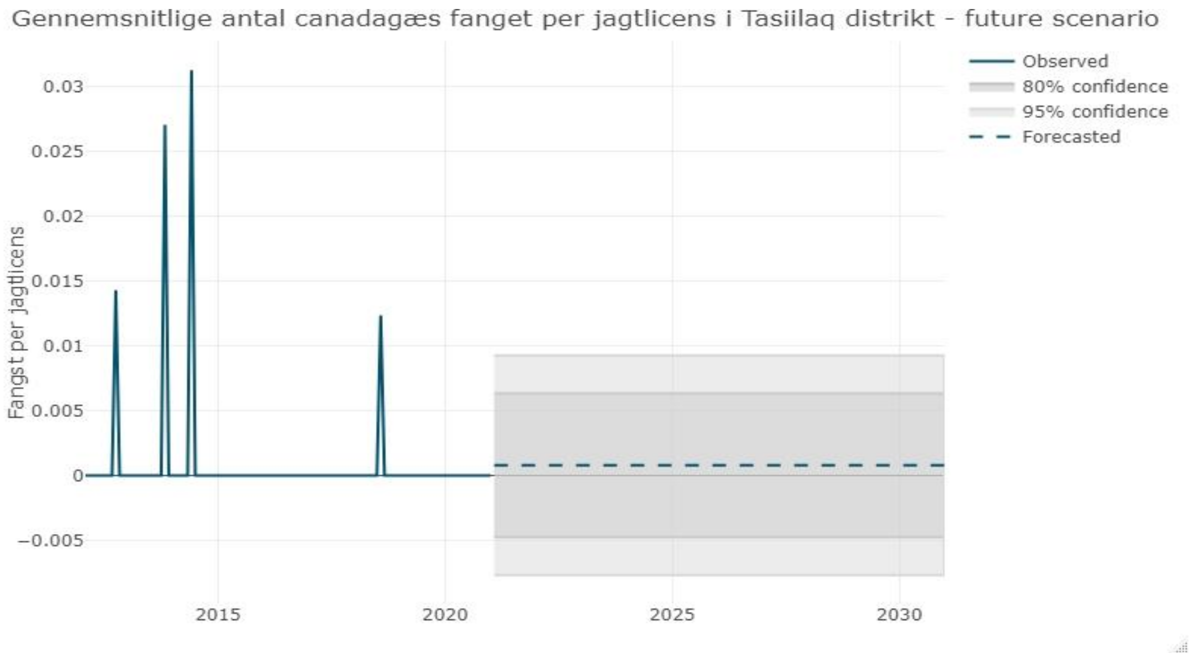


Figure 26.3. Average catch per hunter and forecast for Canada goose in Tasiilaq district.

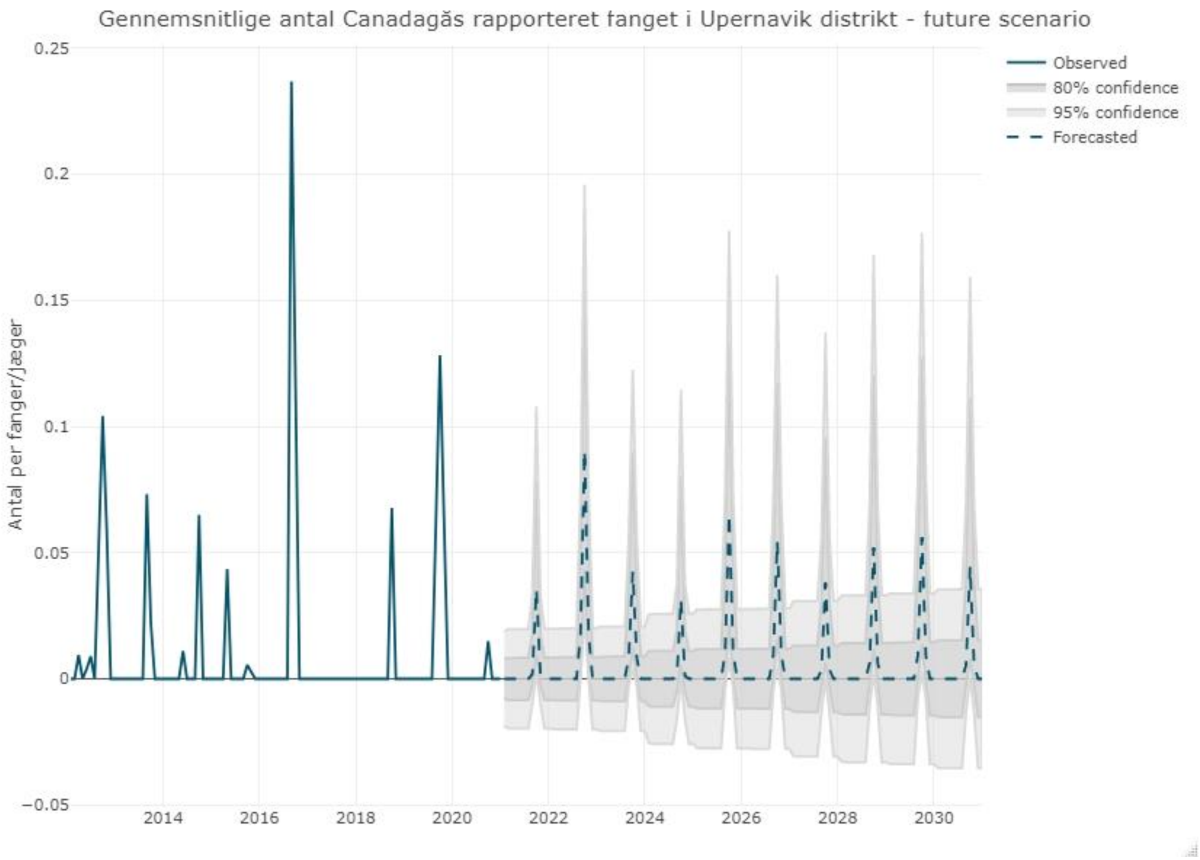


Figure 26.4. Average catch per hunter and forecast for Canada goose in Upernavik district.

The forecasts are not reliable, and data appears insufficient to produce a forecast. Nevertheless, the material was used as a basis for discussion.

Table 26.1. Average annual catch of Canada goose per hunter in the period 2012-2020, in 2020 and 2030 (forecasted) and the percentage change in 2030 relative to 2012-2020 and 2020.

District	2012-2020	2020	2030	Δ 2012-2020	Δ 2020
Ittoqoortoormiit	0,61	0,17	0,31	-50%	85%
Tasiilaq	0,01	0,00	0,01	0%	NA
Upernavik	0,13	0,01	0,01	-56%	272%
Ilulissat	0,46	0,27	0,03	-94%	-90%

26.5. Workshops with Hunter and Fishers Organizations

Scenario	Ittoqortoormiit	Tasiilaq	Upernavik	Ilulissat
Trend scenario	Not recorded consistently. Estimated catch 5-7 per occupational hunter and 5 per part time hunter.	More seen (but uncertain identification)	Not hunted/available	Not hunted/available
Alternative scenario	NA	NA	NA	NA

26.6. Interviews with Scientific Experts

-will follow-

26.7. Preliminary Future Scenarios

Scenario	Ittoqortoormiit	Tasiilaq	Upernavik	Ilulissat
Stock and catch trend scenario				
Underreporting adjustment scenario	Increase to min catch of 5-7 per occupational hunter and 5 per part-time hunter			
Alternative actions scenario				

27. Pink-footed goose (*Anser brachyrhynchus*)

Pink-footed goose	
Anser brachyrhynchus	
Kortnæbet gås	
Nerleq siggukitsoq	

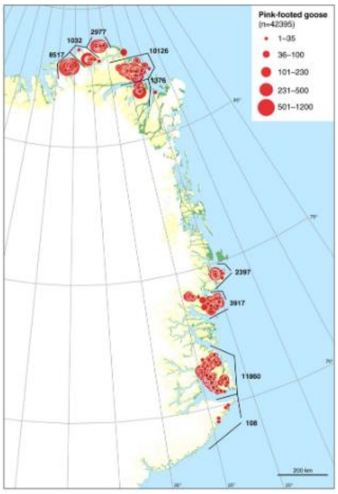


Figure 27.1. Distribution of pink-footed geese observed during all surveys in July and August 2009

The populations in Greenland primarily winter in Scotland. During the period 1988 to 2009, the Pink-footed goose population in Northeast and East Greenland has doubled to reach 364.000 individuals in 2009 (Boertmann et al., 2009). Other surveys in North and Northeast Greenland counted in total, approx. 42.000 pink-footed geese during surveys in 2009 (Boertmann and Nielsen, 2010).

In 1983/84, it was estimated that the habitats on Jameson Land had nearly reached their capacity to accommodate molting Pink-footed geese (Boertmann et al., 2009). However, a significant increase in the population in 2008 and 2009 were found, with over three times as many geese compared to 1988 (Boertmann et al., 2009). During the 2008 surveys on Jameson Land, it was found that the density of geese had nearly doubled since 1983/84, likely due to a climate change-induced boost in the productivity of the graminoid vegetation (Boertmann et al., 2009). Additionally, the molting Pink-footed geese now utilize suboptimal habitats to a greater extent than in previous years. The 1988 survey confirmed a northward expansion of the moulting Pink-footed Geese, which had been observed as early as 1969-71 (Boertmann et al., 2009). This expansion has continued, with large concentrations of geese found up to 550 km north of the northern distribution limit (80° N) recorded in 1988 (Boertmann et al., 2009).

The 1988 surveys estimated a total of 30.000 moulting Pink-footed geese in Northeast Greenland, while twenty years later, a similar approach revealed an estimated 75.000 moulting Pink-footed geese spread across a much wider area, including eastern North Greenland (Boertmann et al., 2009). However, this figure is believed to be considerably lower than the actual number of geese present, as many moult in areas that were not surveyed (Boertmann et al., 2009). Significant numbers of geese may also inhabit the 1,100 km long coastal strip of land between 63° N and Scoresby Sund, although only a few were encountered on the Blosseville Coast during the surveys (Boertmann et al., 2009).

27.1. Climate Change

Future projections for Svalbard show that even moderate warmer climate scenarios propose a large north- and eastward expansion of the potential breeding range into currently unsuitable areas (1 and 2 degree C increase in summer temperature, respectively) (Jensen et al., 2008). Moreover, pink footed geese show with an advanced onset of spring an increase in reproductive success between and a shift from density-dependent to density-independent reproduction 1981–2011 (Jensen et al., 2014). A reduction in spring snow cover between 2003–2006 resulted in earlier breeding (Madsen et al., 2007) and higher number of breeding pairs were observed between 2003–2006 and 2003–2014 (Anderson et al., 2015; Madsen et al., 2007). Moreover, reduction in spring snow cover increase in reproductive success (2003–2006), (2000–2011) (Jensen et al., 2014; Madsen et al., 2007). Overall, the pink footed geese might be one of the winners of climate change, at least in short term (Descamps et al., 2017a)

27.2. Status and Population Trends

West Greenland

Areas	Abundance	Status, change	Trend (Short term~1 generation)	Category of change	Description: physiological,behavioral change	Climate variable & direction	Hunting
	No populations						

East Greenland

Areas	Abundance	Status, change	Trend (Short term~1 generation)	Category of change	Description: physiological,behavioral change	Climate variable & direction	Hunting
	2009: 364 000 (Boertmann et al., 2009).	**Range is expanding northwards** (Boertmann et al., 2009)	**Increased considerably,** doubled from 1988-2009 (Boertmann et al., 2009)				

27.3. Synopsis

Pink-footed geese may benefit from climate change in Greenland. We found moderate evidence for an increase in Greenland. And there is overwhelming generic evidence suggesting that populations are or might increase with a warming climate.

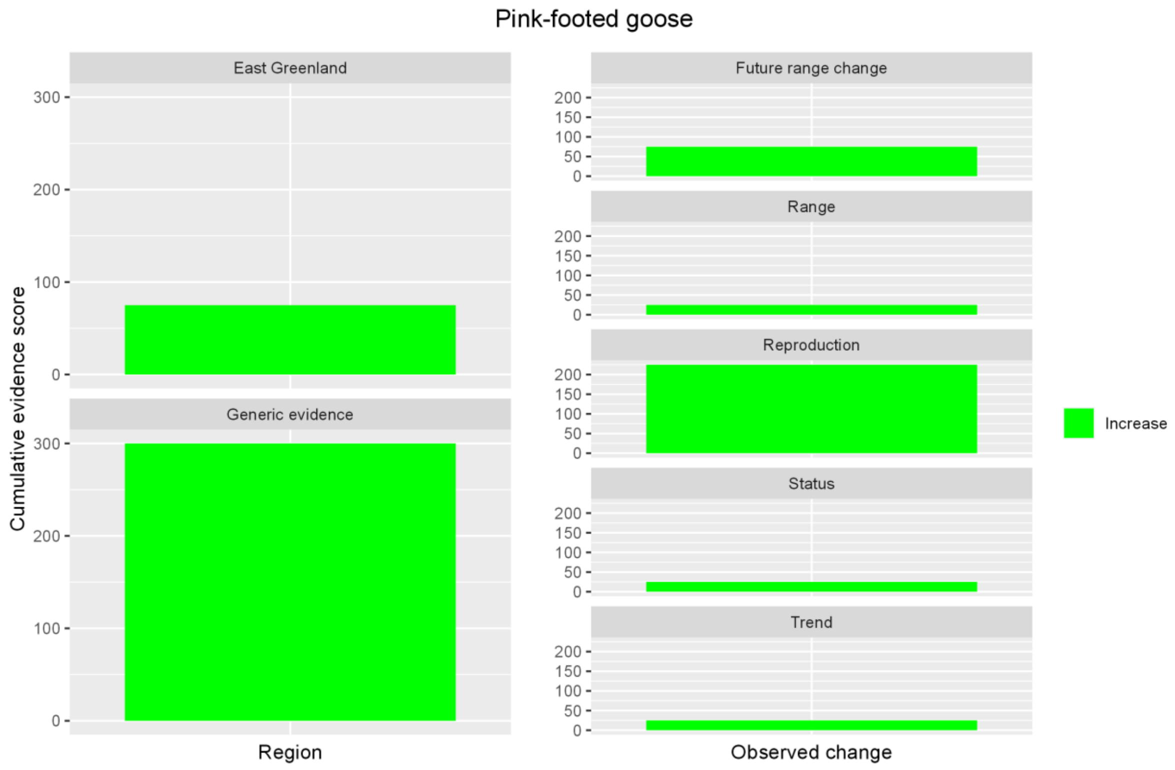


Figure 27.2 Cumulative evidence per region and aspects in which change is observed or expected.

27.4. Catch and Forecast

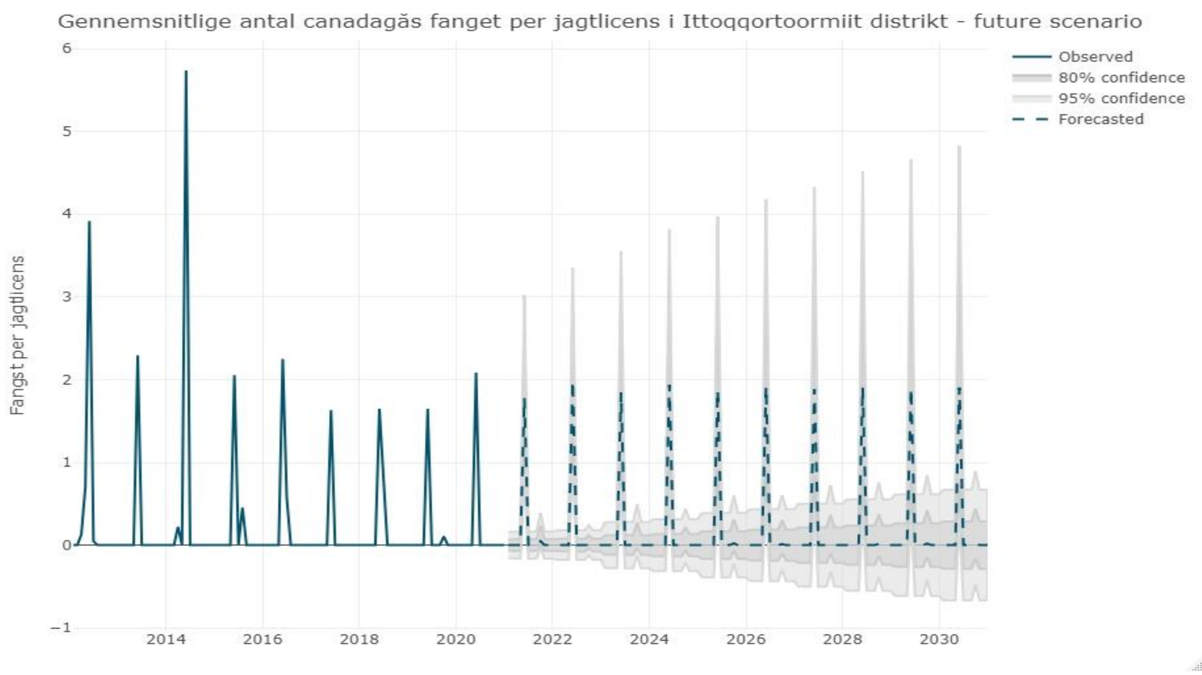


Figure 27.3. Average catch per hunter and forecast for Pink-footed goose in Ittoqortoormiit district.

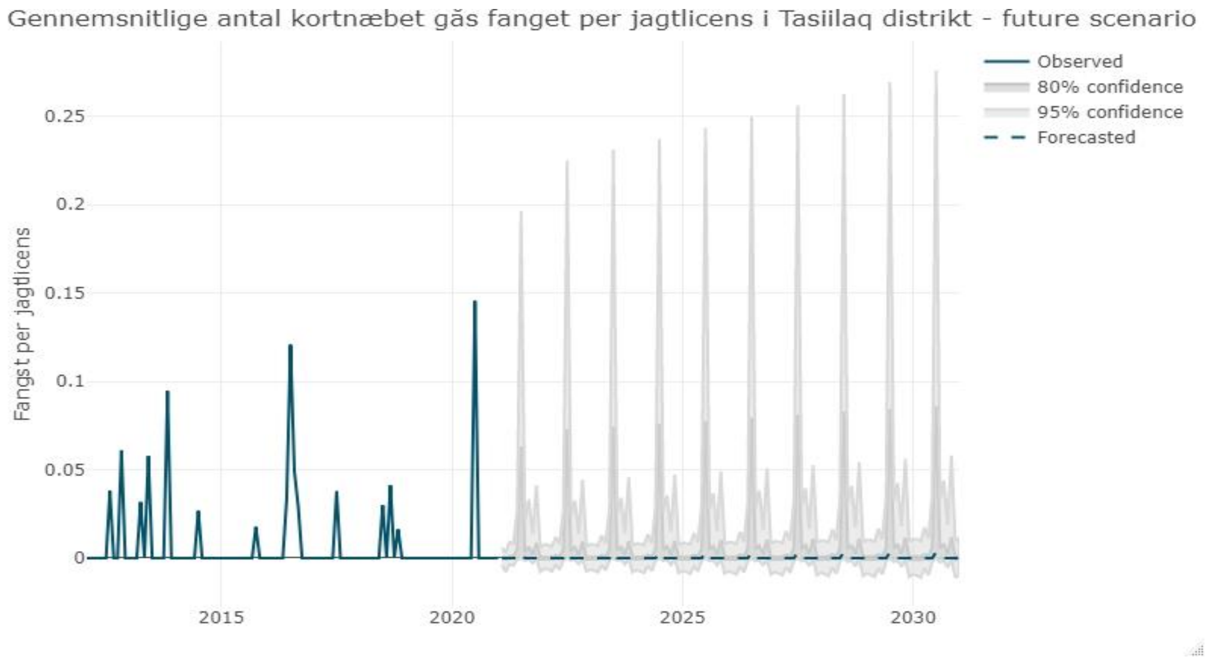


Figure 27.4. Average catch per hunter and forecast for Pink-footed goose in Tasiilaq district.

The forecasts are not reliable and data appears insufficient to produce a forecast. Nevertheless, the material was used as a basis for discussion.

Table 27.1. Average annual catch of Pink-footed goose per hunter in the period 2012-2020, in 2020 and 2030 (forecasted) and the percentage change in 2030 relative to 2012-2020 and 2020.

District	2012-2020	2020	2030	Δ 2012-2020	Δ 2020
Ittoqoortoormiit	2,91	2,08	1,92	-34%	-8%
Tasiilaq	0,09	0,15	0,00	-96%	-98%
Upernavik	0,04	0,00	0,01	-83%	Inf
Ilulissat					

27.5. Workshops with Hunter and Fishers Organizations

Scenario	Ittoqortoormiit	Tasiilaq	Upernavik	Ilulissat
Trend scenario	Uncertain identification. Expects catch of 2 per individual			
Alternative scenario	NA			

27.6. Interviews with Scientific Experts

-will follow-

27.7. Preliminary Future Scenarios

Scenario	Ittoqortoormiit	Tasiilaq	Upernavik	Ilulissat

Stock and catch trend scenario				
Underreporting adjustment scenario	Add two to each hunter			
Alternative actions scenario				

28. Common eider (*Somateria mollissima*)

Common eider	
Somateria mollissima	
Ederfugl	
Miteq siorartooq	

Breeds scattered throughout West Greenland, with the largest concentrations in Northwest Greenland (Merkel, 2004). The birds that overwinter in West Greenland's open water area in 1999 and 2017 were estimated at approx. 500.000 birds (Greenland Institute of Natural Resources, 2021). As a result of excessive exploitation, the breeding population in West Greenland experienced a significant decline throughout the 20th century (Greenland Institute of Natural Resources, 2021; Merkel, 2004). By the late 1990s, the estimated number of breeding pairs in West Greenland had plummeted to approximately 15.000 (Greenland Institute of Natural Resources, 2021; Merkel, 2004). However, a considerable decrease in catches following 2001 promptly reversed the negative trend, leading to multiple instances of doubling the stock size since then (Merkel, 2010). Although the precise current figure for the total breeding population in West Greenland remains unknown, many key breeding areas in Northwest Greenland have observed a consistent annual growth rate of 10-15% over several years (Merkel, 2010).

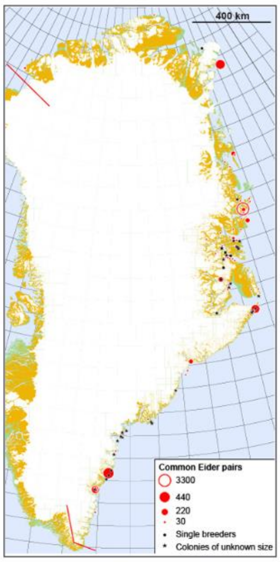


FIG. 4. Distribution and size of Common Eider breeding colonies in East and North Greenland. The black dots indicate observations of solitary nests and single females with chicks. Colonies with fewer than 30 pairs (n = 73) are shown with the symbol for 30 pairs, in order to be visible on the map.

Figure 28.1. Range distribution of the Common eider in Greenland.

The breeding population in Southeast Greenland was estimated at 1600 – 3200 pairs in 2008 (Merkel, 2010). Based on an aerial survey of pre-breeding birds in Northeast Greenland in May 2008, the breeding population here was estimated to be at least 13.000 pairs (Boertmann et al., 2009). In 2018, results from all the colonies reported many fewer (6.000 pairs), which indicates many unknown breeding sites or perhaps a large non-breeding segment of the population (Boertmann et al., 2020).

28.1. Climate Change

In East Greenland, common eiders have extended their breeding range more than two latitudinal degrees towards the north (more than 200 km northwards) since the 1980s (Boertmann et al., 2020). They have now reached areas where no breeding seabirds were observed before (Boertmann et al., 2020). In Iceland, females laid earlier following mild winters, and that year-to-year variation in the number of nests was related to the temperature during the breeding season 2 years previously (D'Alba et al., 2010). Milder summers had positive effects on breeding success and offspring survival and eiders could benefit from a general warming of the climate in this part of their range (D'Alba et al., 2010).

In the high Artic, a high-infection intensity of eiders with cestodes and acanthocephalans was recorded, which seems to have a negative effect on the bird population (Galaktionov et al., 2021). The transmission of helminths is likely promoted by climate warming in the Arctic (Galaktionov et al., 2021).

The breeding dynamics of common eiders (*Somateria mollissima*) in Hudson Bay are intricately tied to sea ice distribution and the timing of its breakup and freeze-up (Mallory et al., 2010). These factors determine the availability and spatial distribution of open water, which is crucial for feeding (Mallory et al., 2010). For eiders, earlier ice breakup allows them to gain earlier access to benthic molluscs, which are vital for acquiring nutrient reserves before breeding (Mallory et al., 2010). Warmer temperatures also benefit the non-migratory eider population in southern Hudson Bay by providing more open water, including larger polynyas and floe edges (Mallory et al., 2010). These expanded areas of open water facilitate the gathering of food supplies necessary for their survival during the winter months (Mallory et al., 2010). In Svalbard, reduced spring sea ice concentration hasw led to a higher number of breeding pairs between 1981–2011 (Hanssen et al., 2013). An increase in air temperature was associated with lower energetic costs of incubation in the period 2012–2014 (Høyvik Hilde et al., 2016).

28.2. Hunting

A high harvest in Greenland during 1993-2000, with a reported annual winter harvest of 55.000-70.000 eiders, compromised the sustainable use of the northern common eider population and led to a steep decline of populations (Gilliland et al., 2009; Merkel, 2004). Eider is still the most frequent catch object in Greenland. Hunting yield has been around 20.000 – 30.000 birds per year (Greenland Institute of Natural Resources, 2021).

28.3. Status and Population Trends

<u>West Greenland</u>

Areas	**Abundance**	**Status, change**	**Trend (Short term~1 generation)**	**Category of change**	**Description: physiological,behavioral change**	**Climate variable & direction**	**Hunting**
West Greenland	**500000** (Greenland Institute of Natural Resources, 2021) **South-west Greenland: 231 651 birds (95% CI: 194 065276 517)** (Merkel et al., 2019)	**Declined** (Merkel, 2004)	**Increasing** (Merkel, 2010). **density was still 42% higher in 2017 then 1999** (Merkel et al., 2019)				

<u>East Greenland</u>

Areas	**Abundance**	**Status, change**	**Trend (Short term~1 generation)**	**Category of change**	**Description: physiological,behavioral change**	**Climate variable & direction**	**Hunting**

East Greenland	**2018: Fewer (6000 pairs), (indicates many unknown breeding sites or a large non-breeding segment of the population)** (Boertmann et al., 2020)	**Expanding , extended their breeding range more than two latitudinal degrees towards the north from 2003-2018** (Boertmann et al., 2020)	**unknown**				

28.4. Synopsis

The common eider may benefit from climate change in Greenland. We found strong evidence for an increase of common eider in East and West Greenland. Moreover, there is strong generric evidence for an increase in this species.

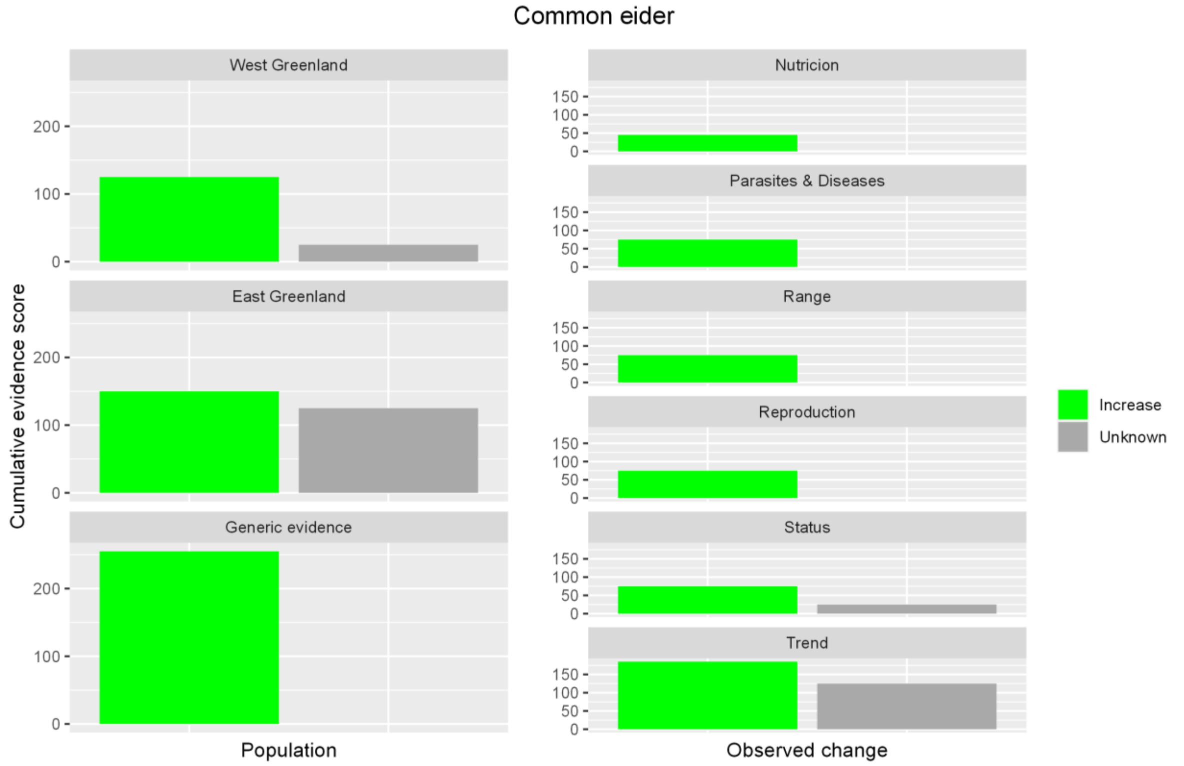


Figure 28.2 Cumulative evidence per region and aspects in which change is observed or expected.

28.5. Catch and Forecast

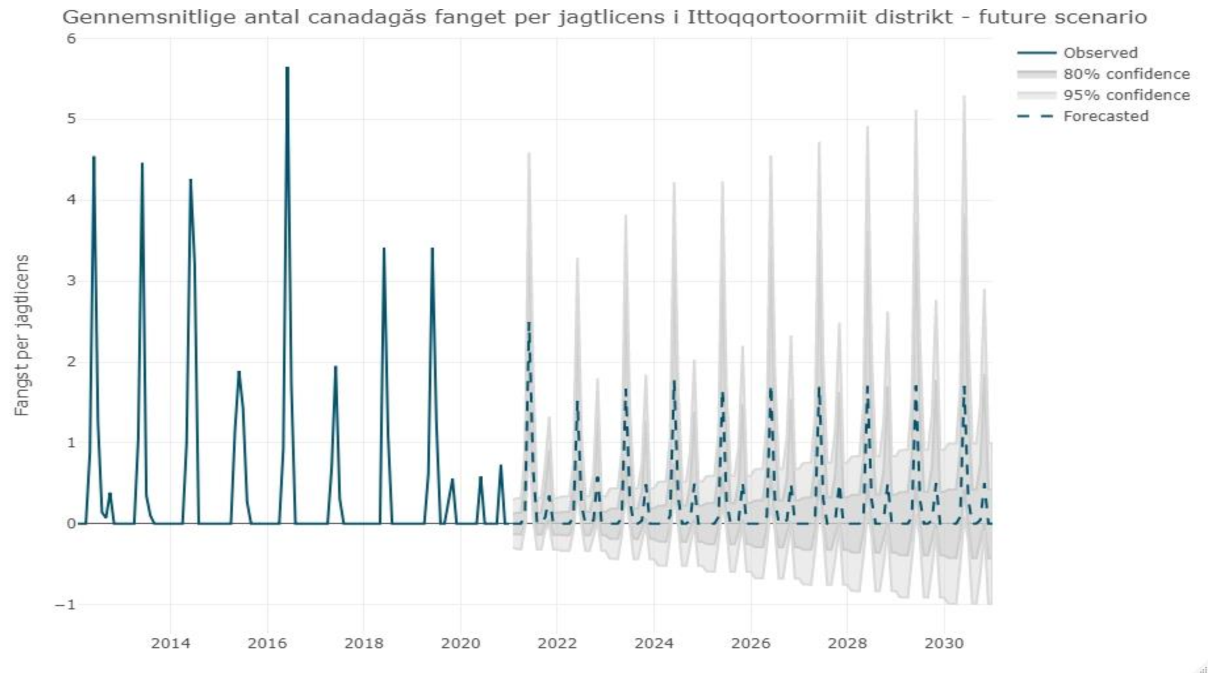


Figure 28.3. Average catch per hunter and forecast for Common eider in Ittoqortoormiit district.

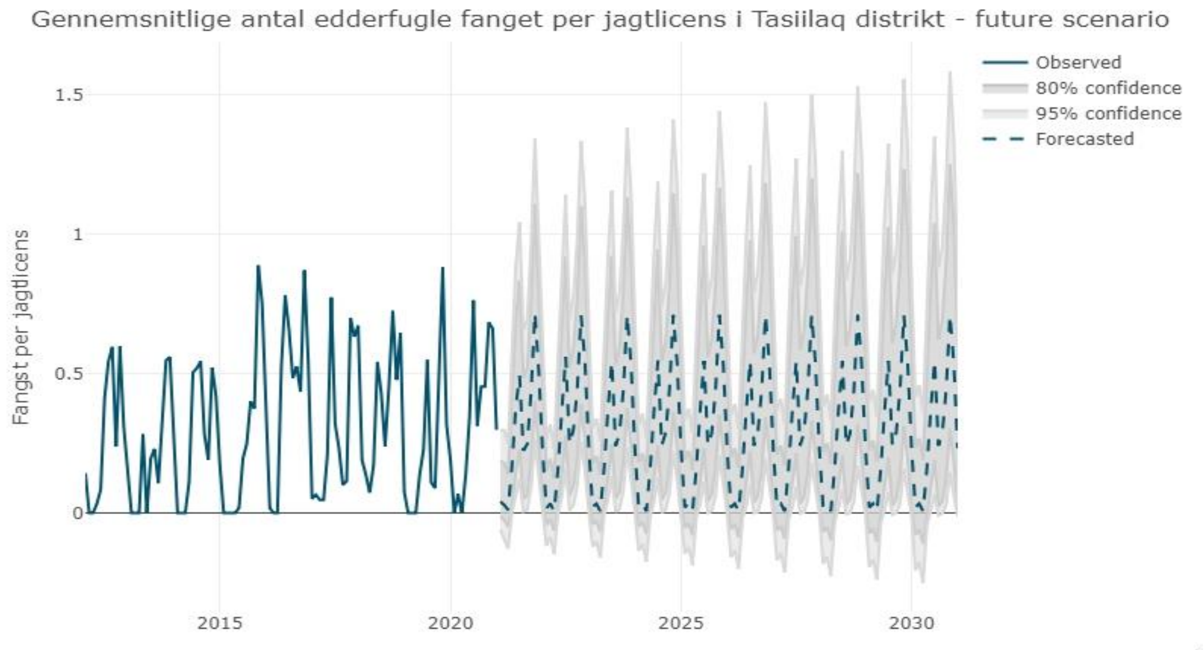


Figure 28.4. Average catch per hunter and forecast for Common eider in Tasiilaq district.

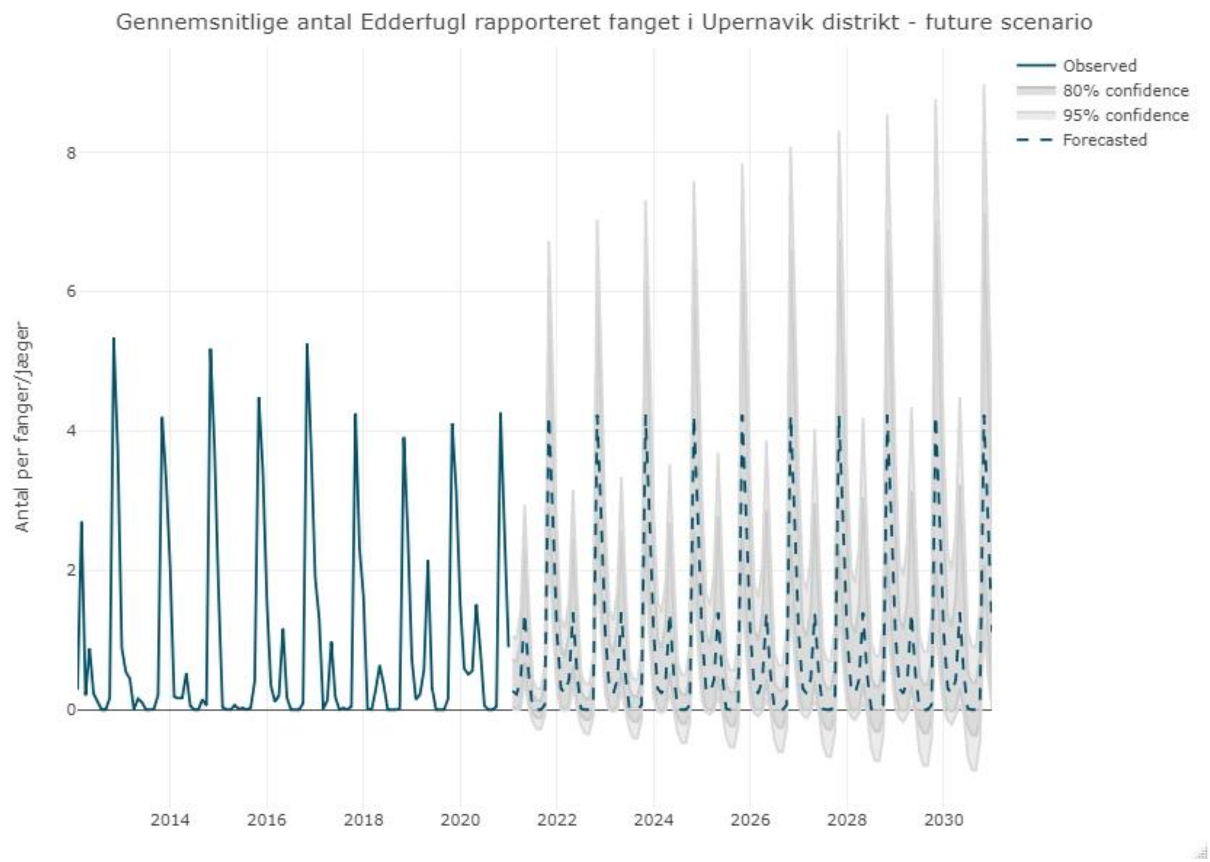


Figure 28.5. Average catch per hunter and forecast for Common eider in Upernavik district.

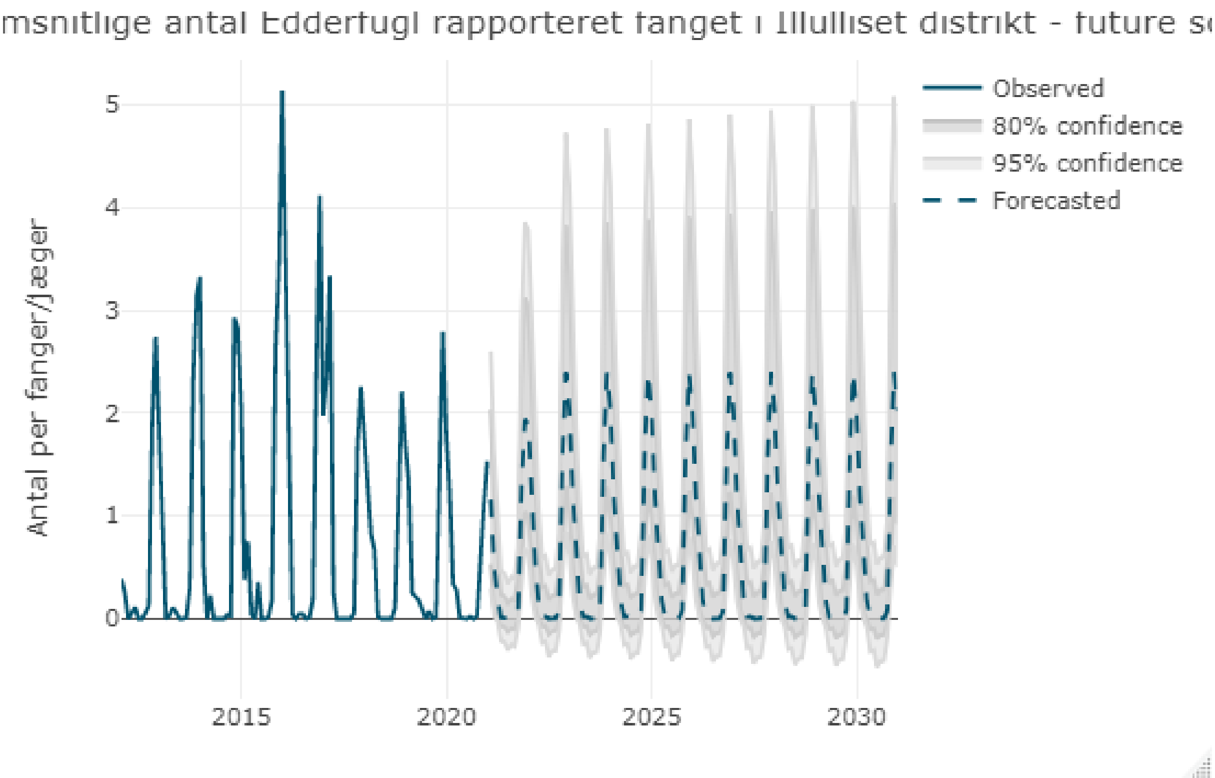


Figure 28.6. Average catch per hunter and forecast for Common eider in Ittoqortoormiit district.

The forecasts are not reliable. Nevertheless, the material was used as a basis for discussion.

Table 28.1. Average annual catch of Common eider per hunter in the period 2012-2020, in 2020 and 2030 (forecasted) and the percentage change in 2030 relative to 2012-2020 and 2020.

District	2012-2020	2020	2030	Δ 2012-2020	Δ 2020
Ittoqoortoormiit	5,52	1,13	2,63	-52%	101%
Tasiilaq	4,74	5,56	3,59	-24%	-36%
Upernavik	11,57	11,83	11,04	-5%	-7%
Ilulissat	9,55	5,23	8,06	-16%	54%

28.6. Workshops with Hunter and Fishers Organizations

Scenario	Ittoqortoormiit	Tasiilaq	Upernavik	Ilulissat
Trend scenario	Fluctuations in catch due to reports of bird flu. Numbers are stable	More observed. But little interest in catching	Rapidly increasing population starting to stay during winter. Part-time hunters underreport catch. Closed season when they are here.	More seen. But hunt is decreasing due to long term effects of restrictions.
Alternative scenario	NA	NA	NA	Collection and trade of down

28.7 Interviews with Scientific Experts

-will follow-

28.8. Preliminary Future Scenarios

Scenario	Ittoqortoormiit	Tasiilaq	Upernavik	Ilulissat
Stock and catch trend scenario	Stable compared to the 2012-20 average	Stable compared to the 2012-20 average	+10% compared to 2012-20 average	-5% compared to 2012-20 average
Underreporting adjustment scenario			Adjust catch of part-time hunters to same numbers as occupational hunters	
Alternative actions scenario				Add income for down trade to occupational

				hunters (yet unclear)

29. Thick-billed murre/Brünnich's guillemot (*Uria lomvia*)

Thick-billed murre/Brünnich's guillemot	
Uria lomvia	
Polarlomvie	
Appat	

The largest and most stable populations are found in the Qaanaaq area (over 60 % of the Greenland breeding population) and northern Upernavik (about 25 %). Today, these breeding sites contain the largest part of Greenland's population (Greenland Institute of Natural Resources, 2021). The guillemot colonies in the rest of the country are much smaller, and most are in decline (Greenland Institute of Natural Resources, 2021). The situation is particularly critical in Disko Bay, southern Upernavik, South Greenland and East Greenland (Merkel et al., 2016) (see Figure 29.1) (Merkel, 2016).

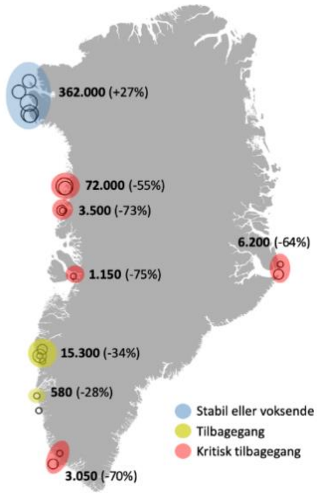


Figure 29.1. The existing 20 guillemot colonies in Greenland and the current population size (2017, counted individuals) in different sub-areas. Population changes (%) in the period 1990 - 2017 are given for the same sub-areas. At Uummannaq one colony became extinct Blue: stable, yellow: decline, red: dramatically decline

The only remaining colony in central West Greenland, in Disko Bay, has declined by 72% since 1980 and 2012, likely due to oceanographic changes (Merkel et al., 2016). In Southwest Greenland, the total abundance in the coastal survey area was 1.821 (95% CI: 1014–3271) in 2017, compared to 125.439 (95% CI: 78 091–201 497) in 1999 (Merkel et al., 2019).

Only two large colonies in East Greenland, both of which are located at the Scoresby Sound polynya (Boertmann et al., 2020). Both show steady declines. In the latest survey in 2018, the colony at Raffles numbered 1.600 pairs, and the colony on Kap Brewster numbered 2.700 pairs (Greenland Institute of Natural Resources, unpubl. data) (Boertmann et al., 2020).

29.1. Climate Change

The timing of breeding was positively correlated with summer ice cover, determined by winter and spring temperatures, in two Arctic colonies close to the northern and southern limits of the species' range in the Canadian Arctic. Spring temperatures also modified the effects of ice conditions on the timing of breeding (Gaston et al., 2005). In regions with low Arctic waters, a decrease in summer ice cover resulted in advancement in the date of egg-laying and a correlation between reduced ice cover and lower chick growth rates and decreased adult body mass was observed (Gaston et al., 2005). This indicates that a decline in summer ice extent has a detrimental impact on reproduction in this area (Gaston et al., 2005).

On the other hand, in the High Arctic, no significant trend was observed in summer ice cover, and there was no detectable change in the timing of breeding (Gaston et al., 2005). Reproduction in this region is less successful during years of late ice formation compared to years with early ice break-up (Gaston et al., 2005). Based on these trends, it is expected that ongoing warming will have a favourable effect on birds breeding at the northern limits of their range while negatively affecting reproduction for those located at the southern margins (Gaston et al., 2005).

In the Arctic and sub-Arctic regions, populations increased most rapidly when SST warmed slightly and showed negative trends with large temperature shifts in either direction (Irons et al., 2008). This pattern was replicated during two climate oscillations in 1977 and 1989 (Irons et al., 2008).

Negative population trends in seabirds presumably indicate the alteration of underlying food webs (Irons et al., 2008). Increasing storms due to climate change might have energetic consequences due to a change in diving behaviours in storms (Finney et al., 1999). The breeding dynamics in Hudson Bay are intricately tied to the distribution of sea ice and the timing of its breakup and freeze-up (Mallory et al., 2010). These factors determine the availability and spatial distribution of open water, which is crucial for feeding. For the murres, which primarily consume fish, earlier ice breakup leads to a mismatch between their breeding timing and the peak abundance of food resources (Mallory et al., 2010). Thus far, these birds have not adjusted their breeding phenology to keep pace with the rapid environmental changes. However, towards the end of the season, delayed freeze-up extends the duration for which the birds can remain in the Bay (Mallory et al., 2010). In Svalbard, an increase in sea temperature and a weakening of the subpolar gyre (winter grounds) decrease in population size between 1988–2010 (Descamps et al., 2013). Increases in winter air temperature (summer grounds) were associated with a higher tick prevalence in 2007–2012 (Descamps, 2013).

29.2. Status and Population Trends

West Greenland

Areas	Abundance	Status, change	Trend (Short term~1 generation)	Category of change	Description: physiological,behavioral change	Climate variable & direction	Hunting
West Greenland	**2017: 457580** (Greenland Institute of Natural Resources, 2021)		**Despite Upernavic, all popuations on decline from 1990-2017 (-308%)** (Greenland Institute of Natural Resources, 2021)				

East Greenland

Areas	Abundance	Status, change	Trend (Short term~1 generation)	Category of change	Description: physiological,behavioral change	Climate variable & direction	Hunting
East Greenland	2018:4300 (Greenland Institute of Natural Resources, unpubl. data)		Steady Decline (-64% from 1990-2017) Greenland Institute of Natural Resources)				

29.3. Synopsis

We found moderate evidence of a decline in the Artic, sub-Artic and low Arctic and strong evidence of a decline in East and West Greenland. There is overwhelming generic evidence that this species is or will decline in Greenland. However, we found moderate evidence that populations in the High Arctic will remain stable and moderate evidence that populations in the Arctic and Subarctic will increase. We found strong evidence for an increase in the colony located in the Upernavik region.

Figure 29.2 Cumulative evidence per region and aspects in which change is observed or expected.

29.4. Catch and Forecast

Piniarneq does not differentiate between lomvie (common guilemot) and polarlomvie (thick-billec murre) and it is likely that these species are reported interchangeably.

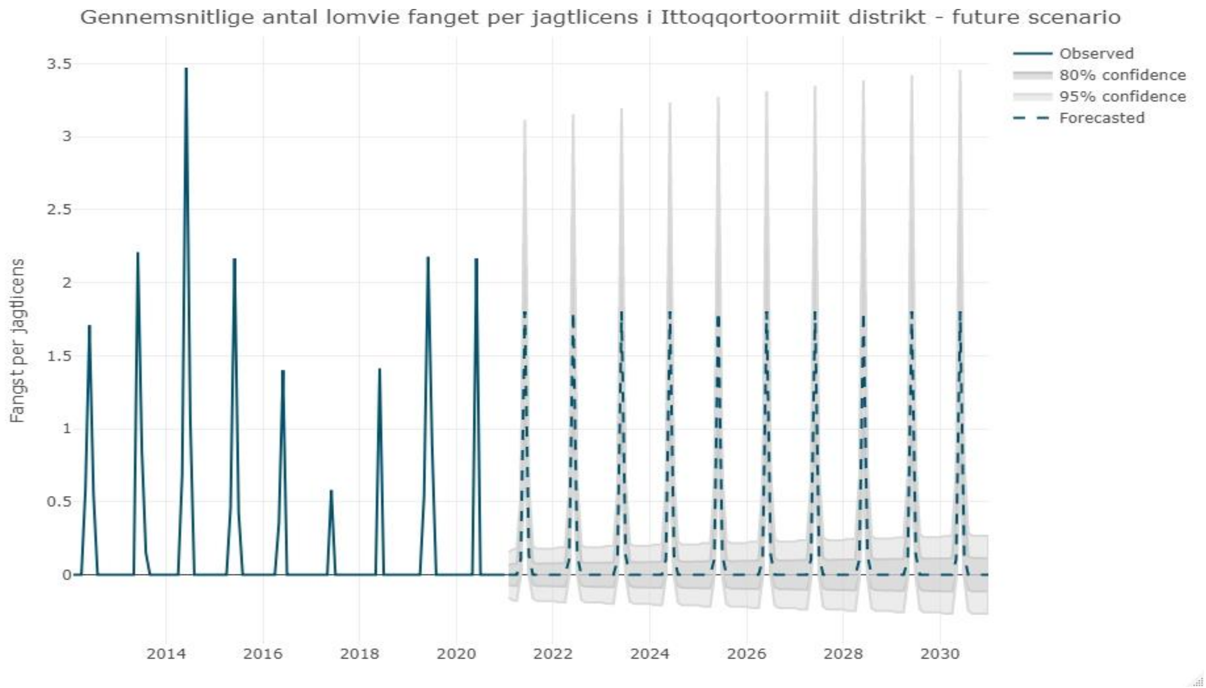


Figure 29.3. Average catch per hunter and forecast for Thick-billed murre in Ittoqortoormiit district.

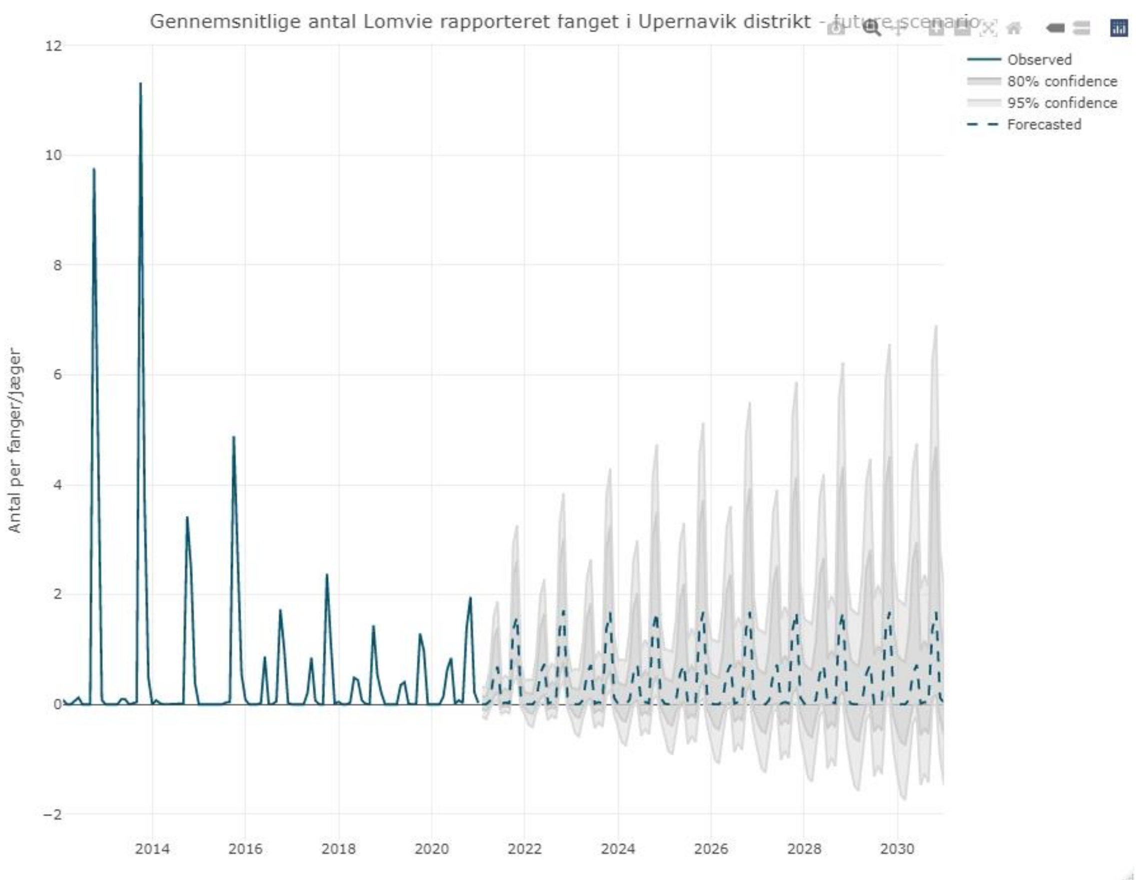


Figure 29.4. Average catch per hunter and forecast for Thick-billed murre in Upernavik district.

The forecasts are not reliable. Nevertheless, the material was used as a basis for discussion.

Table 29.1. Average annual catch of Thick-billed murre per hunter in the period 2012-2020, in 2020 and 2030 (forecasted) and the percentage change in 2030 relative to 2012-2020 and 2020.

District	2012-2020	2020	2030	Δ 2012-2020	Δ 2020
Ittoqoortoormiit	2,65	2,17	2,04	-23%	-6%
Tasiilaq					
Upernavik	7,24	5,32	4,63	-36%	-13%
Ilulissat					

29.5. Workshops with Hunter and Fishers Organizations

Scenario	Ittoqortoormiit	Tasiilaq	Upernavik	Ilulissat
Trend scenario	Stable catch for own consumption. Fewer breeding birds than previous	Little interest in hunting this species	Declining catch due to restrictions and lack of appropriate ammunition	Dissatisfaction with regulations leads to unregistered catch – estimated catch of 10-20 each that may be unreported
Alternative scenario	NA	NA	NA	NA

29.6. Interviews with Scientific Experts

-will follow-

29.7. Preliminary Future Scenarios

Scenario	Ittoqortoormiit	Tasiilaq	Upernavik	Ilulissat
Stock and catch trend scenario	Stable compared to the 2012-20 average	Stable compared to the 2012-20 average	+10% compared to 2012-20 average	-5% compared to 2012-20 average
Underreporting adjustment scenario			Adjust catch of part-time hunters to same numbers as occupational hunters	
Alternative actions scenario				Add income for down trade to occupational hunters (yet unclear)

30. Mallard (*Anas platyrhynchos*)

<table>
<tr><td>Mallard</td><td rowspan="4"></td></tr>
<tr><td>Anas platyrhynchos</td></tr>
<tr><td>Gråand</td></tr>
<tr><td>Qeerlutooq</td></tr>
</table>

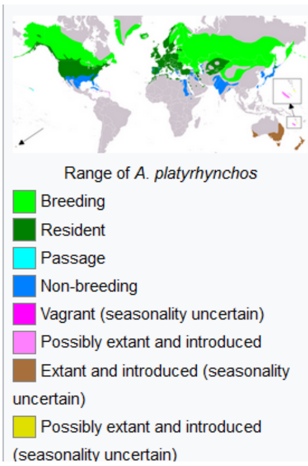


Figure 30.1 Range of mallard

Breeds throughout the temperate and subtropical Americas, Eurasia, and North Africa, and has been introduced to New Zealand, Australia, South America and South Africa (Fig. 30.1). In 2018, Mallards were observed throughout the coastal survey area, and when common in the coastal area, they were usually also frequently observed in the adjacent fjords (Merkel et al., 2019). The key wintering locations for mallards in 2017 included the coastal region and fjords surrounding Kangaatsiaq (approximately 68°N), Nuuk (around 64°N), and Julianehåbsbugten (Merkel et al., 2019). Additionally, the area south of Nuuk, around 63°N, appears significant for mallard wintering.

The estimated total abundance of mallards in southwest Greenland during the winter of 2017 was 7.606 birds (95% CI: 4701–13,442), with at least 1.821 birds observed in the fjords (Merkel et al., 2019). Notably, no mallards were observed north of approximately 65°N or in fjords during the coastal survey conducted in 1999 (Merkel et al., 2019).

30.1. Climate Change

Data on within-winter (December–February) movements (1952–2004) suggest that long-term winter warming in Europe reduces the distance of within-winter movements in mallards (Sauter et al., 2010). Mallards are considered flexible breeders that can quickly adapt to fluctuating environments (Guillemain et al., 2013). Positive relationships between warmer and drier springs and duck nest success and changes in winter distribution were observed in the American prairies (Guillemain et al., 2013).

30.2. Status and Population Trends

<u>West Greenland</u>

Areas	Abundance	Status, change	Trend (Short term~1 generation)	Category of change	Description: physiological,behavioral change	Climate variable & direction	Hunting
	unknown	unknown	unknown				

East Greenland

Areas	Abundance	Status, change	Trend (Short term~1 generation)	Category of change	Description: physiological,behavioral change	Climate variable & direction	Hunting
	2017: 7606 birds (95% CI: 4701–13 442) in south-west Greenland (Merkel et al., 2019)	Expanding	Increasing				

30.3. Synopsis

We found overwhelming evidence of an increase in Mallards in East Greenland, while evidence for West Greenland was absent. We found negligible generic evidence of an increase in Mallards in the region.

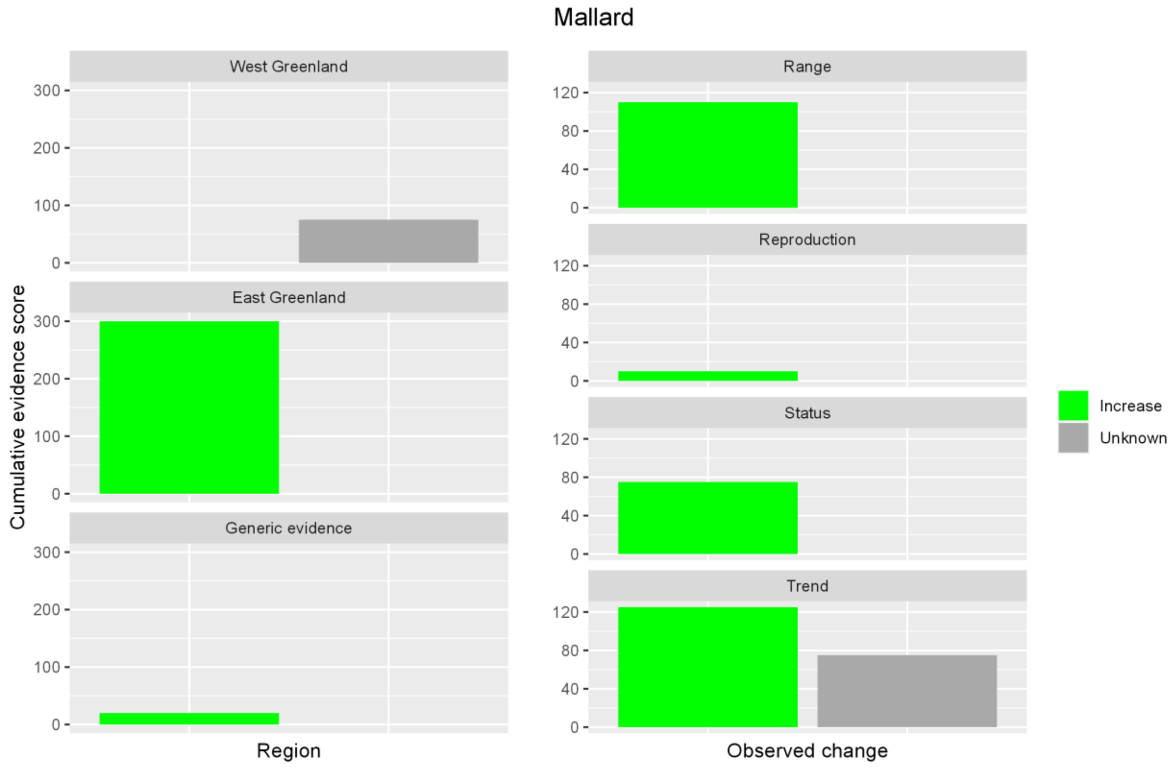


Figure 30.2. Cumulative evidence per region and aspects in which change is observed or expected.

30.4. Catch and Forecast

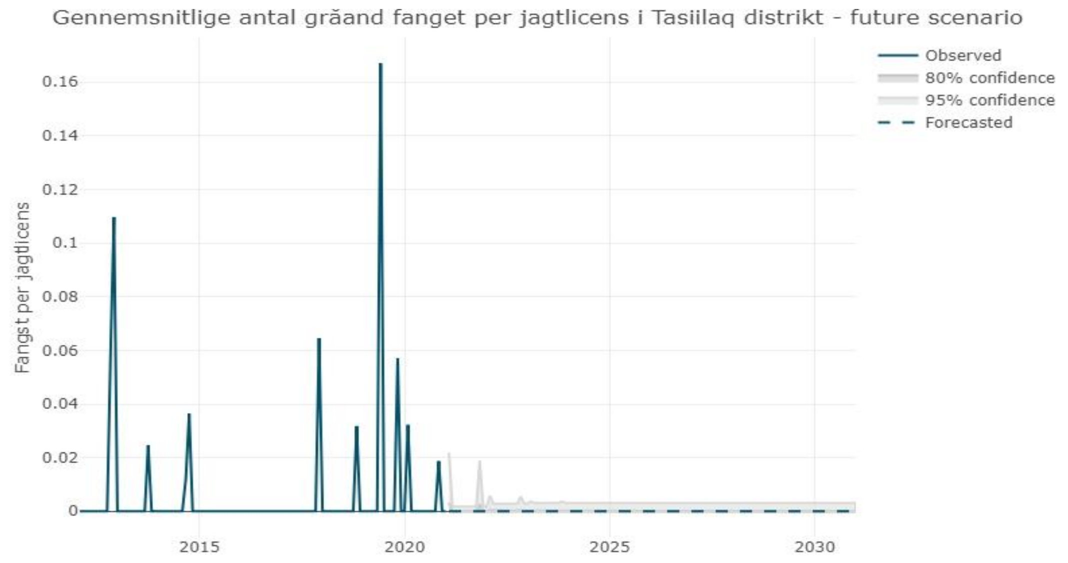


Figure 30.3. Average catch per hunter and forecast for Mallard in Tasiilaq district.

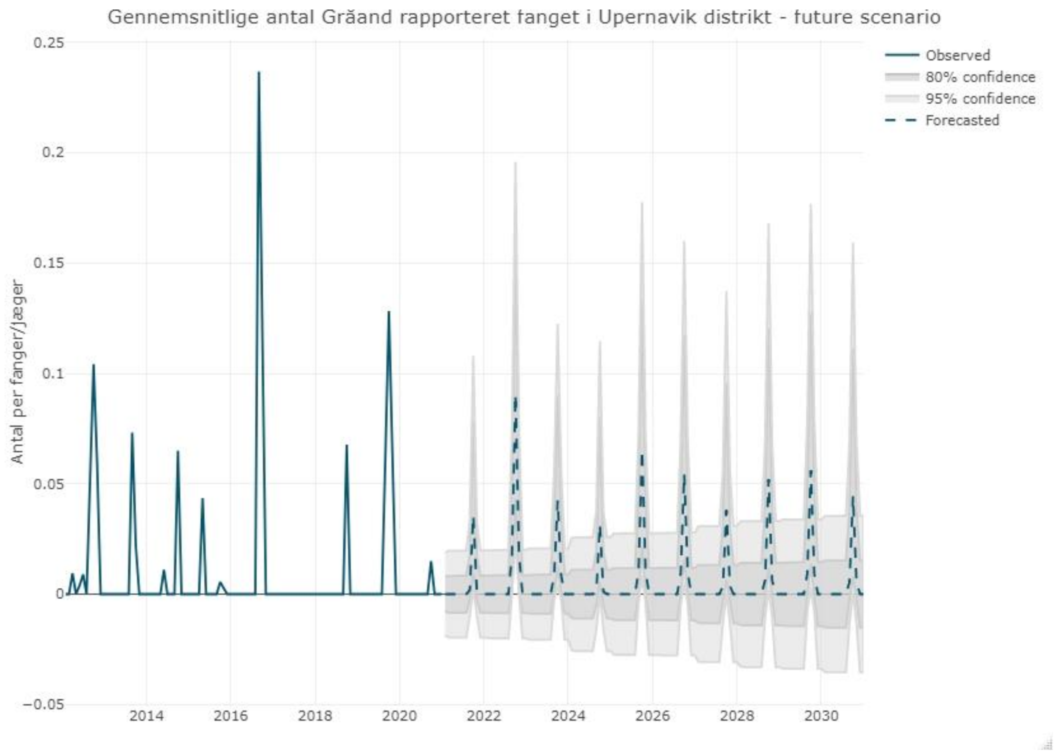


Figure 30.4. Average catch per hunter and forecast for Mallard in Upernavik district.

The forecasts are not reliable. And data is insufficient to produce a forecast for Ilulissat. Nevertheless, the material was used as a basis for discussion.

Table 30.1. Average annual catch of Mallard per hunter in the period 2012-2020, in 2020 and 2030 (forecasted) and the percentage change in 2030 relative to 2012-2020 and 2020.

District	2012-2020	2020	2030	Δ 2012-2020	Δ 2020
Ittoqoortoormiit					
Tasiilaq	0,71	0,05	0,00	-100	-100

Upernavik	0,13	0,01	0,06	-56,29	272,20
Ilulissat					

30.5. Workshops with Hunter and Fishers Organizations

Scenario	Ittoqortoormiit	Tasiilaq	Upernavik	Ilulissat
Trend scenario				Not targeted because it occurs in the city. Bycatch occurs
Alternative scenario				NA

30.6. Interviews with Scientific Experts

-will follow-

30.7. Preliminary Future Scenarios

Scenario	Ittoqortoormiit	Tasiilaq	Upernavik	Ilulissat
Stock and catch trend scenario		2012-20 average	2012-20 average	2012-20 average
Underreporting adjustment scenario				
Alternative actions scenario				

31. Black-legged kittiwake (*Rissa tridactyla*)

Black-legged kittiwake	
Rissa tridactyla	
Ride	
Taateraq	

In 2008, the total Greenland breeding population was estimated to be about 110.000 pairs in 155 colonies, with the vast majority and largest colonies found along the west coast (Labansen et al., 2010). There is an indication that the population has previously been slarger, but there are no good data to assess the overall population development during the 20th century (Greenland Institute of Natural Resources, 2021). The breeding population in the Qaanaaq area appears healthy, whereas the rest of the west coast has experienced declines, especially the north-western region (in the area from Upernavik to Kangaatsiaq) (Labansen et al., 2010). In the 1999 survey, observations were made regularly between 62° and 66°N (47 sightings, 3.232 individuals) and in high densities in the fjord system around Maniitsoq (Boertmann et al., 2020). In East Greenland, the equestrian population has declined recently. In 2017, only a single observation of this species was made close to Maniitsoq (65.3°N).

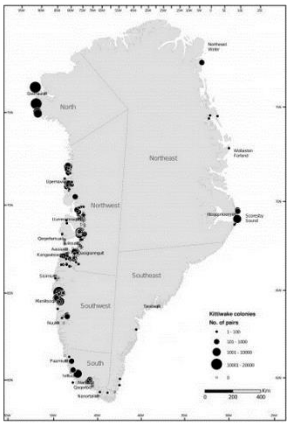


Figure 31.1 The distribution of 246 colonies of kittiwake (Rissa tridatyla) in West Greenland and 16 colonies in East Greenland. The size of the most recently visited colonies is indicated by the size of the circle. Abandoned colonies are indicated by empty circles. Source: Labansen et al., 2009)

31.1. Climate Change

Kittiwakes are pelagic surface feeders, which makes them more vulnerable to reduced food availability, particularly in the breeding season, and in many populations, reductions in breeding populations have occurred after shifts in marine ecosystems (Labansen et al., 2010). The abrupt warming of sea-surface temperature in the 1990s coincided with a steep kittiwake population decline. Periods of moderate warming in sea temperatures did not seem to affect kittiwake dynamics (Descamps et al., 2017b; Labansen et al., 2010). These rapid changes in ocean temperatures have often been assumed to be at the origin of regime shifts in pelagic ecosystems, ultimately altering food webs and the lower availability of forage fish (i.e., kittiwake main prey) (Descamps et al., 2017b). In Svalbard, an increase in sea temperature (summer grounds) has led to earlier breeding (1970–2008) (Moe et al., 2009).

31.2. Hunting

The catch of kittiwake in Greenland has steadily declined since the late 1990s (Greenland Institute of Natural Resources, 2021). In 1993-2001 the catch amounted to about 49.000 individuals per year. When a spring hunting ban was introduced, the annually reported catch dropped to around 8.000 individuals after 2002 and to 4.000 birds since 2017 (Greenland Institute of Natural Resources, 2021).

31.3. Status and Population Trends

West Greenland

Areas	**Abundance**	**Status, change**	**Trend (Short term~1 generation)**	**Category of change**	**Description: physiological,behavioral change**	**Climate variable & direction**	**Hunting**
North (Qaanaaq population)	2008: 35 666 occupied nests (Labansen et al., 2010)		Small population decline of ca. 7% from 1987-2006 (Labansen et al., 2010)				
North-west	2008: 28 376 (Labansen et al., 2010)		Decrease of 39, 79 and 36% in number of AONs in Upernavik, Uummannaq and the Disko Bay area , Maniitsoq area, halved since 1977 (Labansen et al., 2010)				
South-west	2008: 33 376 (Labansen et al., 2010)						
south	2008: 103 348 (Labansen et al., 2010)		Decreased by 60% since the previous (1970–80s) counts (Labansen et al., 2010)				
West Greenland total	2008: 103 348 (Labansen et al., 2010)						

East Greenland

Areas	**Abundance**	**Status, change**	**Trend (Short term~1 generation)**	**Category of change**	**Description: physiological,behavioral change**	**Climate variable & direction**	**Hunting**
North-east	2008: 3537 (Labansen et al., 2010)		Likely improved (Labansen et al., 2010)				
South-east	2008: ca. 200 (Labansen et al., 2010)		Likely improved (Labansen et al., 2010)				
East Greenland	2018: Only a single observation (Merkel et al., 2019)		**Steep decline** (Merkel et al., 2019)				

31.4. Synopsis

We found weak evidence of a decline in the North (Qaanaaq population), in the whole North-West Greenland, in South Greenland and East Greenland. There was weak evidence for an increase in North-east and South-east Greenland. There is moderate generic evidence that this species will decline in Greenland.

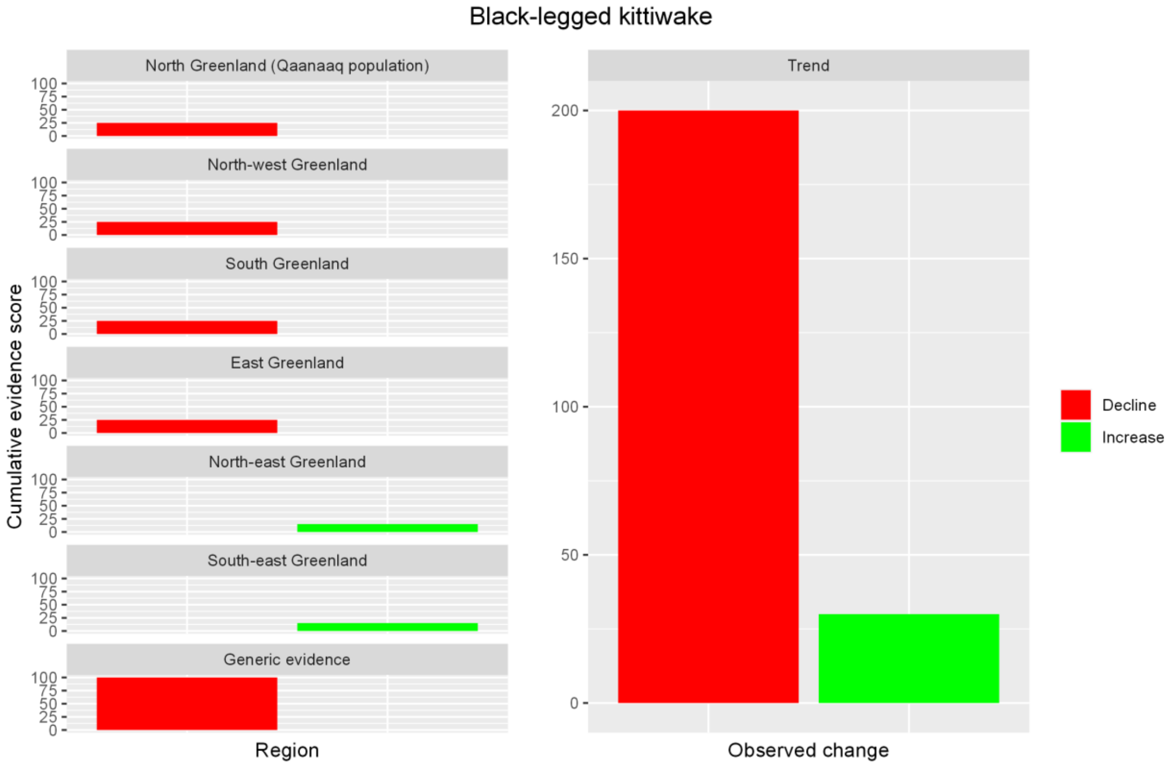


Figure 31.2. Cumulative evidence per region and aspects in which change is observed or expected.

31.5. Catch and Forecast

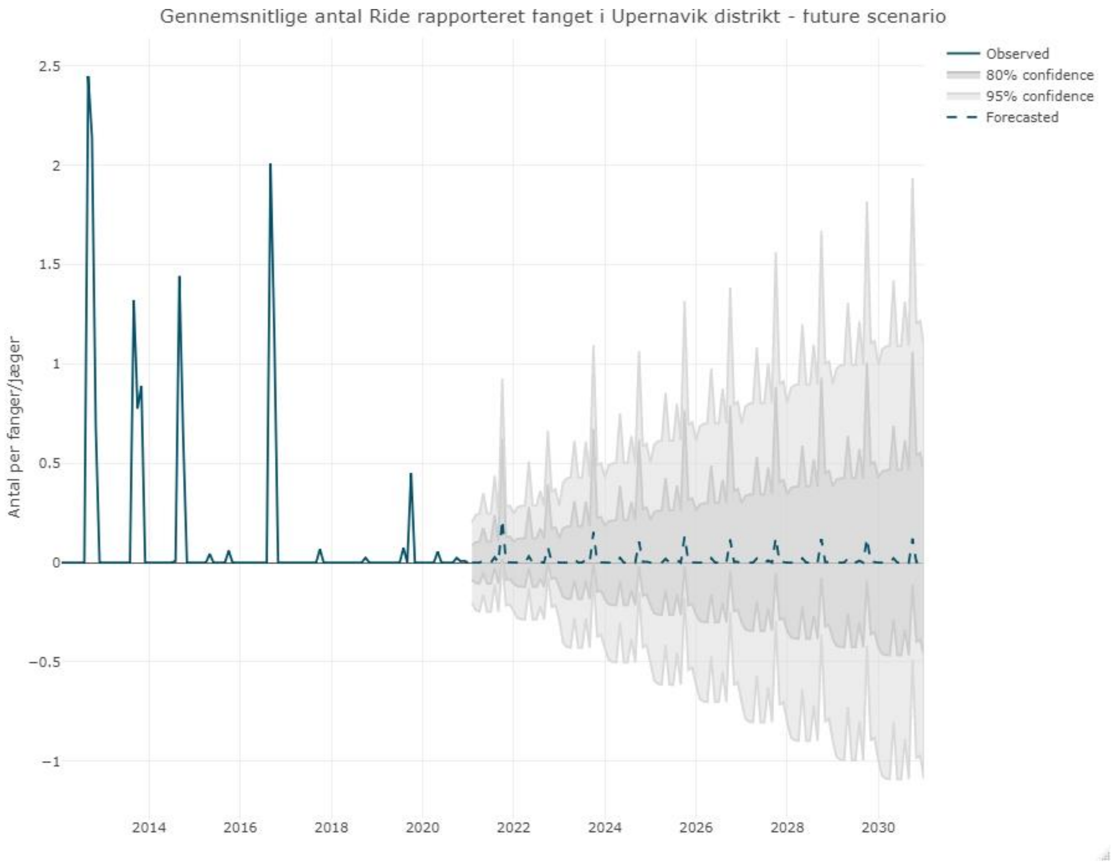


Figure 31.3. Average catch per hunter and forecast for Black-legged kittiwake in Upernavik district.

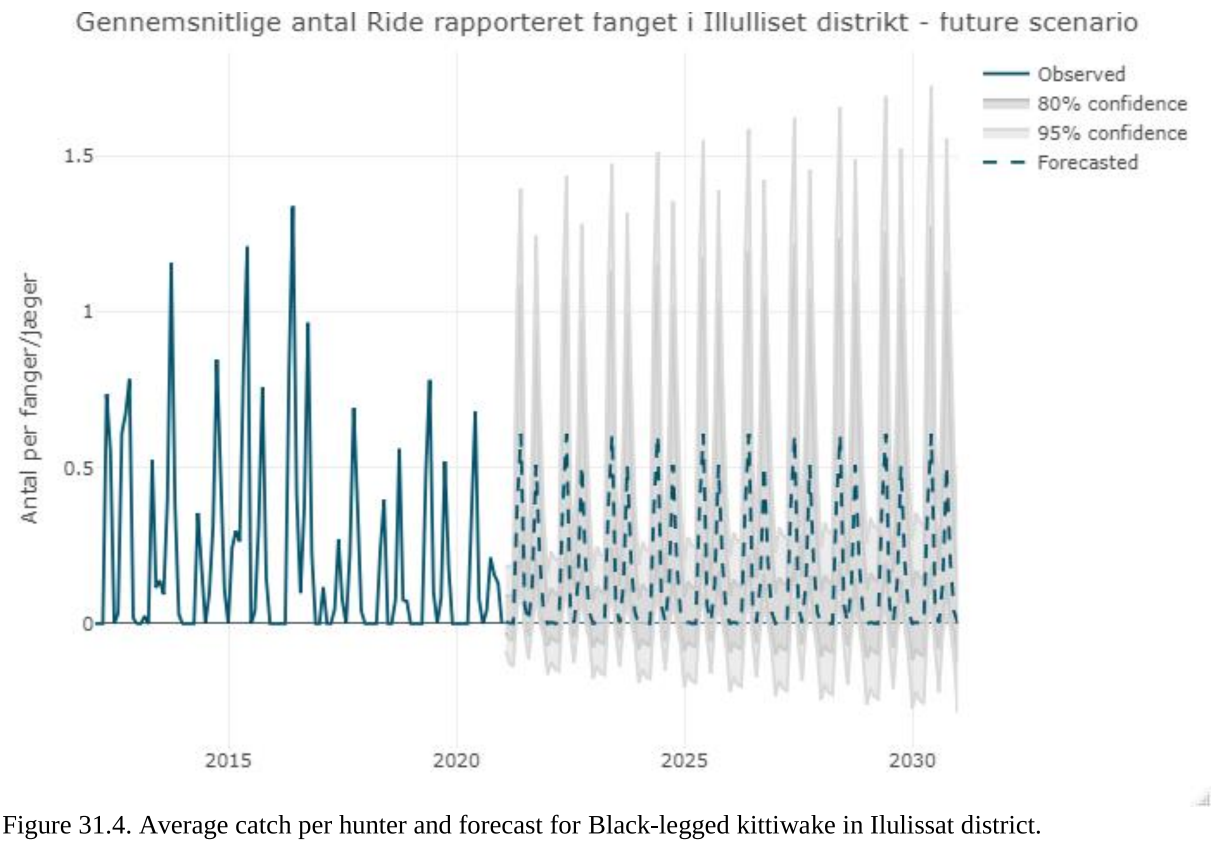


Figure 31.4. Average catch per hunter and forecast for Black-legged kittiwake in Ilulissat district.

The forecasts are not reliable. And data is insufficient to produce a forecast for Ilulissat. Nevertheless, the material was used as a basis for discussion.

Table 31.1. Average annual catch of Black-legged Kittiwake per hunter in the period 2012-2020, in 2020 and 2030 (forecasted) and the percentage change in 2030 relative to 2012-2020 and 2020.

District	2012-2020	2020	2030	Δ 2012-2020	Δ 2020
Ittoqoortoormiit					
Tasiilaq	0,30	0,37	0,27	-10%	-28%
Upernavik	1,59	0,10	0,16	-90%	67%
Ilulissat	2,67	1,65	1,93	-28%	17%

31.6. Workshops with Hunter and Fishers Organizations

Scenario	Ittoqortoormiit	Tasiilaq	Upernavik	Ilulissat
Trend scenario	Increasing numbers but not targeted	Not targeted	Not targeted	
Alternative scenario	NA	NA	NA	NA

31.7. Interviews with Scientific Experts

-will follow-

31.8. Preliminary Future scenarios

Scenario	Ittoqortoormiit	Tasiilaq	Upernavik	Ilulissat
Stock and catch trend scenario			-30% compared to 2012-20 average	-20 compared to 2012-20 average
Underreporting adjustment scenario				
Alternative actions scenario				

32. Common guillemot (*Uria aalge*)

Common guillemot	
Uria aalge	
Lomvie	
Appa	

Among the most abundant seabirds in the Northern Hemisphere exceeding 10 million adults (Tony and David, 2010). Global populations declined during the three decades from 1975-1981 to 2008-2012 (Gall et al., 2017). The majority of populations have shown declines due to high sensitivity to changes in environmental conditions (Tony and David, 2010).

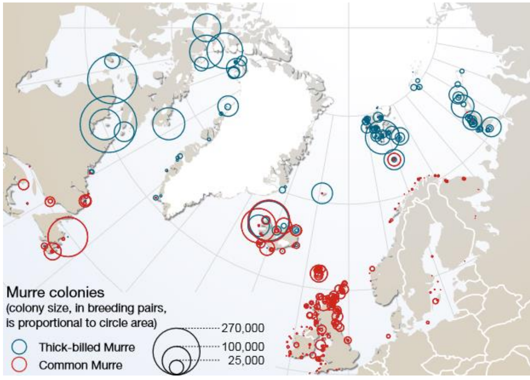


Figure 32.1. The distribution of thick-billed and common murre colonies in the North

32.1. Climate Change

Usually, populations of piscivorous and planktivorous surface-feeding seabirds, e.g., black-legged kittiwakes (*Rissa tridactyla*) and murres (*Uria spp.*), are more sensitive to climate change than diving planktivorous birds (Gall et al., 2017). Population trend data from around the Arctic has shown that common guillemot populations tended to show negative population trends where there was a large change in SST (Irons et al., 2008). Colony growth was most often positive, where conditions remained relatively stable (Irons et al., 2008). However, climate fluctuations affected the survival of bridled and non-bridled common guillemots differently (Reiertsen et al., 2012). In the Arctic and sub-Arctic regions, the temperate species, common murre (*Uria aalge*), showed the most rapid increase with moderate cooling and negative trends with large temperature shifts in either direction (Irons et al., 2008). This pattern was replicated during climate oscillations in 1977 and 1989 (Irons et al., 2008). Negative population trends in seabirds presumably indicate the alteration of the underlying food web) (Irons et al., 2008).

32.2. Status and Population Trends

<u>All populations</u>

Areas	Abundance	Status, change	Trend (Short term~1 generation)	Category of change	Description: physiological,behavioral change	Climate variable & direction	Hunting

	Unknown	**Unknown**	**Unknown**				

32.3. Synopsis

Trends for East and West Greenland are unknown. There is moderate evidence that Common guillemet are declining in the Artic and moderate evidence for decline in the Artic and sub-Arctic. We also found moderate generic evidence for a decline.

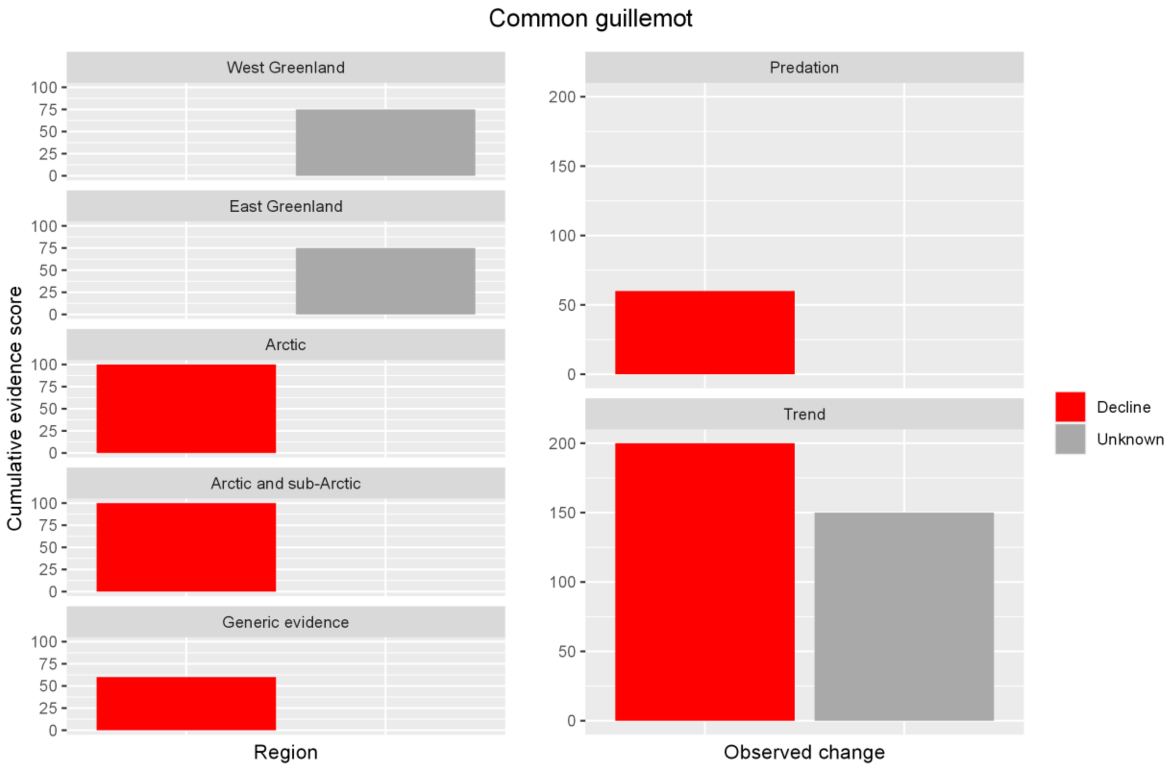


Figure 32.2. Cumulative evidence per region and aspects in which change is observed or expected.

32.4. Catch and Forecast

Piniarneq does not differentiate between lomvie (Common guilemot) and polarlomvie (Thick-billec murre); these species are likely reported interchangeably.

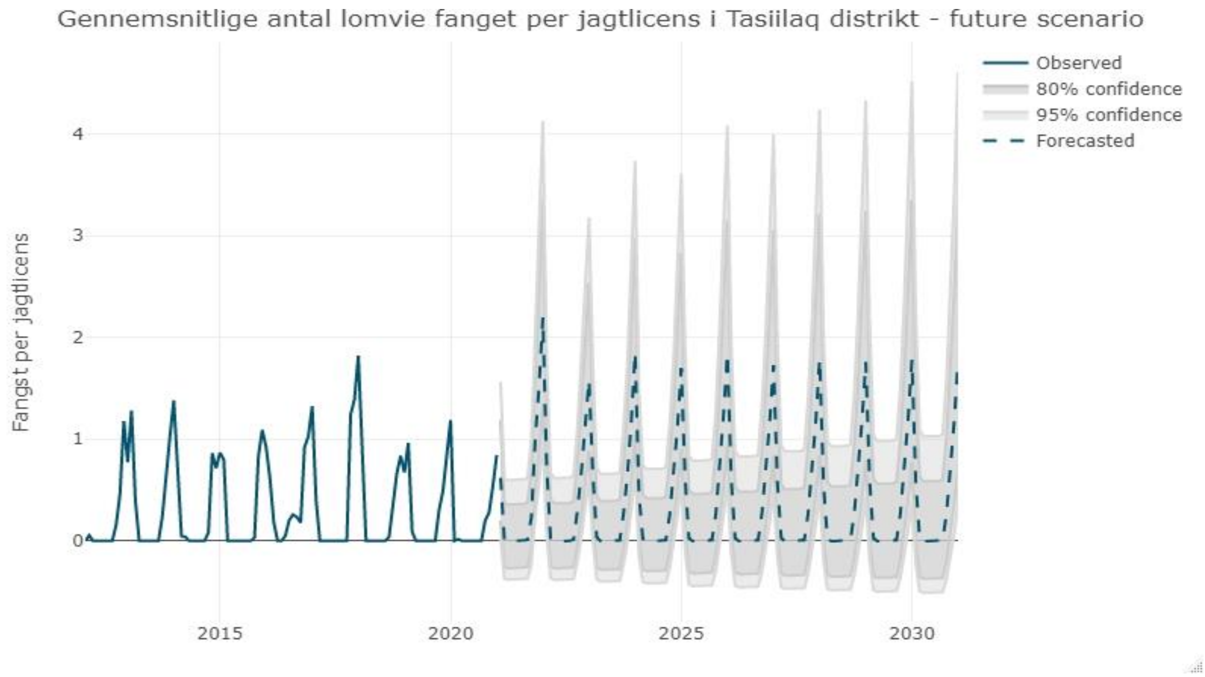


Figure 32.3. Average catch per hunter and forecast for Thick-billed murre in Tasiilaq district.

The forecasts are not reliable. Nevertheless, the material was used as a basis for discussion.

Table 32.1. Average annual catch of Common guillemot per hunter in the period 2012-2020, in 2020 and 2030 (forecasted) and the percentage change in 2030 relative to 2012-2020 and 2020.

District	2012-2020	2020	2030	Δ 2012-2020	Δ 2020
Ittoqoortoormiit					
Tasiilaq	6,40	2,60	4,50	-30%	73%
Upernavik					
Ilulissat					

32.5. Workshops with Hunter and Fishers Organizations

Scenario	Ittoqortoormiit	Tasiilaq	Upernavik	Ilulissat
Trend scenario	Stable catch for own consumption. Fewer breeding birds than previous	Little interest in hunt	Declining catch due to restrictions and lack of appropriate ammunition	Dissatisfaction with regulations leads to unregistered catch – estimated catch of 10-20 each that may be unreported
Alternative scenario	NA	NA	NA	NA

32.6. Interviews with Scientific Experts

-will follow-

32.7. Preliminary Future Scenarios

Scenario	Ittoqortoormiit	Tasiilaq	Upernavik	Ilulissat
Stock and catch trend scenario	+25% compared to the 2012-20 average	Stable compared to the 2012-20 average	-5% compared to 2012-20 average	-5% compared to 2012-20 average
Underreporting adjustment scenario				Add 10-20 to hunters not reporting catch
Alternative actions scenario				

33. Little auk, dovekie (*Alle alle*)

Little auk, dovekie	
Alle alle	
Søkonge	
Appaliarsuk	

Little auk is by far the most abundant bird in East Greenland and in the Atlantic Arctic (Amélineau et al., 2019). In 2003, it was estimated that there were 33.000 000 birds In West Greenland and 3.500 000 birds in East and North Greenland (Merkel et al., 2019). In 2018, a relatively high density of little auks was observed in the Greenland Sea and far fewer in the region south of Scoresby Sund (including Kap Høegh) (Boertmann et al., 2020). However, there are large aggregations in remote areas and on stony slopes. Therefore, only a few reliable counts exist (Boertmann et al., 2020).

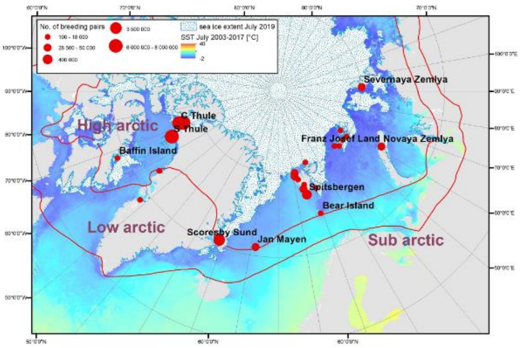


Figure 33.1. Breeding distribution of the Little Auk (colonies indicated by red dots) with sea surface temperature (mean for July 2003–2017; source: Wojczulanis-Jakubas et al. (2022).

33.1. Climate Change

During the breeding season, the little auk relies on sea ice and ice edges for feeding. Recent research in East Greenland suggests that little auks display greater adaptability in their foraging habits than previously believed (Amélineau et al., 2016). They have been observed successfully raising their chicks on a diet of open-water prey. However, considering the future implications, there are potential concerns regarding the species' survival in the Scoresby Sound polynya (Merkel et al., 2019). If the feeding conditions in the neighbouring sea remain favourable, a plausible scenario could involve a northward range shift for the species, as nesting habitats in that area are relatively abundant (Merkel et al., 2019). The East Greenland population's adult body condition and chick growth rate were negatively linked to sea ice concentration and mercury contamination (Amélineau et al., 2019). However, no trend was found, so the potential benefits of milder climatic conditions in East Greenland may be offset by increasing pollution in the Arctic (Amélineau et al., 2019). In Svalbard, an increase in sea temperature (summer grounds) led to a lower survival (2006–2013) (Hovinen et al., 2014a) and lower fledging success (2008–2010) (Hovinen et al., 2014b). Moreover, an increase in air temperature (summer grounds) was associated with earlier breeding between 1963–2008 (Moe et al., 2009).

33.2. Interactions

The little auk plays a crucial role as an ecosystem engineer, fundamentally altering ecosystems throughout a vast expanse of Northwest Greenland (González-Bergonzoni et al., 2017; Mosbech et al., 2018). The approximately 60 –70 million breeding little auks alter terrestrial and freshwater ecosystems by promoting primary and secondary production (González-Bergonzoni et al., 2017). For this and other traits, it is proposed to use this species as an ecological indicator of a changing Arctic and a model organism (Wojczulanis-Jakubas et al., 2022).

33.3. Status and Population Trends

West Greenland

Areas	Abundance	Status, change	Trend (Short term~1 generation)	Category of change	Description: physiological,behavioral change	Climate variable & direction	Hunting
	2003: 33000 000 birds (Merkel et al., 2019)						

East Greenland

Areas	Abundance	Status, change	Trend (Short term~1 generation)	Category of change	Description: physiological,behavioral change	Climate variable & direction	Hunting
	2003: 3500 000 (Merkel et al., 2019)						

33.4. Synopsis

There is strong evidence that Little Auk is declining in East Greenland. For West Greenland, trends are unknown. There is strong generic evidence that populations are or will decline in Greenland with further warming.

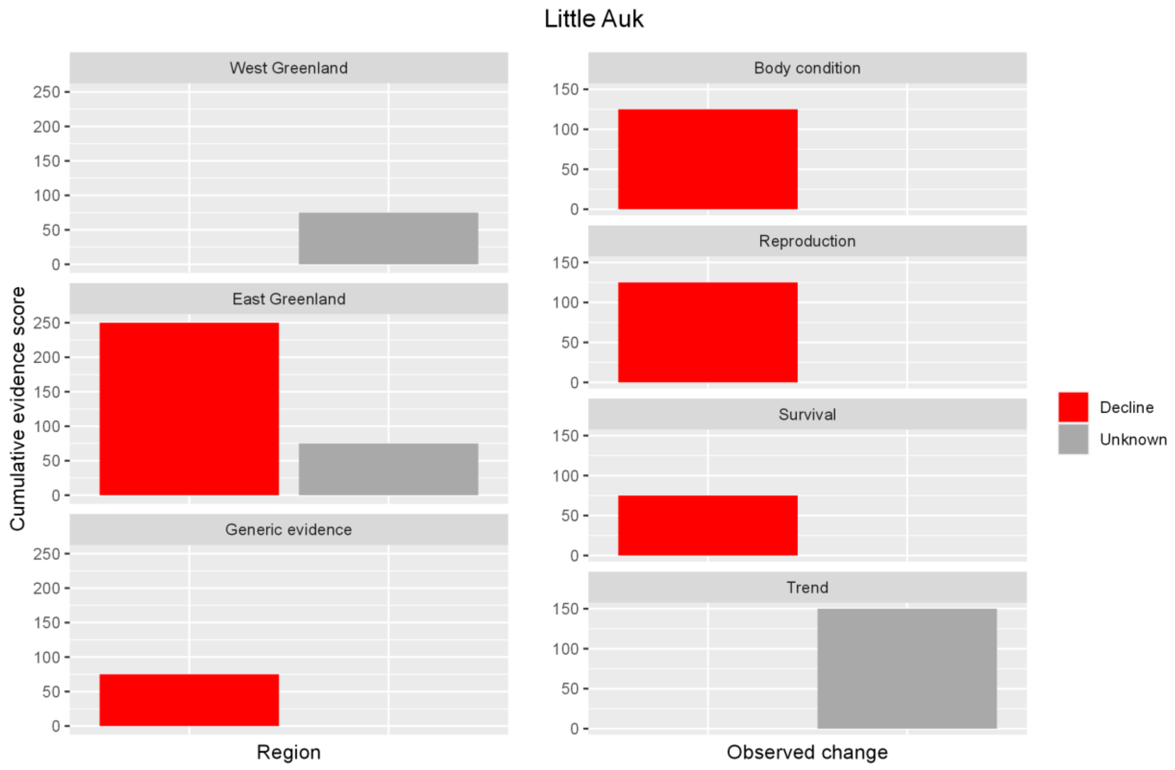


Figure 33.2 Cumulative evidence per region and aspects in which change is observed or expected.

33.5. Catch and Forecast

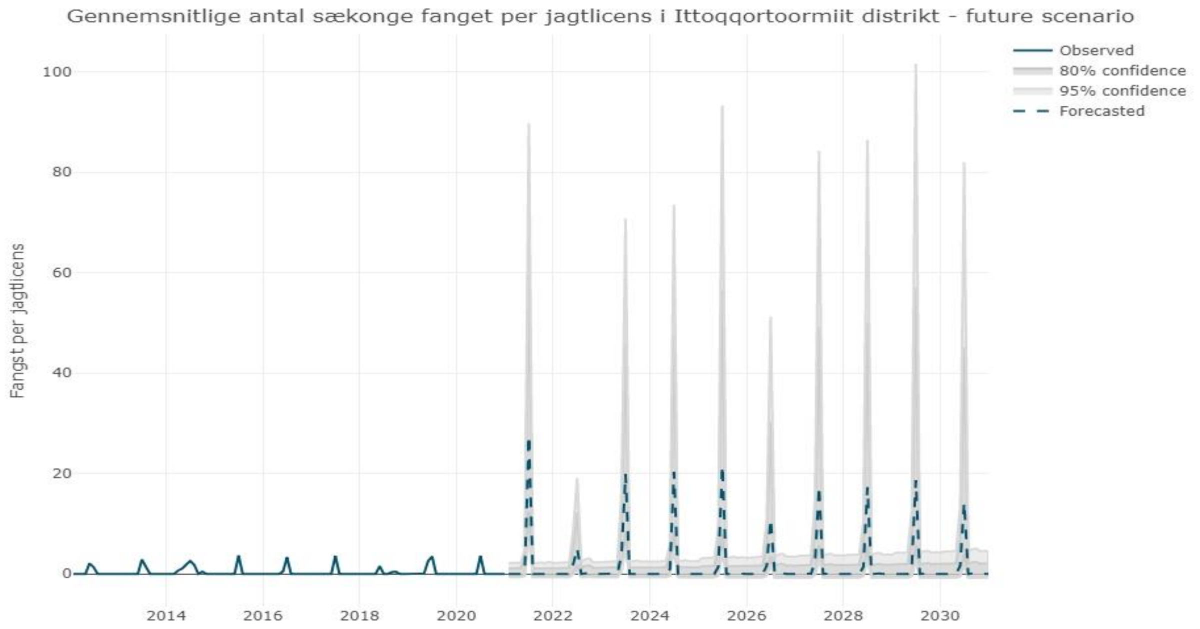


Figure 33.3. Average catch per hunter and forecast for Little Auk in Ittoqortoormiit district.

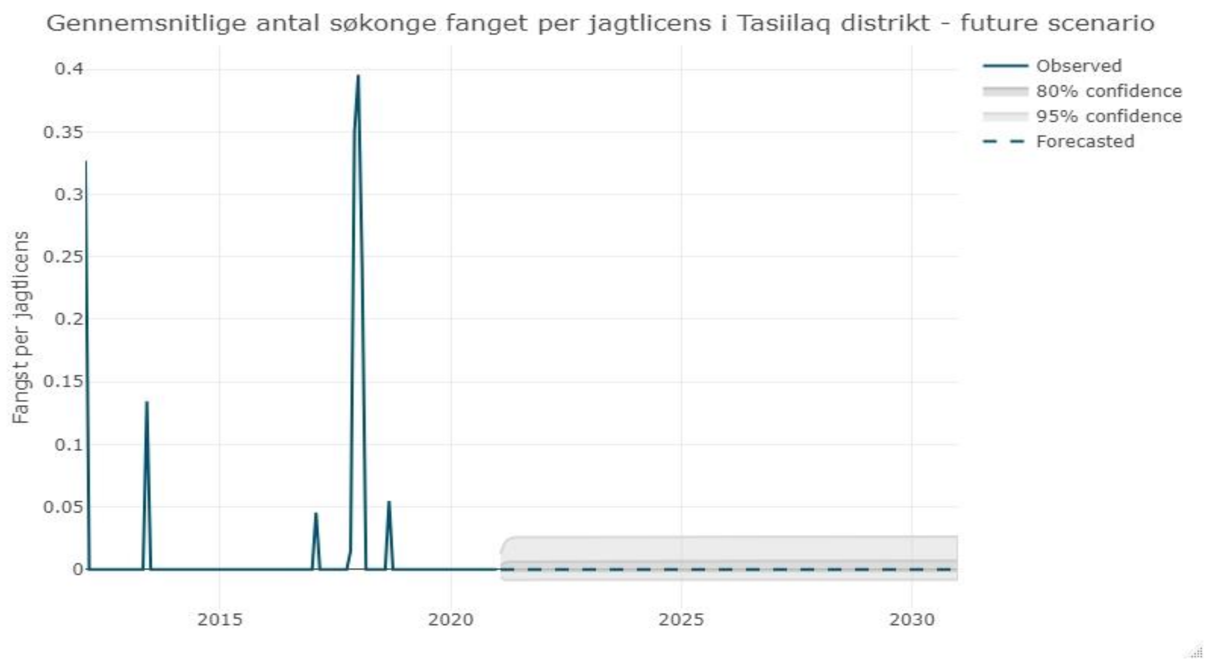


Figure 33.4. Average catch per hunter and forecast for Little Auk in Tasiilaq district.

The forecasts are not reliable, and data was insufficient to make a forecast for Ilulissat. Nevertheless, the material was used as a basis for discussion.

Table 33.1. Average annual catch of Little auk per hunter in the period 2012-2020, in 2020 and 2030 (forecasted) and the percentage change in 2030 relative to 2012-2020 and 2020.

District	2012-2020	2020	2030	Δ 2012-2020	Δ 2020
Ittoqoortoormiit	26,66	34,56	16,02	-40%	-54%
Tasiilaq	0,17	0,00	0,00	-100%	NA
Upernavik					
Ilulissat					

33.6. Workshops with Hunter and Fishers Organizations

Scenario	Ittoqortoormiit	Tasiilaq	Upernavik	Ilulissat
Trend scenario	Poor catch in 2018 due to early summer. Expects stable catch	Few in the area	Few in the area	Not available
Alternative scenario	NA	NA	NA	NA

33.7. Interviews with Scientific Experts

-will follow-

33.8. Preliminary Future Scenarios

Scenario	Ittoqortoormiit	Tasiilaq	Upernavik	Ilulissat
Stock and catch trend scenario	-10% compared to 2012-20 average	0 catch	0 catch	
Underreporting adjustment scenario				
Alternative actions scenario				

34. King eider (*Somateria spectabilis*)

King eider	
Somateria spectabilis	
Kongeedderfugl	
Qingalik	

In West Greenland, the Greenlandic breeding stock is estimated to 19.600 females wintering, plus 211.900 female eiders from Canada wintering in Greenland in 1999-2003. The majority of the king eiders that moult and overwinter in West Greenland originate from Canadian breeding populations (Greenland Institute of Natural Resources, 2021). The North Greenlandic breeding population, which may mix with the Canadian birds in the moulting and wintering areas, is considered small (Greenland Institute of Natural Resources, 2021).

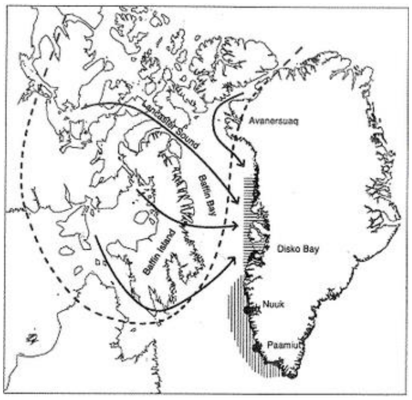


Figure 34.1. King eider migration routes with breeding area within the dotted line. Horizontal lines: Greenlandic main trapping areas, vertical lines: Greenlandic wintering areas. King Eiders from the eastern part of Arctic Canada also migrate from Newfoundland to Maine. Source NERI.

The spring migration towards the breeding colonies begins in early April, but some non-breeding birds remain in West Greenland throughout the summer (Greenland Institute of Natural Resources, 2021). The core areas for the winter population of king eiders are along the coast of Southwest Greenland (though few in the fjords) (Greenland Institute of Natural Resources, 2021).

The breeding range of the king eider is large (more than 200.000 km^2), but the species is generally scarce, and there is limited knowledge of the size of the Greenlandic breeding population (Greenland Institute of Natural Resources, 2021). As the distribution of birds probably varies a lot during the winter and from year to year, it is difficult to compare the different counts. A complete count of the winter population from an aerial survey in 2017 estimated 1.092.705 birds (95% CI: 478.405–2.487.204) birds, of which 99% of the total abundance stayed on St. Hellefiskebanke (Merkel et al., 2019). A survey in 2018 did not find any King eiders along the coast of East Greenland (Boertmann et al., 2020).

34.1. Climate Change

No literature was found.

34.2. Hunting

King eider and common eider are primarily shot in Southwest Greenland in the winter, where they largely overlap in distribution and hunting seasons (Greenland Institute of Natural Resources, 2021). It can be difficult to separate the two species regarding females and juveniles, and studies on the local market in Nuuk suggests that the share of king eiders in the reported combined catch may be up to 30% (Greenland Institute of Natural Resources, 2021). The total catch for the two species has decreased significantly over the last 30 years, from around 75.000 – 85.000 in the 1990s to a current level of around 20.000 – 25.000 birds. The biggest changes occurred around 2001 when hunting seasons were shortened considerably (Greenland Institute of Natural Resources, 2021). However, the reported catch has usually only accounted for about 5% of the total eider catch (both species) (Greenland Institute of Natural Resources, 2021).

34.4. Status and Population Trends

West Greenland

Areas	**Abundance**	**Status, change**	**Trend (Short term~1 generation)**	**Category of change**	**Description: physiological,behavioral change**	**Climate variable & direction**	**Hunting**
West Greenland	2017: 1092 705 birds (95% CI: 478 405–2487 204), 99% on St. Hellefiskebanke (Merkel et al., 2019).	**unkown**	**unknown**				

East Greenland

Areas	**Abundance**	**Status, change**	**Trend (Short term~1 generation)**	**Category of change**	**Description: physiological,behavioral change**	**Climate variable & direction**	**Hunting**
	2018: Survey found no king eiders (Boertmann et al., 2020).	**unkown**	**unkown**				

34.5. Synopsis

We found no literature on trends in Greenland nor generic evidence about the effects of climate change on this species.

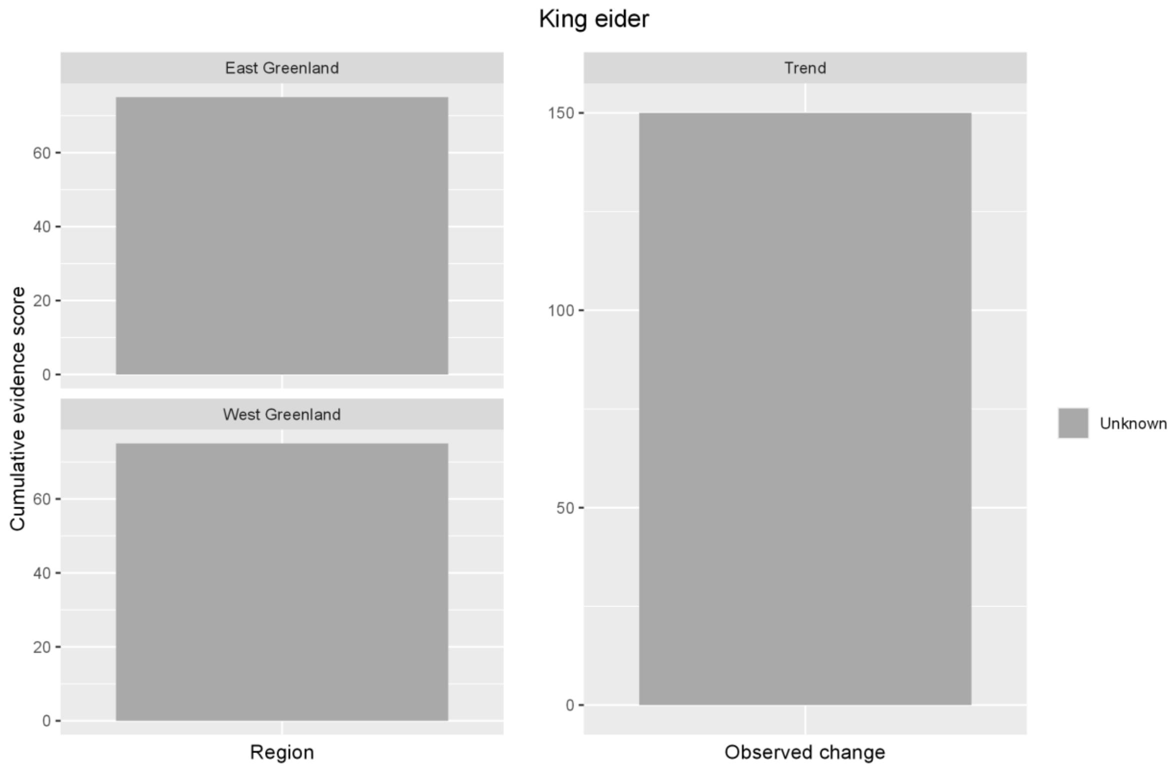


Figure 34.2. Cumulative evidence per region and aspects in which change is observed or expected.

34.6. Catch and Forecast

Hunters report difficulties differentiating between common eider and king eider, and it is likely that these species are reported interchangeably.

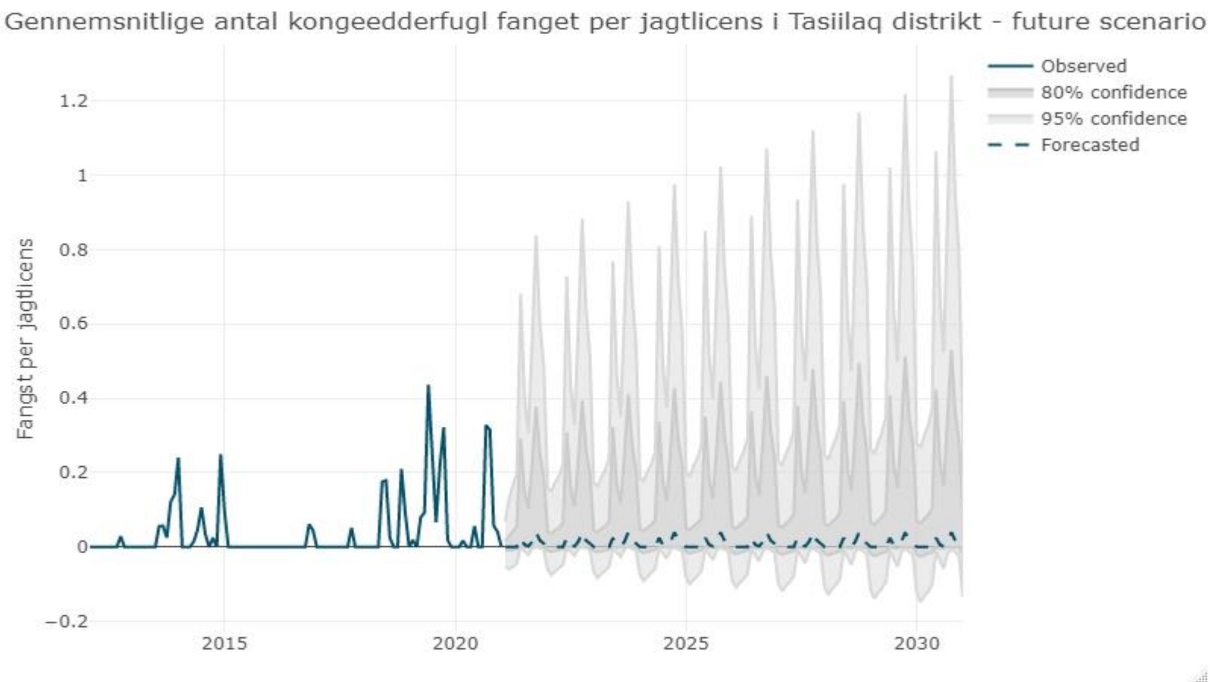


Figure 34.3. Average catch per hunter and forecast for King eider in Tasiilaq district.

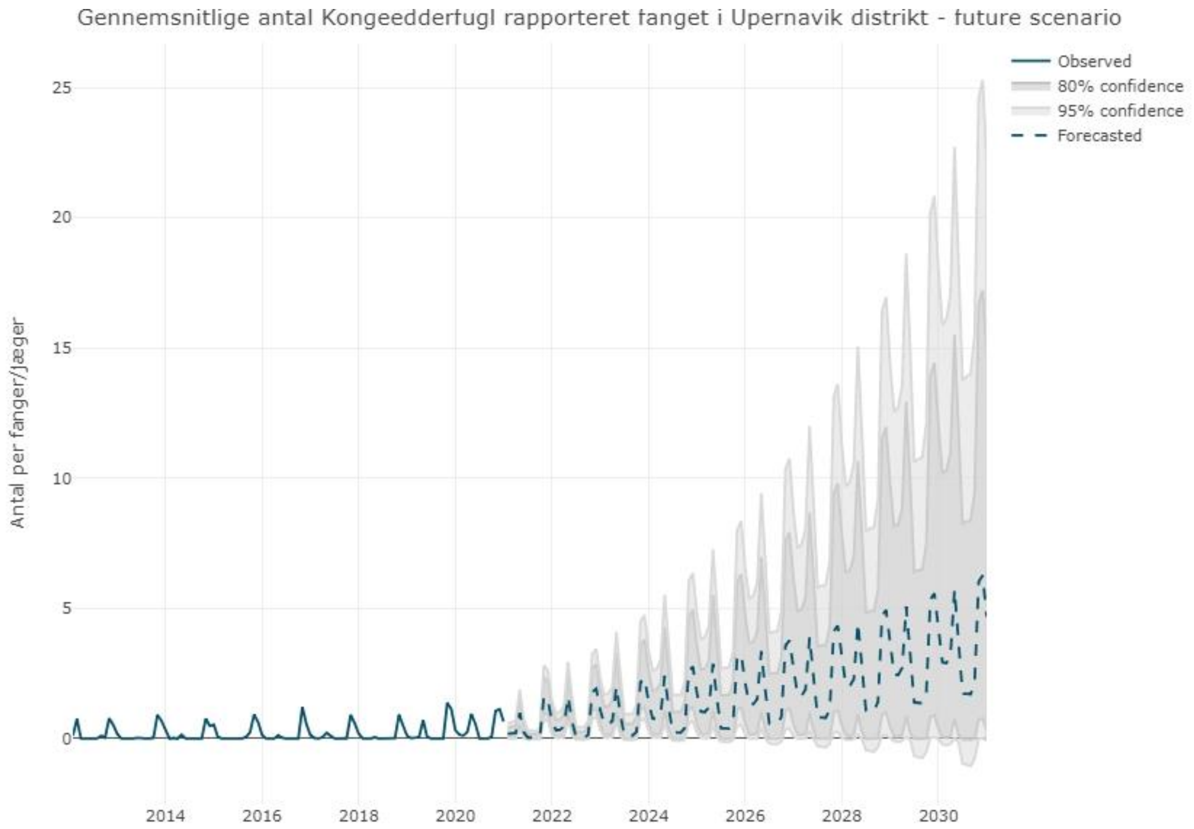


Figure 34.4. Average catch per hunter and forecast for King eider in Upernavik district.

The forecasts are not reliable. Nevertheless, the material was used as a basis for discussion.

Table 34.1. Average annual catch of King eider per hunter in the period 2012-2020, in 2020 and 2030 (forecasted) and the percentage change in 2030 relative to 2012-2020 and 2020.

District	2012-2020	2020	2030	Δ 2012-2020	Δ 2020
Ittoqoortoormiit					
Tasiilaq	0,49	0,81	0,12	-76%	-86%
Upernavik	2,54	4,93	42,71	1580%	767%
Ilulissat					

34.7. Workshops with Hunter and Fishers Organizations

Scenario	Ittoqortoormiit	Tasiilaq	Upernavik	Ilulissat
Trend scenario	More observed but catch remain low			Limited knowledge. Very few shot mainly by misidentification and used for provision
Alternative scenario	NA			NA

34.8. Interviews with Scientific Experts

-will follow-

34.9. Preliminary Future Scenarios

Scenario	Ittoqortoormiit	Tasiilaq	Upernavik	Ilulissat
Stock and catch trend scenario	+2% compared to 2012-20 average	Stable compared to 2012-20 average		+5% compared to 2012-20 average
Underreporting adjustment scenario				
Alternative actions scenario				

35. Long-tailed duck (*Clangula hyemalis*)

Long-tailed duck	
Clangula hyemalis	
Havlit	
Alleq	

Long-tailed ducks breed in tundra across northern Eurasia (in Russia, Finland, Sweden, Norway, Iceland and Greenland) and across northern North America (Alaska and northern Canada). No literature was found about the status of the species in Greenland.

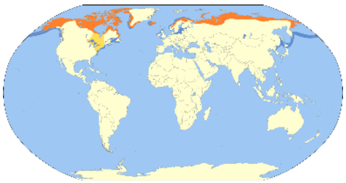


Figure 35.1. Breeding areas (orange) and non-breeding areas (blue)

35.1. Climate Change

No literature found

35.2. Status and Population Trends

All populations

Areas	Abundance	Status, change	Trend (Short term~1 generation)	Category of change	Description: physiological,behavioral change	Climate variable & direction	Hunting
	unknown	unkown	unknown				

35.3. Synopsis

We found no evidence on trends in Greenland or the effects of climate change on this species.

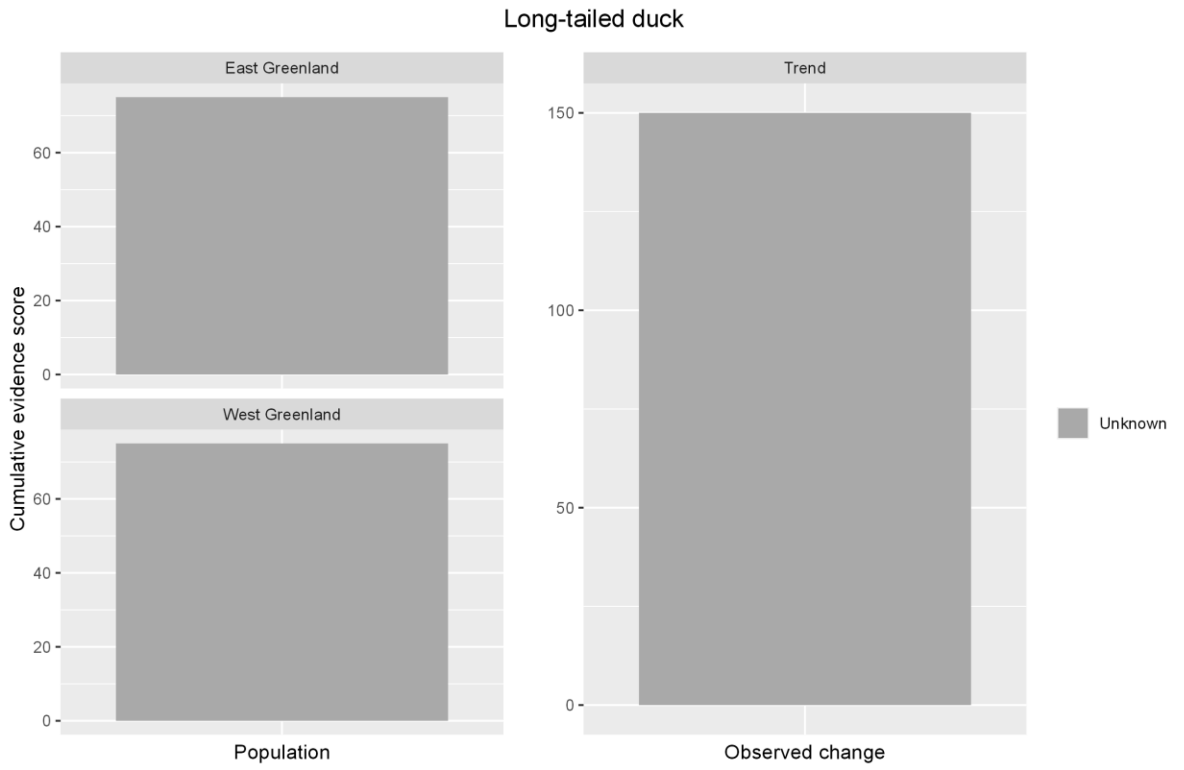


Figure 35.2. Cumulative evidence per region and aspects in which change is observed or expected.

35.4. Catch and Forecast

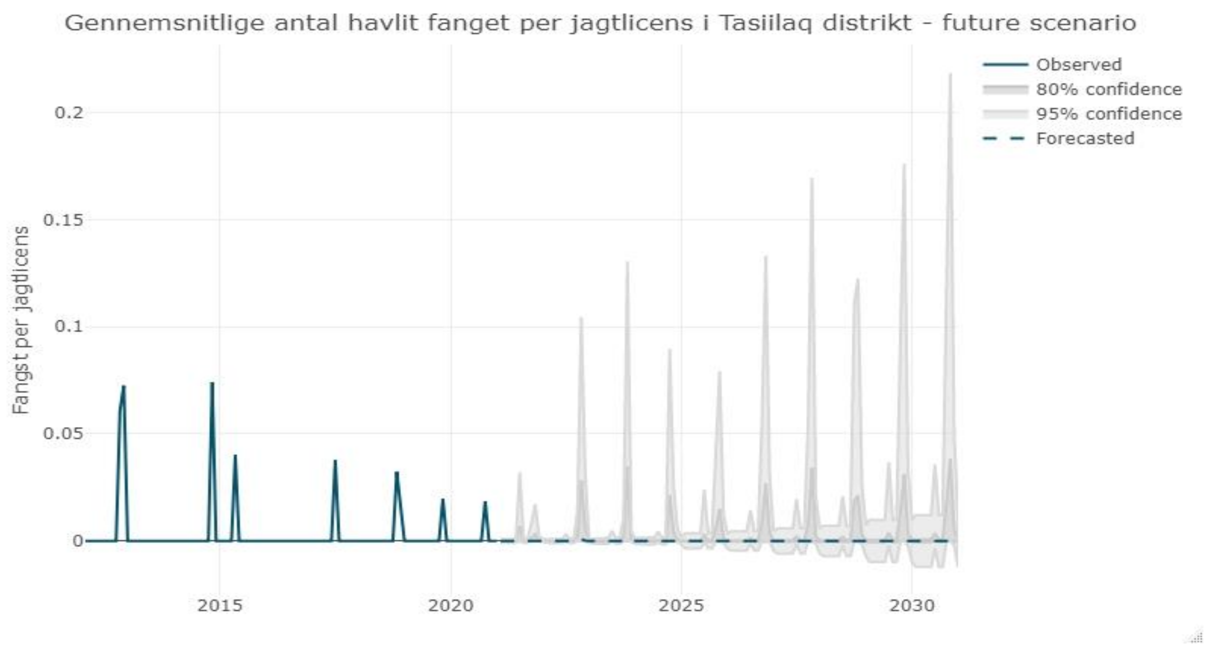


Figure 35.3. Average catch per hunter and forecast for Long-tailed duck in Tasiilaq district.

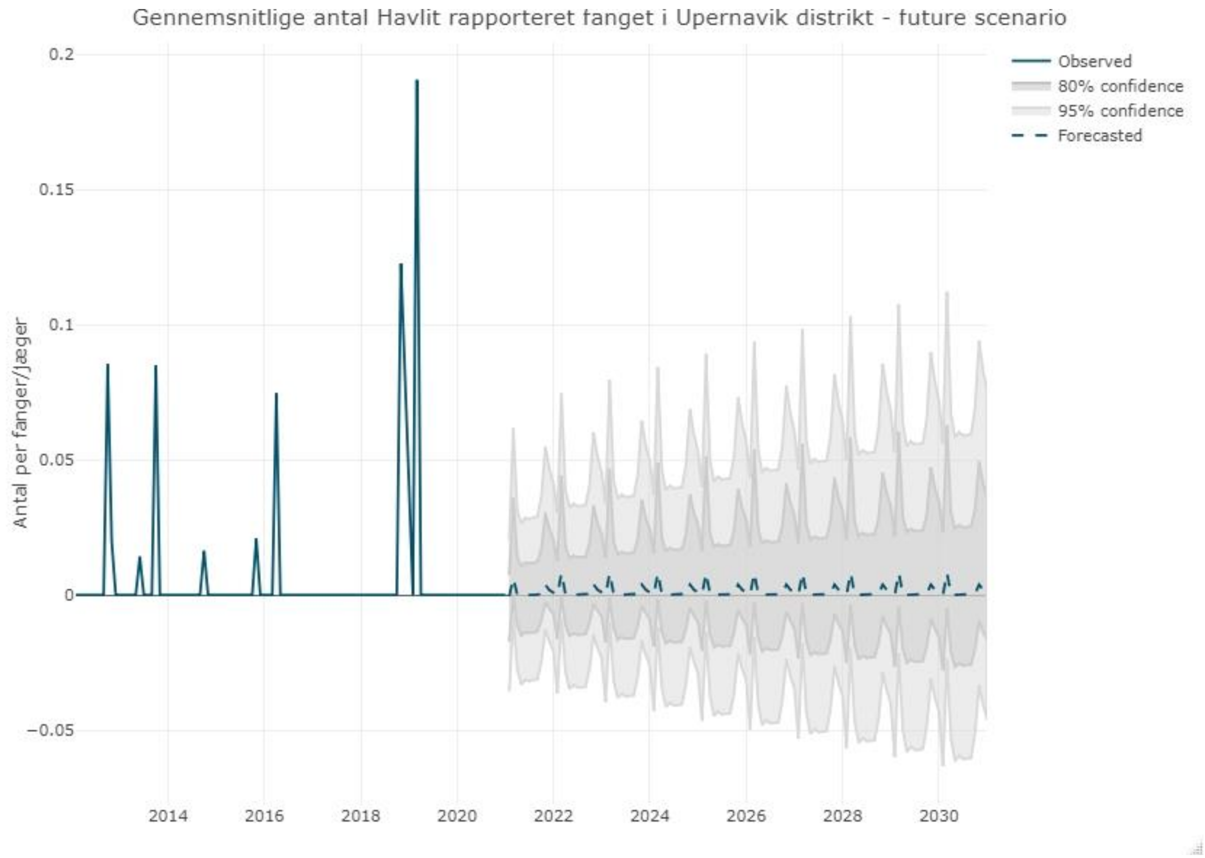


Figure 35.4. Average catch per hunter and forecast for Long-tailed duck in Upernavik district.

The forecasts are not reliable. Nevertheless, the material was used as a basis for discussion.

Table 35.1. Average annual catch of Long-tailed duck per hunter in the period 2012-2020, in 2020 and 2030 (forecasted) and the percentage change in 2030 relative to 2012-2020 and 2020.

District	2012-2020	2020	2030	Δ 2012-2020	Δ 2020
Ittoqoortoormiit					
Tasiilaq	0,04	0,02	0,00	-100%	-99%
Upernavik	0,01	0,00	0,02	-82%	Inf
Ilulissat					

35.5. Workshops with Hunter and Fishers Organizations

Scenario	Ittoqortoormiit	Tasiilaq	Upernavik	Ilulissat
Trend scenario	Has started overwintering but is not targeted	Not targeted	Not available	Not targeted
Alternative scenario	NA	NA	NA	NA

35.6. Interviews with Scientific Experts

-will follow-

35.7. Preliminary Future Scenarios

Scenario	Ittoqortoormiit	Tasiilaq	Upernavik	Ilulissat
Stock and catch trend scenario	0 catch	0 catch		
Underreporting adjustment scenario				
Alternative actions scenario				

36. Common loon/Great northern diver (*Gavia immer*)

<table>
<tr><td>Common loon/Great Northern diver</td><td rowspan="4"></td></tr>
<tr><td>Gavia immer</td></tr>
<tr><td>Islom</td></tr>
<tr><td>Tuullik</td></tr>
</table>

Most common loons live in the northern United States and Canada, the southern parts of Greenland, Iceland, Svalbard, Jan Mayen, and Bear Island in Norway, Alaska, and rarely in Scotland (Jensen and Christensen, 2003). The species is typical in large lakes on the west coast northward to Qaanaaq and on the east coast up to Hochstetter Forland. In most places, it breeds in small numbers (Jensen and Christensen, 2003). In 2008, only very few were observed in north and northeast Greenland, and only one Blosseville coast in East Greenland (Boertmann et al., 2009).

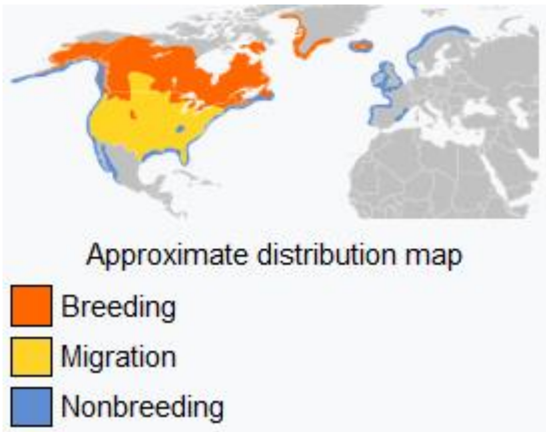


Figure 36.1. Breeding, non-breeding and migration

36.1. Climate Change

In Ontario, a declining trend in common loon reproductive success was associated with low PH and higher mercury, while reproductive success increased with April temperatures (Bianchini et al., 2020). Overall, climate change-induced stress, acting through multiple interacting pathways involving mercury acidity, fish abundance, lake size, and geographic location, may account for declining loon productivity (Bianchini et al., 2020). Analyses from three long-term (1995–2019) datasets from northern Wisconsin, USA, revealed that the winter North Atlantic Oscillation (NAO), a broad-scale climate index immediately preceding the breeding season, and annual changes in developed land cover within breeding areas both had strongly negative influences on adult survival (Saunders et al., 2021). Local summer rainfall was negatively related to fecundity, though this relationship was mediated by a lagged interaction with the winter NAO, suggesting a compensatory population-level response to climate variability (Saunders et al., 2021).

36.2. Status and Population Trends

West Greenland

Areas	Abundance	Status, change	Trend (Short term~1 generation)	Category of change	Description: physiological,behavioral change	Climate variable & direction	Hunting
	unknown	unknown	unknown				

East Greenland

Areas	Abundance	Status, change	Trend (Short term~1 generation)	Category of change	Description: physiological,behavioral change	Climate variable & direction	Hunting
	Only few individuals (Boertmann et al., 2009).	unknown	unknown				

36.3. Synopsis

We found no literature on trends of Common loon in East and West Greenland. We found strong generic evidence of a decline of this bird and moderate evidence of stable populations in Greenland.

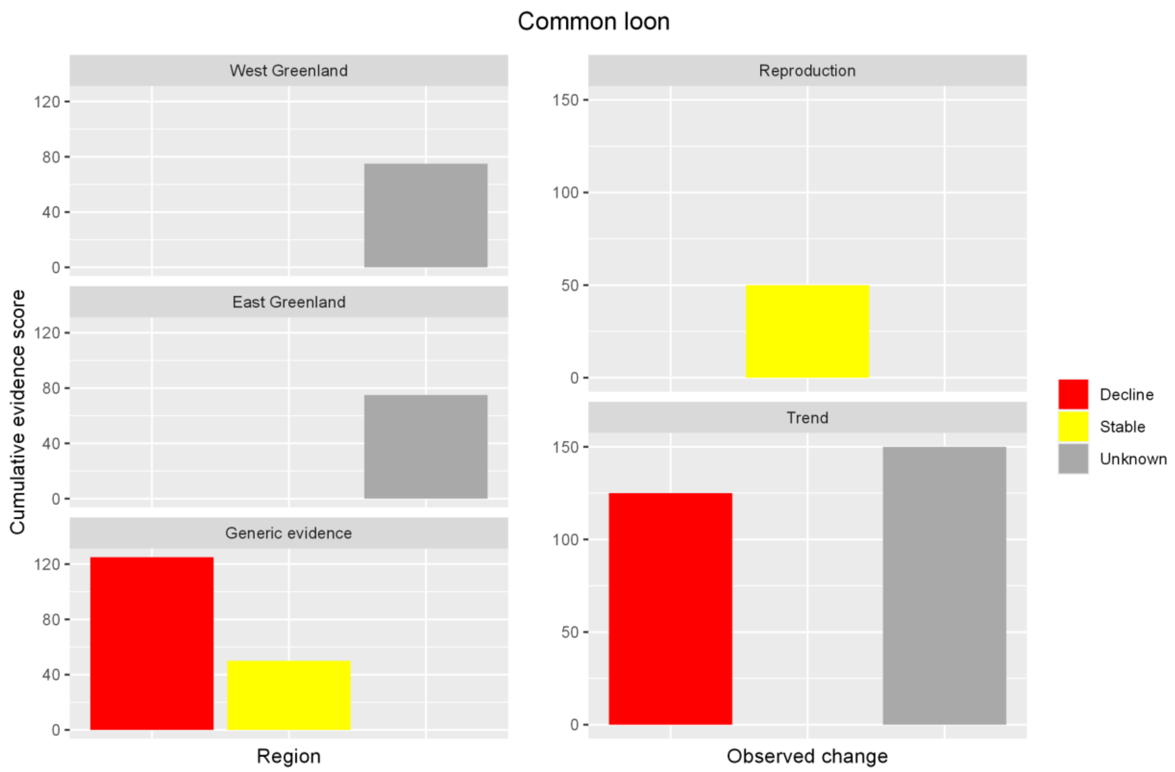


Figure 36.2 Cumulative evidence per region and aspects in which change is observed or expected

36.4. Catch and Forecast

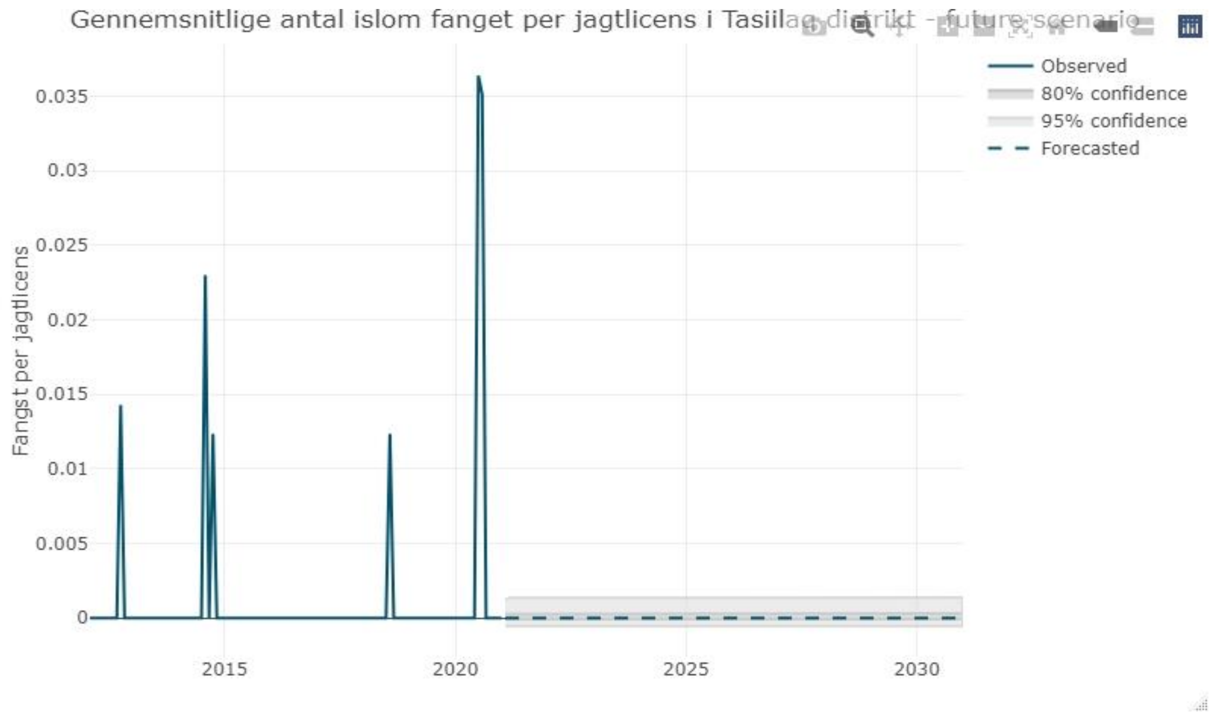


Figure 36.3. Average catch per hunter and forecast for Common loon in Tasiilaq district.

The forecast is not reliable. Nevertheless, the material was used as a basis for discussion.

Table 36.1. Average annual catch of Common loon per hunter in the period 2012-2020, in 2020 and 2030 (forecasted) and the percentage change in 2030 relative to 2012-2020 and 2020.

District	2012-2020	2020	2030	Δ 2012-2020	Δ 2020
Ittoqoortoormiit					
Tasiilaq	0,01	0,07	0,00	-100%	-100%
Upernavik	0,01	0,02	0,05	-38%	-74%
Ilulissat					

36.5. Workshops with Hunter and Fishers Organizations

Scenario	Ittoqortoormiit	Tasiilaq	Upernavik	Ilulissat
Trend scenario	Few are seen	Sporadic catch		
Alternative scenario	NA	NA		

36.6. Interviews with Scientific Experts

-will follow-

36.7. Preliminary Future Scenarios

Scenario	Ittoqortoormiit	Tasiilaq	Upernavik	Ilulissat
Stock and catch trend scenario	Use 2012-20 average	Use 2012-20 average		
Underreporting adjustment scenario				
Alternative actions scenario				

37. Common raven (*Corvus corax*)

Common raven	
Corvus corax	
Ravn	
Tulluaq	

Common Ravens can still be considered common in North-west Greenland, and between 100 and 200 pairs were found in the Uummannaq District, West Greenland (2000) (Burnham et al., 2005). Daily sightings were recorded from Ørsted Dal in Northeast Greenland in 2009, and the species was described as a regular, but sparse breeder in Northeast Greenland (Meltofte and Dinesen, 2009). A large survey of East Greenland in 2018 did not account for ravens (Boertmann et al., 2020).

Figure 37.1. Breeding, non-breeding and resident range

37.1. Climate change

No studies found on climate change.

37.2. Status and Population Trends

<u>West Greenland</u>

Areas	Abundance	Status, change	Trend (Short term~1 generation)	Category of change	Description: physiological,behavioral change	Climate variable & direction	Hunting
	common in North-west Greenland (Burnham et al., 2005).	unkown	unkown				

<u>East Greenland</u>

Areas	Abundance	Status, change	Trend (Short term~1 generation)	Category of change	Description: physiological,behavioral change	Climate variable & direction	Hunting
	regular, but sparse breeder (Meltofte and Dinesen, 2009)	unkown	unkown				

37.3. Synopsis

We found no evidence for trends or effects of climate change for common ravens.

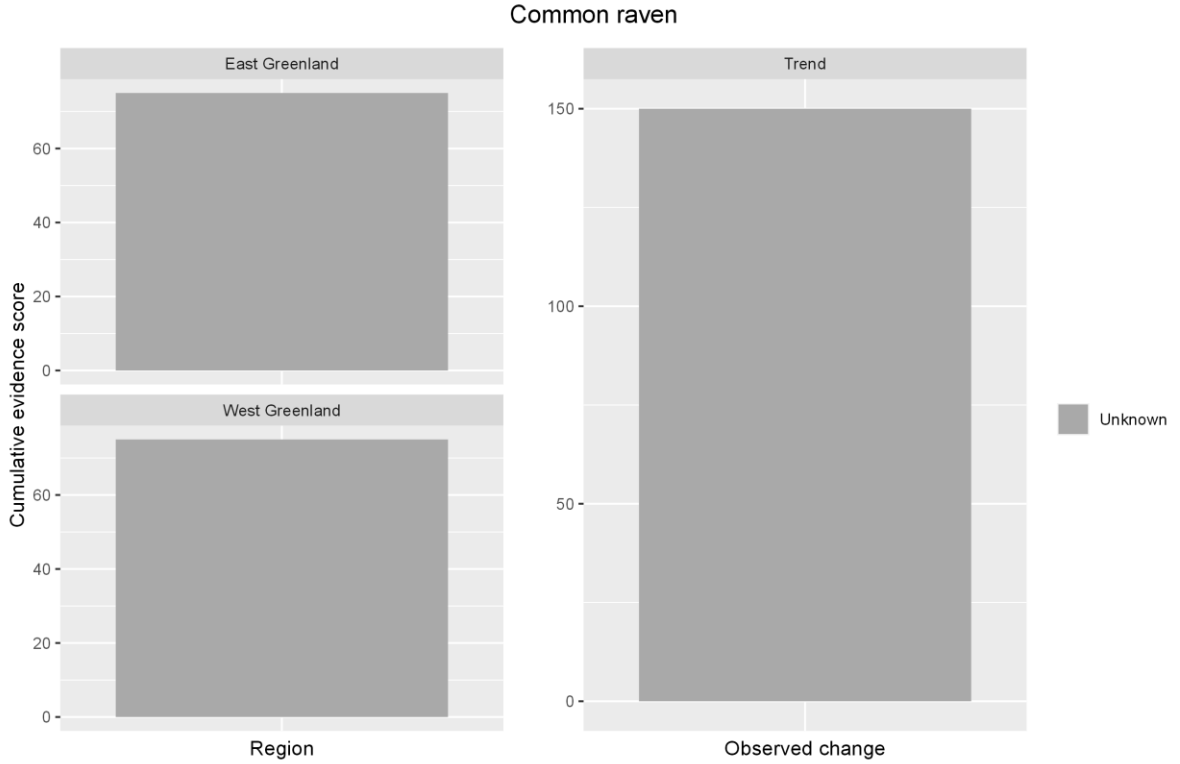


Figure 37.2. Cumulative evidence per region and aspects in which change is observed or expected.

37.4. Catch and Forecast

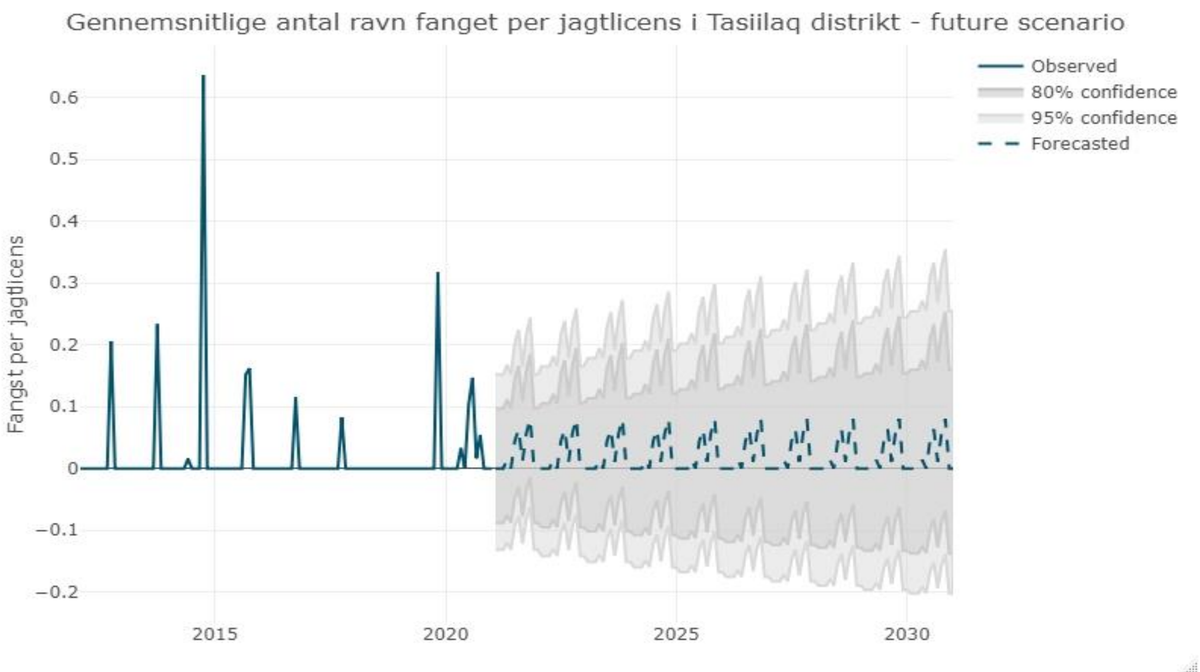


Figure 37.3. Average catch per hunter and forecast for Common raven in Tasiilaq district.

The forecast is not reliable. Nevertheless, the material was used as a basis for discussion.

Table 37.1. Average annual catch of Common raven per hunter in the period 2012-2020, in 2020 and 2030 (forecasted) and the percentage change in 2030 relative to 2012-2020 and 2020.

District	2012-2020	2020	2030	Δ 2012-2020	Δ 2020
Ittoqoortoormiit					
Tasiilaq	0,07	0,00	0,00	-100%	0%
Upernavik					
Ilulissat					

37.5. Workshops with Hunter and Fishers Organizations

Not hunted and not discussed.

37.6. Interviews with Scientific Experts

-will follow-

37.7. Preliminary Future Scenarios

Scenario	Ittoqortoormiit	Tasiilaq	Upernavik	Ilulissat
Stock and catch trend scenario		2012-20 average	2012-20 average	2012-20 average
Underreporting adjustment scenario				
Alternative actions scenario				

38. Great cormorant (*Phalacrocorax carbo*)

Great cormorant	
Phalacrocorax carbo	
Skarv	
Oqaatsoq	

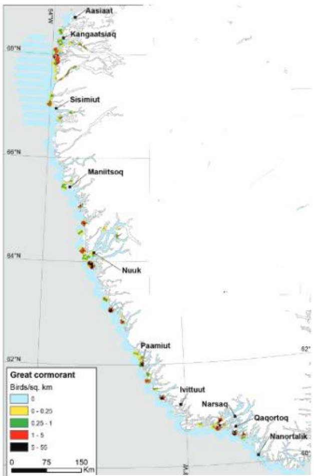


Figure 38.1. Survey Southwest Greenland in 2017

One of the ten most abundant species in South-West Greenland (Merkel et al., 2019). During a survey in 2017, they were observed throughout the coastal survey area (Merkel et al., 2019). They were scarce in some regions and were absence from around Maniitsoq and north to around Sisimiut (ca. 65–67°N) (Merkel et al., 2019). The highest densities were detected in the coastal survey area and fjords of the Kangaatsiaq area (ca. 68°N), the coastal area around Nuuk (ca. 64°N) and the outer range of the fjords in the northern part of Julianehåbsbugten (ca. 61°N). Cormorants were not common in the fjords, except for the two areas just mentioned.

The total abundance estimate for wintering great cormorants in south-west Greenland in 2017 was 7.701 birds (95% CI: 4.025–15.077), with the vast majority (95%) in the coastal survey area (Merkel et al., 2019). The abundance of great cormorants was not estimated in 1999, but the overall distribution pattern was the same (Merkel et al., 2019).

The Great cormorant has recently immigrated to East Greenland (Boertmann et al., 2020). The total population in the region numbers fewer than 50 pairs (Boertmann et al., 2020). Only three breeding colonies are known, and all are from cliffs in the Sermilik (Isortoq) area west of Tasiilaq According to local sources, the colonies were established in the period 2000–05, and there may be more colonies in the region (Boertmann et al., 2020). However, this small population is very isolated. The nearest breeding populations are located in Iceland (600 km) and in West Greenland (1500 km apart) (Boertmann et al., 2020).

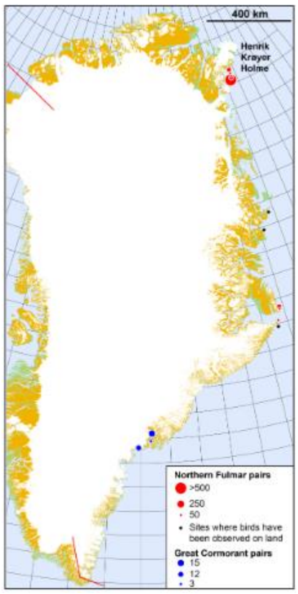


Figure 38.2. Survey East Greenland in 2018

38.1. Climate Change

Great Cormorants (Phalacrocorax carbo) possess a plumage that is only partially water-resistant, making them ill-adapted for foraging in Arctic waters. Nevertheless, the growth rates of Cormorant colonies in the vicinity of Disko Bay, Greenland, during the period 1946–2005 exhibited a positive correlation with sea surface temperature, implying that these birds might thrive in a warming Arctic (White et al., 2011). It, therefore, seems likely that a warming Arctic will also benefit the main prey of Cormorants sculpin, capelin and cod (White et al., 2011).

38.2. Status and Population Trends

West Greenland

Areas	Abundance	Status, change	Trend (Short term~1 generation)	Category of change	Description: physiological,behavioral change	Climate variable & direction	Hunting
	7701 birds (95% CI: 4025–15 077) (Merkel et al., 2019)		**Seems stable** (Merkel et al., 2019).				

East Greenland

Areas	Abundance	Status, change	Trend (Short term~1 generation)	Category of change	Description: physiological,behavioral change	Climate variable & direction	Hunting
	50 pairs (Boertmann et al., 2020).	**Immigrated** (Boertmann et al., 2020).	**Increasing** (Boertmann et al., 2020).				

38.3. Synopsis

We found strong evidence of an increase in East Greenland and moderate evidence of a stable population and strong evidence of an increase in West Greenland.

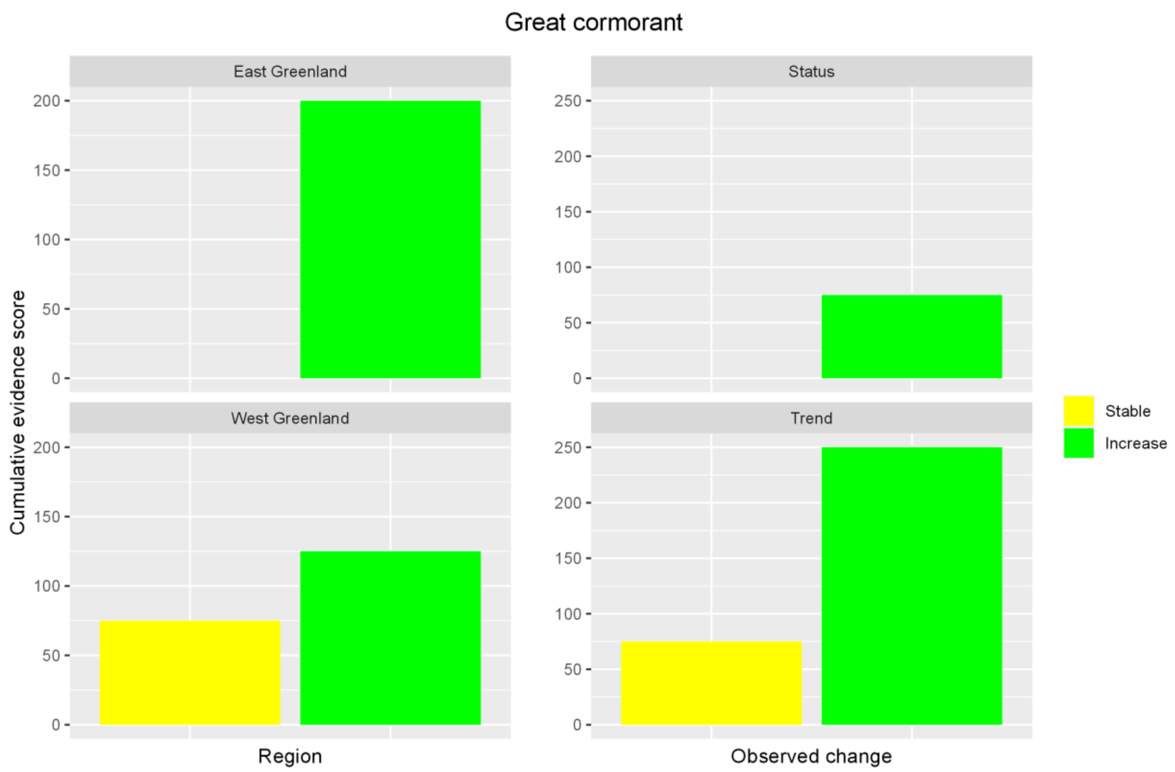


Figure 38.2 Cumulative evidence per region and aspects in which change is observed or expected.

38.4. Catch and Forecast

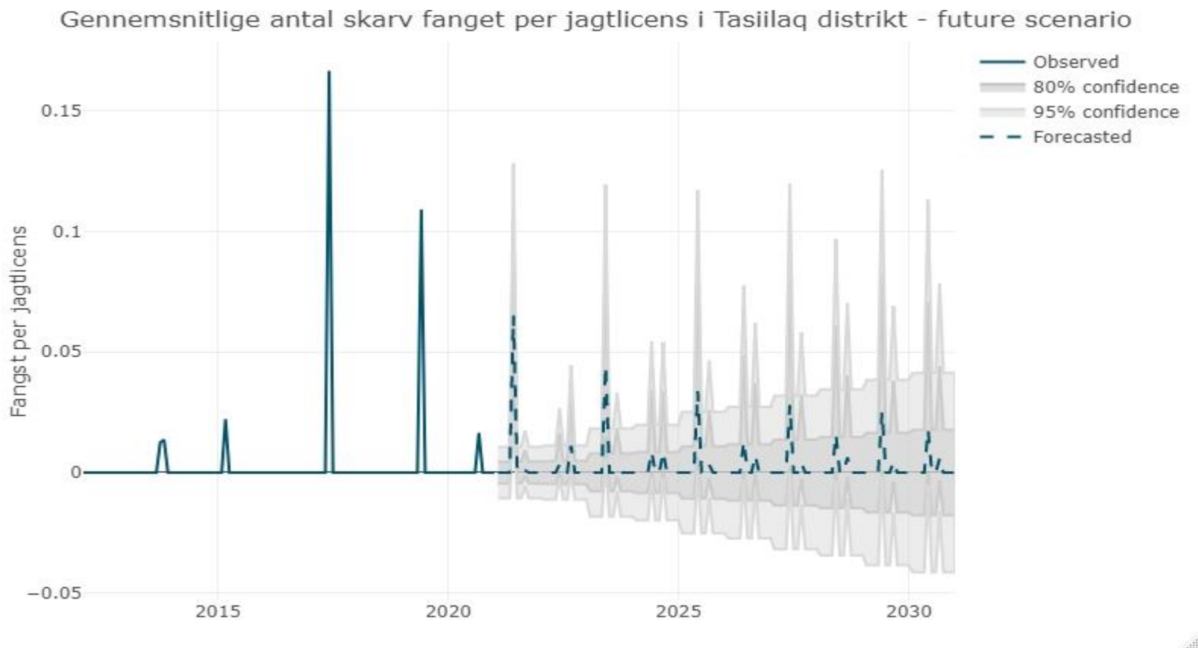


Figure 38.3. Average catch per hunter and forecast for Great cormorant in Tasiilaq district.

The forecast is not reliable. Nevertheless, the material was used as a basis for discussion.

Table 38.1. Average annual catch of Great comorant per hunter in the period 2012-2020, in 2020 and 2030 (forecasted) and the percentage change in 2030 relative to 2012-2020 and 2020.

District	2012-2020	2020	2030	Δ 2012-2020	Δ 2020
Ittoqoortoormiit					
Tasiilaq	0,04	0,02	0,02	-38%	44%
Upernavik	0,04	0,00	0,00	-98%	Inf
Ilulissat					

38.5. Workshops with Hunter and Fishers Organizations

Scenario	Ittoqortoormiit	Tasiilaq	Upernavik	Ilulissat
Trend scenario		Increasing rapidly. Not targeted		
Alternative scenario		Eradication campaign		

38.6. Interviews with Scientific Experts

-will follow-

38.7. Preliminary Future Scenarios

Scenario	Ittoqortoormiit	Tasiilaq	Upernavik	Ilulissat
Stock and catch trend scenario				2012-20 average
Underreporting adjustment scenario				
Alternative actions scenario		Select a number and a price offered in eradication campaign		

39. Glaucous gull (*Larus hyperboreus*)

Glaucous gull	
Larus hyperboreus	
Gråmåge	
Naajarujussuaq	

Glaucous gull breeds exclusively in the circumpolar Arctic. The Arctic population consists of approximately 138.600 to 218.600 breeding pairs (equivalent to 277.200 to 437.200 breeding individuals) residing in at least 2.768 colonies. Certain local populations are exhibiting notable declines (Petersen et al., 2015). In Greenland, data on population trends are fragmentary and not systematic (Petersen et al., 2015). The Greenland Seabird Colony Register includes 830 colonies or breeding sites, totalling approximately 12.000 pairs (Petersen et al., 2015). It is breading widespread throughout Greenland and occurs mainly in small colonies and as solitary pairs, often within or close to colonies of other seabirds (Petersen et al., 2015).

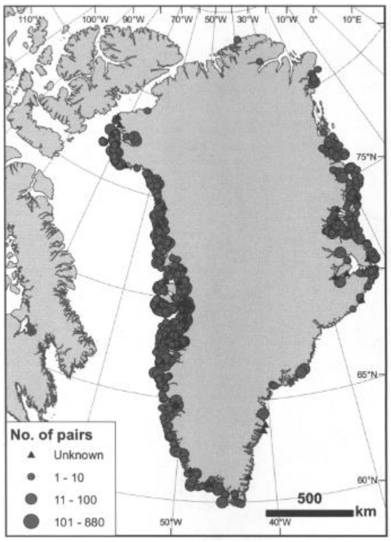


Figure 39.1. Distribution of Glaucous Gull breeding sites in Greenland, as recorded in the Greenland Seabird Colony Register (n = 829). Survey effort in North and Southeast Greenland is very low, and the literature indicates that the species is more widespread (Petersen et al., 2015)

Although many populations worldwide are declining, there seems to be a slightly positive trend in West Greenland (Petersen et al., 2015). In West Greenland, 86 colonies were surveyed more than once in the period 1988-2008 (Petersen et al., 2015). Overall, 45 (52%) colonies (56° N, 79.5° W) were unchanged, 17 (20%) were increasing, and 24 (28%) were declining. In Upernavik municipality (72°-75° N), 15 colonies supported 329 pairs in 1965, but this number had increased to 419 pairs by 1994, and surveys of the fjords south of Disko Bay (67°-69° N) between 1954 and 2005 suggested overall increases in gull numbers (Boertmann et al., 2006). In southwest Greenland (south of 61° N), 1997), three colonies decreased in numbers since the previous survey, while six new colonies were established, resulting in an overall increase of almost 100% in the number of pairs (Petersen et al., 2015). Overall, the population size in West Greenland is estimated to be 60.000 birds, and populations show a slight positive trend, an impression also shared with biologists and people living in Greenland (Petersen et al., 2015). In 2017, a survey counted the highest densities in South-west Greenland around Kangaatsiaq, Sisimiut, Maniitsoq and Nuuk (Merkel et al., 2019). The total abundance estimate for wintering white gulls within the survey area in 2017 was 76.025 birds (95% CI: 45 744–136 085), including 2.734 birds (95% CI: 678–11.033) on Store Hellefiskebanke and a minimum of 10.522 birds in the fjords (Merkel et al., 2019). White gulls were not recorded in 1999. White gulls—glaucous gulls and

Iceland gulls, were lumped together as they are difficult to tell apart from a fast-moving survey aeroplane (Merkel et al., 2019).

In 2018, 403 breeding sites of Glaucous Gulls were recorded from East and North Greenland (Boertmann et al., 2020). These included solitary pairs (n = 139), either alone or at colonies of other species (n = 48), and colonies with up to 100 pairs (average eight pairs) (Boertmann et al., 2020). Breeding sites are found along all coasts, as far north as 83°30′ N in the east and in Washington Land in the west, with concentrations at Tasiilaq, Scoresby Sound, at the Sirius Water, Dove Bay, and to a lesser extent at the Northeast Water Polynya (Boertmann et al., 2020). Very few colonies have been located north of 78° N at the Northeast Water Polynya (Boertmann et al., 2020). The most recent surveys add up to 2200 pairs (Boertmann et al., 2020). However, this figure represents a minimum estimate of the population size, as many solitary pairs are overlooked, and considerable numbers may hide in the unsurveyed coasts—especially in the inner fjords (Boertmann et al., 2020).

39.1. Climate Change

The duration of polar bear presence during summer is progressively extending. Over a period of 10 years following their initial arrival on land, polar bears have shifted their arrival dates by approximately 30 days earlier (Prop et al., 2015). Field observations specifically targeting nest predation have revealed that the reproductive success of various bird species, including the barnacle goose (*Branta leucopsis*), common eider (*Somateria mollissima*), and glaucous gull (*Larus hyperboreus*), may be significantly impacted by polar bear activity (Prop et al., 2015).

39.2. Status and Population Trends

<u>West Greenland</u>

Areas	**Abundance**	**Status, change**	**Trend (Short term~1 generation)**	**Category of change**	**Description: physiological,behavioral change**	**Climate variable & direction**	**Hunting**
	2008: 60 000 birds (Petersen et al., 2015) 2017: 76 025 birds (95% CI: 45 744–136 085) (White gulls—glaucous gull and Iceland gull—lumped together) (Merkel et al., 2019)		**Slightly increasing** (Petersen et al., 2015)				

<u>East Greenland</u>

Areas	**Abundance**	**Status, change**	**Trend (Short term~1 generation)**	**Category of change**	**Description: physiological,behavioral change**	**Climate variable & direction**	**Hunting**
	2018: 2200 pairs (Boertmann et al., 2020).						

39.3. Synopsis

We found strong evidence of an increase in Gluacous gull in West and East Greenland. We found moderate generic evidence for an increase of this bird.

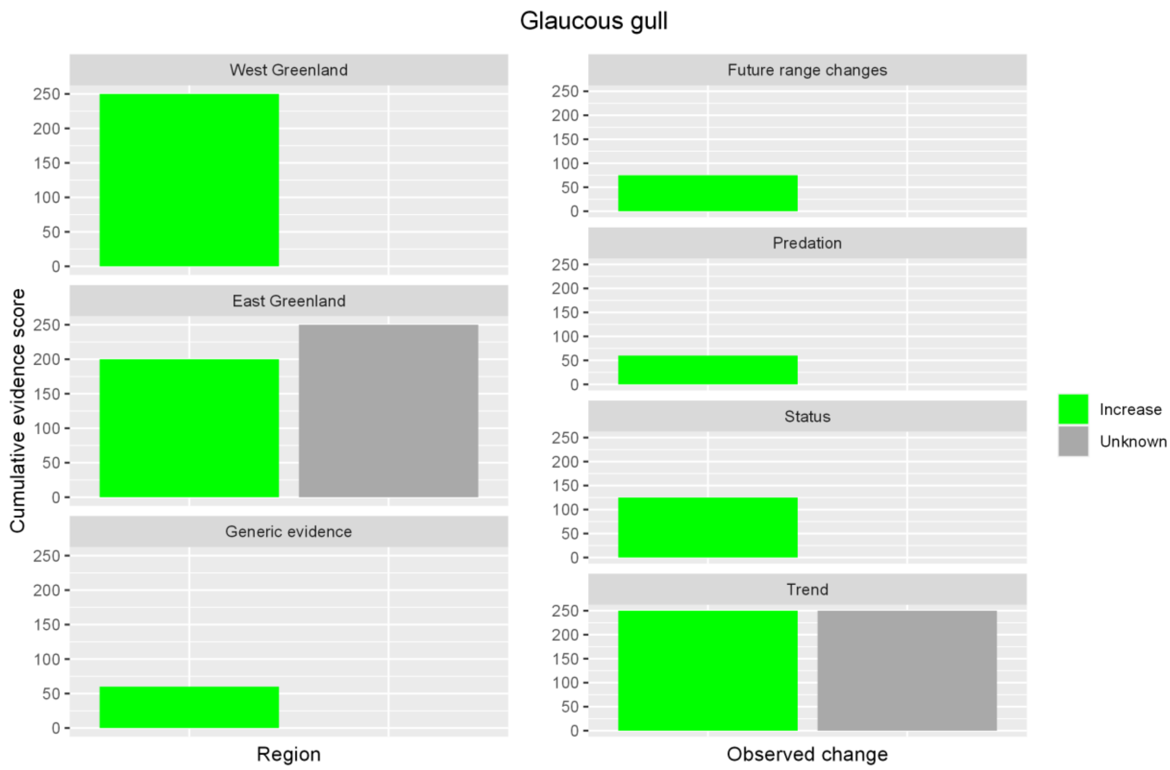


Figure 39.2 Cumulative evidence per region and aspects in which change is observed or expected.

39.4. Catch and Forecast

No recorded catch. However, it is likely that Icelandic gulla and Glaucous gull are conflated.

39.5. Workshops with Hunter and Fishers Organizations

-not discussed-

39.6. Interviews with Scientific Experts

-will follow-

39.7. Preliminary Future Scenarios

Scenario	Ittoqortoormiit	Tasiilaq	Upernavik	Ilulissat

Stock and catch trend scenario				
Underreporting adjustment scenario				
Alternative actions scenario				

40. Iceland gull (*Larus glaucoides*)

Iceland gull	
Larus glaucoides	
Hvidvinget måge	
Naajaq	

A medium-sized gull that breeds in the Arctic regions of Canada and Greenland but not in Iceland (as its name suggests). In 2017, a survey in South East Greenland classified glaucous gulls and Iceland gulls together as "white gulls" due to the challenges of distinguishing between them from a fast-moving survey aeroplane (Merkel et al., 2019). Both species were found throughout the coastal survey area and in the fjords. The white gulls ranked as the second most abundant "species." However, the flocks were generally small, with 56% of the sightings consisting of single birds (Merkel et al., 2019).

Figure 40.1. Survey in 2017 in Southeast G

In the coastal survey area, the white gulls were also observed in the offshore western region, indicating that their distribution extends into offshore areas, similar to Store Hellefiskebanke (Fig. 40.1). The highest densities of white gulls were observed around Kangaatsiaq, Sisimiut, Maniitsoq, and Nuuk (Merkel et al., 2019).

The total estimated population of wintering white gulls within the survey area in 2017 was 76.025 birds (95% CI: 45.744–136.085), which included 2.734 birds (95% CI: 678–11,033) on Store Hellefiskebanke and a minimum of 10.522 birds in the fjords (Merkel et al., 2019). The Greenland Seabird Colony Register counted 100.000 for West Greenland in 2010, with a probably stable trend (Boertmann et al., 2010).

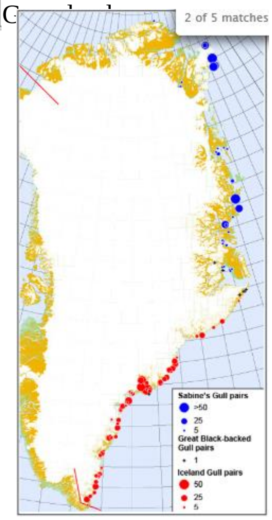


Figure 40.2. Survey in 2018 in East Greenland

The Greenland Seabird Colony Register counted 1.000 for East Greenland in 2010 with a probably stable trend (Boertmann et al., 2010). In East Greenland, there are 58 known breeding colonies of Iceland gulls (Boertmann et al., 2020). The northernmost colony is located at 69°30'N, with the largest concentration found in the Tasiilaq area (Fig. 0.15). These colonies are relatively small, typically consisting of up to 55 breeding pairs (Boertmann et al., 2020). A more recent survey in 2018 recorded a total of 750 pairs across all colonies (Boertmann et al., 2020). However, it is highly probable that there are additional colonies along the unsurveyed coasts in Southeast Greenland that have not been accounted for. Whether the colonies found north of 68˚N in 2008 and 2016 are the result of a range expansion or just of increased observation effort is not known.

40.1. Climate Change

However, Iceland gulls are expected to increase and extend their ranges in East Greenland in the future (Boertmann et al., 2020).

40.2. Status and Population Trends

West Greenland

Areas	Abundance	Status, change	Trend (Short term~1 generation)	Category of change	Description: physiological,behavioral change	Climate variable & direction	Hunting
	2017: 76,025 birds (95% CI: 45,744–136,085) (Merkel et al., 2019)	**Expanding** (Merkel et al., 2019)	**Increasing** (Merkel et al., 2019)				

East Greenland

Areas	Abundance	Status, change	Trend (Short term~1 generation)	Category of change	Description: physiological,behavioral change	Climate variable & direction	Hunting
	2018: 750 pairs (Boertmann et al., 2020).	**Unkown** (Boertmann et al., 2020).	**Unkown** (Boertmann et al., 2020).				

40.3. Synopsis

We found strong evidence for an increase in West and East Greenland. Although trends are unknown in East Greenland, it is assumed that abundance and range will increase.

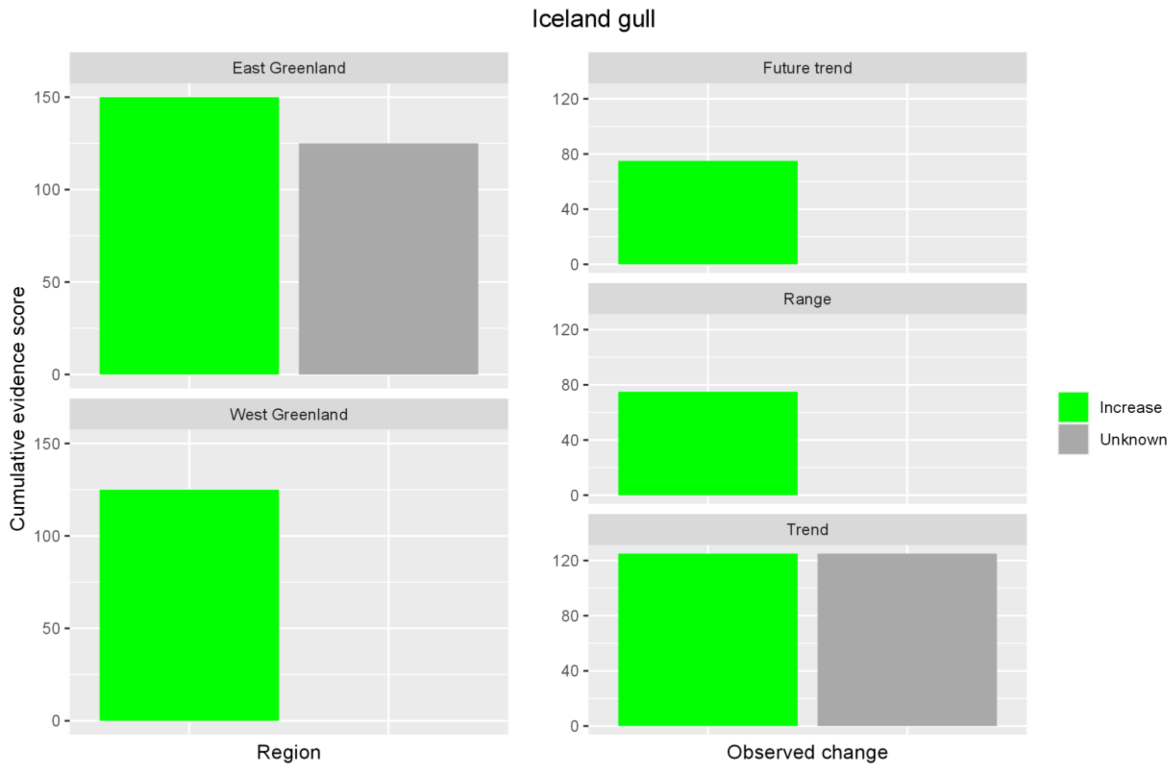


Figure 40.3 Cumulative evidence per region and aspects in which change is observed or expected

40.4. Catch and Forecast

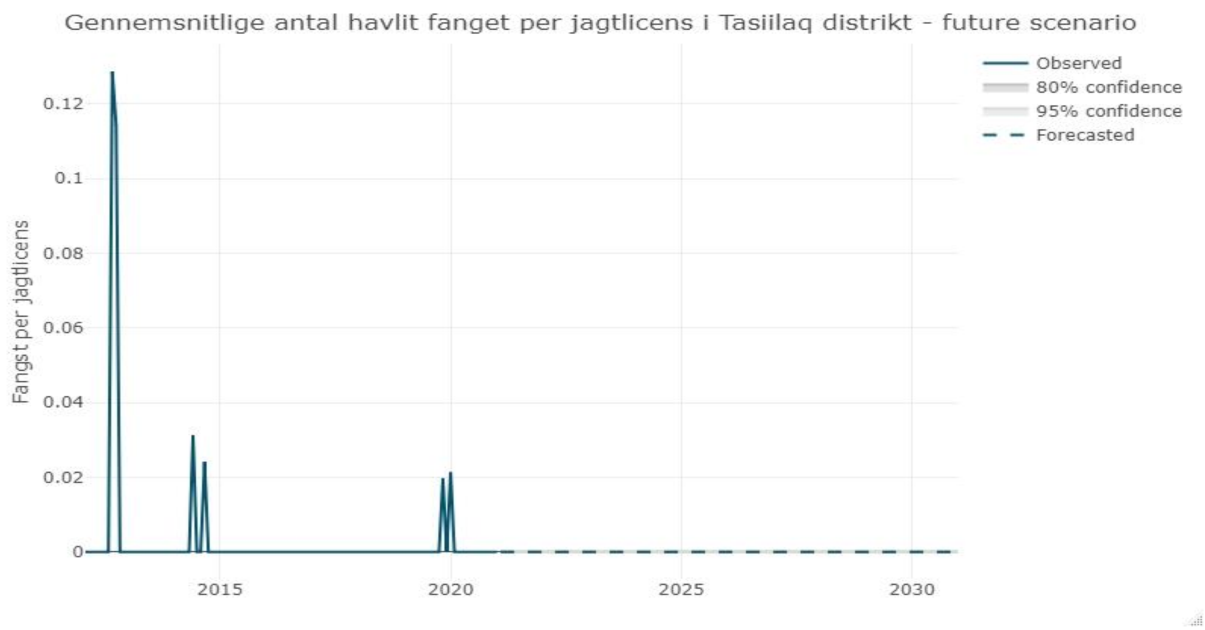


Figure 40.4. Average catch per hunter and forecast for Icelandic gull in Tasiilaq district.

The forecast is not reliable. Nevertheless, the material was used as a basis for discussion.

Table 40.1. Average annual catch of Icelandic gull per hunter in the period 2012-2020, in 2020 and 2030 (forecasted) and the percentage change in 2030 relative to 2012-2020 and 2020.

District	2012-2020	2020	2030	Δ 2012-2020	Δ 2020
Ittoqoortoormiit					
Tasiilaq	0,04	0,00	0,00	-100%	NA
Upernavik	0,06	0,06	0,03	-59%	-55%
Ilulissat					

40.5. Workshops with Hunter and Fishers Organizations

-not discussed-

40.6 Interviews with Scientific Experts

-will follow-

40.7. Preliminary Future Scenarios

Scenario	Ittoqortoormiit	Tasiilaq	Upernavik	Ilulissat
Stock and catch trend scenario				
Underreporting adjustment scenario				
Alternative actions scenario				

41. Great black-backed gull (*Larus marinus*)

Great black-backed gull	
Larus marinus	
Svartbagen	
Naajarluk	

The largest member of the gull family and widespread in West Greenland. The current breeding distribution range from the southern tip at Cape Farewell (59° N) to the northern Upernavik District at 75° N (Figure 0.17). The core area for the breeding population is central West Greenland between 64° N and 68° N. Besides exposed coastal habitats, they are also found breeding up to 130 km inside some deep fjord systems.

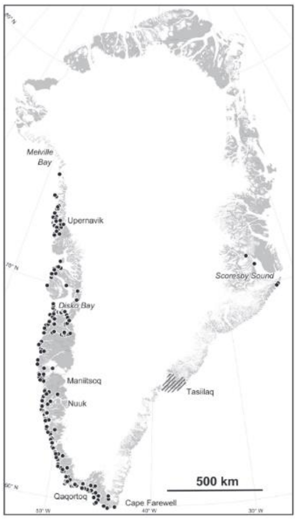


Figure 41.1. Breeding distribution of Great Black-backed Gull in Greenland based on information in the Greenland Seabird Colony Register.

Great black-backed gulls are restricted to two regions in East Greenland (the Tasiilaq area and the Scoresby Sound Fjord complex; Fig. 41.1.) (Boertmann et al., 2020; Boertmann and Frederiksen, 2016). In Tasiilaq, only one breeding site was located during surveys in 2008, 2014, and 2016. From the Scoresby Sound Fjord area, the Great Black-backed Gull is known from six sites (four at colony sites with other species) (Boertmann and Frederiksen, 2016). The number of breeding pairs is very low, and the total population hardly exceeds 20 pairs (Boertmann et al., 2020).

Since 1981, the range has expanded 500 km northward from Disko Bay (70° 40′ N) to the northern Upernavik District and since 1994, Great Black-backed Gulls has been a widespread and common breeder in the coastal parts of the Upernavik (Boertmann and Frederiksen, 2016). Great Black-backed Gulls in West Greenland are sedentary in the southern part of the range, while northern birds migrate to winter quarters in West Greenland south of 68° N (Lyngs 2003). The present Great Black-backed Gull population is estimated at ≥ 5,000 pairs (Boertmann and Frederiksen, 2016). However, information in the register is too scarce, with a lack of repeated surveys in specific regions, to quantify population trends (Boertmann and Frederiksen, 2016).

Globally, the species has declined by 43%–48% between 1985–2021, from an estimated 291.000 breeding pairs to 152.000–165.000 breeding pairs and North American populations declined more steeply than European ones (68% and 28%, respectively) (Langlois Lopez et al., 2023). For Greenland, a decrease of 59% was calculated for three generations by comparing countings from 1995 and 2014 (Langlois Lopez et al., 2023). The drivers of this change remain largely unknown (Langlois Lopez et al., 2023).

41.1. Climate Change

The population in West Greenland has shown a notable increase since the 1960s, and this growth has been attributed to the establishment of a modern fishery primarily targeting Atlantic cod (*Gadus morhua*) (Boertmann and Frederiksen, 2016). This fishery created a new food source for scavenging marine birds. However, the cod fishery experienced a significant decline after 1970, nearly disappearing altogether (Boertmann and Frederiksen, 2016). Surprisingly, the expansion and population rise of the Great Black-backed Gull in Greenland appears to have been unaffected by this shift in food availability. This suggests that other factors, such as the decrease in winter ice coverage in West Greenland during recent decades, may have played a role in the observed changes in the gull population (Boertmann and Frederiksen, 2016).

41.2. Status and Population Trends

West Greenland

Areas	**Abundance**	**Status, change**	**Trend (Short term~1 generation)**	**Category of change**	**Description: physiological,behavioral change**	**Climate variable & direction**	**Hunting**
	2014: ≥ 5,000 pairs(Boertmann and Frederiksen, 2016).	**Range is expanding**	**Declining** (Langlois Lopez et al., 2023).				

East Greenland

Areas	**Abundance**	**Status, change**	**Trend (Short term~1 generation)**	**Category of change**	**Description: physiological,behavioral change**	**Climate variable & direction**	**Hunting**
	Population hardly exceeds 20 pairs (Boertmann et al., 2020).	**Range is expanding**	**Declining** (Langlois Lopez et al., 2023).				

41.3. Synopsis

There is strong evidence of an increase and decrease West Greenland. For East Greenland, there is strong evidence of a decline in the population.

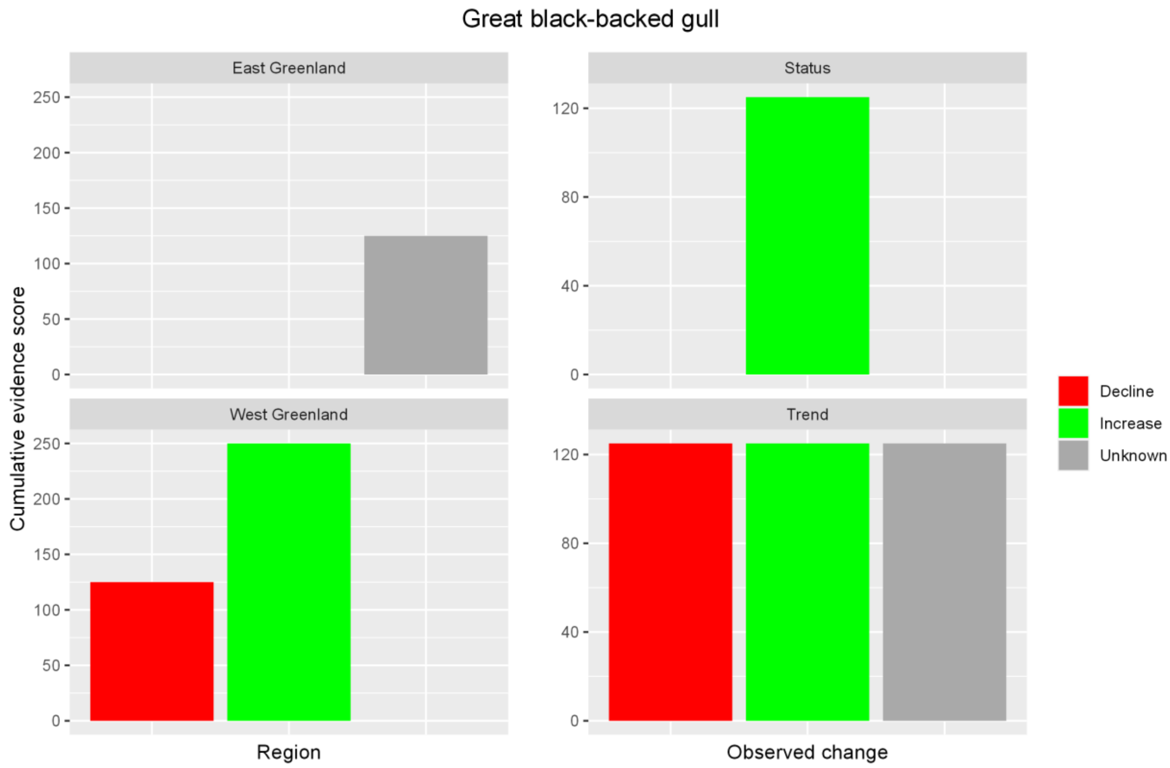


Figure 41.2 Cumulative evidence per region and aspects in which change is observed or expected.

41.4. Catch and Forecast

-none-

41.5. Workshops with Hunter and FRishers Organizations

-not discussed-

41.6. Interviews with Scientific Experts

-will follow-

41.7. Preliminary Future Scenarios

Scenario	Ittoqortoormiit	Tasiilaq	Upernavik	Ilulissat
Stock and catch trend scenario				
Underreporting adjustment scenario				

Alternative actions scenario				

42. Rock Ptarmigan (*Lagopus mutus*)

Rock Ptarmigan	
Lagopus mutus	
Fjeldrype	
Aqisseq	

Breeds across Arctic and Subarctic Eurasia and North America, and in Greenland on rocky mountainsides and tundra. North and Northeast Greenland populations show high fluctuations across the period 1977-2006 (Hansen et al., 2008).

Figure 42.1 Map over the distribution range in North America-Greenland

42.1. Climate Change

The rock ptarmigan, which has low fecundity, high survival, a long generation time, and slow population recovery, is adapted to arctic and alpine environments (Hotta et al., 2019). In Europe, *L. muta* populations are likely to decline under warming scenarios, with a projected 54% decline in suitable climate space from the present to the 2080s (Smith et al., 2013). In the swiss alpes, models predict that, based on increasing temperatures during the breeding season, potential habitat will decrease by up to two-thirds until the year 2070 (Revermann et al., 2012). At the same time, a shift of potential habitat towards the mountain tops is predicted. In the European and Japanese alpes, there are increasing observations at higher elevations (Hotta et al., 2019; Pernollet et al., 2015). In Svalbard, the Svalbard rock ptarmigan showed a short-term decrease in population growth rate between 1997–2010 after extreme winter events that reduced the availability of winter forage due to ice cover (Hansen et al., 2013).

A maximum entropy (MaxEnt) algorithm and Schoener's D niche overlap index were used to assess shifts and changes in the overlap of species-specific distributions under recent (1979–2013) and future (2061–2080; representative concentration pathways [RCPs] 2.6, 4.5 and 8.5) bioclimatic conditions in the Northeast Greenland National Park (Beest et al., 2021). The probabilities of species occurrences during 1979–2013 were highest in the mid-eastern section of the Northeast Greenland National Park (especially for rock ptarmigan) and lowest in the northern parts of the study area. The change in probability of occurrence over time and space was mainly negative for rock ptarmigans (most pronounced under scenario RCP 2.6 and less so under scenario RCP 8.5) (Beest et al., 2021). Moreover, o northwards shift was observed (Beest et al., 2021).

42.2. Status and Population Trends

West Greenland

Areas	Abundance	Status, change	Trend (Short term~1 generation)	Category of change	Description: physiological,behavioral change	Climate variable & direction	Hunting
	unknown	unknown	unknown				

East Greenland

Areas	Abundance	Status, change	Trend (Short term~1 generation)	Category of change	Description: physiological,behavioral change	Climate variable & direction	Hunting
	unknown	unknown	unknown				

42.3. Synopsis

Little is known about populations. We found strong evidence for a decline in the Northeast Greenland National Park and strong generic evidence of a future decline of this species.

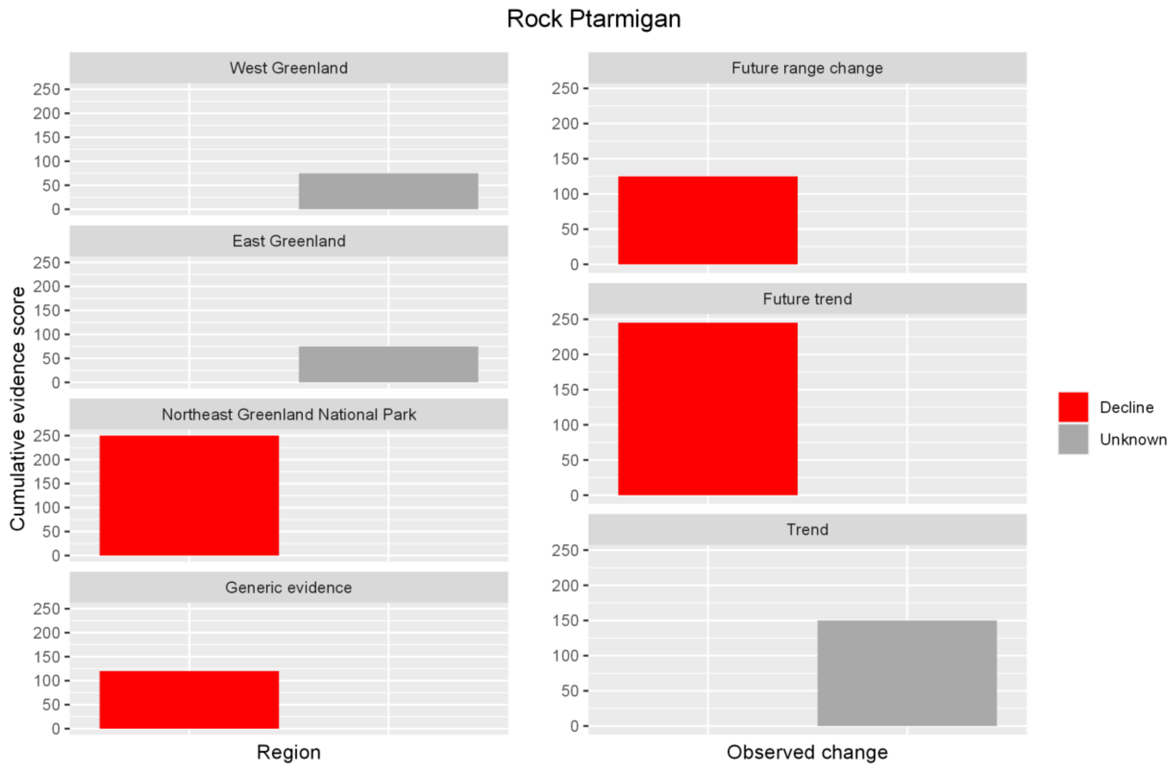


Figure 42.2 Cumulative evidence per region and aspects in which change is observed or expected.

42.4. Catch and Forecast

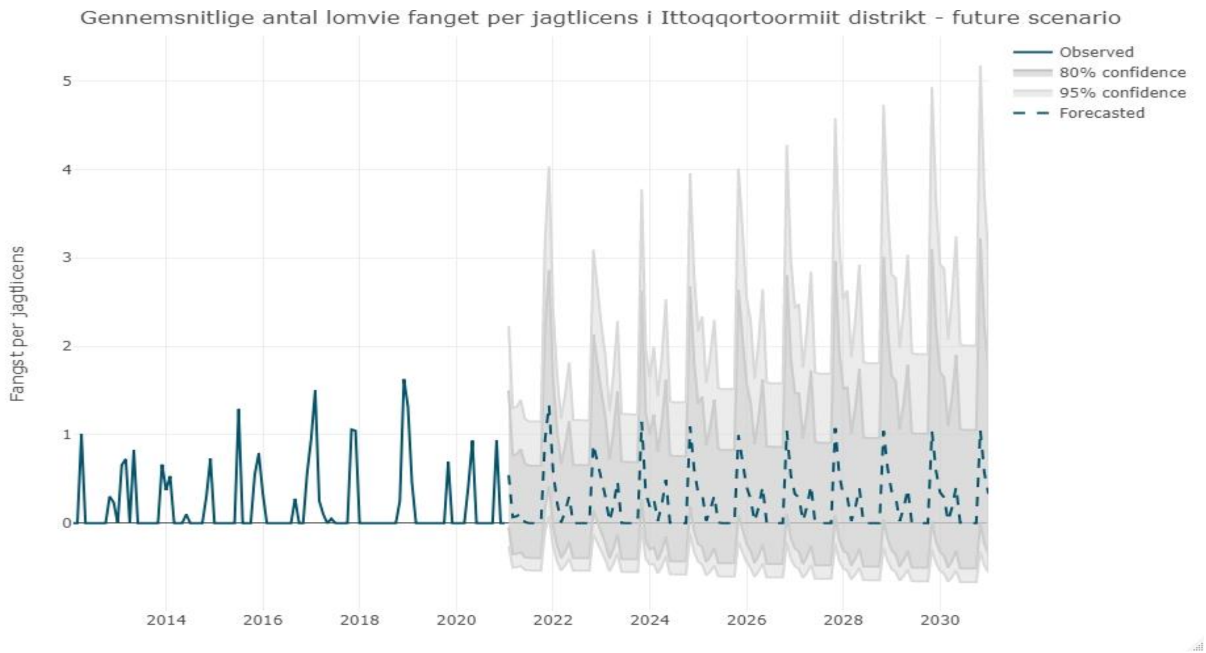


Figure 42.3. Average catch per hunter and forecast for Rock ptarmigan in Ittoqortoormiit district.

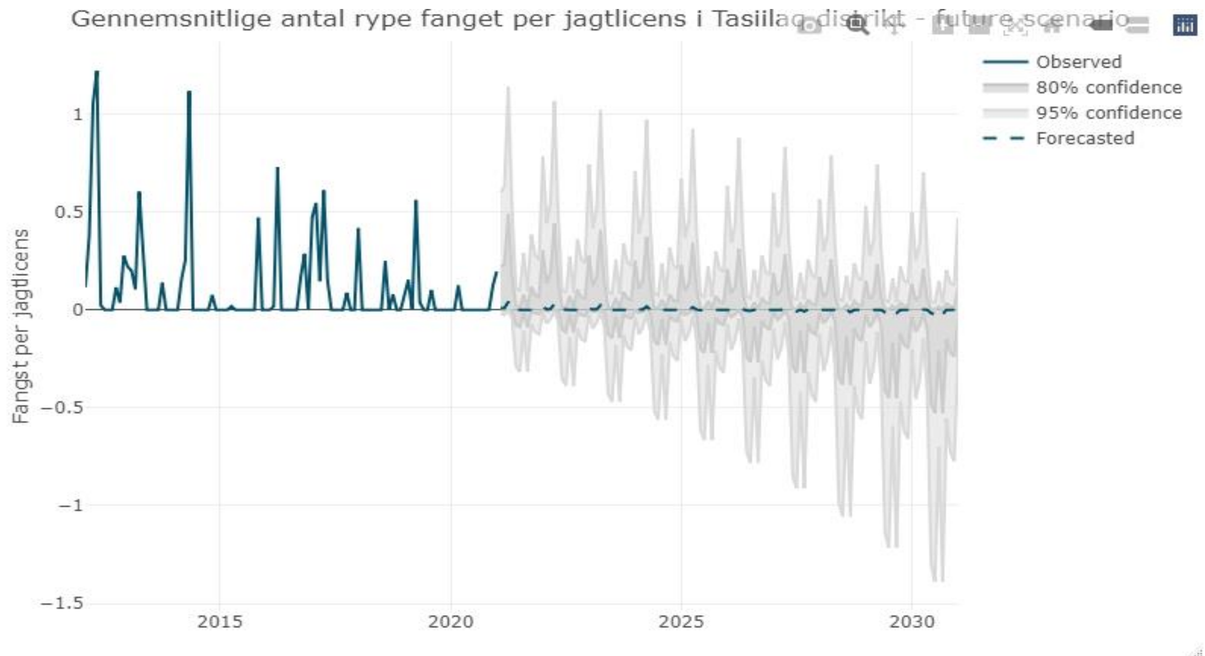


Figure 42.4. Average catch per hunter and forecast for Rock ptarmigan in Tasiilaq district.

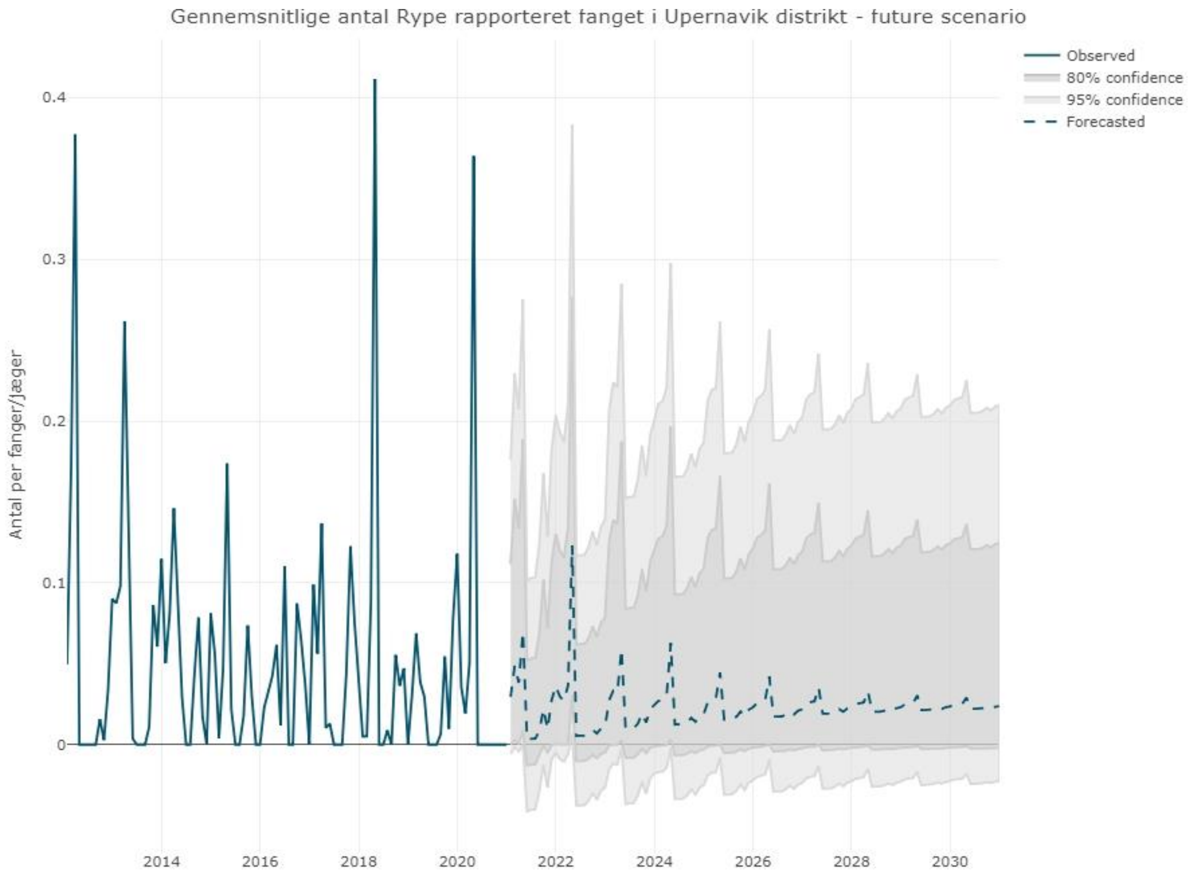


Figure 42.5. Average catch per hunter and forecast for Rock ptarmigan in Upernavik district.

The forecasts are not reliable. Nevertheless, the material was used as a basis for discussion.

Table 42.1. Average annual catch of Rock ptarmigan per hunter in the period 2012-2020, in 2020 and 2030 (forecasted) and the percentage change in 2030 relative to 2012-2020 and 2020.

District	2012-2020	2020	2030	Δ 2012-2020	Δ 2020
Ittoqoortoormiit	4,11	3,62	2,87	-30%	-21%
Tasiilaq	1,36	0,44	0,00	-100%	-100%
Upernavik	0,58	0,47	0,29	-51%	-39%
Ilulissat					

42.5. Workshops with Hunter and Fishers Organizations

Scenario	Ittoqortoormiit	Tasiilaq	Upernavik	Ilulissat
Trend scenario	Rarely targeted	Population has a cyclical trend and is declining now	Mainly caught by part time hunters. Cyclical development. Last year was high density peak	

Alternative scenario	NA	NA	NA	

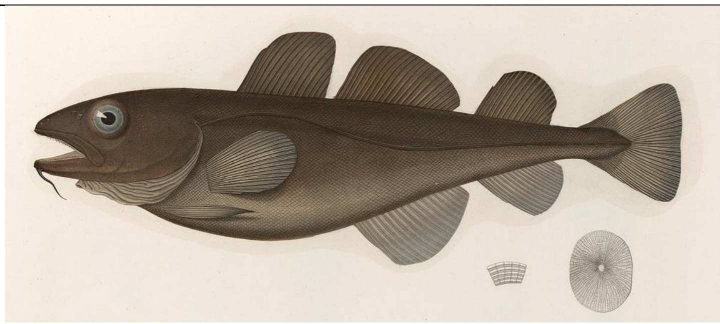
42.6. Interviews with Scientific Experts

-will follow-

42.7. Preliminary Future Scenarios

Scenario	Ittoqortoormiit	Tasiilaq	Upernavik	Ilulissat
Stock and catch trend scenario	-10% compared to 2012-20 average	-10% compared to 2012-20 average	-5% compared to 2012-20 average	2012-20 average
Underreporting adjustment scenario				
Alternative actions scenario				

43. Greenland cod (*Gadus macrocephalus/Gadus ogac*)

Greenland cod	
Gadus macrocephalus/ Gadus ogac	
Uvak	
Uuvaq	

A marine and brackish and demersal fish, ranging in depth from 10 to 1.280 m (FishBase, 2023). The range extends from Alaska to West Greenland, then southwards along the Canadian coast to the Gulf of St. Lawrence and Cape Breton Island (FishBase, 2023). Greenland cod is mainly used for human consumption as dried or frozen fish sold in the local Greenlandic market (Nygaard et al., 2022). It is also fished commercially, but landings have been significantly reduced recently (Nygaard et al., 2022). Greenland cod is mostly bycatch in other fisheries in fjords, where it is abundant (Nygaard et al., 2022). Total reported landings in 2021 amounted to 59 tons, of which the majority was landed in factories inshore in division 1B (Nygaard et al., 2022). No publications were found on the current trends in Greenland.

Figure 43.1. NAFO Divisions

43.1. Climate Change

No literature found on effects of climate change.

43.2. Status and Population Trends

All populations

Areas	Abundance	Status, change	Trend (Short term~1 generation)	Category of change	Description: physiological,behavioral change	Climate variable & direction	Hunting
	unknown	unknown	unknown				

43.3. Synopsis

No literature found on trends or generic evidence.

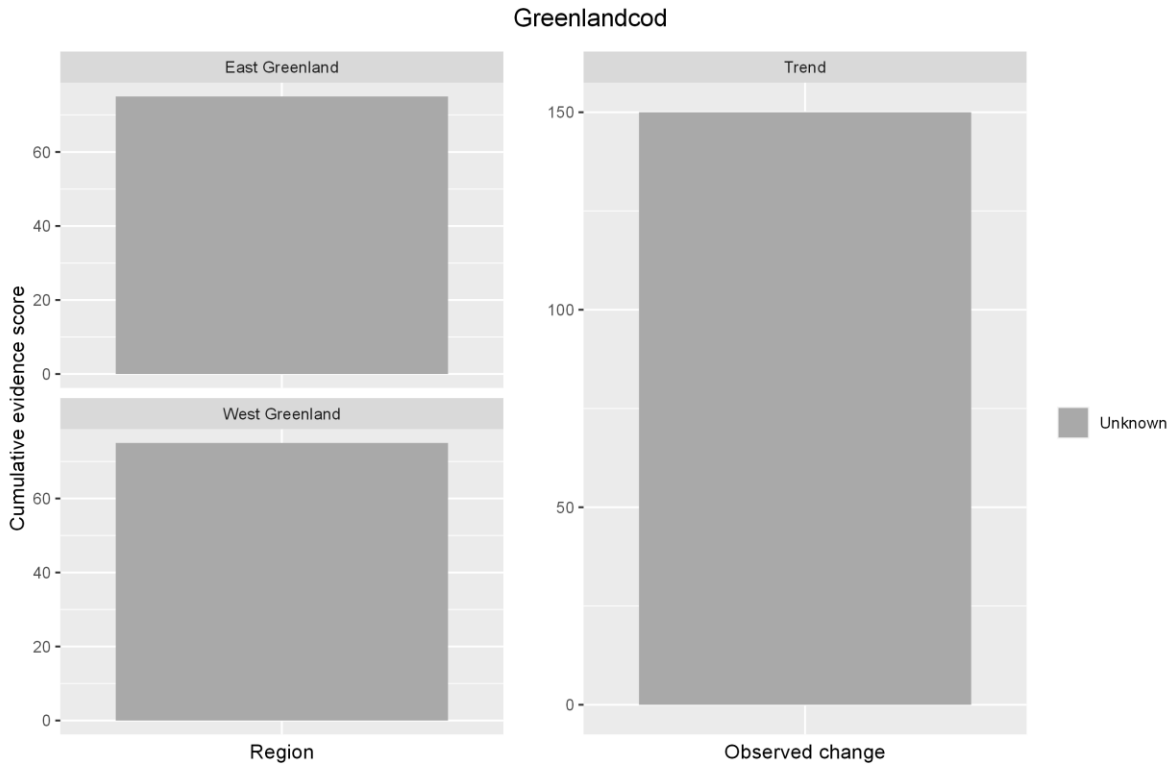


Figure 43.2 Cumulative evidence per region and aspects in which change is observed or expected.

43.4. Catch and Forecast

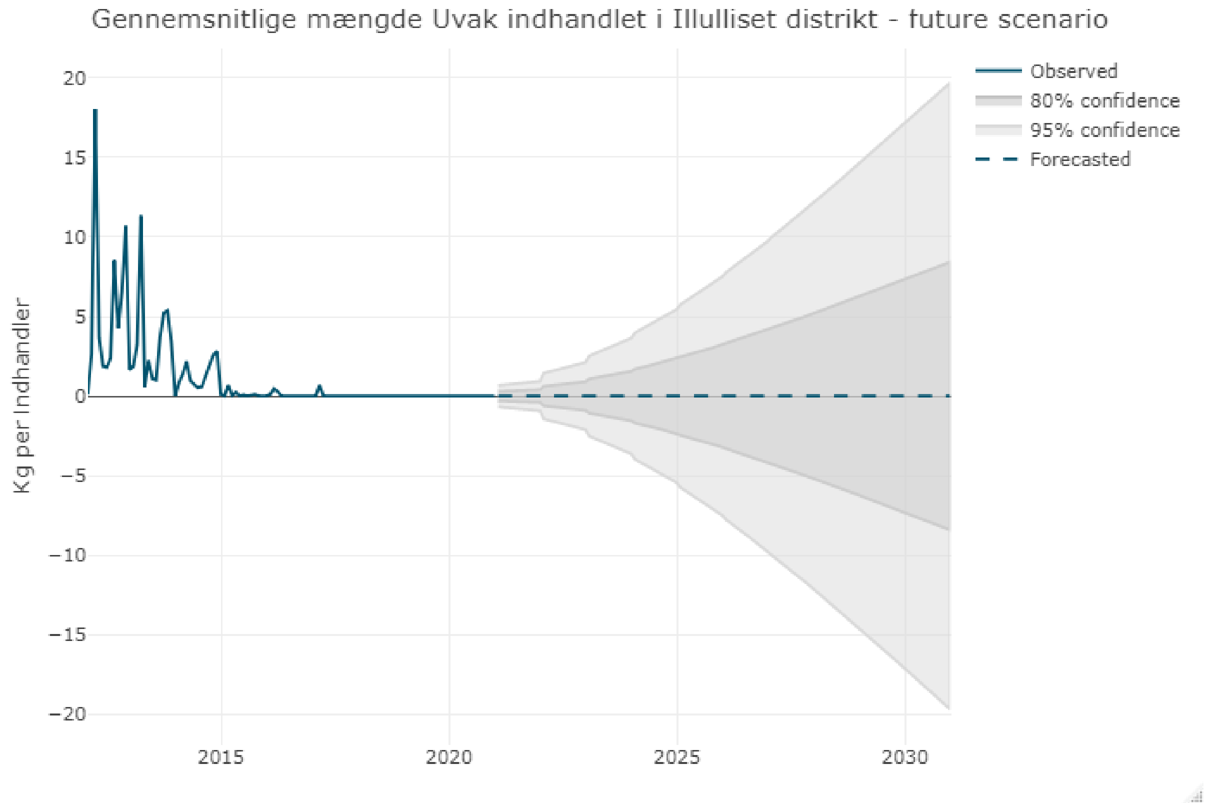


Figure 43.3. Average kg sold per trader and forecast for Greenlandic cod in Ilulissat district.

The forecast is not reliable. Nevertheless, the material was used as a basis for discussion.

Table 42.1. Average annual sale of Greenlandic cod per trader in the period 2012-2020, in 2020 and 2030 (forecasted) and the percentage change in 2030 relative to 2012-2020 and 2020.

District	2012-2020	2020	2030	Δ 2012-2020	Δ 2020
Ittoqoortoormiit					
Tasiilaq					
Upernavik					
Ilulissat					

43.5. Workshops with Hunter and Fishers Organizations

-not discussed-

43.6. Interviews with Scientific Experts

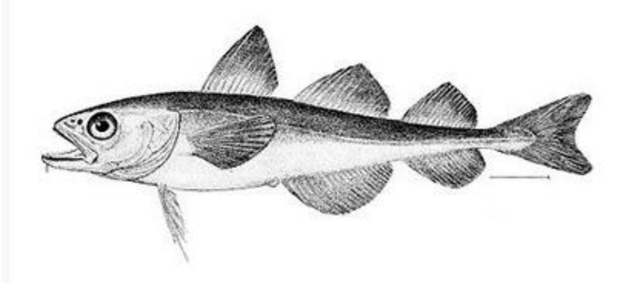
-will follow-

43.7. Preliminary Future Scenarios

Scenario	Ittoqortoormiit	Tasiilaq	Upernavik	Ilulissat

Stock and catch trend scenario				
Underreporting adjustment scenario				
Alternative actions scenario				

44. Polar cod (*Boreogadus saida*)

Polar cod	
Boreogadus saida	
Polartorsk	
Eqalugaq	

This species is found further north than any other fish (beyond 84°N), with a distribution spanning the Arctic seas off northern Russia, Alaska, Canada, and Greenland (FishBase, 2023). Polar cod is a pelagic or cryopelagic species with a circumpolar distribution in cold Arctic waters. It may form large aggregations and schools in some areas, often in the deeper part of the water column or close to the bottom in shelf waters (Boertmann and Mosbech, 2017).

Ice- dependent and cold-tolerant species like Polar cod are declining (Straneo et al., 2022). Polar cod in the East Greenland– Iceland area has been declining as temperatures have increased. However, the trend was not significant (Astthorsson, 2016). It is assumed that in long-term forage fish of boreal origin, such as capelin and sand lance, will displace Arctic cod (Straneo et al., 2022).

Figure 44.1.
Distribution of polar cod (Boreogadus saida) b ased on participation in research sampling, ex amination of museum voucher collections and the literature (Hedges et al. 2017)

Reported catches is mainly as bycatch in the shrimp fishery and directed fishery from small boats near glaciers and used directly for bait in the longline fishery targeting Greenland halibut. In 2021, 87 tons were reported, of which 46 were landed in factories, mainly from small boats (Nygaard et al., 2022).

44.1. Climate Change

Continued warming above 5·5° C revealed a large variability among individuals in the upper thermal limits that triggered cardiac arrhythmia (Drost et al., 2014). The presence of polar cod along the east coast of Greenland appears to align closely with the East Greenland ice edge (Astthorsson, 2016). Consequently, the ongoing reduction of sea ice in the Greenland Sea, combined with local warming, is expected to have implications for the distribution of polar cod along Greenland's east coast (Astthorsson, 2016). This changing environment could potentially hinder the movement of young pelagic fish and restrict the migration of older fish into Icelandic waters (Astthorsson, 2016). If these warming trends persist, there is a possibility that polar cod may eventually vanish from Icelandic waters (Astthorsson, 2016). No publications were found on the current trends in Greenland.

44.2. Interactions

Polar cod plays a very important role in the Arctic marine food webs and constitutes an important prey for many marine mammals and seabird species, notably ringed seal, harp seal, white whale, narwhal, thick-billed murre, northern fulmar, black-legged kittiwake, and ivory and Ross's gulls.

44.3. Status and Population Trends

All populations

Areas	Abundance	Status, change	Trend (Short term~1 generation)	Category of change	Description: physiological,behavioral change	Climate variable & direction	Hunting
	unknown	unknown	unknown				

44.4. Synopsis

We found moderately strong evidence for a decline in West Greenland and Greenland. We found weak generic evidence for a decline.

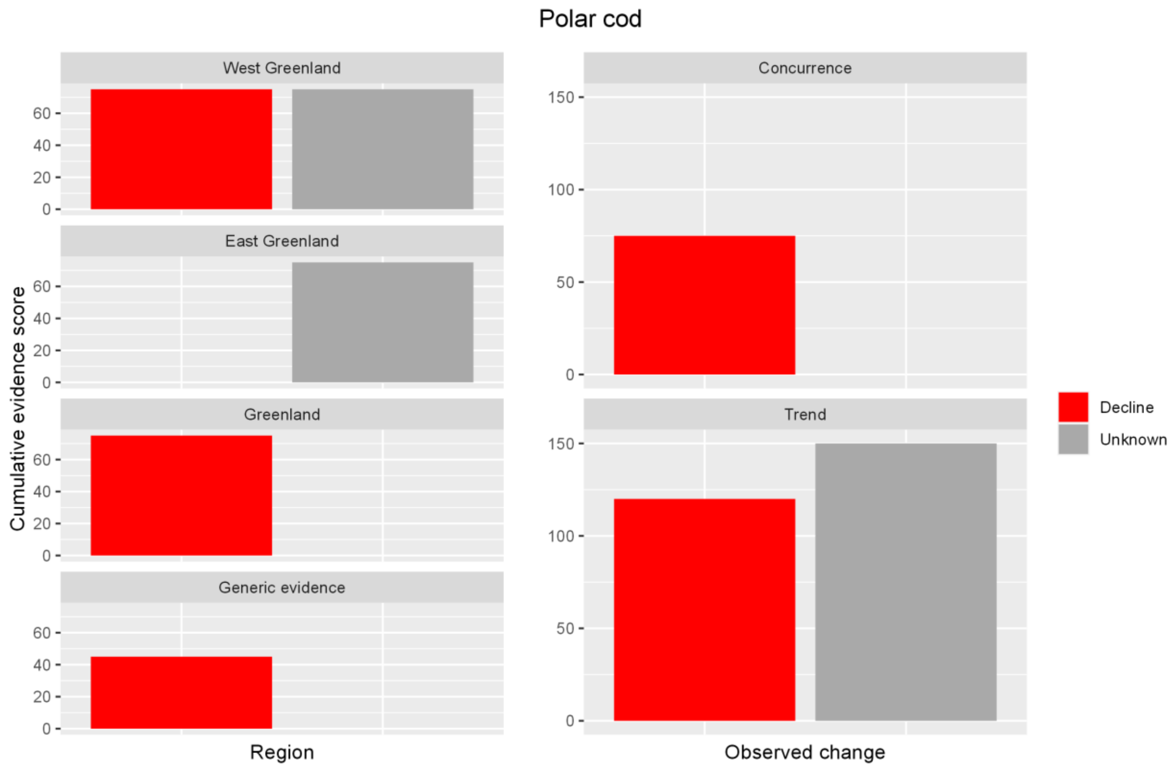


Figure 44.2 Cumulative evidence per region and aspects in which change is observed or expected.

44.5. Catch and Forecast

No reported landings in the relevant communities.

44.6. Workshops with Hunter and Fishers Organizations

-not discussed-

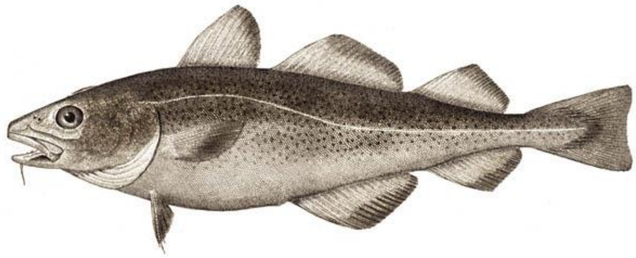
44.7. Interviews with Scientific Experts

-will follow-

44.8. Preliminary Future Scenarios

Scenario	Ittoqortoormiit	Tasiilaq	Upernavik	Ilulissat
Stock and catch trend scenario			2020 average	2020 average
Underreporting adjustment scenario			Plus 200 kg own catch	Plus 80 kg own catch
Alternative actions scenario				

45. Atlantic cod (*Gadus morhua*)

Atlantic cod	
Gadus morhua	
Torsk	
Saarulik	

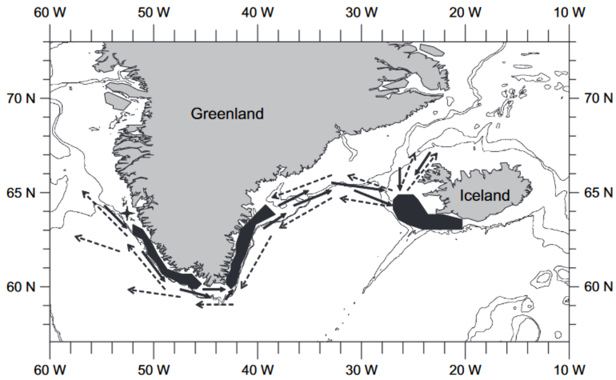


Figure 45.1. Dark shaded areas off West and East Greenland and southwest Iceland delimit main cod spawning areas, dashed arrows indicate pelagic drift of early life stages (eggs, larvae, and 0-group), and solid arrows indicate homing migration of adult fish.

Today, three cod stocks are known to live and reproduce (spawn) in Greenland: the inshore West Greenlandic, the offshore West Greenlandic and the East Greenlandic/Icelandic stock. Atlantic cod occurs from Upernavik in Northwest Greenland to the area around Tasiilaq in East Greenland (Greenland Institute of Natural Resources, 2021). Cod from the East Greenlandic/Icelandic stock also migrate to West Greenland and stay there - some years in large numbers - but migrate back to East Greenland or Iceland for spawning. Cod from the West Greenlandic stocks rarely leave West Greenland (Greenland Institute of Natural Resources, 2021). Genetic samples showed that the cod stock in Godthåbsfjorden in 2017 comprised approx. 20% East Greenlandic/Icelandic cod, approx. 30% cod from the West Greenlandic offshore stock and approx. 50% from the local inshore stock (Greenland Institute of Natural Resources, 2021). Atlantic cod is a highly opportunistic predator that preys upon many fish species present in East Greenland (Emblemsvåg et al., 2022b).

This fishery arose around 1920, as warming currents brought in Atlantic cod (Hamilton et al., 2003). The largest landing was in 1962, when 400,000 tonnes of cod were landed in West Greenland. Fishing declined sharply in the early 1970s, when water was cooling again (Hamilton et al., 2003), and in 1976 and 1980, only 25,000 and 15,000 tonnes were caught (Greenland Institute of Natural Resources, 2021). The West Greenland cod fishery collapsed completely in 1991, and there was no fishing until 2005, when a small trial fishery of 5.000 tonnes per year was introduced (Greenland Institute of Natural Resources, 2021). The majority of the historically high fishing took place offshore in West Greenland, and in 2021, the offshore West Greenlandic cod fishery has not yet been re-established (Nygaard et al., 2022). The majority of the historically high fishing took place offshore in West Greenland, and in 2021, the offshore West Greenlandic cod fishery has not yet been re-established. Substantial short-term recovery of the Greenland cod stock remains unlikely (Rätz and Lloret, 2005). As the cod fisheries vanished it was replaced by halibut and shrimp fisheries (Hamilton et al., 2003)

In 2021, the West Greenland offshore catches in the fishery amounted to a total of 96 tons on the main fishing grounds Tovqussaq Bank, Dana Bank, Fyllas Bank, Fiskenæs Bank, and

Narssalik Bank (Nygaard et al., 2022). The inshore cod fishery took 13.580 tons in 2021 (Nygaard et al., 2022).

45.1. Climate Change

The cod is the fish that has historically had the most significant economic importance for Greenland (Greenland Institute of Natural Resources, 2021). Over the last 200 years, Greenland has experienced alternating shorter and longer periods with many cod ("cod periods") and periods with almost no cod (Greenland Institute of Natural Resources, 2021). Warm periods, in particular, have produced much cod, but temperature cannot explain everything (Greenland Institute of Natural Resources, 2021). This larger, more motile generalist species can undergo rapid range shifts and has been entering Arctic regions in increasing abundance (Frainer et al., 2021).

Cod prefer cold and shallow habitats, environments that are also the most susceptible to rapid climate change. Ocean acidification, caused by increasing atmospheric concentrations of CO_2, has the potential to act as an additional source of natural mortality (Frommel et al., 2012). Another study showed that expected levels of ocean acidification (~1100 µatm according to the IPCC RCP 8.5) at 2100 resulted in a doubling of daily mortality rates compared to present-day CO_2 concentrations during the first 25 days post-hatching, and overall recruitment was reduced to an average of 8 and 24% of current recruitment (Stiasny et al., 2016). Overall, the impacts of climate scenarios might depend on whether climate change favours some prey species over others, th and the consequences to cod as a prey taxon (Link et al., 2009). For example, reductions in the extent or duration of sea ice might cause declines in seal populations, which, in turn, might promote increases in cod populations (Link et al., 2009). In the still relatively cold Barents Sea, the cod benefit from improved food conditions in the recent ice-free polar region but at the energetic cost of lengthier and faster-spawning migrations (Kjesbu et al., 2023).

45.2. Interactions

The populations of some marine mammals, such as Northwest Atlantic harp seals and Scotian Shelf grey seals, have increased dramatically during recent decades as they have rebounded under less-intensive harvesting or culling (Link et al., 2009). These and other mammals, such as minke whales, have not been adversely affected by the declines in cod populations because cod is generally a small portion of their diet, and they are sustained by other prey, most notably forage fish (Link et al., 2009).

45.3. Status and Population Trends

West Greenland

Areas	**Abundance**	**Status, change**	**Trend (Short term~1 generation)**	**Category of change**	**Description: physiological,behavioral change**	**Climate variable & direction**	**Hunting**
	Declined	**Increasing in range** (Frainer et al., 2021).	**Likely increasing** (Frainer et al., 2021).				

East Greenland

Areas	Abundance	Status, change	Trend (Short term~1 generation)	Category of change	Description: physiological,behavioral change	Climate variable & direction	Hunting
	Declined	**Increasing in range** (Frainer et al., 2021).	**Likely increasing** (Frainer et al., 2021).				

45.4. Synopsis

We found moderate evidence of an increase in East and West Greenland. We further found strong generric evidence for an increase and moderate evidence for future declines with a warming climate.

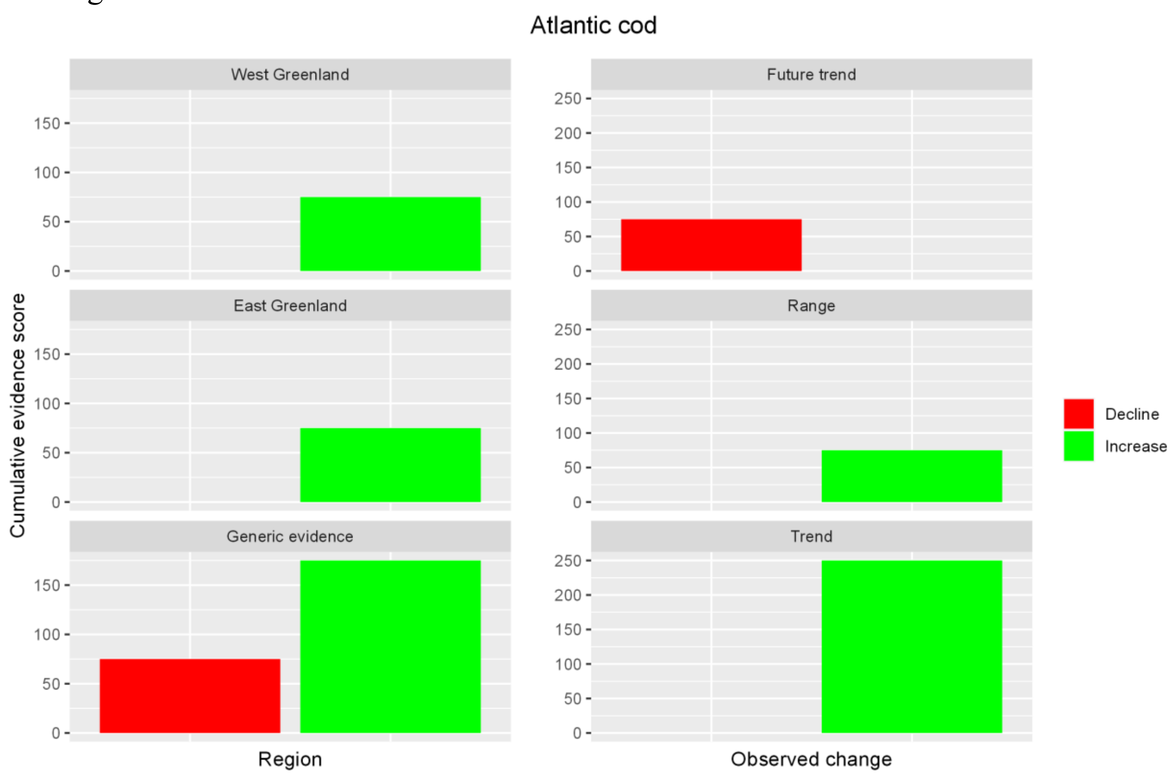


Figure 45.2. Cumulative evidence per region and aspects in which change is observed or expected.

45.5. Catch and Forecast

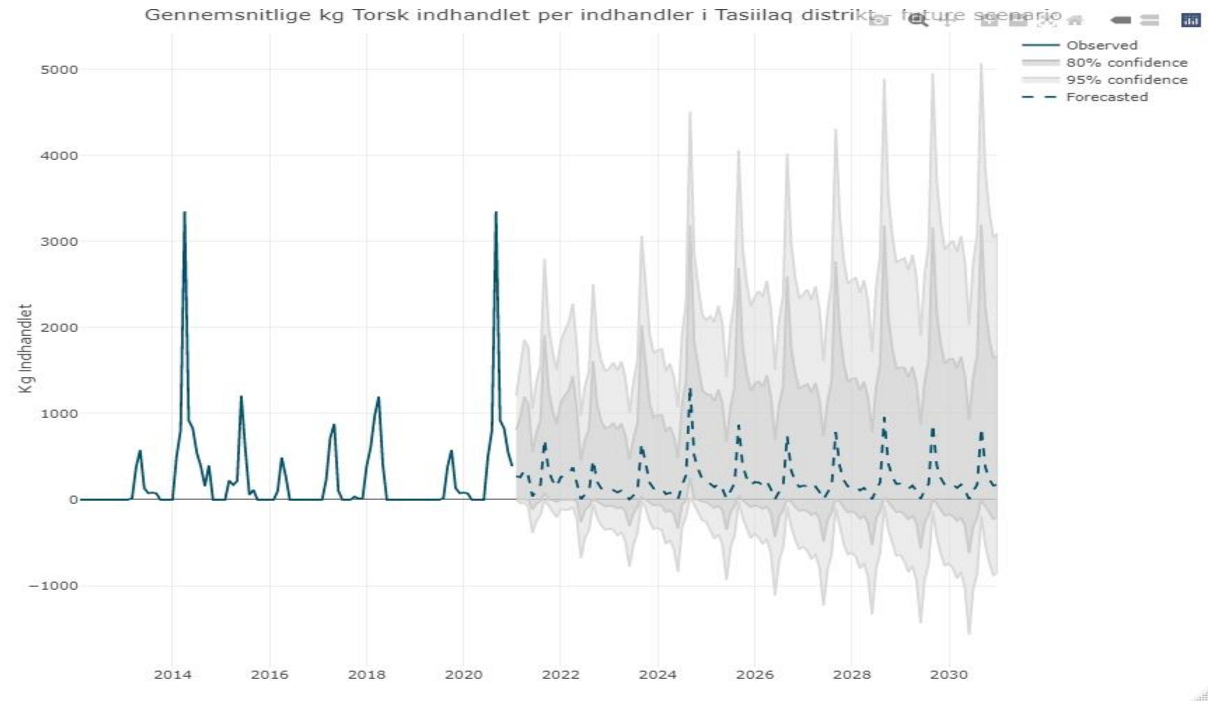


Figure 45.3. Average kg sold per trader and forecast for Atlantic cod in Tasiilaq district.

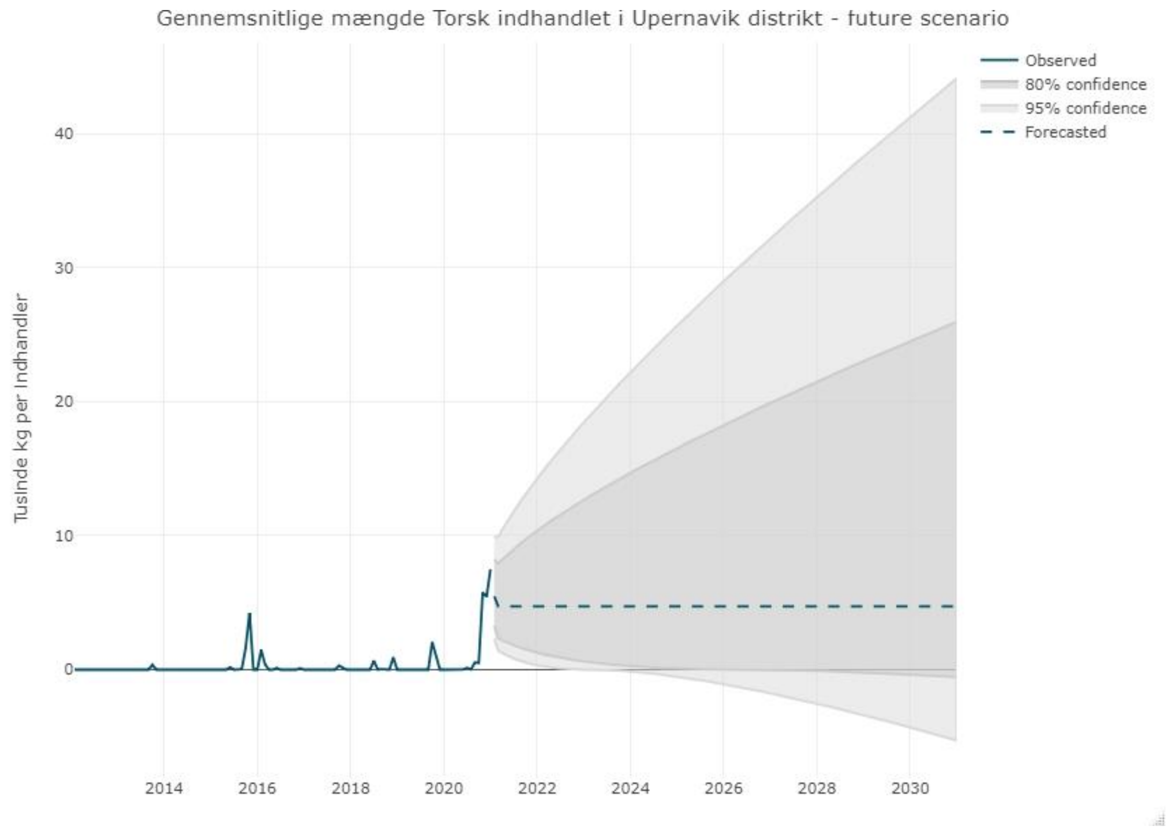


Figure 45.4. Average kg sold per trader and forecast for Atlantic cod in Upernavik district.

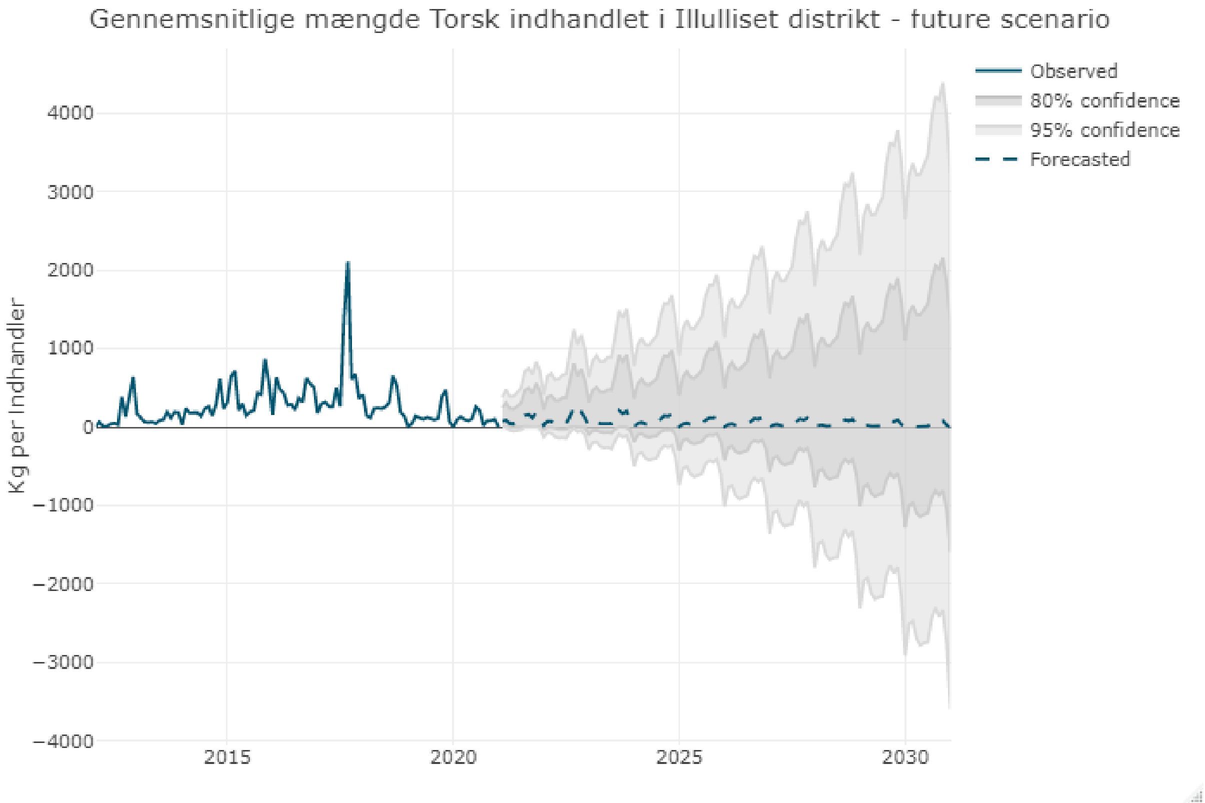


Figure 45.5. Average kg sold per trader and forecast for Atlantic cod in Ilulissat district.

The forecasts are not reliable. Nevertheless, the material was used as a basis for discussion.

Table 45.1. Average annual sale of Atlantic cod per trader in the period 2012-2020, in 2020 and 2030 (forecasted) and the percentage change in 2030 relative to 2012-2020 and 2020.

District	2012-2020	2020	2030	Δ 2012-2020	Δ 2020
Ittoqoortoormiit					
Tasiilaq					
Upernavik					
Ilulissat					

45.6. Workshops with Hunter and Fishers Organizations

Scenario	Ittoqortoormiit	Tasiilaq	Upernavik	Ilulissat
Trend scenario		Is returning slowly	Is returning slowly. Can only be traded in some settlements. Catch 200 kg for own use and local trade	Catch determined by quota. Catch 350 kg for own use and local trade
Alternative scenario		Expects increasing catch (triple)		

		but depends on the price of halibut. With development area subsidies to buy larger vessels, the catch may increase tenfold		

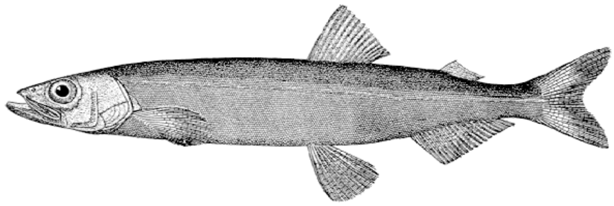
45.7. Interviews with Scientific Experts

-will follow-

45.8. Preliminary Future Scenarios

Scenario	Ittoqortoormiit	Tasiilaq	Upernavik	Ilulissat
Stock and catch trend scenario		2020 catch	2020 catch	2020 catch
Underreporting adjustment scenario		Plus 200 kg for own use and sale by occupational hunters	Plus 200 kg for own use and sale by occupational hunters	Plus 350 kg for own use and sale by occupational hunters
Alternative actions scenario		2020 catch multiplied by 3 2020 catch multiplied by 10		

46. Caplin (*Mallotus villosus*)

Caplin	
Mallotus villosus	
Lodde	
Ammassak	

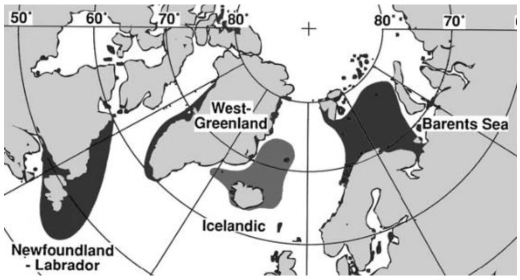


Figure 46.1. Map of current distribution of capelin (*Mallotus villosus*) and likely migration routes from North Pacific to North Atlantic (2005).

Capelin has a circumpolar distribution, and it is found from the southern tip of Greenland up to 73° N on the west and 70° N on the east coast, respectively. In recent years its range has moved north, and it occurs regularly now in the Qaanaaq area (Boertmann and Mosbech, 2017). Found in temperatures from -1.5 to 14 °C, preference: -1 to 6 °C.

Capelin stock size is highly variable because of the short life span and its dependence on recruitment (Rose, 2005a). Presently the stock size is very low and below the biomass reference point (NAFO, 2023). Reported catches of capelin amounted to 357 tons in 2021 and comprised a mix of factory-landed capelin (326 tons) for bait, human and animal consumption landed from small open boats mostly, and logbook-reported bycatch in other fisheries (Nygaard et al., 2022). No directed fishing was advised through 2022- 2024 (NAFO, 2023). Capelin abundance in the Irminger Sea and the Denmark Strait peaked in the mid-1990s and has been on a steady decline since then (Heide-Jørgensen et al., 2022).

46.1. Climate Change

Sea surface temperature changes of 1 °C can change the distribution over hundreds of kilometres, and larger changes of several degrees can result in much larger displacements (Rose, 2005a). As they react quickly to environmental changes, capelin have been considered an early warning sea ‘‘canary’’ for changes (Rose, 2005a). Further northward shifts are expected from Barents to Arctic Northeast Greenland (Andrews et al., 2019). Capelin are most often found in temperature and salinity regimes between −1 and 6°C and salinities between 33 and 35 psu, and they are known to prefer the border zones between cold Arctic and warmer Atlantic water. A large- scale shifts in occurrence of capelin have been documented since the early 2000s, probably due to changing sea temperatures (Bárðarson et al., 2021; Heide-Jørgensen et al., 2022). The spatial distribution of juveniles shifted from the north of Iceland and east of the South East Greenland shelf break. After the early 2000s, juvenile capelin occupied shelf waters closer to the East Greenland coast than before ca. 2000 (a shift of several 100 km westward), and the distribution of feeding areas of adult capelin has shifted further to the west and north (Bárðarson et al., 2021; Heide-Jørgensen et al., 2022). The spatial distribution of young juvenile capelin expanded farther south on the shelf into the Denmark Strait, where previously, these age classes were absent. The increase in sea temperatures in the coastal and shelf area off South East Greenland and north of Iceland is likely driving the observed range shift of capelin toward the East Greenland coast and also declining recruitment to the stock (Jansen et al., 2021). In general, 2003 was observed to be a year of abrupt changes for South East Greenland (Heide-Jørgensen et al. 2022).

For a scenario of temperature increases of 2-4 C in the 21st century and strictly northerly shifts in capelin, analysis suggests a maximal shift of approximately 400 to 1800 km (4 to 18-degree latitude) (Rose, 2005a). During warm years in the eastern Bering Sea (EBS) ecosystem, the mean catch per unit effort (CPUE) of capelin was notably lower compared to cold years (Andrews et al., 2016). Additionally, the lengths of capelin and herring remained relatively consistent across different climate periods (Andrews et al., 2016). An observed switch to less energetic prey for these forage fishes during warm years may have implications for fitness and future recruitment (Andrews et al., 2016). After a regime shift in the marine community of the Newfoundland and Labrador Shelf in the early 1990s, the capelin stock severely declined in 1991 and has not yet recovered. Spawning became protracted and was delayed up to four weeks, while size and age at maturity, and somatic condition declined (Buren et al., 2014). An analysis of a long-term time series (20 years) of capelin population biomass and time of peak spawning explained the time of peak spawning as a linear function of the maximum annual extent of sea ice and capelin biomass as a dome-shaped function of the start time of ice retreat, with maximal biomass at approximately the 95 day of the year (Buren et al., 2014). Maximum capelin biomass occurs when the sea ice retreats northward in early April and low biomasses if ice retreats earlier than February 19 (Buren et al., 2014). This likely creates a match/mismatch phenomenon between the timing of the onset of the spring bloom, triggered by the retreat of sea ice, and the abundance of emergent *Calanus finmarchicus* (capelin's main prey) from diapause, with its effects percolating to capelin via nutritional stress (Buren et al., 2014).

46.2. Interactions

Capelin has a central role as a keystone species for the bottom-up control through the food web (Buren et al., 2014). Capelin is a key prey for many predators in the system, such as cod, harp seals, Greenland halibut, whales and seabirds (Buren et al., 2014). Capelin faces significant predation from cod and Atlantic salmon (*Salmo salar*), which are the primary fish predators of capelin, as well as from Harp seals (*Phoca groenlandica*) and minke whales (*Balanaeoptera acutorostrata*) (Friis-Rødel, 2002). Additionally, other species such as Greenland halibut (*Reinhardtius hippoglossoides*), fjord cod (*Gadus ogac*), Arctic char (*Salvelinus alpinus*), and hooded seals (*Cystophora cristata*) prey on capelin, although limited studies have been conducted to estimate the quantity of fish prey consumed by these predators off the coast of Greenland (Friis-Rødel, 2002).

46.3. Status and Population Trends

West Greenland

Areas	Abundance	Status, change	Trend (Short term~1 generation)	Category of change	Description: physiological,behavioral change	Climate variable & direction	Hunting

	Low (NAFO, 2023).	**Declined** (NAFO, 2023).	**Fluctuating** (NAFO, 2023).		**Expanding**		

<u>East Greenland</u>

Areas	**Abundance**	**Status, change**	**Trend (Short term~1 generation)**	**Category of change**	**Description: physiological,behavioral change**	**Climate variable & direction**	**Hunting**
	Low (Heide-Jørgensen et al., 2022).	**Declined** (Heide-Jørgensen et al., 2022).	**Declining** (Heide-Jørgensen et al., 2022).		**Expanding**		

46.4. Synopsis

We found strong evidence for a decline in East Greenland and stable populations in West Greenland. For Northeast Greenland, we found strong evidence for an increase. The generic evidence points strongly to an overall decline.

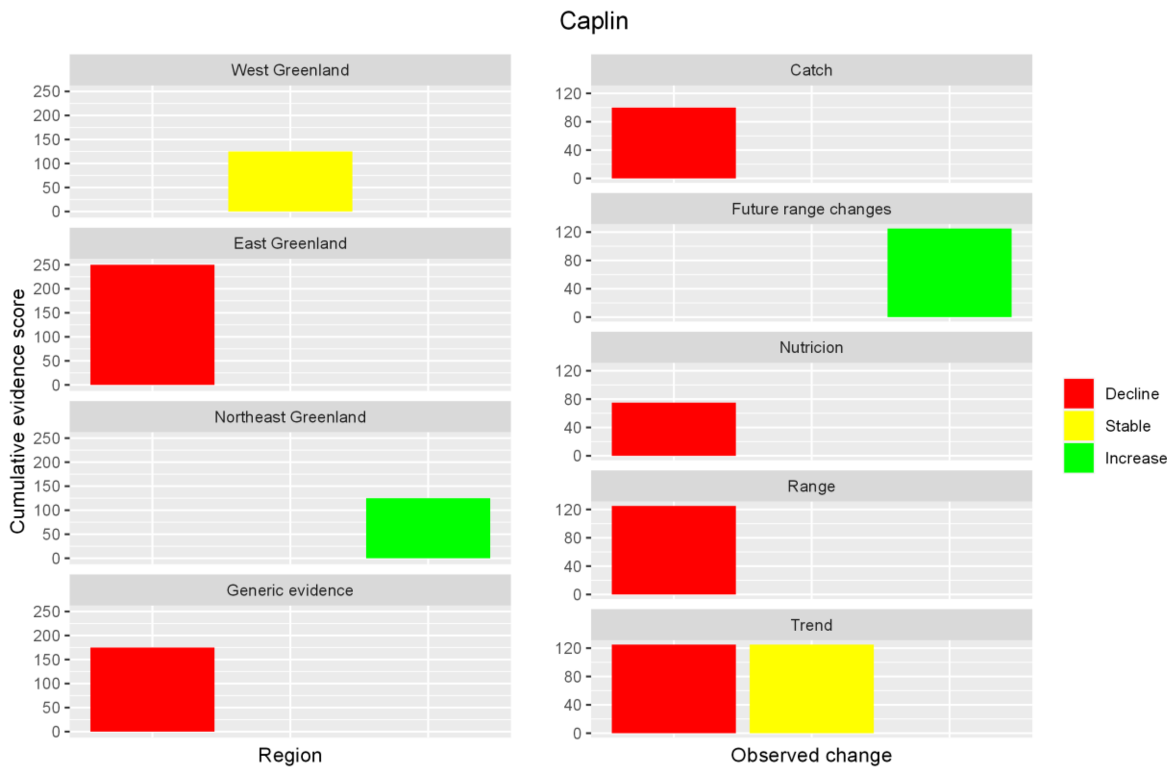


Figure 46.1 Cumulative evidence per region and aspects in which change is observed or expected.

46.5. Catch and Forecast

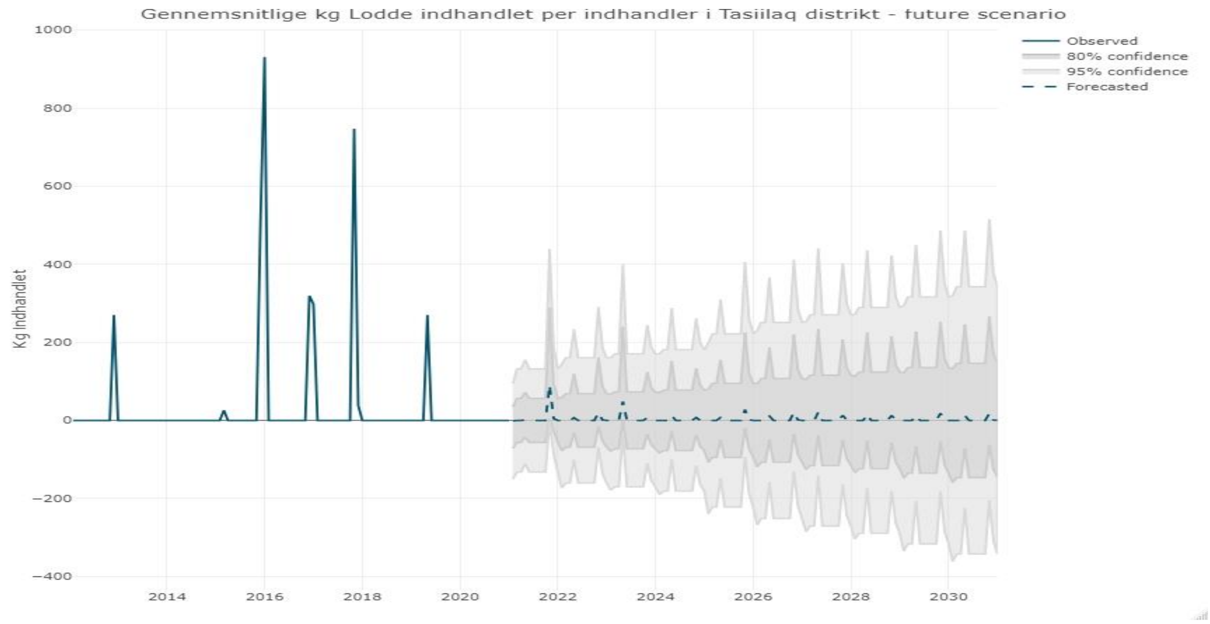


Figure 46.2. Average kg sold per trader and forecast for Capelin in Tasiilaq district.

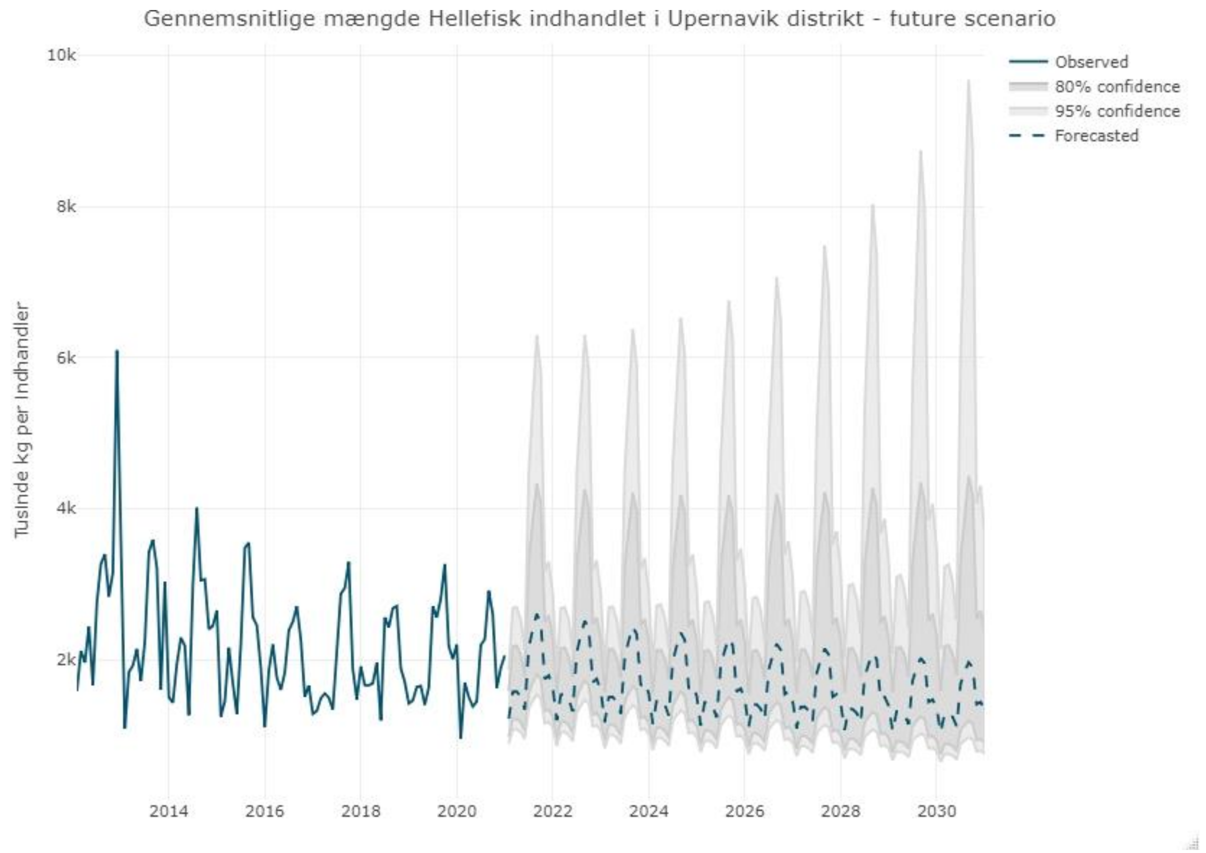


Figure 46.3. Average kg sold per trader and forecast for Capelin in Upernavik district.

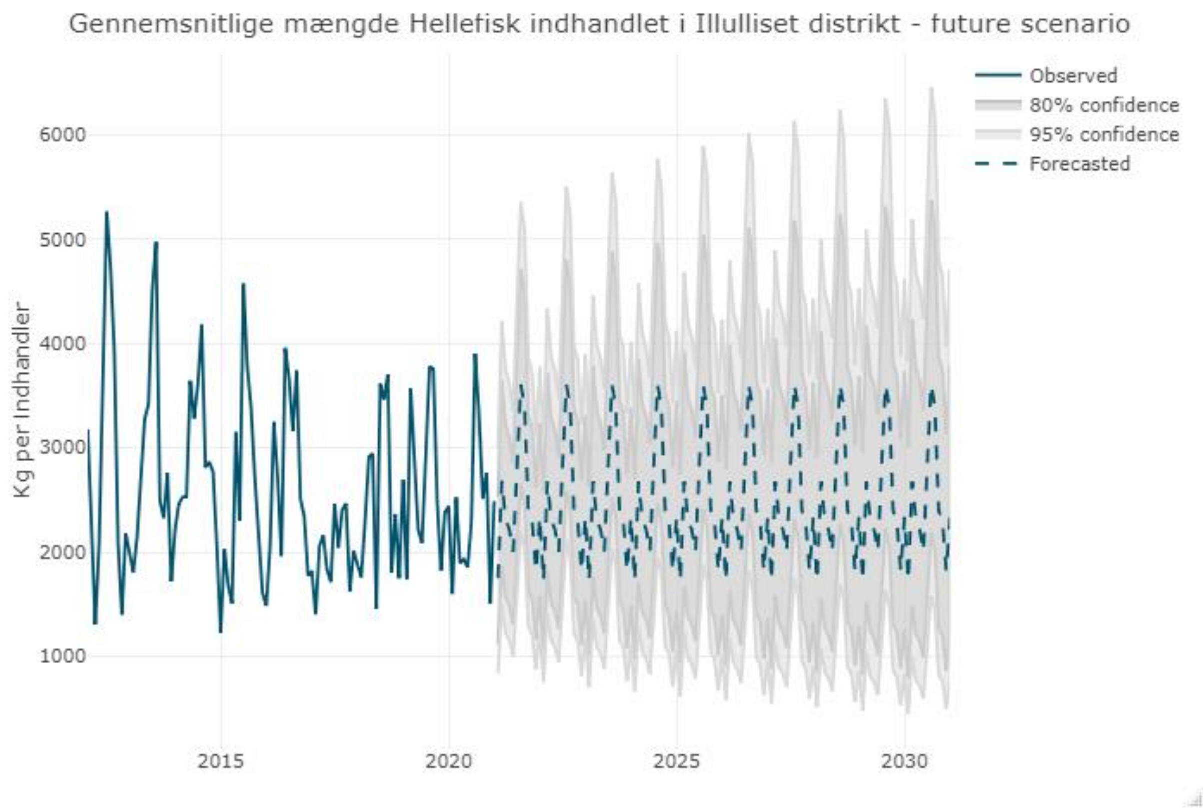


Figure 46.4. Average kg sold per trader and forecast for Capelin in Ilulissat district.

The forecasts are not reliable. Nevertheless, the material was used as a basis for discussion.

Table 46.1. Average annual sale of Capelin per trader in the period 2012-2020, in 2020 and 2030 (forecasted) and the percentage change in 2030 relative to 2012-2020 and 2020.

District	2012-2020	2020	2030	Δ 2012-2020	Δ 2020
Ittoqoortoormiit					
Tasiilaq	379,39	0,00	31,26	-92%	NA
Upernavik					
Ilulissat					

46.6. Workshops with Hunter and Fishers Organizations

Scenario	Ittoqortoormiit	Tasiilaq	Upernavik	Ilulissat
Trend scenario		Catch determined by trade quota and use as bait. Considerable own use	Catch determined by trade quota, own use and use as bait. At the limit of range and mainly caught in southern settlements	Caught by the same 5 boats and determined by quota and ice
Alternative scenario		Increasing catch if halibut	Northward range expansion.	Larger quota of 22 ton plus

		fishery factory is build		

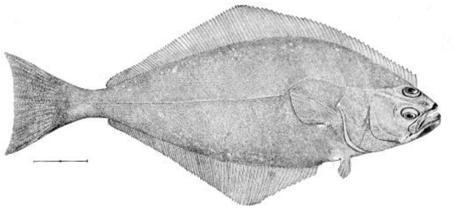
46.7. Interviews with Scientific Experts

-will follow-

46.8. Preliminary Future Scenarios

Scenario	Ittoqortoormiit	Tasiilaq	Upernavik	Ilulissat
Stock and catch trend scenario		2020 catch	2020 catch	2020 catch
Underreporting adjustment scenario		plus 250 kg for own use	plus 2-3 tones in the southern settlements	plus 60 tones for local trade and own use shared between the five people landing
Alternative actions scenario		Match the expected landings at the new factory	Match the halibut fishery quota	landing Increase to 22 tons

47. Greenland halibut (*Reinhardtius hippoglossoides*)

Greenland halibut	
Reinhardtius hippoglossoides	
Hellefisk	
Qaleralik	

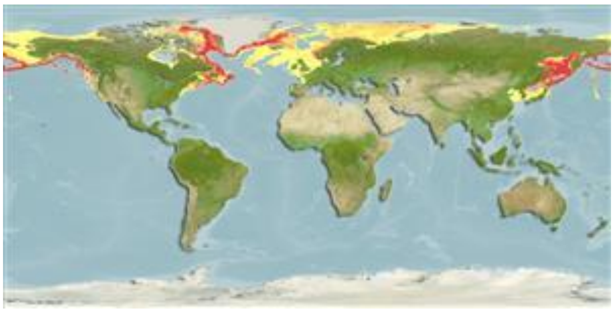


Figure 47.1. Map of range

The Greenland Halibut fishery is currently the largest and most valuable fishery in the Baffin Bay-Davis Strait regions (Government of Nunavut, 2016). The highest fishing effort takes place south of 67°N and minor effort north of 67°N (Greenland Institute of Natural Resources, 2021). Also, in Southeast Greenland, the value of this commercial fishery now accounts for the largest part of the economy (47% on average between 2012 and 2020), surpassing ringed seal (31%) and harp seal (11%), which were the most important species in the past in terms of coastal resources (Straneo et al., 2022). Greenland Halibut is a demersal flatfish usually found in waters 500-1000 m deep (DFO, 2017; Anderson et al., 2018). Catches of Greenland halibut, both inshore and offshore, dominate in West Greenland (Nuttall, 2020). In Upernavik and Qaanaaq, the inshore coastal fishery for Greenland halibut uses long lines from small open boats in the summer or dog sledges through holes in the sea ice during winter. It provides income and employment in production and processing (Nuttall, 2020).

Assessments by fisheries biologists suggest that Greenland halibut stocks have increased in recent years while the average size of individual fish landed has decreased (Nuttall, 2020). The Greenland fishing industry, particularly on the east coast, is poised to grow in the coming years as some of the distribution ranges of commercially harvested species continue to shift northward into newly productive waters (Straneo et al., 2022). New opportunities have arisen for the development of a Greenland halibut catch in Kangerlussuaq because of fish movements further north (Nuttall, 2020). The Greenland halibut stock is currently at full reproductive capacity with sustainable fishing pressure in accordance with maximum sustainable yield (Nogueira and Jorgensen, 2018).

47.1. Climate Change

The thermal range we calculated for the Arctic stenotherm, specifically the Greenland halibut, was remarkably constrained, spanning from -1.89°C to 8.07°C (Ruth et al., 2023). This narrow range stands out in comparison to the thermal tolerances observed in the majority of other fish species (Ruth et al., 2023). With ocean temperatures experiencing the swiftest rise in the Arctic as a result of climate change, and considering the limited ability of species in these regions to migrate towards higher latitudes, it may indicate that global warming could have severe implications for Arctic stenotherms such as Greenland halibut (Ruth et al., 2023). Moreover, there is an optimal temperature range, which was surpassed at 7.5°C, which is critical for the survival and healthy growth of juvenile Greenland halibut (Ghinter et al., 2021). Any further rise in temperature would lead to a substantial decrease in survival rates and hinder the growth of the species.

Considering the ongoing warming trends in the Estuary and Gulf of St. Lawrence, particularly in deep-water areas, there is a potential risk of impaired recruitment and a negative impact on commercial fishing activities targeting Greenland halibut in the near future (Ghinter et al., 2021). During a specific period spanning from the mid-1980s to the mid-1990s, characterized by notably cold ocean conditions, Greenland halibut exhibited a tendency to inhabit deeper waters and migrated towards offshore areas located further south (Wheeland and Morgan, 2019). Notably, the most noticeable shifts in distribution across periods with distinct thermal conditions were observed among the youngest age groups of the species (Wheeland and Morgan, 2019).

47.2. Status and Population Trends

West Greenland

Areas	Abundance	Status, change	Trend (Short term~1 generation)	Category of change	Description: physiological,behavioral change	Climate variable & direction	Hunting
	unkown	**unkown**	increased in recent years while the average size of individual fish landed has decreased (Nuttall, 2020)		Expanding northwards		

East Greenland

Areas	Abundance	Status, change	Trend (Short term~1 generation)	Category of change	Description: physiological,behavioral change	Climate variable & direction	Hunting
	unkown	**unkown**	increased in recent years while the average size of individual fish landed has decreased (Nuttall, 2020)		Expanding northwards		

47.3. Synopsis

We found strong evidence of an increase in East and West Greenland. The generric evidence shows strong evidence for a future decline of this species due to the temperature niche.

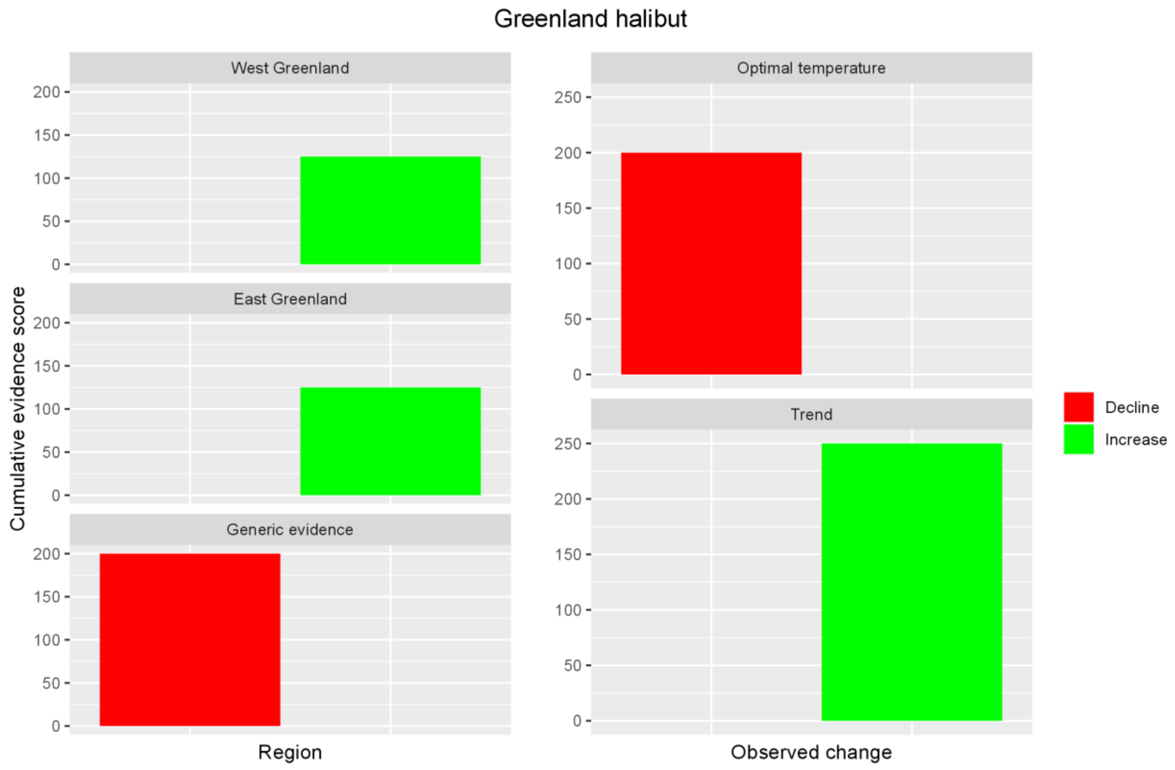


Figure 47.2 Cumulative evidence per region and aspects in which change is observed or expected.

47.4. Catch and Forecast

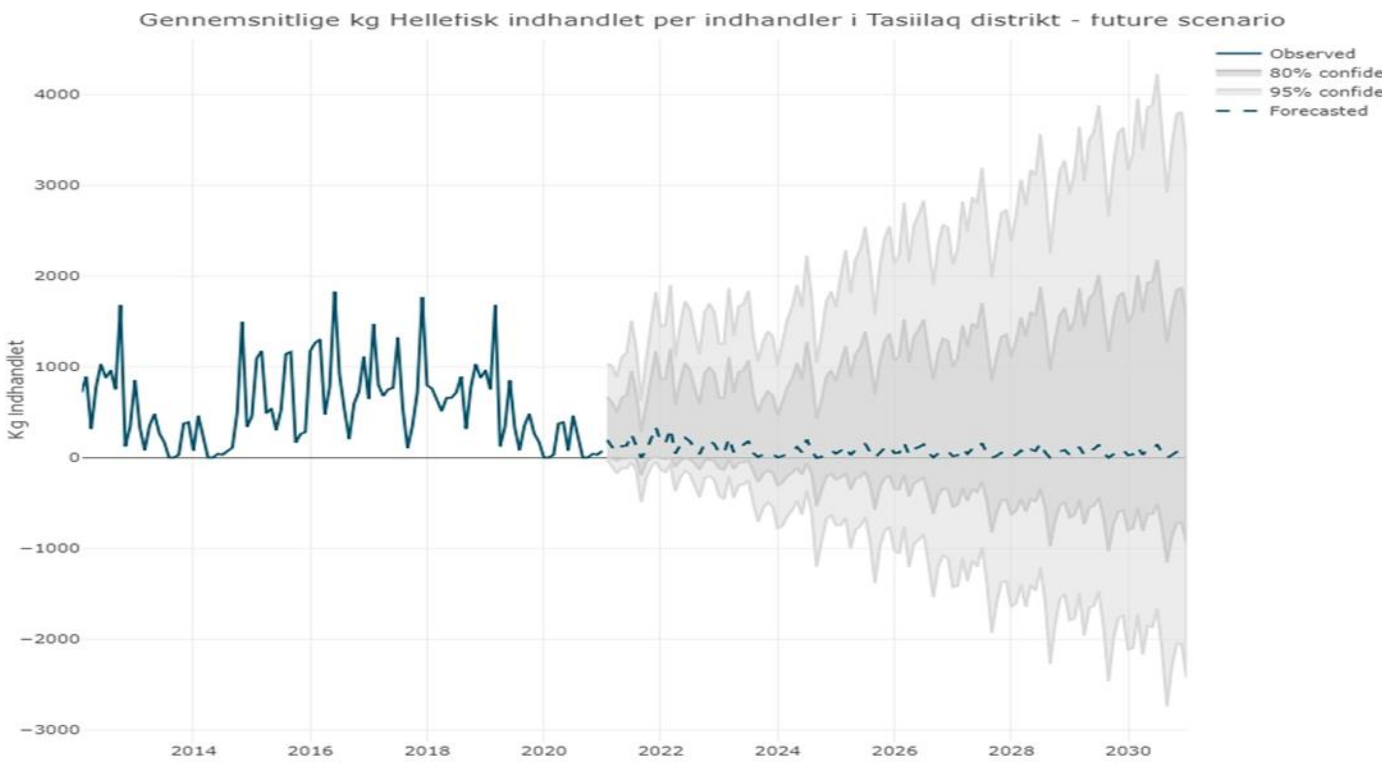


Figure 47.3. Average kg sold per trader and forecast for Greenlandic halibut in Tasiilaq district.

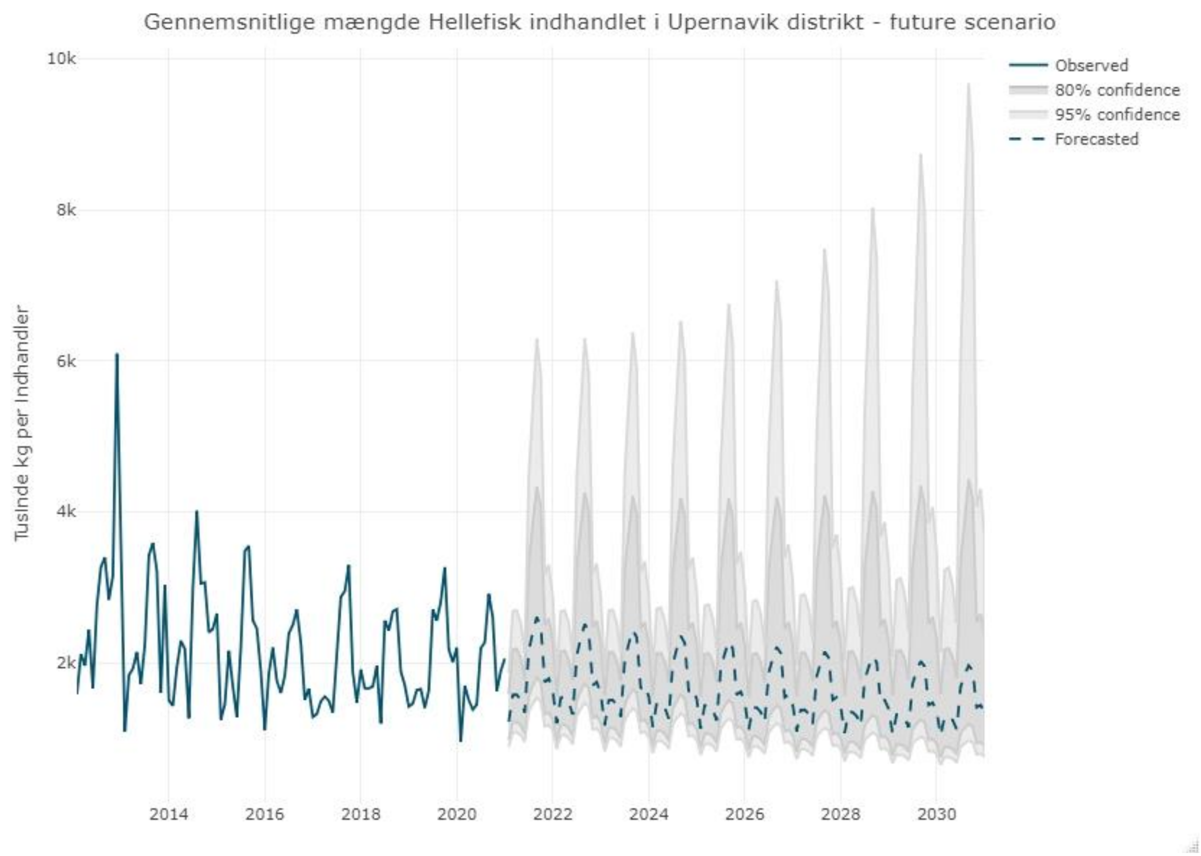


Figure 47.4. Average kg sold per trader and forecast for Greenlandic halibut in Upernavik district.

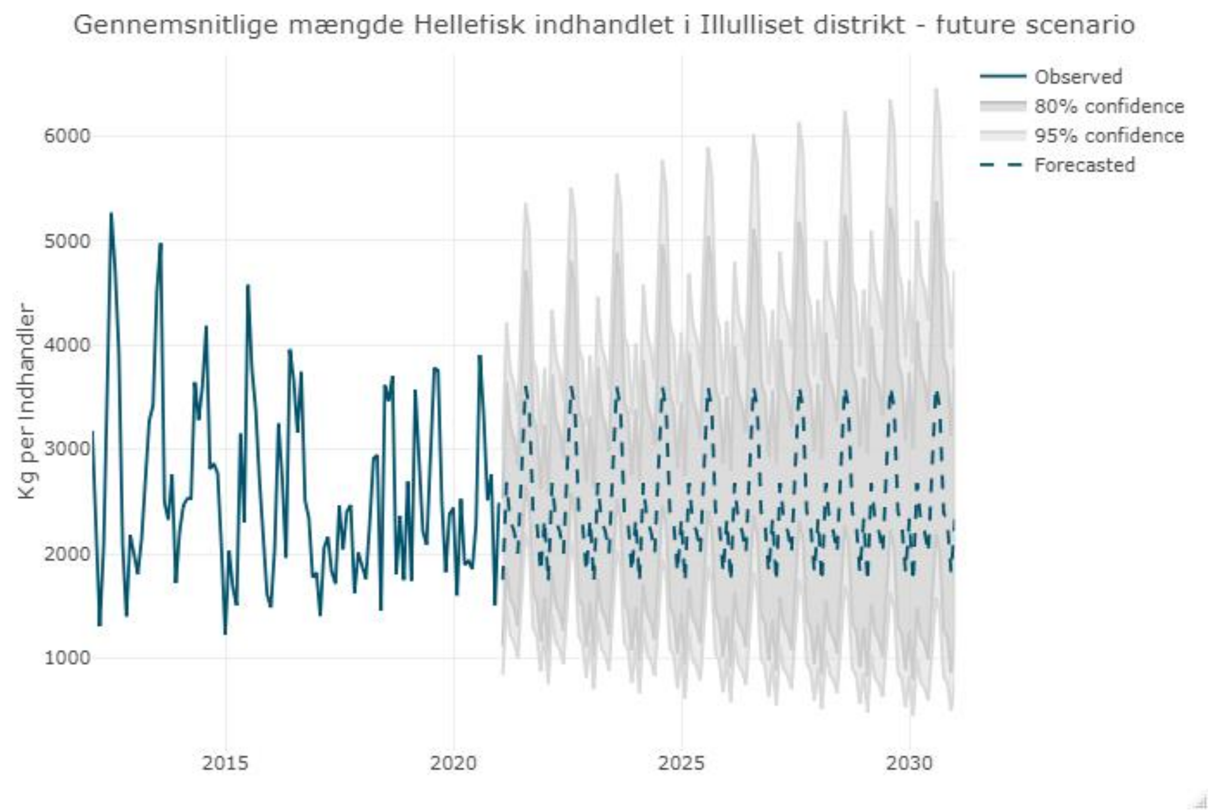


Figure 47.5. Average kg sold per trader and forecast for Greenlandic halibut in Ilulissat district.

The forecasts are not reliable. Nevertheless, the material was used as a basis for discussion.

Table 47.1. Average annual sale of Greenlandic halibut per trader in the period 2012-2020, in 2020 and 2030 (forecasted) and the percentage change in 2030 relative to 2012-2020 and 2020.

District	2012-2020	2020	2030	Δ 2012-2020	Δ 2020
Ittoqoortoormiit					
Tasiilaq	6727,37	1726,53	744,78	-89%	-57%
Upernavik	26206,00	22523,93	17539,47	-33%	-22%
Ilulissat	31196,54	28587,17	29623,39	-5%	4%

47.5. Workshops with Hunter and Fishers Organizations

Scenario	Ittoqortoormiit	Tasiilaq	Upernavik	Ilulissat
Trend scenario		Catch determined by trade quota. Considerable fluctuations in access	Catch is determined by trade quota., which is declining. But thinks the stock is stable. Continuously finding new areas.	Stable stock.
Alternative scenario		Factory expected opening enabling increased landings (look up quota)	Ice edge fishers excluded	Ice edge fishers excluded

47.6. Interviews with Scientific Experts

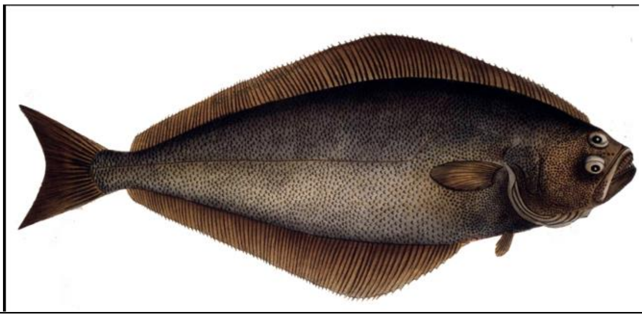
-will follow-

47.7. Preliminary Future Scenarios

Scenario	Ittoqortoormiit	Tasiilaq	Upernavik	Ilulissat
Stock and catch trend scenario		2012-20 average	2020 trade	2020 trade
Underreporting adjustment scenario			Plus 300 kg for own use	Plus 100 kg for own use and local trade

Alternative actions scenario		Catch matching expected factory quota	Individuals without a boat or catching less than 15 ton excluded	Individuals without a boat or catching less than 15 ton excluded

48. Atlantic halibut (*Hippoglossus hippoglossus*)

<table>
<tr><td>Atlantic halibut</td><td rowspan="4"></td></tr>
<tr><td>Hippoglossus hippoglossus</td></tr>
<tr><td>Helleflynder</td></tr>
<tr><td>Nataarnaq</td></tr>
</table>

The largest flatfish in the world, the Atlantic halibut is a right-sided flounder. Found from southwestern Greenland and Labrador, Canada to Virginia in the USA (FishBase, 2023). Catches of Atlantic halibut peaked at the beginning of the 1960s and the mid-1980s at a level of 600 to 1000 tons per year (Nygaard et al., 2022). In 2021, only a few hundred kg were reported in logbooks, and 12 tons were landed in factories (Nygaard et al., 2022).

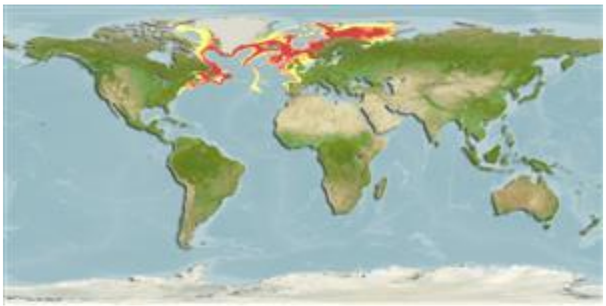


Figure 48.1. Map of distribution.

48.1. Climate Change

Projections until 2050 of future distribution and potential catches of exploited flatfishes from computer simulation models show that the majority (67%) of the flatfish stocks in the North Atlantic and North Pacific (N = 97) were projected to shift poleward by an average rate of shift of 39.1 km decade−1 to and a maximum of over 100 km decade−1 (under an RCP 8.5. scenario) (Cheung and Oyinlola, 2018). Total maximum catch potential from the 47 exploited flatfish species decreased highest in tropical regions and increased in the Arctic-North Atlantic region (Cheung and Oyinlola, 2018). Potential marine area suitable for flatfish production of Atlantic halibut was particularly suitable in the western part, down from Uppernavik and to a lesser extent at the southern East Coast (Cheung and Oyinlola, 2018). In Canada, Atlantic halibut's thermal habitat has increased due to warming, possibly contributing to its expansion (Shackell et al., 2022).

48.2. Status and Population Trends

West Greenland

Areas	Abundance	Status, change	Trend (Short term~1 generation)	Category of change	Description: physiological,behavioral change	Climate variable & direction	Hunting

	unkown	**Reduced** (Nygaard et al., 2022)	**unkown**				

East Greenland

Areas	**Abundance**	**Status, change**	**Trend (Short term~1 generation)**	**Category of change**	**Description: physiological,behavioral change**	**Climate variable & direction**	**Hunting**
	unkown	**Reduced** (Nygaard et al., 2022)	**unknown**				

48.3. Synopsis

We found moderate evidence for a decline in East and West Greenland. We found moderate evidence for an increase in Greenland and the Upernavic region due to future range shifts and trends related to climate change. We found moderate generic evidence for an increase of this species.

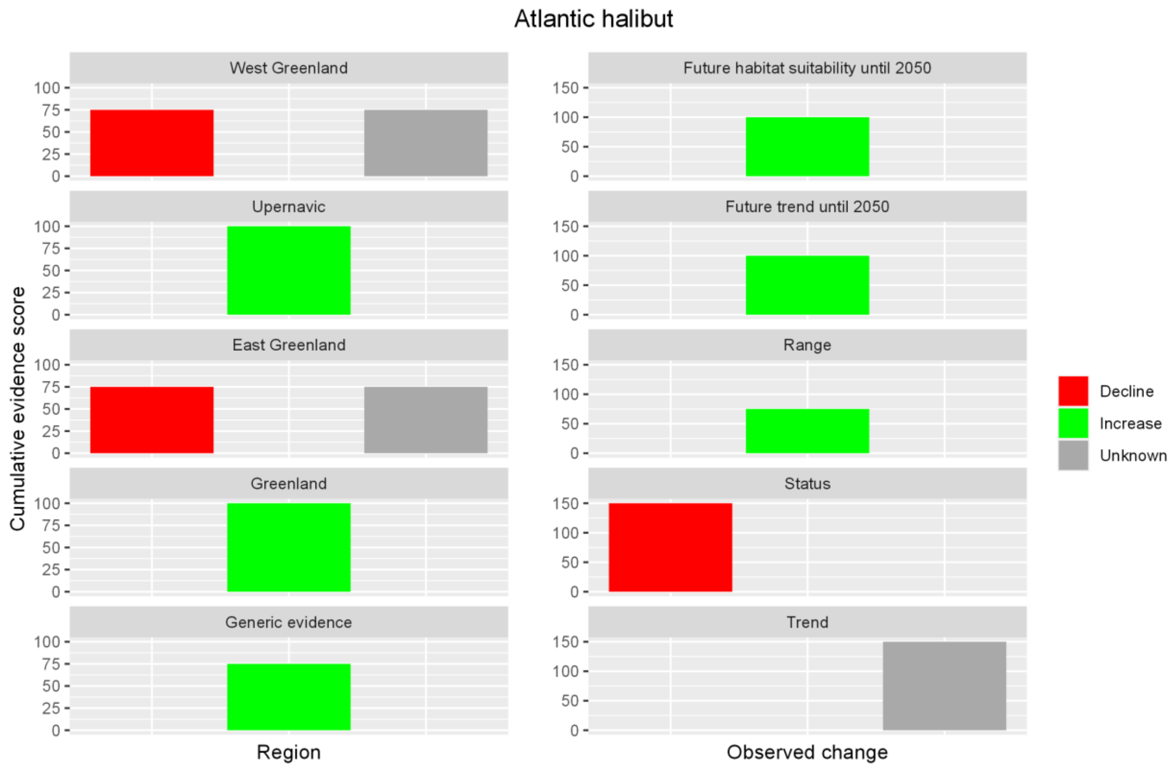


Figure 48.2 Cumulative evidence per region and aspects in which change is observed or expected.

48.4. Catch and Forecast

None reported.

48.5. Workshops with Hunter and Fishers Organizations

Scenario	Ittoqortoormiit	Tasiilaq	Upernavik	Ilulissat
Trend scenario		Not available	Not available	Not available
Alternative scenario				

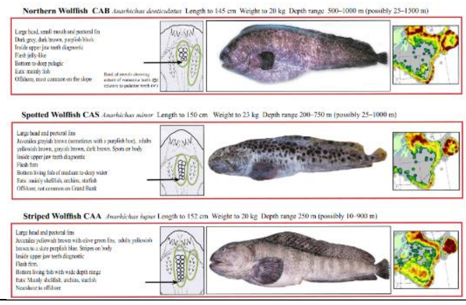
48.6. Interviews with Scientific Experts

-will follow-

48.7. Preliminary Future Scenarios

Scenario	Ittoqortoormiit	Tasiilaq	Upernavik	Ilulissat
Stock and catch trend scenario				
Underreporting adjustment scenario				
Alternative actions scenario				

49. Catfish/wolffish (*Anarhichas spp.*)

Catfish/wolffish	
Anarhichas spp.	
Havkat	
Qeeraq	

Catfish is a bottom-dwelling, demersal, oceanodromous fish that inhabits rocky bottoms, sometimes over sand or mud, at a depth range of 1-600 meters, but typically found at depths of 18-110 meters in temperate waters (FishBase, 2023). Its distribution spans from 82°N to 40°N and from 75°W to 61°E (FishBase, 2023). Three species of wolffish inhabit Greenland waters, including Atlantic wolffish (*Anarhichas lupus*), spotted wolfish (*Anarhichas minor*) and Northern wolffish (*Anarhichas denticulatus*), but only the two first are of commercial interest (Nygaard, 2020). Reported catches of this species decreased during the 1980s and were very low during the 1990s, increased from 2003 and stabilized at around 1000 tons until 2014 (Nygaard, 2020). However, catches decreased again in 2015 and continued to decline until 2019, with only 190 tons caught. This may be due to the fishery focusing on more profitable species (Nygaard, 2020). However, the abundance of spotted and striped catfish has increased since 2010 on the West Coast, largely due to the introduction of sorting grids in shrimp fishing (Greenland Institute of Natural Resources, 2021). In the Greenland SFW survey, both species' abundance index seems to increase steadily (fig 3 and 4 right). Since the 1990's, the biomass of spotted wolffish / Atlantic wolffish has gradually changed from 50:50 to 85:15, varying a little from year to year (Nygaard, 2020). The slower somatic growth rate of Atlantic halibut could explain the slower increase in the biomass index for Atlantic wolffish, compared to spotted wolfish (Nygaard, 2020).

Figure 49.1. Map of distribution range.

49.1. Climate Change

The optimal temperature for the growth of early juveniles (geometric mean weight 7.5 g) was determined as 12.1 °C, while the upper critical temperature was very close to 15 °C (Árnason et al., 2019). As fish at that temperature had stunted growth, they showed increased mortality and external signs of skeletal deformities (Árnason et al., 2019). In Canada, the predicted denning habitat, limited by the occurrence of suitable rocky substrate, is most prevalent in shallow waters (<22 m), which is exposed to seasonal maximum temperatures that exceed the threshold for normal Atlantic wolffish egg development (Novaczek et al., 2017).

49.2. Status and Population Trends

West Greenland

Areas	Abundance	Status, change	Trend (Short term~1 generation)	Category of change	Description: physiological,behavioral change	Climate variable & direction	Hunting
	unkown	Unknown	Increasing (Greenland Institute of Natural Resources, 2021)				

East Greenland

Areas	Abundance	Status, change	Trend (Short term~1 generation)	Category of change	Description: physiological,behavioral change	Climate variable & direction	Hunting
	unkown	unkown	unkown				

49.3. Synopsis

We did not find literature on trends in East and West Greenland. We found weak generic evidence of a decline due to the optimal temperature range.

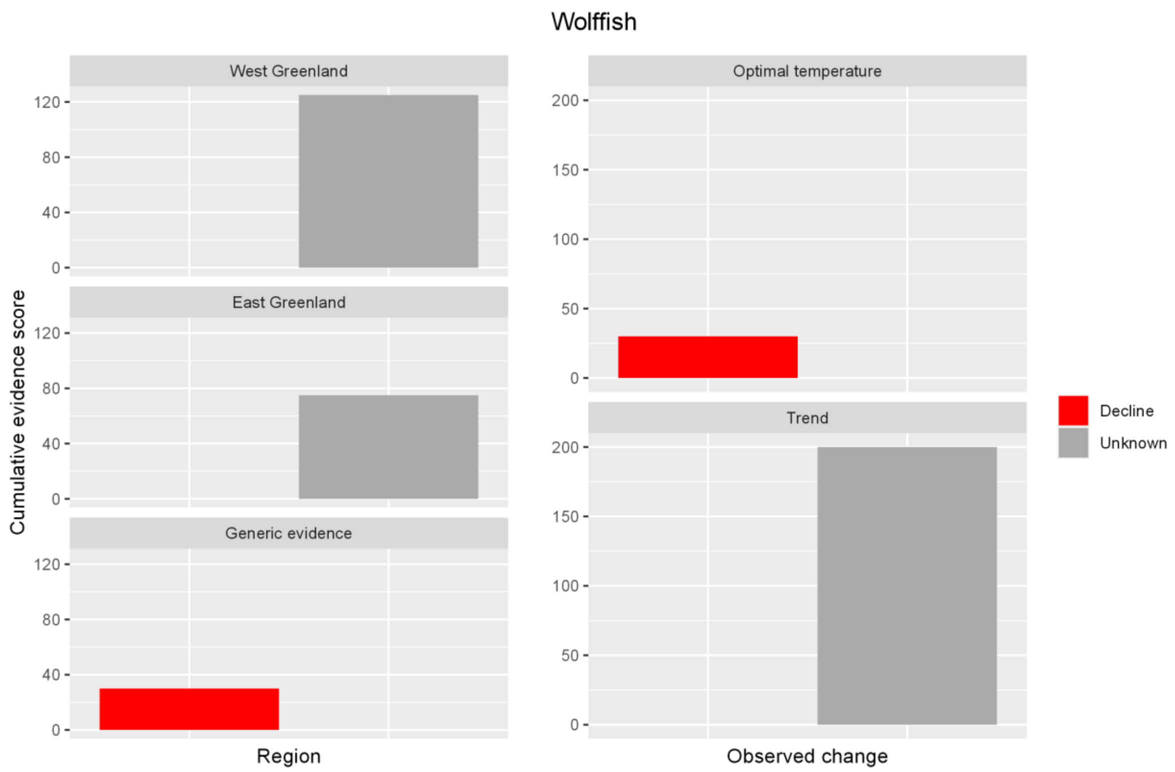


Figure 49.2 Cumulative evidence per region and aspects in which change is observed or expected

49.4. Catch and Forecast

No catch reported.

49.5. Workshops with Hunter and Fishers Organizations

Scenario	Ittoqortoormiit	Tasiilaq	Upernavik	Ilulissat
Trend scenario		No commercial trade. Catch 250 kg for own use and for bait	Not common. Mainly seen as bycatch	Catch determined by trade quota. Catch 50 kg for own use and as bait
Alternative scenario		NA	NA	NA

49.6. Interviews with Scientific Experts

-will follow-

49.7. Preliminary Future Scenarios

Scenario	Ittoqortoormiit	Tasiilaq	Upernavik	Ilulissat
Stock and catch trend scenario		2012-20 average	2012-20 average	2012-20 average
Underreporting adjustment scenario		Plus 250 kg for occupational hunters		Plus 50 kg for occupational hunters
Alternative actions scenario				

50. Atlantic salmon (*Salmo salar*)

<table>
<tr><td>Atlantic salmon (Salmo salar)</td><td rowspan="4"></td></tr>
<tr><td>Salmo salar</td></tr>
<tr><td>Laks</td></tr>
<tr><td>Kapisilik</td></tr>
</table>

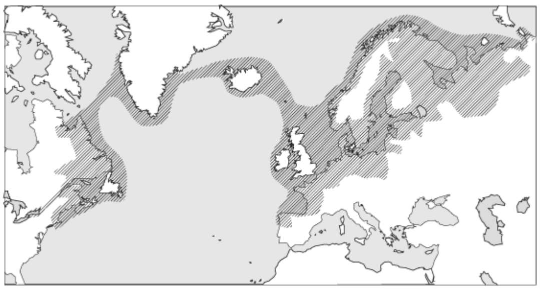


Figure 55.1. Endemic range of Salmo salar. Distribution in the ocean is approximate reproduced with permission from the Minister of Public Works and Government Services, Canada).

Salmon is widespread along most of the Greenlandic coast (Greenland Institute of Natural Resources, 2021). Salmon fishing in Greenland occurs near the coast, and the salmon caught in Greenland typically originate from North American or European populations that swim to Greenland to feed (Greenland Institute of Natural Resources, 2021).

In Greenland, only one population of spawning salmon is found, which resides in the Kapisillit River at the bottom of the Godthåbsfjord (Greenland Institute of Natural Resources, 2021). The local salmon in Kapisillit is on the Greenlandic red list, where it is categorized as "vulnerable", and over the last 57 years, the salmon population has been reduced by 52% (Greenland Institute of Natural Resources, 2021). In 2016, it was estimated that there were just under 6.000 smolts in the river system at Kapisillit, and about 300 individuals went up the river to spawn (Greenland Institute of Natural Resources, 2021).

The Atlantic salmon fishery in Greenland waters commenced in approximately 1960 and reached its peak during the early 1970s, with an annual catch exceeding 2,000 tons (Nygaard and Nogueira, 2020). In 1972, the fishery became regulated by quotas, but due to declining salmon stocks, the North Atlantic Salmon Conservation Organization (NASCO) decided in June 1998 that no commercial fishing for salmon should be permitted (Nygaard and Nogueira, 2020). Instead, the catch in West Greenland was limited to domestic consumption. As a result, the export of salmon from Greenland has been prohibited by law since then, and the fishery has been scaled down to an internal subsistence fishery exclusively within Greenland.

Starting from 1997, it became mandatory to report personal catches of salmon. In 2002, licensed fishermen were granted permission to sell salmon solely to institutions, local markets, and restaurants (Nygaard and Nogueira, 2020). However, in 2012, due to pressure from fishermen, a limited number of factories were allowed to receive salmon landings for the Greenlandic domestic market (Nygaard and Nogueira, 2020). Nevertheless, factory landings were discontinued after 2015. In 2019, a total reported catch of 30 tons was documented, with 28.3

tons originating from West Greenland (Nygaard and Nogueira, 2020). In 2021, total catches of 41 tons were reported (40 tones in West Greenland).(Nygaard et al., 2022).

50.1. Climate Change

The Atlantic salmon (*Salmo salar*) was abundant in marine cooling periods, in the 70s and in 1600 and 1810 in West Greenland (Dunbar, 1981). Increased temperatures can affect the survival and growth of eggs, juveniles, and adult salmon (Jonsson and Jonsson, 2009). Warmer water can also increase the susceptibility of salmon to diseases and parasites (Callaway et al., 2012). Extreme variations in water flow and temperature can have detrimental effects on the recruitment and survival of anadromous salmonids (Jonsson and Jonsson, 2009). A northward shift is anticipated due to climate change, and reduced production and even population extinctions in the southern regions (Jonsson and Jonsson, 2009). Increased frequency of extreme weather events, sea level rise, and changes in freshwater availability can further degrade spawning and rearing habitats.

When water temperatures exceed 22–28° Cand 22–25° C for *S. salar*, the fish will die unless they can move to cooler water (Elliott and Elliott, 2010). Deep pools with cooler water near the bottom serve as refugia in streams and rivers. The egg stage is the life stage with the lowest thermal tolerance and few eggs will survive if temperatures exceed 7–8° C (Elliott and Elliott, 2010).

A spatially explicit individual-based model (IBM) showed that in western and northern locations, higher temperatures led to faster parr growth, earlier smolting, increased smolt production, higher egg deposition, and elevated recruitment into parr. However, in the southern location, density-dependent mortality of parr due to reduced summer wetted-areas resulted in lower predicted future smolt production compared to other locations. These findings suggest that climate change can have both positive and negative impacts on anadromous fish abundance depending on the geographical region within the subarctic-Arctic (Hedger et al., 2013).

50.2. Status and Population Trends

<u>All populations</u>

Areas	**Abundance**	**Status, change**	**Trend (Short term~1 generation)**	**Category of change**	**Description: physiological,behavioral change**	**Climate variable & direction**	**Hunting**
	unkown	**unkown**	**unkown**				

50.3. Synopsis

We found moderate evidence on a decline in West Greenland. There is overwhelming evidence that this species is or might decline with an ongoing warming

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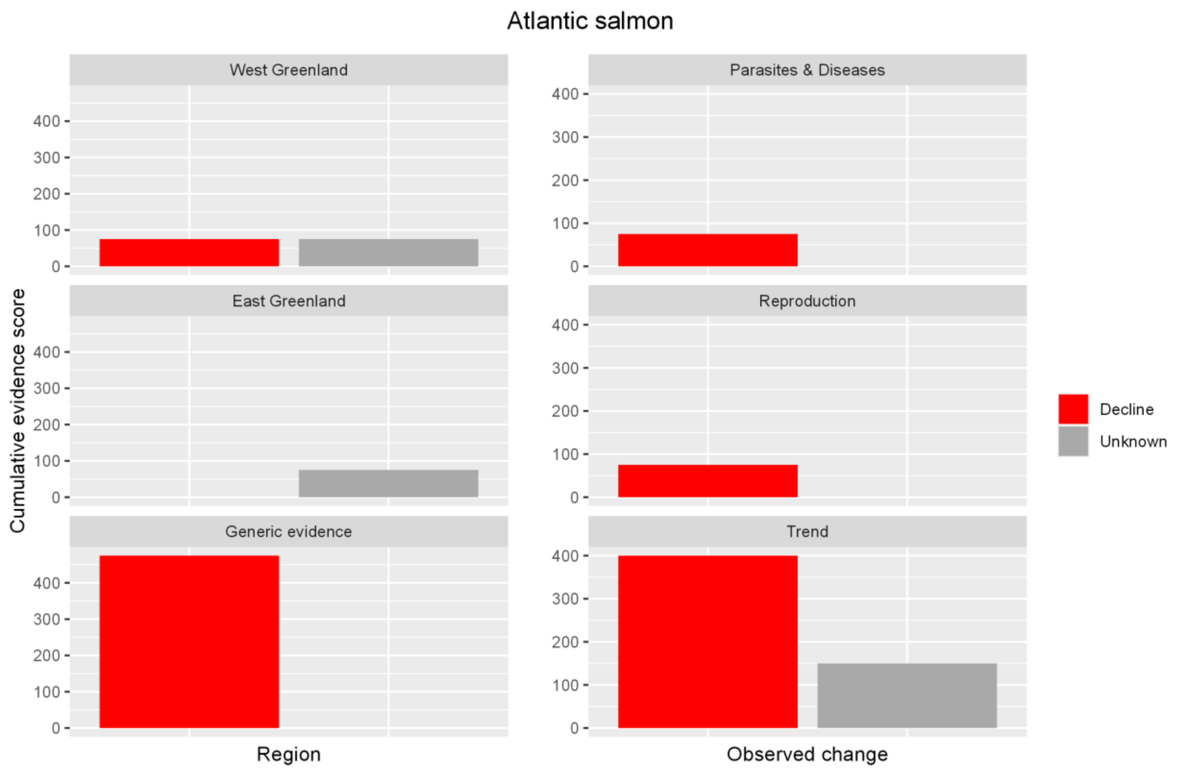


Figure 50.2 Cumulative evidence per region and aspects in which change is observed or expected.

50.4. Catch and Forecast

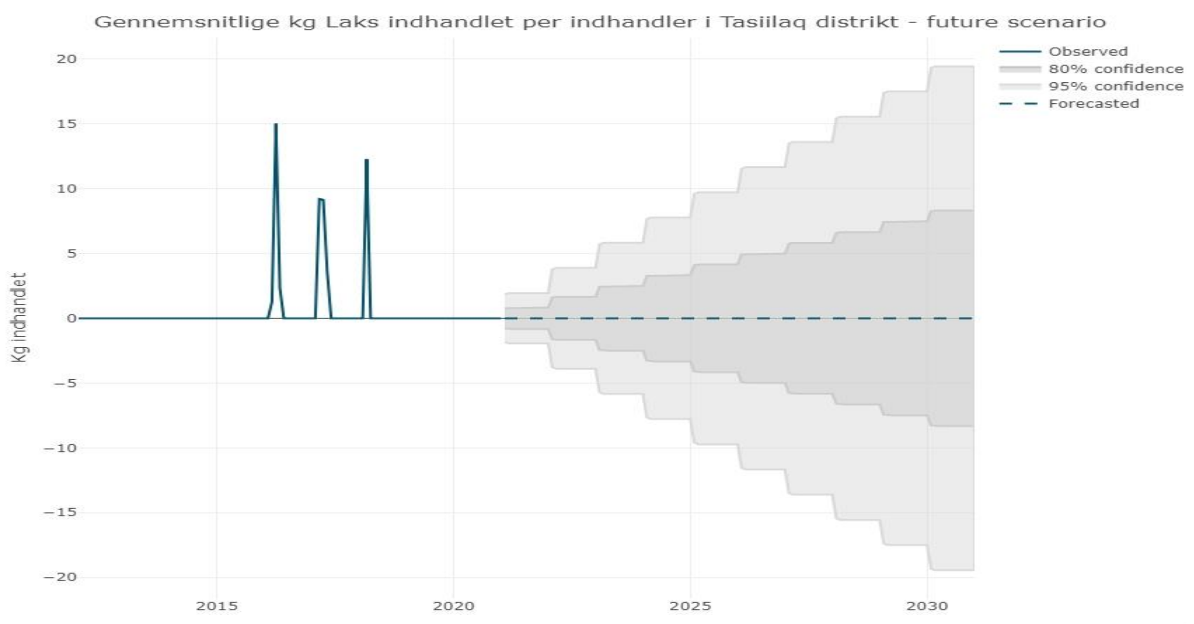


Figure 50.2. Average kg sold per trader and forecast for Atlantic salmon in Tasiilaq district.

The forecasts are not reliable. Nevertheless, the material was used as a basis for discussion.

Table 50.1. Average annual sale of Atlantic salmon per trader in the period 2012-2020, in 2020 and 2030 (forecasted) and the percentage change in 2030 relative to 2012-2020 and 2020.

District	2012-2020	2020	2030	Δ 2012-2020	Δ 2020
Ittoqoortoormiit					
Tasiilaq	5,88	0,00	0,00	-100%	NA
Upernavik					
Ilulissat					

50.5. Workshops with Hunter and Fishers Organizations

Scenario	Ittoqortoormiit	Tasiilaq	Upernavik	Ilulissat
Trend scenario		Staying longer. Sporadic catch	Limited catch in southern settlements	Very limited catch in southern settlements
Alternative scenario		NA	NA	Have requested quota

50.6. Interviews with Scientific Experts

-will follow-

50.7. Preliminary Future Scenarios

Scenario	Ittoqortoormiit	Tasiilaq	Upernavik	Ilulissat
Stock and catch trend scenario		2012-2020 average	2012-2020 average	2012-2020 average
Underreporting adjustment scenario				
Alternative actions scenario				

51. Arctic char (*Salvelinus alpinus*)

Arctic char	
Salvelinus alpinus	
Fjeldørred	
Eqaluit	

Arctic charr is the most northern-ranging freshwater fish and it can be found in marine, freshwater, and brackish environments and it is a benthopelagic and anadromous species (Boertmann and Mosbech, 2017; FishBase, 2023). It is of great importance in the Arctic region, as it is often the only fish species in the lakes at these latitudes, thereby playing an important role as an apex predator of these ecosystems (Hansen et al., 2017). Their depth range is from 0 to 70 meters, but they are usually found at 0-1 meter depths. They live in temperate waters with temperatures ranging from 4 to 16 degrees C and can be found at latitudes from 82°N to 41°N and longitudes from 180°W to 180°E (FishBase, 2023).

Figure 51.1, Map of distribution.

Population studies have estimated that Arctic char is represented by 50,000 populations worldwide, with Greenland and Iceland holding approximately 1000 populations (Hansen et al., 2017). Factory landings were 10 t in 2019 and 2021 and here is no reporting required for private fisheries, which presumably is considerably larger (Nygaard et al., 2022; Nygaard and Nogueira, 2020).

51.1. Climate Change

Arctic char lives at summer temperatures (−0.6 to 9.1 °C) that are optimal for activity, but an increase in temperature expected with climate change, could have an impact on life cycle events and fitness-related tasks for this northern population (Hansen et al., 2017). Arctic char may lose 63% of its current distribution in Canada by 2050, given projected temperature and precipitation patterns (Chu et al., 2005). Arctic char will likely lose 73% of its range in Sweden by 2100 and attributed predicted extinctions to simulated temperature increases and to invasion by pike (*Esox lucius*) (Hein et al., 2012). In Alaska, it was observed that even minor alterations in the duration of ice-free days greatly affected the arctic char populations (Budy and Luecke, 2014). As a result, researchers anticipated that with the increasing frequency of longer growing seasons due to climate change, there would be higher growth rates among young char. This prolonged growing season would act as a "resource pulse," enabling a specific group of small char to experience accelerated growth and consequently influence the overall population structure (Budy and Luecke, 2014).

51.2. Status and Population Trends

All populations:

Areas	Abundance	Status, change	Trend (Short term~1 generation)	Category of change	Description: physiological,behavioral change	Climate variable & direction	Hunting
	unkown	unkown	unkown				

51.3. Synopsis

We did not find information on trends in West and East Greenland. However, there is overwhelming evidence that this species will decline with a waring climate.

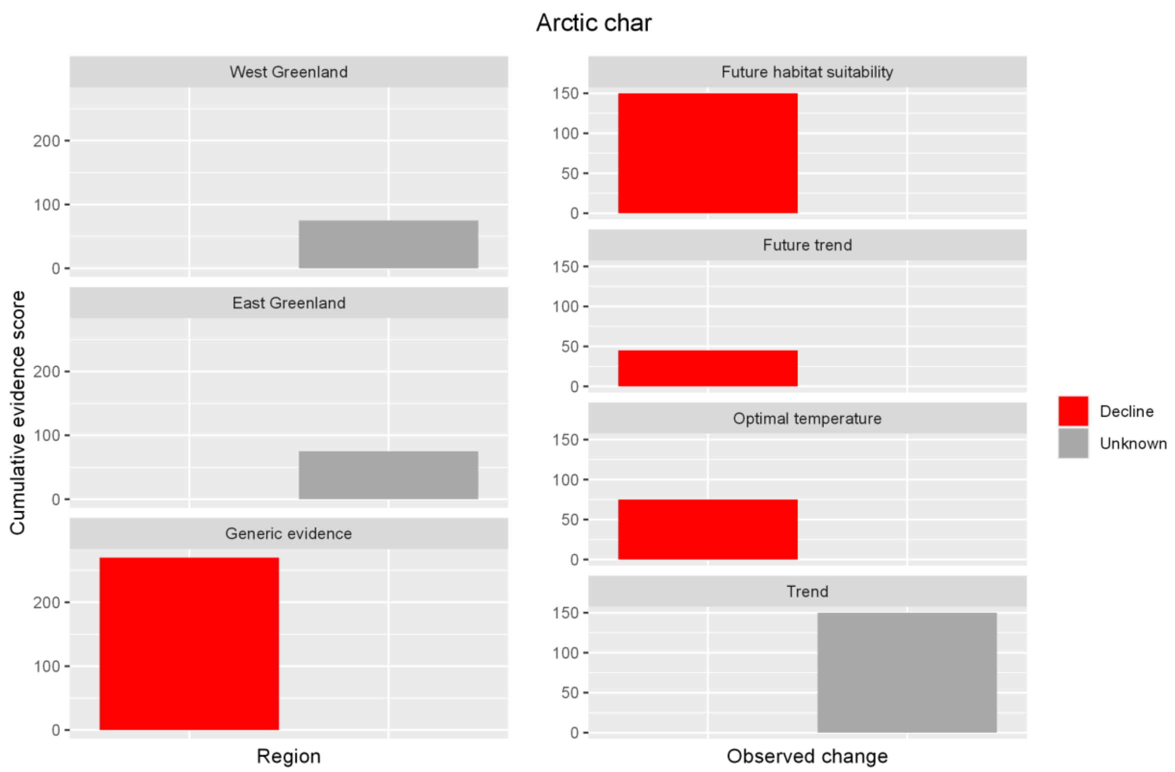


Figure 51.2 Cumulative evidence per region and aspects in which change is observed or expected.

51.4. Catch and Forecast

-None-

51.5. Workshops with Hunter and Fishers Organizations

Scenario	Ittoqortoormiit	Tasiilaq	Upernavik	Ilulissat

Trend scenario		Very abundant. Catch 100 kg for own consumption and local trade	Not available	Arrives late. Catch 100 kg for own use
Alternative scenario		Commercial exploitation based on quota		NA

51.6. Interviews with Scientific Experts

-will follow-

51.7. Preliminary Future Scenarios

Scenario	Ittoqortoormiit	Tasiilaq	Upernavik	Ilulissat
Stock and catch trend scenario		2012-20 average		2012-20 average
Underreporting adjustment scenario		Plus 100 kg		Plus 100 kg
Alternative actions scenario				

52. Redfish (*Sebastes spp.*)

<table>
<tr><td>Redfish</td><td rowspan="4"></td></tr>
<tr><td>Sebastes spp.</td></tr>
<tr><td>Rødfisk</td></tr>
<tr><td>Suluppaagaq</td></tr>
</table>

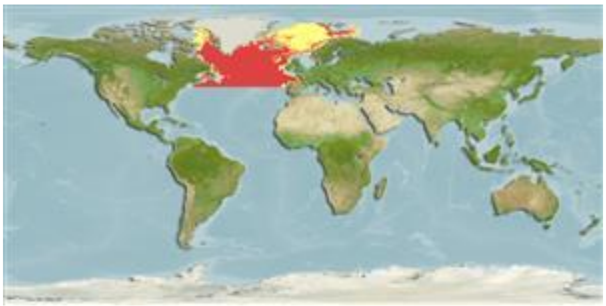


Figure 52.1. Map of distribution

The redfish is a bathypelagic, oceanodromous fish species found at depths ranging from 300 to 1.441 meters. It inhabits deep waters and can be found in the range of 79°N - 41°N, 67°W - 35°E (FishBase, 2023). There are three species of redfish in Greenlandic waters: deep-sea redfish (*Sebastes mentella*), golden redfish (*Sebastes norvegicus*), and viviparous redfish (*Sebastes viviparus*) (Greenland Institute of Natural Resources, 2021). Viviparous redfish are most commonly found offshore on the east coast, while deep-sea redfish and golden redfish are found both inshore and offshore on Greenland's east and west coasts. In Greenland, deep-sea redfish in East Greenland and golden redfish in West Greenland are managed as separate stocks (Greenland Institute of Natural Resources, 2021). In both areas, stocks have declined over the past ten years, with particular concern for the prolonged lack of young fish (recruits) that will form the basis of future fisheries (Greenland Institute of Natural Resources, 2021). Since 2019, NAFO has recommended that no redfish be caught on Greenland's west coast, a recommendation that was previously 1 tonne for both species combined (NAFO, 2023). In 2021, ICES recommended for the first time that no deep-sea redfish be caught on Greenland's east coast (ICES, 2023).

52.1. Climate Change

An environmental niche modelling using species occurrence data and environmental parameters to model habitat suitability under present-day (1951–2000) and high emissions future (2081–2100) climate projections (RCP8.5 scenario) projected the expansion of suitable habitat by 2100 for the redfish species *Helicolenus dactylopterus* and *Sebastes mentella* (20%–30%), mostly through northern latitudinal range expansion (Morato et al., 2020). A fuzzy logic expert system with species biogeographical data to assess the risks of climate impacts to the population viability of 32 species of exploited demersal deep-sea species across the global ocean identified species that most are at very high risk of climate impacts and highly vulnerable to fishing. This included Antarctic toothfish (*Dissostichus mawsoni*), rose fish (*Sebastes norvegicus*), roughhead grenadier (*Macrourus berglax*), Baird's slickhead (*Alepocephalus bairdii*), cusk (*Brosme brosme*), and Portuguese dogfish (*Centroscymnus coelepis*) (Cheung et al., 2022). Atlantic cod (*Gadus morhua*), haddock (Melanogrammus aeglefinus), golden redfish (*Sebastes norvegicus*) and beaked redfish (*Sebastes mentella*) that have boreal affinities and display substantial responses to climate warming in terms of poleward shifts and biomass increases in the arctic region of the Barents Sea (Fossheim et al., 2015; Kortsch et al., 2015)

52.2. Status and Population Trends

West Greenland

Areas	Abundance	Status, change	Trend (Short term~1 generation)	Category of change	Description: physiological,behavioral change	Climate variable & direction	Hunting
	unkown	**unkown**	**Declining** (NAFO, 2023)				

East Greenland

Areas	Abundance	Status, change	Trend (Short term~1 generation)	Category of change	Description: physiological,behavioral change	Climate variable & direction	Hunting
	unkown	unkown	**Declining** (ICES, 2023).				

52.3. Synopsis

We found strong evidence of a decline in East and West Greenland. There is moderate generic evidence on an increase and decrease of this species.

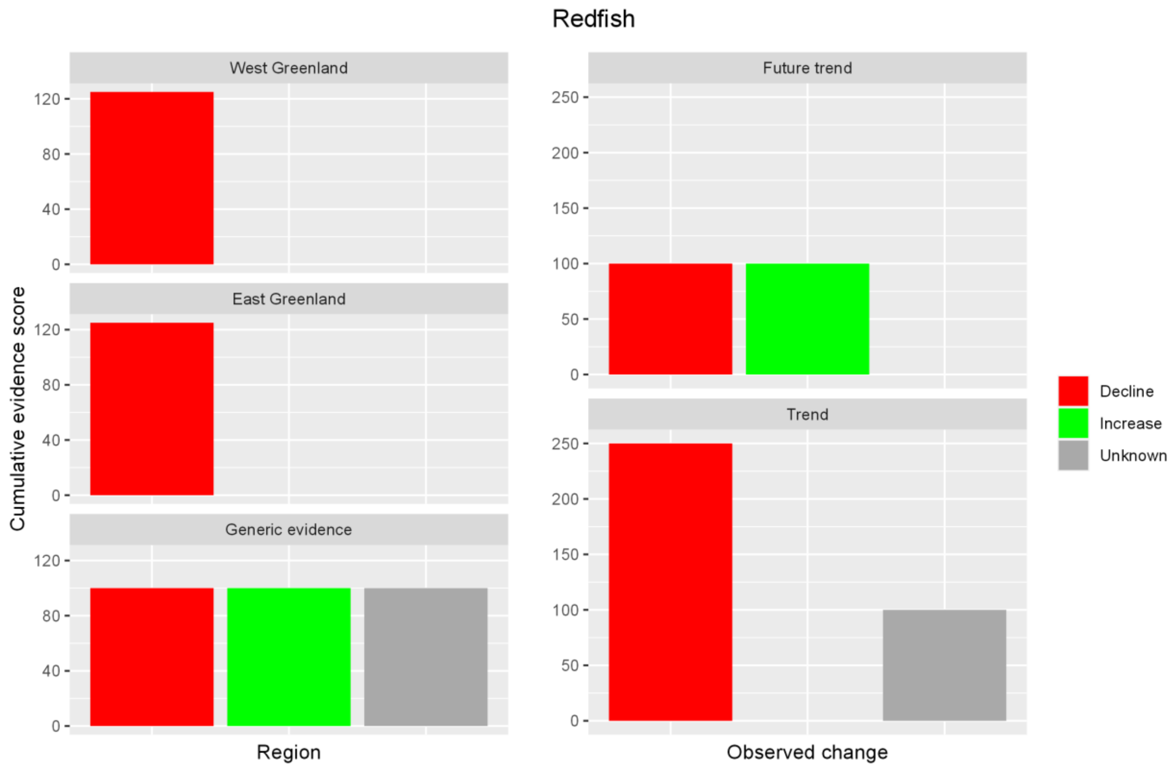


Figure 52.2 Cumulative evidence per region and aspects in which change is observed or expected.

52.4. Catch and Forecast

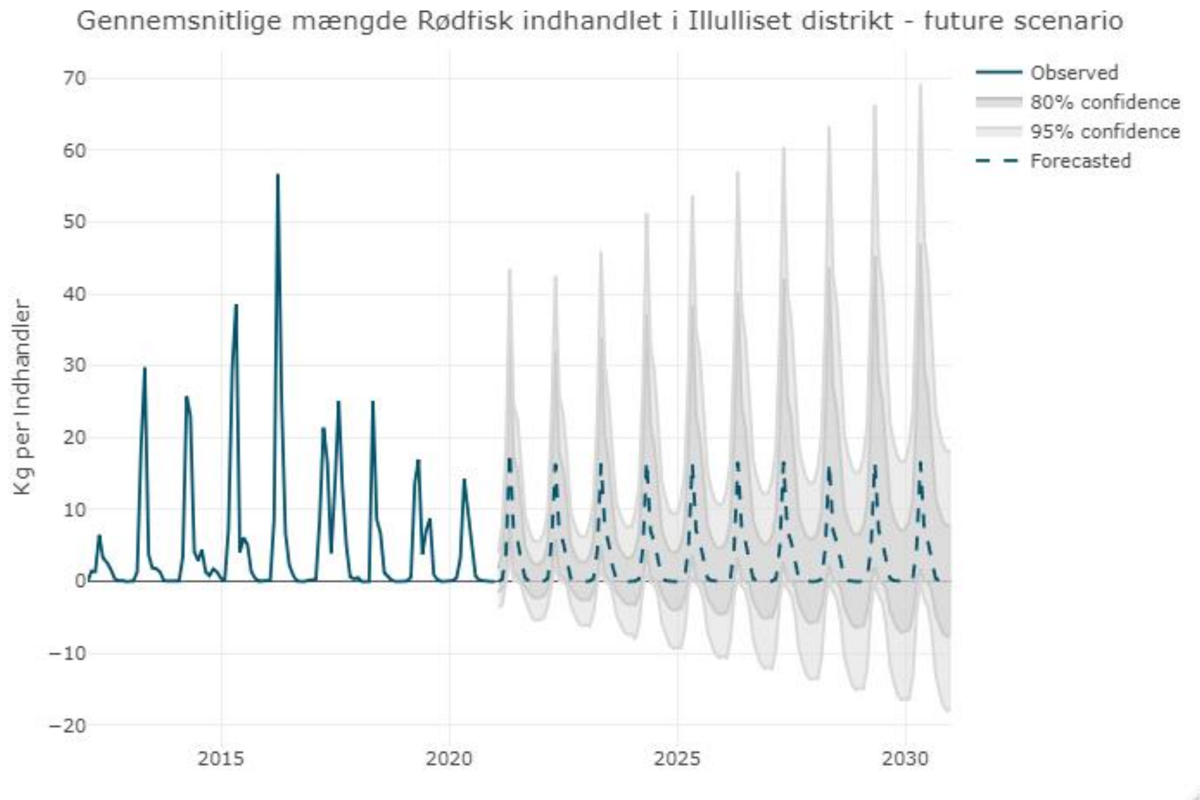


Figure 52.3. Average kg sold per trader and forecast for Redfish in Ilulissat district.

The forecasts are not reliable. Nevertheless, the material was used as a basis for discussion.

Table 52.1. Average annual sale of Redfish per trader in the period 2012-2020, in 2020 and 2030 (forecasted) and the percentage change in 2030 relative to 2012-2020 and 2020.

District	2012-2020	2020	2030	Δ 2012-2020	Δ 2020
Ittoqoortoormiit					
Tasiilaq					
Upernavik					
Ilulissat	63,70	32,41	37,25	-42%	15%

52.5. Workshops with Hunter and Fishers Organizations

Scenario	Ittoqortoormiit	Tasiilaq	Upernavik	Ilulissat
Trend scenario			Bycatch. Take 10 kg for own consumption	Bycatch. Take 25 kg for own consumption
Alternative scenario			NA	NA

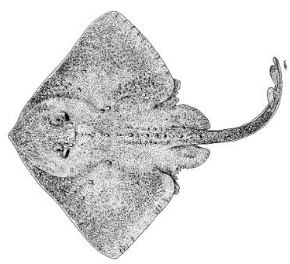
52.6. Interviews with Scientific Experts

-will follow-

52.7. Preliminary Future Scenarios

Scenario	Ittoqortoormiit	Tasiilaq	Upernavik	Ilulissat
Stock and catch trend scenario			2012-20 average	2012-20 average
Underreporting adjustment scenario			Plus 10 kg	Plus 10 kg
Alternative actions scenario				

53. Skate (*Raja spp.*)

<table>
<tr><td>Skate</td><td rowspan="4">Starry ray (Raja radiata)
</td></tr>
<tr><td>(Raja spp.)</td></tr>
<tr><td>Rokke spp.</td></tr>
<tr><td>Eqalussuup nulia</td></tr>
</table>

Skate species catched in Greenland are mostly starry ray (thorny skate) (*Amblyraja radiata*) and to a lesser extent spinetail ray (*Bathyraja spinicauda*) and Arctic skate (*Raja hyperborea*) (NAFO, 2023). The thorny skate is bottom-living species found in the North and south-eastern Atlantic Ocean in depths ranging from 20 to 1.000 m (66–3.281 ft) and water temperatures from −1 to 14 °C (30–57 °F) (FishBase, 2023) (NAFO, 2023). The stock has been stable at recent catch levels (approximately 3.710 tons per year, 2017 - 2021). Given the low resilience to fishing mortality and higher historic stock levels, Scientific Council of NAFO advises no increase in catches (NAFO, 2023). In 2018, with thorny skate showing the highest bycatch rate in the Greenland Sea (1.80 specimens per monitored days-at-sea) (ICES, 2022).

53.1. Climate Change

Using a two-stage generalized additive model to project future thorny skate abundances under two different climate scenarios suggests that abundances will decrease by ~22% –80% in the Gulf of Maine, depending on the emission scenario and model use (Grieve et al., 2021). The overall biomass in this region has already decreased from 5.6 kg/tow in the 1970s to 0.17 kg/tow from 2013–2015, less than 5% of its historical peak (Grieve et al., 2021). These results indicate that climate change will negatively impact thorny skate populations in the Gulf of Maine by reducing thermally suitable habitats in the southern extent of their range (Grieve et al., 2021).The decreasing abundance and range contraction of thorny skate in the Gulf of Maine in recent decades might be related to habitat selection. Skates were noticed swimming at depths ranging from 27 to 201 meters and in water temperatures varying between 2.5 and 12.5°C (Rose, 2005b). The observations revealed that both the depth and temperature fluctuated with the changing seasons (Rose, 2005b). The prevalence of sedentary behaviour in skates raises concerns about the species being vulnerable to local depletion and climate change, but also the potential effectiveness of implementing spatial closures to facilitate the recovery of their population (Rose, 2005b). In the southern Gulf of St Lawrence, the geographic range contracted sharply, and distribution shifted into a narrow band of warm deep waters in the 1990s (Swain and Benoit, 2006). This coincided with a decline in skate biomass and a cooling of bottom waters (Swain and Benoit, 2006). However, the shift in the distribution of skates was more closely related to the skate biomass than to the temperature conditions (Swain and Benoit, 2006).

In the southern North Sea, a long-term analysis of fishery-independent survey data from 1902 to 2013 shows significant changes in the distribution and occurrence of elasmobranchs (sharks, skates, and rays) (Sguotti et al., 2016). A shift from a historical dominance of larger commercially valuable species to a current prevalence of smaller, more productive species with lower commercial value has been observed. Larger species, such as thornback ray, tope, and spurdog, have experienced declines over time, and the largest species, like the common skate complex and angelshark have become locally extinct. On the other hand, smaller species like spotted ray, starry ray, lesser-spotted dogfish, and smooth-hound have shown increases, possibly due to their ability to withstand fishing pressure and/or adapt to climate change (Sguotti et al., 2016). However, some trends have reversed in recent years, with starry ray, which prefers colder waters, now declining while thornback ray is increasing (Sguotti et al., 2016). This shift can be attributed to factors such as fishing practices (especially mechanized beam trawling introduced in the 1960s-1970s) and historical targeting of elasmobranchs, climate change favouring warm-water species over cold-water species, and habitat loss, including potential degradation of coastal and estuarine nursery habitats (Sguotti et al., 2016). It is expected that parallel changes in elasmobranch communities will occur in other regions in the future (Sguotti et al., 2016).

Within the skate assemblage, starry ray was the only species that increased over the course of the second half of the 20th century (albeit with an apparent decrease since 2000). Starry ray is the least sensitive skate to fishing pressure, which may relate to its comparatively small size, early age at maturity, preference for deeper areas, which are generally trawled less, and the high proportion discarded. The starry ray is typically found in colder waters and prefers the boreal biogeographical region (Sguotti et al., 2016). The species would have thrived during the cooler conditions of the 1960s-1970s. However, the recent warming of the southern North Sea may have played a role in the decline of the starry ray at the southern edge of its habitat range (Dulvy and Reynolds, 2002). As a result, the species have retreated to deeper and/or cooler areas as a response to the changing environmental conditions (Sguotti et al., 2016). Due to their slow generational turnover rate, Skates are especially susceptible to quick environmental changes (Vilmar and Di Santo, 2022). When predicting how they will respond to climate change, researchers often rely on models that simulate geographic shifts. However, there is a lack of empirical studies examining the ability of elasmobranchs, including skates, to swim effectively under simulated future ocean conditions (Vilmar and Di Santo, 2022).

53.2. Status and Population Trends

West Greenland

Areas	Abundance	Status, change	Trend (Short term~1 generation)	Category of change	Description: physiological,behavioral change	Climate variable & direction	Hunting
	unkown	unkown	unkown				

East Greenland

Areas	Abundance	Status, change	Trend (Short term~1 generation)	Category of change	Description: physiological,behavioral change	Climate variable & direction	Hunting
	unkown	unkown	**Increasing (Thorny skate)** (ICES, 2022).				

53.3. Synopsis

We found moderate evidence of an increase in Skate in East Greenland. We found no information on trends in West Greenland. There is weak generic evidence for a decline of this species with climate warming.

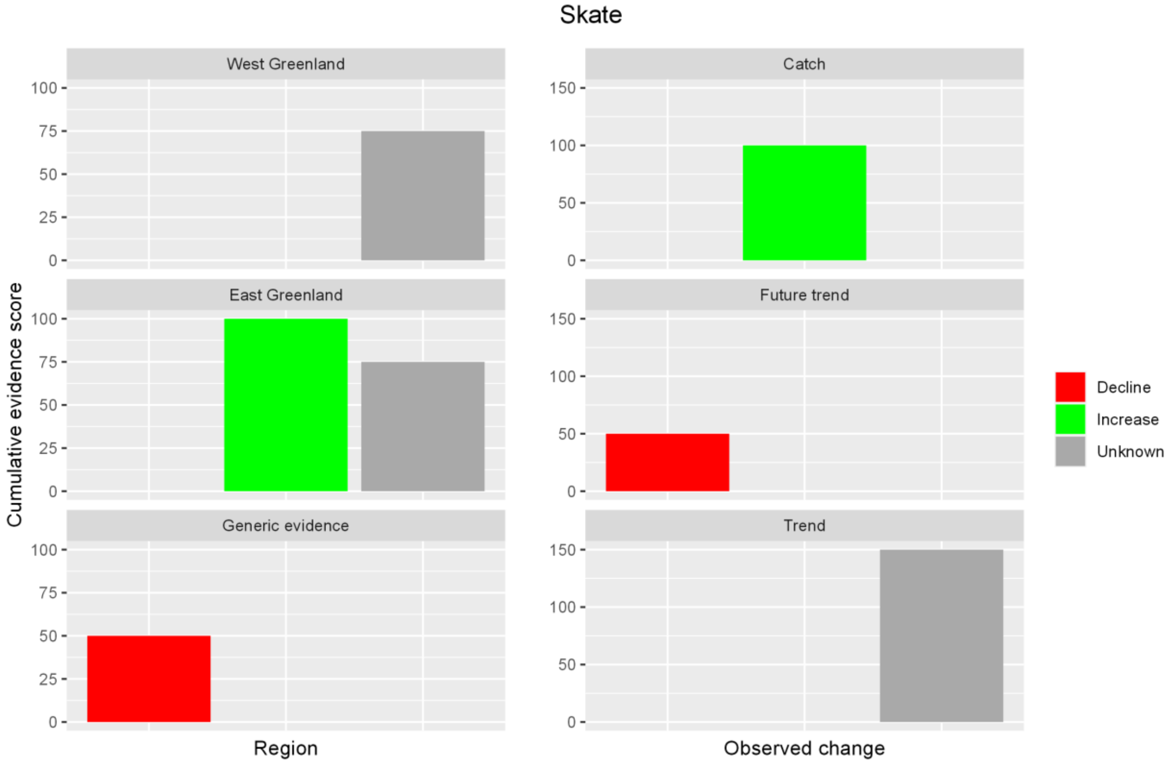


Figure 53.1 Cumulative evidence per region and aspects in which change is observed or expected.

53.4. Catch and Forecast

No catch reported.

53.5. Workshops with Hunter and Fishers Organizations

-not discussed-

53.6. Interviews with Scientific Experts

-will follow-

53.7. Preliminary Future Scenarios

Scenario	Ittoqortoormiit	Tasiilaq	Upernavik	Ilulissat
Stock and catch trend scenario				
Underreporting adjustment scenario				
Alternative actions scenario				

54. Lumpfish (*Cycloperus lumpus*)

Lumpfish	
Cycloperus lumpus	
Stenbidder	
Nipisa	

The lumpfish is a a semi-pelagic/semi-demersal, non-shoaling, coldwater marine fish in the family Cyclopteridae (lumpsuckers) and is the only member of the genus Cyclopterus (Kennedy et al., 2019). The lumpfish is distributed in the North Atlantic and adjacent parts of the Arctic Ocean, with its southernmost limit reaching Chesapeake Bay (rare south of New Jersey) on the North American coast and Spain (rare south of the English Channel) on the European coast (Kennedy et al., 2019).

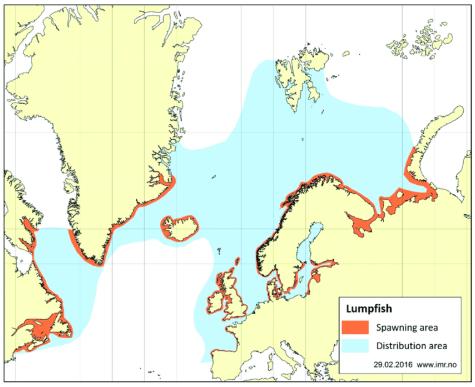


Figure 54.1. Map of distribution.

The fishery for this species is exclusively conducted along the western coast of Greenland (from 60 to 70ºN). According to data from NAFO, total landings of lumpfish (in NAFO Subarea 1 increased from 1.200 tons in 2000 to nearly 9.000 tons in 2003 and remained at a high level until 2011, where catches reached 11.443 tons (NAFO, 2023). However, after that, landings decreased to 4.547 tons in 2021.

54.1. Climate Change

With climate change, the range of the species is expected to shift northwards and towards the east of Greenland (Rodríguez-Rey and Whittaker, 2023). It might also lose parts of the southern range because lumpfish are unable to survive prolonged exposure above 15 °C (Rodríguez-Rey and Whittaker, 2023).

54.2. Status and Population Trends

West Greenland

Areas	**Abundance**	**Status, change**	**Trend (Short term~1 generation)**	**Category of change**	**Description: physiological,behavioral change**	**Climate variable & direction**	**Hunting**
	unkown	**Shift northwards**	**unkown**				

54.3. Synopsis

We found moderate evidence for a decline in is Greenland and in the future if climate warming continues.

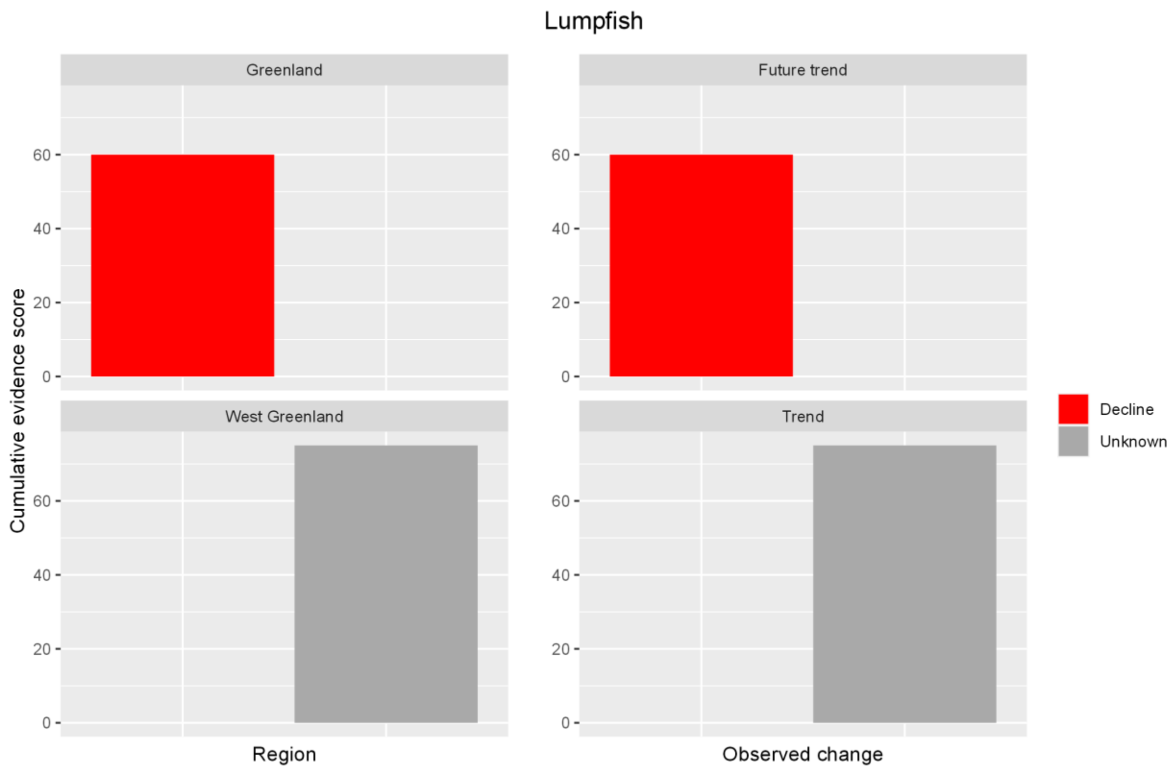


Figure 54.2 Cumulative evidence per region and aspects in which change is observed or expected.

54.4. Catch and Forecast

Insufficient reported catch to produce any forecasts.

54.5. Workshops with Hunter and Fishers Organizations

Not discussed.

54.6. Interviews with Scientific Experts

-will follow-

54.7. Preliminary Future Scenarios

Scenario	Ittoqortoormiit	Tasiilaq	Upernavik	Ilulissat
Stock and catch trend scenario				
Underreporting adjustment scenario				
Alternative actions scenario				

55. Blue whiting (*Gadus poutassou*)

Blue whiting	
Gadus poutassou	
Blåhvilling	
Saarulliusaaq	

Blue whiting is a commercially and biologically significant mesopelagic gadoid fish species with a wide distribution in the North Atlantic (Post et al., 2019). The importance is highlighted by the fact that the fishery was ranked as the third-largest in the world during the early 2000s (Post et al., 2019). Blue whiting occurs along the west, south and east coasts of Greenland from 59.4 °N – 71.0 °. Currently in low abundance around Greenland, and the highest densities during surveys were found at the shelf-slope south of Dohrn Bank. Meanwhile, the highest commercial catches occur at Kolbeinsey Ridge off East Greenland (Post et al., 2019).

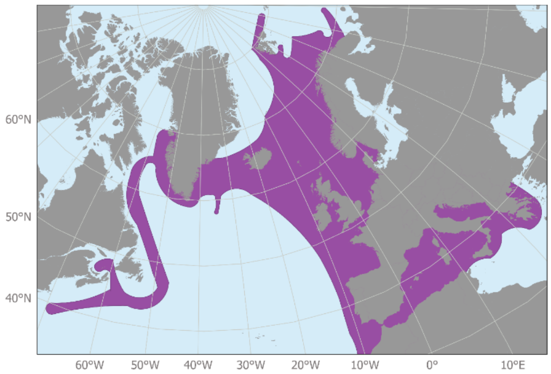


Figure 1. Distribution of blue whiting. Redrawn after Mecklenburg *et al.*, (2018) and paper I.

Scouting surveys and experimental fishing for blue whiting in Greenland waters have for several decades been tried on and off (NAFO, 2023). Blue whiting was only caught in few hauls, and the landings could not cover the expenses. Maximum catches within one year were ~ 400 t, and the average for the last 20 years was ~ 50 t per year (NAFO, 2023).

55.1. Climate Change

Fluctuating abundance is expected to occur more frequently with rising temperatures (Post, 2021). There is a relationship between blue whiting abundance and specific oceanographic circulation patterns, as well as increased abundance during periods of warmer ocean temperatures (Post, 2021).

55.2. Status and Population Trends

<u>All populations</u>

Areas	Abundance	Status, change	Trend (Short term~1 generation)	Category of change	Description: physiological,behavioral change	Climate variable & direction	Hunting

	low abundance around Greenland (Post, 2021).	**unkown**	**unkown**				

55.3. Synopsis

We found moderate evidence of an increase of Blue whiting in Greenland, especially under warming conditions.

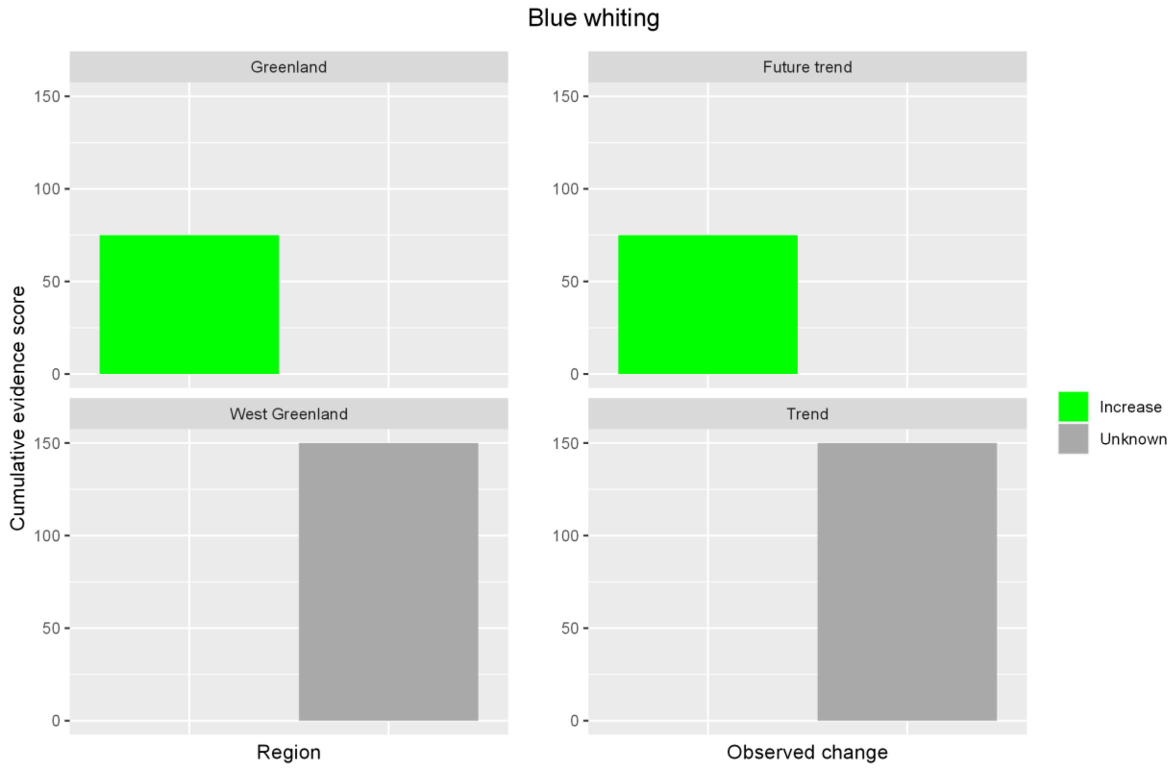


Figure 55.1 Cumulative evidence per region and aspects in which change is observed or expected.

55.4. Catch and Forecast

Insufficiently reported catch from the relevant districts to produce forecasts.

55.5. Workshops with Hunter and Fishers Organizations

Not discussed.

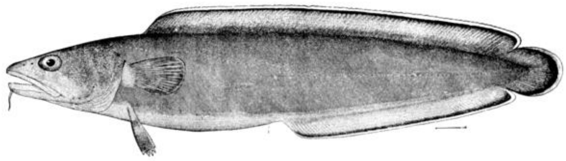
55.6. Interviews with Scientific Experts

-will follow-

55.7. Preliminary Future Scenarios

Scenario	Ittoqortoormiit	Tasiilaq	Upernavik	Ilulissat
Stock and catch trend scenario				
Underreporting adjustment scenario				
Alternative actions scenario				

56. Cusk or tusk (*Brosme brosme)*

Cusk or tusk	
Brosme brosme	
Brosme	
Tinguttooq/savip puua	

Distribution of cusk (in blue)

The Cusk or tusk (*Brosme brosme*) is a boreal species and a demersal fish, which lives close to or on the seafloor and is found on continental shelves and slopes, as well as in deeper waters (FishBase, 2023). It belongs to the boreal fish species that are invading Greenland waters when temperatures rise (Emblemsvåg et al., 2022a). Both the northern Atlantic and Indo-Pacific regions share the presence of boreal species, namely tusk and the greater argentine (Emblemsvåg, 2022). Initially, tusk was mainly found at the southern tip of Greenland, occasionally appearing in East Greenland (Emblemsvåg, 2022). Abundance was low in the Labrador and Irminger Sea waters in the late 1980s and early 1990s and increased in the mid and late 1990s, which coincided with an increase in temperature (Post et al., 2021). In the East of Greenland, in a transition zone between Atlantic and Arctic water, the abundance of boreal species with a generalist diet, like greater argentine (Argentina silus) and Tusk (Brosme brosme) increased, whereas the abundance of Arctic fish benthivores like Lycodes spp. and northern wolffish (Anarhichas denticulatus) decreased (Emblemsvåg, 2022). Tusk, which was previously scarce in these regions, has shown significant growth in population (Emblemsvåg, 2022). The increased abundance of tusk in East Greenland can likely be attributed to environmental changes and redistribution prompted by these factors (Emblemsvåg, 2022).

56.1. Climate Change

A fuzzy logic expert system with species biogeographical data show that some exploited deep-sea demersal species, such as Antarctic toothfish (*Dissostichus mawsoni*), rose fish (*Sebastes norvegicus*), roughhead grenadier (*Macrourus berglax*), Baird's slickhead (*Alepocephalus bairdii*), cusk (*Brosme brosme*), and Portuguese dogfish (*Centroscymnus coelepis*), face both significant climate-related risks and high vulnerability to fishing (Cheung et al., 2022). Most deep-sea fish species exploited by fishing are likely to face a greater risk of local or even global extinction due to their susceptibility to climate change and fishing pressures (Cheung et al., 2022). Geographically, a concentration of deep-sea species that are susceptible to climate impacts is predicted in the northern Atlantic Ocean and the Indo-Pacific region (Cheung et al., 2022).

A species niche model combined with the output from an ensemble of climate models show that climate change may reduce appropriate thermal habitat and increase habitat fragmentation in the Northwest Atlantic Ocean (Hare et al., 2012). It is projected that tusk's distribution will shift due to a mismatch between suitable habitat and temperature (Hare et al., 2012).

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56.2. Status and Population Trends

West Greenland

Areas	Abundance	Status, change	Trend (Short term~1 generation)	Category of change	Description: physiological,behavioral change	Climate variable & direction	Hunting
	unkown	unkown	unkown				

East Greenland

Areas	Abundance	Status, change	Trend (Short term~1 generation)	Category of change	Description: physiological,behavioral change	Climate variable & direction	Hunting
	unkown	unkown	**Increase** (Emblemsvåg, 2022).				

56.3. Synopsis

We found strong evidence for an increase in East Greenland. We found strong generric evidence for a decline of this species with a warming climate.

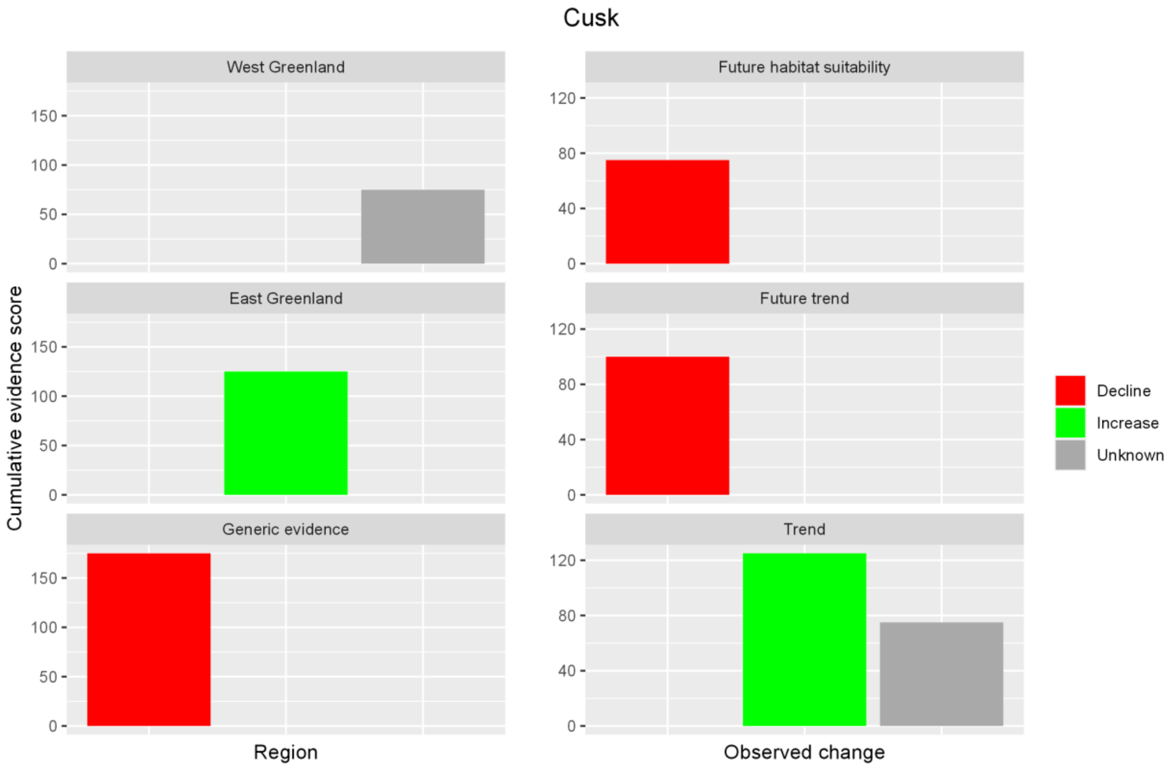

Figure 56.1 Cumulative evidence per region and aspects in which change is observed or expected.

56.4. Catch and Forecast

Insufficient reported catch to produce forecasts.

56.5. Workshops with Hunter and Fishers Organizations

Not discussed.

56.6. Interviews with Scientific Experts

-will follow-

56.7. Preliminary Future Scenarios

Scenario	Ittoqortoormiit	Tasiilaq	Upernavik	Ilulissat
Stock and catch trend scenario				
Underreporting adjustment scenario				
Alternative actions scenario				

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