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Understanding Marine Biodiversity Shifts in Southeast Greenland with Indigenous and Local Knowledge

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Abstract

We contribute to the identification of marine biodiversity status and changes in the coastal area of Southeast Greenland through consultation with holders of local and Indigenous knowledge (LEK/IK). Through in-depth interviews with coastal fishers and hunters in the Ammassalik area, we explore a range of changes to known and new species in relation to ecosystem dynamics. Key observations include diminishing presence of polar cod (*Boreogadus saida*), new abundance of known fish species (*Gadus morhua*, *Salvelinus alpinus*, *Reinhardtius hippoglossoides*, *Cyclopterus lumpus*), inflow of new/rare species of whales, fish, and shellfish (*Oncorhynchus gorbuscha*, *Lamna nasus*, *Paralithodes camtschaticus*, *Physeter macrocephalus*, *Globicephala melas*, *Megaptera novaeangliae*, *Phocoena phocoena*), and increasing absence in the fjords of some local seal species (*Cystophora cristata and Pusa hispida*). Observed changes in local abundances are understood with reference to the physical changes in temperature, ocean currents, glacier melt, and snowfall. Changed dynamics in prey-predator relationships are observed to mediate the local presence of target species. Other environmental changes include an influx of new food items in food chains and increased seaweed growth. Our study confirms the relevance and timeliness of systematically incorporating local and Indigenous knowledge to enhance the understanding of coastal marine dynamics in the context of climate change and the geographical 'opening' of the East Greenlandic region.

Keywords Marine biodiversity · Arctic coastal fisheries · Indigenous knowledge · Local ecological knowledge · Climate change · Ammassalik · East Greenland

Introduction

Local Ecological Knowledge (LEK) and Indigenous Knowledge (IK) offer a particularly rich source for understanding complex marine changes in Arctic areas from a holistic ecosystem perspective (Berkes & Berkes, 1999; Inuit Circumpolar Council, 2022). LEK and IK complement scientific disciplines in monitoring and assessing biodiversity and changes to local fish abundance and help fill knowledge gaps about cause-and-effect processes or local dynamics in governing ecosystems (Danielsen et al., 2014; Schiøtt et al., 2021 with reference to Thornton & Sheer, 2012). Greenland, an Inuit Homeland with a population close to 57,000, is a Self-Governing region in the Arctic with high reliance on fisheries and the marine environments for national income (Bianco, 2019), for local food security (Goldhar & Ford, 2010), and for participating in activities that enhance health, sense of well-being, freedom, and quality of life (Hauptman et al., 2019; Steenholdt, 2020). Interview studies with fishers, hunters, farmers, and other community members in Greenland reflect a rapidly changing marine ecosystem over the past 15 years (Holm, 2010; Hedeholm et al., 2016; Minor et al., 2019; Schiøtt et al., 2021; Jacobsen et al., 2023; Jungsberg & Wendt-Lucas, 2023). These reports demonstrate the vast scope and in-depth character of what has intermittently been termed local, traditional, Indigenous, or Inuit knowledge. This knowledge obtained through often lifelong and inter-generational engagement with local marine environments in Greenland has persistently pointed to some key processes first documented by Holm (2010), including changes to seasons, shifting weather patterns, warming sea temperatures, and changing sea ice conditions. Greenlandic

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LEK/IK also reflects the complexity of change as long-term warming trends interact with annual fluctuations in local weather, currents, sea temperatures, and glacier melt. A cross-comparison of available studies on regional diversity in environmental conditions and responses of local fish species over the past 10–15 years reveals an overall trend of northward migration of shrimp (*Pandalus borealis*) and Atlantic cod (*Gadus morhua*), benefitting northern settlements that subsequently adapt their fishing practices to the increasingly ice-free conditions (Schiøtt et al., 2021; Jacobsen et al., 2023). In contrast, South Greenland has continued to rely on a fluctuating cod fishery (Jacobsen et al., 2023). Reports in 2020 from fishers in Attu, Northwest Greenland, provide details on freshening fjord waters, causing Atlantic cod (*Gadus morhua*) to seek deeper, saltier waters in certain years (https://pisuna.org). Although polar cod (*Boreogadus saisa*) abundance is known to vary from year to year, fishers from Uummannap Kangerlua and Sullorsuaq, Northwest Greenland reported 2022 a year with unusually few polar cod (Bouchard et al., 2023).

Despite existing platforms to engage in community monitoring programs (Opening Doors to Local Knowledge, n.d.) and increased climate change research activity in Greenland (including interviews in local communities), published and internationally accessible LEK/IK studies on marine biodiversity change in Greenland are scarce in contrast to the contextual richness of local observations and the dynamic character of the subject matter. With significant regional diversity and an extensive settlement pattern, many temporal and spatial gaps can be identified in the available LEK/IK reports, the coastal fisheries in Southeast Greenland being a case in point. With the notable exception of some exemplary co-designed LEK/IK studies of polar bears (*Ursus maritimus)* (Laidre et al., 2018) and collaborative GIS-mapping of hunting areas (Flora et al., 2019), no LEK/IK studies of fisheries are available from Southeast Greenland, where a significant marine regime shift has been taking place as the region has virtually ceased to experience summer sea ice coverage since 2003, affecting the northward migration of marine mammals into and out of the region (Heide-Jørgensen et al., 2023) and providing increased physical access and periodically new (pelagic) fishing opportunities for the offshore fishery (Jacobsen et al., 2023). We address a knowledge gap in the understanding of how marine biodiversity changes in this region are observed and experienced *inshore* by coastal fisheries in the context of local and indigenous knowledge systems through a qualitative interview study conducted in 2023 to obtain an LEK/IK-informed status of the most important biodiversity changes observed and experienced by coastal fishers in the Ammassalik area, Southeast Greenland.

Fisheries in the Ammassalik Region

The 2.700 km long East Greenland coastline is sparsely populated by 3.000 people, distributed between two settlement areas: Ammassalik and Ittorqqortormiit. Most people live in the Ammassalik area in Tasiilaq town (1,829 inhabitants in 2024) and five villages: Sermiligaaq (198), Isertoq (48), Kulusuk (227), Tilieqilaaq (94), and Kuummiut (269). Hunting has a long tradition in Ammassalik and Ittorqqortormiit, where there is still a mixed subsistence/cash economy (Fig. 1).

The existence of commercial fisheries is more recent, and landings are low compared to West Greenland. In 2018–2022, the number of fishers selling catches to the single landing site in the Ammassallik area in Kuummiut fluctuated between 57 and 82. They were primarily landing Atlantic cod and Greenland halibut (*Reinhardtius hippoglossoides*), with some capelin (*Mallotus villosus*) and catfish (*Anarchichas minor*). During this period, most fishers (60%) made less than 7,500 USD from the commercial fisheries. In Greenland, coastal fishers' decisions to catch fish for commercial sale are highly dependent on the availability of local marketing options and fish prices (Jacobsen et al., 2023). In 2024, the Greenlandic government launched a fishery development plan for the region aiming to "… secure an economic, social, and scientifically sustainable development of the fishery, which can contribute to self-support, self-sufficiency, and employment in East Greenland" (Naalakkersuisut, 2024: 28). In 2023 (at the time of the interviews), it was decided that a second landing facility will be established in the region (Tasiilaq) to improve fishers' market options.

Coastal fishers and hunters shift between multiple species according to season, physical accessibility (ice, weather), technological equipment, market options, and landing prices (see also Flora et al., 2019). Generally, the fishers we interviewed engage in multiple hunting activities (whales, seals, polar bears) and combine this with longline fisheries for Greenland halibut and Atlantic cod for sale and own consumption. Some fish capelin for bait, and Arctic char (Salvelinus alpinus) are used for consumption.

Research Design and Methodology

Our methodology was guided by a previous LEK/IK study in West-Greenland (Jacobsen et al., 2023) using a semi-structured interview guide with open-ended questions: (1) your fishery and its seasons; (2) changes to your fishery since you started fishing; (3) observations of any 'new' species compared to when you were child, 10 or 20 years ago; (4) historical observations of polar cod; (5) other observations of changes in the fishery or the eco-system

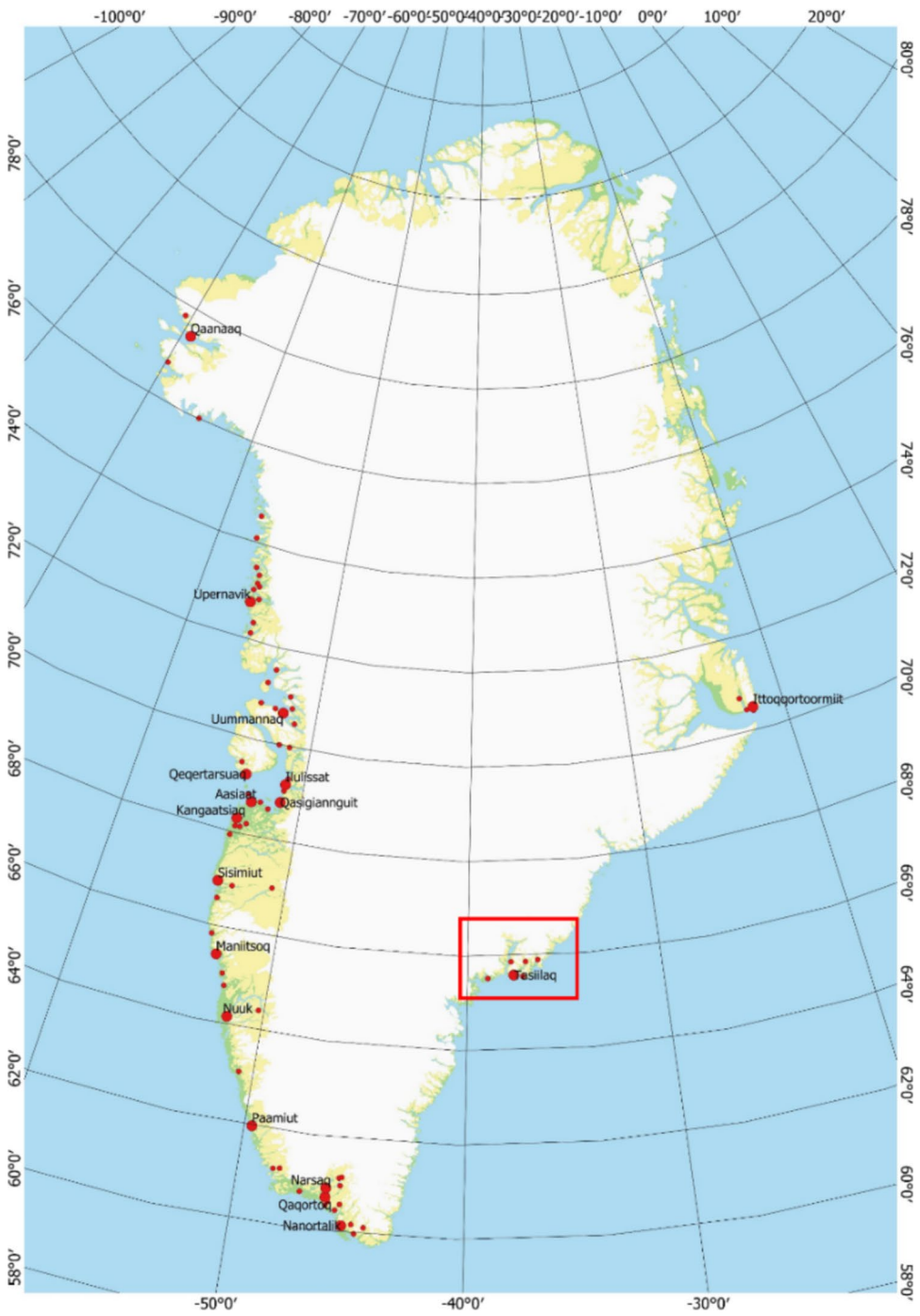

Fig. 1 The study area in East Greenland

including (i) species you see more or less frequently; (ii) changes in ice cover, fresh water layering, salinity, temperature, and currents; (iii) algae and seaweed growth, mud and stones from glaciers; (iv) stomach content of your catch; (v) the condition of animals and fish (skin, fat liver, size, etc.) (vi) New locations of animals and fish; (vii) weather and storms – good and bad fishing days; 6) identification of needs to continue and benefit from the fisheries.

Two local research assistants from Tasiilaq recruited fishers for our study, conducted the interviews in the fishers' first language (East or West Greenlandic) and synthesized the data into resumes in Danish. One of the research assistants also partakes in fisheries activities in the area and is known to many fishers. The interviews were conducted in the spring and summer of 2023 at times and locations suitable to the fisher. Depending on the interview location and the preferences of the fishers, interviews were conducted with or without audio recordings. Eight fishers from four of the six towns in the Ammassalik area participated (Tasiilaq, Kulusuk, Tiilerilaaq, and Kuummiut). The fishers, all male,

were between the ages of 27 and 68 and had been actively fishing and hunting in the Ammassalik area from early childhood. As adults, they are engaged in commercial fisheries, fishing, and hunting for household consumption. All the interviewees are Greenlandic fishers, and their knowledge is approached as Indigenous and local knowledge systems (UNESCO, 2017). The purpose of the interview, formal consent forms, and interview questions in the interviewees' first language were presented and explained 2–3 months before the interviews. Some fishers declined the invitation to participate, and in one community, several fishers referred to the same fisher they considered to be particularly knowledgeable, who agreed to participate. Preferences for non-participation were respected, and fishers assisted in increasing the locally perceived validity of the LEK/IK through the inclusion of the generally recognized most knowledgeable fisher. The two non-local authors attended a 3-day fishery seminar (with Danish/East-Greenland translation) in Tasiilaq in April 2024 organised by the Greenlandic Ministry of Fisheries also attended by 11 local fishers and representatives of all the local fisher and hunter organisations in the Ammassalik area, including three of the interviewed fishers. The seminar provided an opportunity to communicate our study's process and key results, clarify responses, document further accounts of experienced changes, and discuss focus and methods for future fisher-science cooperation.

Interview resumes were translated from Danish into English and manually coded inductively with Microsoft Word. We also conducted a structured search for keywords such as glacier, mud, rock, stone, melt, sea ice, weather, storm, wind, climate, rain, seaweed, cod, lumpfish, Arctic char, crab, polar cod, Greenland halibut, capelin, new species, polar bear, and seal. Below, we synthesize observations across the eight in-depth interviews, re-organizing quotations from the individual interviews (resumes) according to themes, from physical processes to changes in biological environment, and eventually focusing on status and changes to a broad range of fish and mammal species caught in the region.

Observation of Physical and Environmental Changes

One of the most noticeable physical environmental changes is the impact of glacial meltwater in the fjords, releasing extensive amounts of sediment and rocks into the water. One fisher observed that in Sermilik Fjord:

> When the glaciers break apart, big rocks come to the surface, so when it melts, the big rocks sink to the bottom, making it hard to fish there. Now I go elsewhere in Sermilik Fjord. It's the same at Ikaasatsivaq; there are many rocks in the water from the glacier.

The fishers all agreed that stones and mud in the water make traditional fishing methods, such as long lines, increasingly difficult and sometimes impossible. Another described a similar challenge with using long lines in the fjord:

> I've tried the long line at Sermilik Fjord, but there are lots of stones at the bottom of the water, so I couldn't get the long line up again.

This difficulty disrupts fishing activities and poses a risk to the equipment, adding an economic burden for the fishers. In addition to the shared agreement of increased sedimentation in the fjords, the fishers collectively agreed on the observation that the region has experienced an increase in storms over recent years (10–15 years), affecting fishing activities:

> "During the last 10–15 years, the weather has changed a lot. I've noticed the weather has started to change much faster than before, causing problems for us fishers as ocean currents shift and sea temperatures change."

Another fisher observed:

> Our weather here in East Greenland has changed. I mean, it's always changing, but even though I usually know the weather, it has become more difficult for me to foresee weather changes because it happens so quickly.

And another noted that changes to the physical surroundings are evident through various phenomena, such as the warming of the sea:

> I think the warmer currents are getting closer, which is why the fjords around Tasiilaq no longer freeze. This could also explain why more cod are returning - because of the warmer currents. When I was a child, there was a lot of cod here, even though it was very cold. Maybe the sea was warm even though the weather was cold?

Changes to sea ice cover have been observed to occur over the years with later formation, thinning, and earlier onset of melting. One fisher explained:

> As said, the sea ice freezes slower but melts much faster. Back in time, we had longer lasting sea-ice. When I was younger and during my childhood, the drift ice came in October or in the beginning of November. Back then the ice melted only late July, but since the beginning of the 2000'end, the drift ice has drifted away during June.

Another recalled:

> When I was young, I started going with hunters when they went on hunting trips. The sea ice then formed

> in late November or early December. And it was very thick sea ice at that time. When we were younger, we would go dog sledding in June, and the sea ice towards Tunu wouldn't break up until July. Since the early 2000s, it can take until January before the sea ice forms, and when spring comes, the sea ice melts very quickly. For example, you can go boating in Tunu in June. So, one can say the ocean temperature is rising, as we can see the sea ice freezing very slowly and melting faster.

Also, the drift ice coming from the North has diminished:

> "I would also like to mention the ice, in the past year there have been a lot of changes to ice. In the past there was a lot of drift ice, but in recent years there has been some drift ice, and the rest looks a lot like cotton. Back in time, when the drift ice came, all maritime traffic stopped. But for the past 3–5 years I can sail whenever I want. Small drift ice and the rest is like cotton, I noticed that too. Over the past year, I have noticed the ice layer is getting thinner".

Over the past five decades, retreat of glaciers have become very visible:

> There is a glacier near Kulusuk called Apusiaaik; a big part of the glacier has melted over the last 50 years. When I first sailed into the Apusiaaik Fjord, it was only possible (to sail) to an island near the coast because the glacier was bigger back then. Now the glacier no longer goes into the sea; everything is on land, and when there is low tide, you can see the sea floor.

The fishers shared their observations on historically colder waters, with seaweed previously found frozen beneath the ice, standing in stark contrast to the current climate where such phenomena are no longer occurring. One recalled:

> My father, when I was a kid, used to tell stories—when you cut open the sea ice to harvest seaweed, the seaweed used to be completely frozen. Maybe back then, the sea was very cold, but it's not like that anymore.

The fishers recounted how, historically, seaweed was much smaller and shorter, but today's observations show larger sizes and greater distribution:

> The previous generations tell us about the many plants from the sea, such as seaweed, which back in the day was only about 20 cm at its longest. But today's seaweed can reach up to 50 cm. You could maybe say that the plants in the sea are starting to live longer.
> In the past, when we sailed north to Kangerlussuaq, we never observed seaweed. But today, there is seaweed everywhere, and it's getting longer and longer.

Only one fisher mentioned his lack of observation on seaweed but revealed that other people had observed that it is not where it is usually found and does not occur in the same quantities as before, indicating a potential divergence about seaweed. Throughout the interviews, fishers speculated about reduced salt content affecting seawater's nutrient levels, potentially impacting marine ecosystems, while also noting the challenges that the increased distribution of seaweed poses to fishing equipment.

Ecosystem changes were also observed in the influx of more prey species into the marine food chain. Over the last ten years, Arctic char, Atlantic cod, and Greenland halibut have consumed more small squid (unidentified), small lumpfish (Cyclopterus lumpus), and small shrimp. A fisher described how:

> ….when we catch Arctic char in the fall, when it's on its way back to the lakes, we see it has small squid and small lumpfish in its stomach. There are also usually some small shrimps in the stomach of the Arctic char (…). I'm sure the squids and lumpfish are coming closer and becoming more. Because Arctic char is frequently caught with lumpfish and squid in the stomach.

Another fisher also noted this change:

> The cod's stomach contains small squid and small shrimp; this hasn't changed for several years. But I've noticed there are now more and more shrimp in the stomach because it's getting warmer and warmer.

Collectively, the fishers agreed that warming waters, leading to an increase in shrimp populations, could be a potential cause of this dietary shift.

Changes to Fish Species and Mammals

Historically abundant in the region, polar cod have substantially declined in the Ammassalik area since the late 1900s. All interviewees broadly shared this observation and ascribed it to climate change. One fisher shared his detailed observations of the lack of spawning polar cod in the area in the last decade:

> "In the past, we ate a lot of polar cod, but we used it mostly as bait. When the polar cod was to be found here, it mostly showed up during February-March. In April-May, when the capelin arrived, the polar cod disappeared. When the polar cod was here, you could catch them in very deep water, and some of them would stay at the edge of the ice, at the surface of the water. You just had to sink the hook just below the surface. But some polar cod can dive down to around 40 meters. If we look back ten years, the polar cod was no longer to be found in the fjord. It

has become increasingly rare to catch polar cod in this area. I have never seen the polar cod spawn, only a few times I have tried catching polar cod with roe. I don't know where they breed."

Local fishers jointly described this phenomenon as connected to several factors, including rising sea temperatures, increased predation by other species, and introducing new fish species into the ecosystem. According to one:

"For the past 30 years there have been polar cod close to Kuummiut, mostly caught during winter. But as soon as spring arrives, the polar cod move to colder waters, probably because the sea temperature rises in the summer. In recent times, one doesn't catch as many polar cod anymore."

Throughout the interviews, the fishers shared their common belief that the polar cod are moving north to deeper, colder waters, citing Isertoq and Sermiligaaq, and areas near glaciers, such as Helheim Glacier, are as locations where polar cod can still be found likely because they remain colder. However, the fishers have changed their fishing patterns and are no longer targeting polar cod as much as they used to, partly because the fish are harder to find and partly because of a shift in focus to other species like capelin for bait.

Observations of Atlantic cod reveal a history marked by periods of abundance and sharp declines, particularly notable in the 1990s. One fisher explained that:

20 years ago, the Atlantic cod disappeared, but after 4–5 years they came back, and they were very abundant.

Several fishers in the area validated these observations, stating a noticeable increase in the Atlantic cod population but also an increase in their size, indicating a strong recovery:

The cod stock is increasing, I have heard there are more and more cod (…) But you can definitely feel that the cod population is returning, also the size itself, some of them grow very large.

Another added:

Cod sometimes disappear, in the 90s, there was almost no cod, only very small amounts, but they come back in abundance.

According to all the fishers, cod made a resurgence by 2010, returning in big numbers to the fjords:

Ever since the 1960s, there have always been spawning cod here, but they started to disappear during the 90s. But after 2010, the big cod returned to the fjords, and the population grew and grew. For the past five years, you can always find cod in the area.

The fishers agreed that this recovery is connected to environmental factors such as sea temperature shifts and prey availability variations. Recent years have seen a further increase in cod sightings, coinciding with observations of receding sea ice cover, suggesting a relationship between rising temperatures and cod distribution. As one fisher recalled:

When I was younger, there was lots of ice, and everything was frozen, not anymore (…) I think the warm currents are getting closer, so it might not freeze in the fjords around Tasiilaq anymore. Maybe that's why there are more cod again, because of warm currents.

Arctic char populations in East Greenland are thriving, presenting new opportunities for local fishers, with more community members engaging in Arctic char fishing throughout the fishing season:

I've noticed the population of Arctic char has increased significantly, there are more people now fishing for Arctic char. It's best to fish and catch Arctic char when the season starts until Arctic char arrive in the lakes in the mountains in the fall. But you can easily catch Arctic char all summer long. People think they taste the best when the[y] have put on weight in July and August.

The distribution of Arctic char extends across various inland locations:

Arctic char can be caught from June to September. Arctic char can be caught everywhere, in many different places; each (fisher) have their favourited spot – for example, Ningerduluk – all the way up there, you can catch Arctic char – people usually do it from Sermiligaaq, also all the way south to Skjoldungen, a deserted village further south from Isertoq.

According to the local fishers, Arctic char in the area follow known regional patterns of seasonal migration:

The Arctic char in Kulusuk might have a certain route when they enter the ocean, then they swim around and get fat until they swim back into lakes. I think most Arctic char areas are like that. I've noticed the Arctic char in Kulusuk, they swim down into the ocean, get fat, and come back up to the lake where they came from.

Meanwhile, the prey of Arctic char is observed to be changing:

I haven't tried to feel the stomachs of the fish I've caught, but when I caught Arctic char at the islands between Kulusuk and Sermiligaaq I noticed their

stomachs contained small squid. The Arctic char was at sea, and they were eating 1–2 cm long squid. I don't know where the Arctic char caught the small squid, and at that time, I noticed that many Arctic chars had squid in their stomachs.

Arctic chars are nested in the knowledge of local procurement and consumed within the community:

When we catch Arctic char, we put them in freezers, and some of them are hung to dry. We also eat them while they are fresh.
I usually catch them in Sermilik Fjord, Kuummiut Fjord, but I like it best when their fillets are very red. Of course, all taste good, but the ones with strong, red-coloured meat are the best.

Considering increasing abundance, fishers proposed including Arctic char as a marketable species alongside Atlantic cod and salmon (*Salmo salar*):

Cod has come back well after 2015, but mostly in the autumn, and I think it would be a good idea to start selling other fish species, such as Arctic char and salmon. Greenland halibut, catfish, and redfish (*Sebastes mentella/norvegicus*) can also be traded. I imagine if you could start trading Arctic char and salmon, it would be a great advantage for fishers.

In Kuummiut Fjord, the arrival of lumpfish is understood as a key ecological change. A fisher suggested that warmer waters may be driving the migration of lumpfish into fjord systems where they were previously absent:

I also think you can feel the climate changes. The current has become warmer, so other kinds of fish come, other kinds of salmon, for example. In recent years, lumpfish have arrived in Kuummiut Fjord; I had never seen them there before.

In the fisher interviews, it was also noted that:

Over the past ten years, lumpfish have been spawning in the fjords, which is something new for us.

The fishers generally expressed an interest in understanding the local distribution further, supporting their shared interest in expanding their knowledge and fishing activities:

"We know there are lumpfish in this area, we just don't know where they are. If there was funding for lumpfish surveys, we could investigate it further."

Another added:

We've also started catching lumpfish with rods, maybe there are a lot of lumpfish in the fjord?

Overall, there is general agreement that lumpfish have arrived and are thriving in the Ammassalik area, but the phenomenon is yet to be explored fully. As we have noted elsewhere, the fishers shared many observations on lumpfish in the stomachs of other animals, supporting the general recognition of an increase in lumpfish in the Ammassalik area.

The local fishers described the presence of crab populations in the Sermiligaaq Fjord ecosystem, including Red King crabs (*Paralithodes camtschaticus*), said to have increased in past years, impacting traditional fishing practices through a new focus on the crab fisheries. One fisher stressed the long-term presence of crabs in the area:

We have had crabs in this area for many years, those who try to catch crabs have been successful. I also believe the Red King crab population will grow as the sea temperature is rising.

However, the presence of the Red King crab is new for some of the local fishers. One fisher described his first encounters with a crab species (supposedly the Red King crab):

There's also crab, a different kind of crab - they have thin long legs - it is different from what they catch on the west coast. I don't usually catch them. I have, however, caught them while I'm fishing for Greenland halibut with the long line out in Sermiligaaq Fjord and at the entrance to Johan Petersen Fjord. At that time, they seemed scary to look at because we had never seen anything like that before.

Several fishers noted that crabs, and small shrimp have begun to consume bait intended for Greenland halibut:

We have only caught crabs a few times with longline, and I have also noticed that small shrimp and crabs have started to eat our bait when we fish Greenland halibut with the longline.

The fishers indicated that Greenland halibut remains of cultural- and economic importance. The Greenland halibut population is recognised to be stable and abundant, and the preferred fishing technique is longline. One fisher noted no noteworthy changes in the location of Greenland halibut over the past decade but observed their seasonal movements and spawning behaviours:

For the past ten years, there has been no change in the Greenland halibut location, just now you can follow the Greenland halibut which is heading out from the edge of the ice sheet in late June and early July. The Greenland halibut chases the capelin; they feed well on the capelin's roe. And in the fall, the Greenland halibut go down to deeper areas in September, and in the spring, in May or late April, it starts to spawn in fjords.

> What I mean, is that the big ones come into the fjords and spawn. We always follow their route and fish them.

Despite challenges such as temporary disruptions by whales entering the fjord scaring off Greenland halibut, and economic challenges, including fluctuating prices, fishers describe how they adapt their techniques and priorities to maintain their livelihood. A fisher noted:

> I usually save a lot for winter, enough to have Greenlandic food all year round. For example, for fall, I usually fish enough Greenland halibut for the winter. When I'm done fishing it, then I fish another kind that I can save for the winter. If I don't have enough Greenland halibut after one day, I go out again and fish more to make sure I have enough for the whole year, only then do I catch another kind of fish or seals, for example.

Another fisher pointed out the low profitability due to current market prices, emphasizing that economic constraints heavily influence fishing practices:

> I fish Greenland halibut and cod because that's what you can land in the factory. So that's the opportunity I have to make money from my fishing. But it's difficult because the price is very low, so I don't make much money from fishing.

The interviewees generally agreed upon this observation, which added to the discussion on future landing possibilities in the area.

The local fishers provided insights into the key seasonal role of capelin in coastal food chains and how locals have successfully utilized them as bait in recent years. The difficulty in obtaining polar cod has elevated the importance of freshly caught capelin as bait. Capelin, described as a crucial species in the coastal ecosystem, typically arrives around May. A local fisher reflected:

> We haven't investigated which routes capelin use when they are on their way into the area. But now we have learned when they can be caught, so we drive with the dog sleds and catch the first capelin. There are capelin throughout the Tasiilaq area.

Capelins are favoured prey for Greenland halibut and Atlantic cod:

> The cod come from the deep waters and feed well on capelin when the capelin are on their way to deeper water.

Capelin also attracts whales waiting their emergence from the fjords:

> Mammals such as humpback whales (*Megaptera novaeangliae*) and common minke whale (*Balaenoptera acutorostrata*) are abundant when the capelins are on their way out of the fjord, as they feed on them.

Fishers discussed capelins' role in commercial trade:

> If we think about what season we are in, there is also the possibility of catching capelin, which on average are 18–20 cm long. It would be great to sell them abroad.

This observation supports the fishers' general call for future landing possibilities and marked expansions in Greenland.

The local fishers collectively agreed on observations on the emergence of new fish species, which they attribute to factors such as rising sea temperatures and shifting migration patterns likely driven by climate change. One fisher remarked:

> When I was growing up, there weren't that many different species of fish, but in the last year, there have been so many different species. Like the Icelandic fish (unidentified), which is rarely caught in this area, there is also a new species that has arrived, the humpback salmon (*Oncorhynchus gorbuscha*).

Another added:

> There are more species of Arctic char and more species of salmon arriving in September. An Icelandic fish with orange-coloured eye rims has also arrived. In our fjord, we have also noticed 2–3 new fish species."[1]

Some fishers have encountered another species of Arctic char from Canada with black spots and sharp teeth in rivers near Kulusuk:

> I caught that type of Arctic char in Kangerlussuatsiaq two years ago and between the islands near Kulusuk.

Based on follow-up discussions at a fisheries seminar in Tasiilaq, this new Arctic char is likely to be pink salmon, also mentioned by another fisher as humpback salmon. Further, some fishers have noted the occasional arrival of mackerel (*Scomber scombrus*):

> There are more species than before of whales and fish, including mackerel. It hasn't been that long since mackerel arrived. They are considered very rare here, only caught now and then when fishing for salmon with nets.

Another fisher speculated on temperatures and a connection to new unknown species:

> Now that you mentioned global warming, more and more species are showing up. Some of them are bizarre and have never been in the Tasiilaq area. I think there will be more strange species coming to the area.

[1] We were not able to identify the species in follow-up dialogues.

This sentiment was echoed by another observation of a new shark species, subsequently identified as Porbeagle (*Lamna nasus*):

> We have also seen a shark that originates from warmer countries. The Greenland shark is grey with straight teeth, but the new species that has arrived has triangular teeth. I saw a Greenland shark bitten by a shark from warmer countries with triangular teeth for the first time ten years ago, and now it's getting caught more and more often.

During the interviews, fishers agreed that many new species were entering the Ammassalik area.

The fishers agreed on an increase in new whale sightings in recent years, which they connected to changes in migration patterns, prey availability, and sea temperatures. The observations included new whale species in the Ammassalik area:

> More species of whales have arrived, such as sperm whales (*Physeter macrocephalus*) and pilot whales (*Globicephala melas*). So many different whales have arrived in the last few years, there are also many humpback whales that have come near Tasiilaq. Humpback whales eat cod and polar cod, so it's a big problem. Global warming affects whales which come closer to the coast.
>
> If we look back ten years, there are now more species of whales. Such as the Faroese pilot whale (*Globicephala melas*) and porpoise (*Phocoena phocoena*). Normally, white-beaked dolphins (*Lagenorhynchus alberostres*) are in this area (…) There have been porpoises/dolphins in the area for many years, but in recent years, they have been spotted in fjords, and the population is growing.

Populations of orcas (*Orcinus Orca*) have also increased, causing issues for the fishers due to their predation on other species:

> When there isn't much catch during the summer, whales can be the reason. Because there have been so many more species of whales. Especially the orca, it can eat anything.

Another fisher reflected on historical changes to the presence of whales and fishers' interactions with the whales:

> There have always been orcas, but we don't usually hunt them because back in time we used only kayaks and small boats, so we were afraid of them. But now we can, we are not afraid of them anymore, with our bigger boats we can now catch them. When I was a child, there were not many whales because everybody used to catch them around the world, so there were not so many in our areas, but different species of whales come to our areas now, so we can catch them.

The fishers also agreed that they had adapted their fishing techniques by sailing further out to sea:

> We have noticed that many whales are to be found out by the ocean, so we usually go out there. In the past, we didn't go fishing out there because we didn't know if there was anything to be found. Also, because the vessel was not big enough. Usually, we find whales out there, but we spend many hours trying to find them. Maybe there were many whales to be found out there, but we just didn't sail out.

Fishers also discussed their seal hunting grounds and seasonal hunting techniques:

> In the summer, I mostly catch seals in Sermiligaaq Fjord or just outside Tasiilaq and Kulusuk, or around Sermiligaaq.

They also explained that sea ice is of great importance to seal hunting activities as it supports local techniques and traditions in seal hunting:

> In the fall, we always wait for the ice to come. When the ice arrives in December, I use a sled to set seal nets at Tunu, which is further up in the Kuummiut fjords. At the same time, there are many places where seals can be found, depending on what is reachable with the ice and where there is open water. We usually sled out to the ice edges, and that's where we set seal nets.

All fishers noted how the presence of whales harms their combined hunting and fishing activities:

> When there are whales, there are no longer seals and not as many fish in the water, so you must wait some days before they return or go fishing somewhere else. Also, because more and more whales are coming, then it happens more and more that it affects my fishery. Because I also like hunting seals as well as some whales.

There was general agreement on sea ice conditions, access, and competition from other species that impact seal hunting grounds. A seasoned fisher shared his perspective and his detailed observations of seasonal variation in seal blubber, which affects the seals' resilience, and how hooded seals (*Cystophora cristata*) seem to have changed their migration patterns:

> Before the 1980s, there was an abundance of mammals such as ringed seal pups (*Pusa hispida*) and hooded seals in the fjord. But in recent years, there are not many of them left, with only a few seals entering

> the fjord. Ringed seal pups that enter the fjord in the fall seem very thin, and we keep catching them with nets, so the ringed seal pups don't gain much weight. But when a ringed seal pup stays in the fjord all year round, and spring begins, we see they usually gain weight. I've noticed hooded seals don't stay in our fjords anymore; they are usually out on the ice when the drift ice is heading south. I've noticed only a few hooded seals come into the fjord. The seal, which is slightly larger than the ringed seal, has also become rare in the area.

Fishers generally agreed that the decline in hooded seals is due to factors such as temperature changes and snowfall patterns:

> There is a certain place where the snow gathers during the winter, even when it's spring, it can snow there. Our ancestors have told us about this place. If the snow melts, there won't be many seals in the summer. If it snows a lot, there will be a lot of seals in the summer. If half of the snow falls, there won't be as many seals in the summer, either. This statement may be true this year; half of the snow fell, and we have noticed that there are not so many seals, especially the hooded seal. When July begins or June ends, there are plenty of hooded seals at the beach. This year, there are not so many.

Polar bear hunting remains important for sustenance and inter-generational knowledge:

> We have been eating Greenlandic food for many generations, everything from sea to land mammals. I expect that I will continue to hunt Greenlandic animals and pass on information to future generations.

One fisher reported a shift in the polar bear diet with observations of polar bears consuming seaweed. One fisher explained that this is considered unprecedented, invoking some degree of scepticism towards the consumption of polar bear meat:

> As biologists say, the population is in a dangerous situation of extinction because polar bears eat seals. But upon closer examination of the polar bear's stomach, I've noticed it can contain seal meat and blubber, and if it goes on land, it can contain flowers, blueberries, and plants. But this is the first time I've seen plants from the sea where the polar bear itself is very thick. Nothing but plants from the sea. As I find this very mysterious, I've said that I will never eat polar bear meat again.

Despite this interesting observation, changes regarding the polar bear did not arise in most interviews.

Conclusion

LEK/IK communicated in interviews with fishers from the Ammassalik area, documented changes in ecological interactions in the past decades, and explicitly cited climate change factors, like shifting ocean currents, diminishing sea ice cover, and variation in snowfall. The knowledge held by fishers offered further perspectives on the impacts of a recently identified marine regime shift in Southeast Greenland (Heide-Jørgensen et al., 2023). Fishers' LEK/IK assessed possible connections and impacts of changing biodiversity on all species of interest, identifying a long-term local decrease in local polar cod; a current trend of increasing abundance of Atlantic cod, Arctic char, and Greenland halibut; inflows of new species to the area (pink salmon, porbeagle, 'Icelandic fish,' red King crab, sperm whale, pilot whales, humpback whales, and porpoise); and an increasing absence of seals (specifically hooded seal and ringed seal) in the fjord. Notably, fishers also bore witness to a degree of stability in local ecosystem dynamics, such as the continued role of capelin as a key species in the ecological dynamic of the local fjord system.

It is generally recognized that LEK/IK operates with an inherently holistic sensitivity to interconnections (Berkes & Berkes, 1999; ICC, 2022; Schiøtt et al., 2021). In our study, fishers' LEK/IK pointed to the physical impact of sea currents and temperatures on preferred fish habitats. It revealed the mediating factor of an influx of new food items (more small squid, shrimp, and lumpsucker) and the importance of the prey-predator relationship to local abundance (an increase of whales has scared off Greenland halibut and seals). Such data is key to explaining when and how 'climate change' impacts the target species (seals and fish) of local hunting/fishing activities.

The fishers interviewed during the spring and summer of 2023 unanimously expressed a desire to continue their traditional fishing and hunting activities and to expand commercial coastal fisheries in their communities. They pointed to the need for better fishing boats and the establishment of another fish factory in the region to obtain higher sale prices and the opportunity to land a more diverse range of species. Consequently, the East Greenlandic region may soon come to represent a case of Arctic fisheries seeking to benefit from climate change by adapting to biodiversity shifts. The coastal fishery in Southeast Greenland will, however, be expanding from a particularly low level with the primary aim of contributing to local community development (Government of Greenland, 2024) in an area that has historically been characterised by a high degree of 'disconnection' in terms of infrastructure and market access. Considering the demonstrated quality and value of LEK/IK in this remote and scientifically understudied region, it is an opportune moment to integrate LEK and IK from the Ammassalik area as a key resource in future marine monitoring and development initiatives and programs in the East Greenlandic eco-region.

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