

## Research Article

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# Noteworthy occurrences among six marine species documented with community engagement in the Canadian Arctic

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**Abstract:** Arctic marine ecosystems are changing, one aspect of which appears to be distributional expansions of sub-arctic species. For Arctic marine systems, there is limited occurrence information for many species, especially those found in restricted habitats (e.g., ice-covered, far north, or deep-water). Increasing observations through on-going Fisheries and Oceans Canada (DFO) community-based monitoring programs (e.g., Arctic Coast, Cambridge Bay Arctic Char stock assessment, Arctic Salmon, and Kugluktuk coastal surveys), community observation networks, and local media have augmented opportunities to document new occurrences of marine fishes. Combined data from historical records and contemporary observations at the local scale can then delineate these among

three types of occurrences: gradual distributional expansion, episodic vagrants, and rare endemics. Here we document nine occurrences of unusual sightings across six fish species (Pink Salmon *Oncorhynchus gorbuscha*, Bering Wolffish *Anarhichas orientalis*, Greenland Shark *Somniosus microcephalus*, Broad Whitefish *Coregonus nasus*, Banded Gunnel *Pholis fasciata* and Salmon Shark *Lamna ditropis*) from six northern Canadian communities and classify the nature of each observation as rare, vagrant, or expanding distributions. Uniting scientific and local observations represents a novel approach to monitor distributional changes suitable for a geographically large but sparsely populated area such as the Canadian Arctic. The new occurrences are important for discerning the potential effects of the presence of these species in Arctic ecosystems. These observations more broadly will build on our understanding of northern biodiversity change associated with warming Arctic environments.

**Keywords:** Arctic, biodiversity, observation networks, fishes, community-based research

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## 1 Introduction

The distribution of a particular species in northern waters is determined by its thermal tolerance, dispersal capability, and availability of resources needed to complete key life events [1], as well as historical factors such as effects of Pleistocene glaciations [2]. Depending on the habitat requirements of a species, the extent of geographic shift will vary [3]. Recent periods of extreme warming and sea-ice loss have facilitated the presumptive northward expansion of species from the Pacific [4] and Atlantic

oceans [5-7] into the Canadian Arctic, which may have been previously limited by thermal or other physiological barriers [8]. The success of a species' ability to colonize these regions will also depend on their mobility, interactions with endemic species, ability to forage, ability to overwinter in conditions often near or below zero, and their ability to establish or produce viable and surviving offspring in these new habitats [9,10]. The change in a species distribution is likely the result of both environmental shifts and increased variability among environmental conditions required to inhabit Arctic marine systems. Evidence of these large-scale shifts has been documented for species found outside their normal distribution [4, 7, 11, 12]. Such data are vital for understanding how endemic fish species will respond as climate change drives biodiversity shifts in the region.

Species may naturally occur outside their known geographic distribution (i.e., without direct anthropogenic relocation) via three different scenarios. First, a new species occurrence may be the result of gradual expansion (decades), possibly in response to warming climate that renders habitats in new regions more hospitable (e.g., Pacific salmon *Oncorhynchus* spp.; [12, 13, 14]). In this case, the spatial distance between observations is relatively small as the presence and abundance of a species gradually increases over time [13]. This incremental shift is generally linked to a trend in changing environmental conditions, for example, altered temperature regimes [8]. Under short time scales (year to year) the observed shift is often highly variable and spatially sporadic, largely as a result of the magnitude of environmental shifts [14]. Second, a new occurrence may also be in response to highly unusual environmental variability or an event, leading to a vagrant species being found far outside its normal distribution. This scenario likely results from dramatic environmental changes (e.g., warming seafloor temperature, marine heat waves) within that year, leading to abrupt shifts in a species' distribution [4]. The extent of environmental variation and shift, combined with the different mechanisms that are driving these unusual occurrences, make documenting biodiversity change in the Canadian Arctic extremely challenging. Lastly, a species may be endemic and within its distribution, but be rare or occupy specialized habitats, and thus not previously documented at that location. There is limited knowledge of distribution and habitat use for most fish species, as is the case for many species across much of the Canadian Arctic [15, 16].

Given the vast geographic area of the Canadian Arctic, coupled with the relative rarity of these types of occurrences, multiple strategies are often needed to document novel observations. Communication among scientists,

community-based monitors, and local media to facilitate observations has proven to be a useful and necessary tool for tracking biodiversity change in remote regions, where many knowledge gaps still exist [17, 18]. A network of collaborations formed by local fishers and the scientific community not only assists with the documentation of a noteworthy occurrence, but it aids in the determination of likely cause. These different sources for reporting change are complementary in meeting the need for ongoing observations across the Canadian Arctic, and all are useful to delineate the type of occurrence (i.e., rare, expanding or vagrant). The objectives of this study are to 1) document the new occurrences of a species in the marine environment, 2) infer the nature of each species occurrence (i.e., expansion, vagrant or rare) and 3) highlight the importance of networking as an example of enhanced monitoring that incorporates information gained from scientific surveys, community-based monitoring, and local knowledge. These networks of researchers and communities are examples of collaborative knowledge sharing platforms, that are essential for documenting biodiversity change in future years.

## 2 Materials and Methods

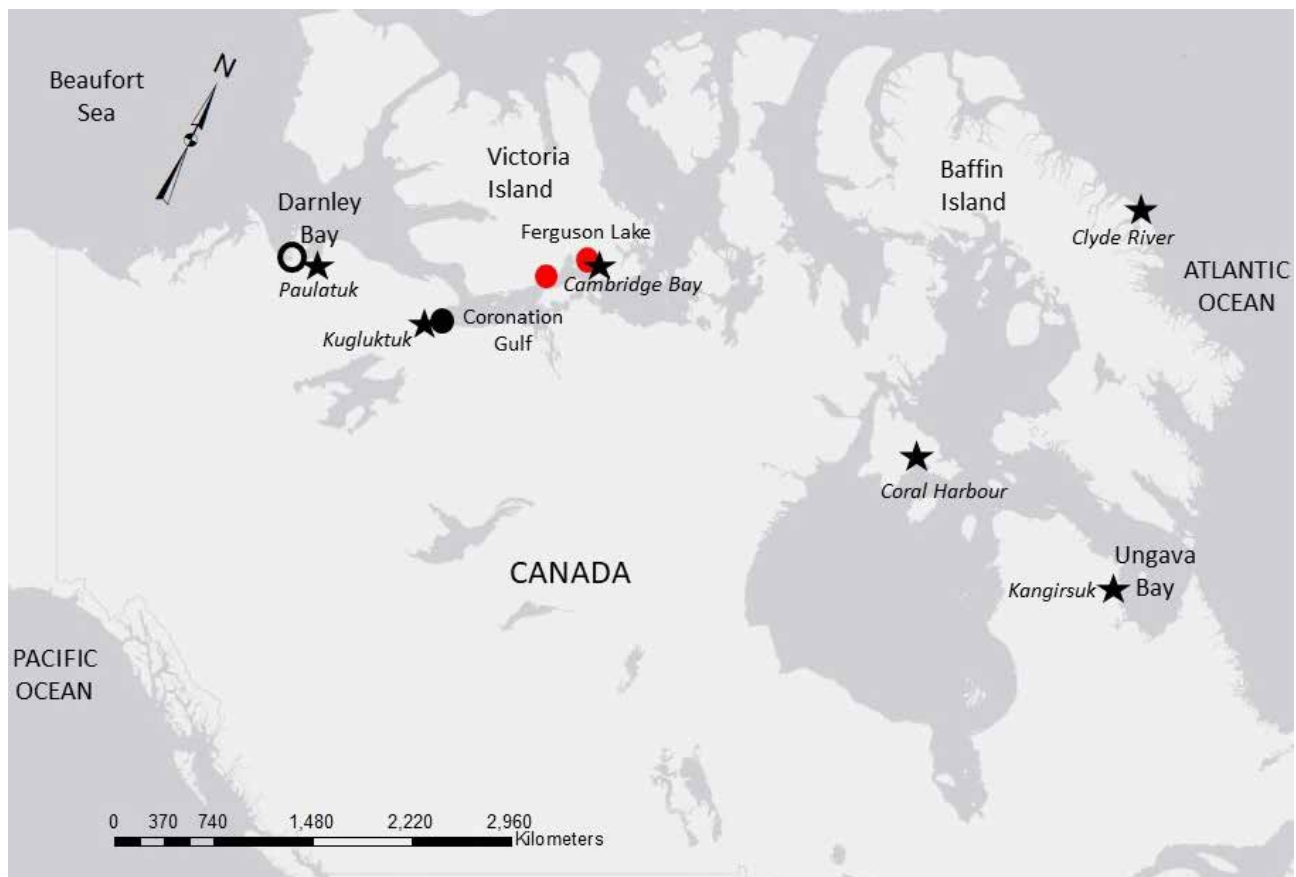
The occurrences, locations, dates of capture, and biological data of expanding, vagrant or rare fishes were documented through three different approaches including 1) community observation networks, 2) on-going Fisheries and Oceans Canada (DFO) monitoring programs, and 3) local media. The information was then compiled to present a more comprehensive understanding of biodiversity change across the Canadian Arctic. Species identifications were completed by trained biologists using key biological characteristics for each species while in the field, using a reference photo, or in the lab using thawed voucher specimens. Taxonomy was confirmed using morphometric indices (e.g., lateral line scales, total length, orientation of teeth), colouration and patterns (e.g., presence or absence of bars and/or par marks), presence and location of dorsal spots, and/or spawning features (e.g., pronounced kype, dorsal hump). Taxonomic keys [19, 20] were used to verify the suspected species and confirm if the occurrence was outside its known geographic distribution. The records presented here were found between 2017 and 2019 near to the communities shown in Figure 1. These years were selected based on the large number of new marine occurrences during this period that were shared specifically within this network of fish biologists

and community-based harvesters. It is likely that other similar occurrences were present, including within and beyond this timeframe and also among different habitats (i.e., fresh water) that are not represented in this manuscript.

## 2.1 Community observation networks

Observations made by community members regarding unusual fishes are essential for documenting biodiversity change in remote locations that are difficult to access. Open communication among local harvesters, conservation officers, wildlife managers and scientists provided occurrence data, date and location of capture, photograph, and if possible, samples of an unusual species that could be investigated further. These lines of communication have taken years to develop though community engagement and coordination among researchers so that a sample may be received, assessed within the broader context of an on-going program, and community-driven

questions addressed. The Arctic Salmon project is a DFO-led, community-based program established in 2000 with the purpose of tracking the generally increasing trend in occurrences and expanding distributions of Pacific salmon in the Canadian Arctic [11, 13]. The Arctic Salmon project is also designed to document new occurrences through community-based observation, such as those reported here, and it serves as a point of contact among collaborators for reporting unusual fishes and exchanging information. Collaborations among Indigenous, non-government organizations (e.g., Makivik Corporation or Hunters and Trappers Organizations), DFO, and harvesters allowed for samples to be collected in Nunavik, Québec (QC), which were then identified and processed by scientists for basic life history information (i.e., length, mass, sex, maturity). In Clyde River, Nunavut (NU), a noteworthy occurrence was documented by a local harvester and reported to the DFO office in Iqaluit, NU by wildlife biologists, who then connected the local harvester to Arctic Salmon. Similarly, in the Kitikmeot Region, conservation officers in Kugluktuk, NU, were able to connect local harvesters who caught



**Figure 1:** Communities nearest to where new occurrences were reported (star) and locations of DFO research programs (Arctic Coast (open circle), Kugluktuk coastal survey (solid circle), Cambridge Bay stock assessment (red circles)), which were affiliated with the collection of these records.

an unusual fish with Arctic Salmon biologists to identify the species and better understand why it was found outside its known distribution. The observations gathered in Nunavik, Clyde River, and Kugluktuk as a result of the community observation network are summarized here on behalf of the Arctic Salmon project.

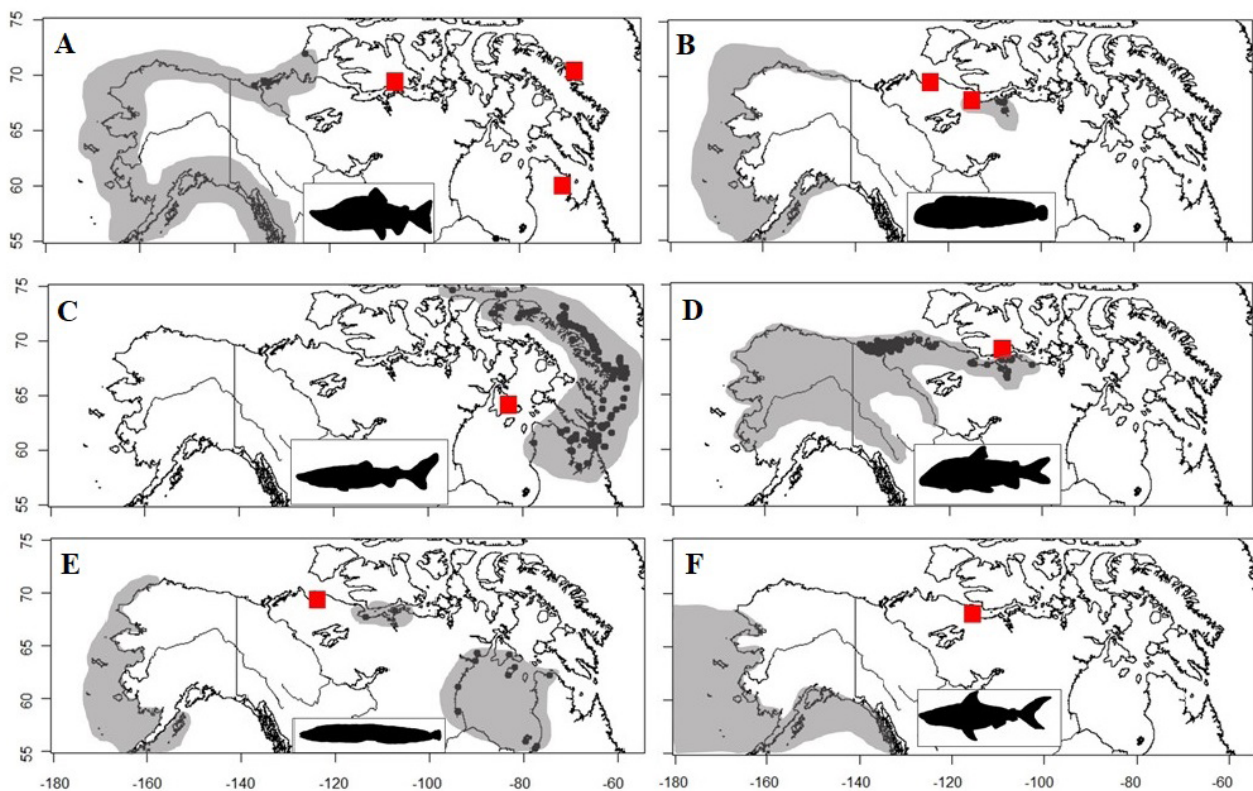
## 2.2 On-going DFO monitoring programs

The occurrences of unusual fishes were also documented by ongoing DFO monitoring programs that typically operate each year during the summer and fall seasons. DFO-led fish stock assessment surveys, research programs, as well as projects designed to assess or monitor coastal ecosystems including biologically or ecologically significant areas (e.g., Arctic Coast), serve as additional sources for documenting unusual fishes. The Kugluktuk, NU coastal survey was led by DFO researchers, at the request of the community, to better understand gadids (*Gadus* spp.) and chars (*Salvelinus* spp.) in the Coronation Gulf (including any associated freshwater habitats

for anadromous fishes) due to concerns of declining fish numbers. This survey was conducted in the summer of 2019 to provide a baseline assessment for these coastal fishes. Also, in the Kitikmeot Region, the DFO-led Arctic Char *Salvelinus alpinus* stock assessment program based out of Cambridge Bay, NU is a long-established monitoring program [21, 22] that has been operating each summer since 2009 and serves to sample and monitor commercially harvested Arctic Char in the region. Lastly, Arctic Coast is a DFO-led, community-based coastal sampling program that collects environmental and ecological data in multiple communities across the Canadian Arctic, including the Anguniaqvia niqiqyuan Marine Protected Area (ANMPA) near Paulatuk, Northwest Territories (NT). The Arctic Coast program in the ANMPA has been conducted annually in the summer since 2014.

## 2.3 Media (social or news)

Local northern media (e.g., Nunavut News, Nunatsiaq News) and community-specific social media pages (e.g.,



**Figure 2:** Locations of unusual sightings (red squares) for A) Pink Salmon, B) Bering Wolffish, C) Greenland Shark, D) Broad Whitefish, E) Banded Gunnel and F) Salmon Shark. Known distributions are shaded in grey [19, 20, 36], while specific historical occurrences (black dots) are only shown for Canadian observations [20]. Latitudes are presented on the left vertical axis, and longitudes are presented on the bottom horizontal axis to the nearest decimal degree.



Facebook) provide a source of information regarding unusual harvests in the area. Using these platforms, local harvesters can share information regarding noteworthy occurrences faster and more broadly than ever before. Often a post on social media quickly becomes an online news article that can then be investigated further by biologists or local monitors. An article presented in this report was shared among scientists and harvesters until it reached DFO biologists who specialize in biodiversity change. This observation was then used in this study to add to the growing evidence of ecological change in the Canadian Arctic.

### 3 Results

Between August 27, 2017 and September 18, 2019, a total of nine unusual sightings among six fish species were reported beyond their current geographic distribution, from six northern communities. The location of each noteworthy occurrence in relation to their known geographic distribution are provided in Figure 2. The specific geographic coordinates and biological data for each individual are listed in Table 1. Sex and/or maturity data are available for species that were processed by biologists, whereas records that were only reported through media (i.e., the Greenland Shark) or through photos sent through the community network (i.e., Pink Salmon in Clyde River and Ferguson Lake) do not have corresponding life history data. Total length (mm) and mass (g) indicate that all the individuals documented here are within their morphological limits as documented by taxonomic keys [19, 20].

Between 2017 and 2019, there were three new occurrences of Pink Salmon *Oncorhynchus gorbuscha* in the Canadian Arctic (Fig. 2A). In 2017, Clyde River, NU, a Pink Salmon was reported to the DFO Iqaluit, NU office, which then provided harvester contact details to the Arctic Salmon project. The harvester provided a geo-tagged reference photo of the fish next to Arctic Char (Fig. A1), although no samples were received by biologists. In August 2019, another Pink Salmon (Fig. A2) displaying spawning characteristics (evidenced by its colouration, pronounced kype and body shape) was caught in Ferguson Lake by commercial fishers from Cambridge Bay. This individual was provided to DFO stock assessment biologists who later shared information with the Arctic Salmon program. Later that fall in September 2019, a Pink Salmon was also found in Ungava Bay approximately 75 km upstream in the Arnaud River and was provided by a community-based fisher from Kangirsuk, QC. The photo of

this Ungava Bay salmon (Fig. A3) confirms that this individual was also in spawning condition (i.e., pronounced kype and dorsal hump). Harvesters provided the sample to the Makivik Corporation, where it was processed by the wildlife technician at the Nunavik Research Centre in Kuujuaq, QC. Biological data, and reference photos were shared at a later date with the Arctic Salmon project.

Unusual sightings of Bering Wolffish *Anarhichas orientalis* were reported in 2018 and 2019 in Coronation Gulf and Darnley Bay respectively (Fig. 2B). In August of 2018, during a DFO-led coastal survey near Kugluktuk, four wolffish (Fig. A4) were collected and processed as a component of the Kugluktuk coastal survey. Although these are not the first records of this species in Coronation Gulf [23], their rare occurrence was considered noteworthy by local harvesters. The first record of this species in the Northwest Territories and the Canadian Beaufort Sea was recorded in the ANMPA in July 2019. Community-based monitors collected the individual (Fig. A5) in Argo Bay, where the habitat is generally less saline, warmer, and soft-bottomed relative to the northern parts of the MPA [24].

The first known occurrence of a Greenland Shark *Somniosus microcephalus* in Coral Harbour was reported in October 2018 by a local harvester (Fig. 2C). Information regarding this individual was provided by local news (<https://nunavutnews.com/nunavut-news/greenland-shark-creates-a-buzz-in-coral-harbour/>), including harvest date, length, mass, and a photograph to confirm the species (Fig. A6).

The first Broad Whitefish *Coregonus nasus* to be confirmed to species level on Victoria Island was captured during a summer survey in 2018 near Cambridge Bay (Fig. 2D). Although another *Coregonus* sp. had been previously observed on the west side of Victoria Island [20], this is the first to be confirmed to the lowest possible taxonomic level. This individual was collected and processed by the Arctic Char stock assessment program including length, mass, sex, maturity and a reference photo (Fig. A7).

The first record of a Banded Gunnel *Pholis fasciata* in the Northwest Territories occurred at Bennett Point, within the Darnley Bay ANMPA, located approximately 45 km north of Paulatuk (Fig. 2E). This individual was collected during a community-based survey in July 2019, and processed for length, sex, maturity and a reference photo (Fig. A8). The habitat at this location is characterized generally by a hard-bottomed substrate and extensive macroalgae beds [24], which is consistent with the habitat preferences of this species [25].

In September 2019, a Salmon Shark *Lamna ditropis* was harvested near Kugluktuk, NU (Fig. 2F). This is the

**Table 1:** List of new or noteworthy occurrences of species found across the Canadian Arctic from 2017-2019. Associated location information, source for associated data or observations (network participants are both provided), photo, and life history data are provided. Local names are provided based on the dialect spoken in the community nearest to the recorded observation.

Common Name	Scientific Name	Local Name	Date	Location	Coordinates	Associated Project(s)	Type of Occurrence	Photo	Total Length (mm)	Mass (g)	Sex	Maturity
Pink Salmon	<i>Oncorhynchus gorbuscha</i> (Walbaum, 1792)	N/A	27-Aug-2017	Clyde River, NU	70.4848 -68.5168	DFO Iqaluit / Arctic Salmon (DFO)	Expansion	Figure A1	-	-	-	-
		N/A	24-Aug-2019	Cambridge Bay, NU (Ferguson Lake)	69.4144 -106.1760	Cambridge Bay Stock Assessment (DFO)	Expansion	Figure A2	-	-	-	-
Bering Wolffish	<i>Anarhichas orientalis</i> Pallas, 1814	N/A	17-Sept-2019	Ungava Bay, QC (Arnaud River)	60.0713 -71.1818	Makivik Corporation / Arctic Salmon (DFO)	Expansion	Figure A3	540	1700	M	Ripe
		Aqaaksaaq (Inuktitut)	18-Aug-2018	Kugluktuk, NU	67.8856 -115.2240	Kugluktuk Coastal Research (DFO)	Rare	Figure A4	477	818	F	-
			22-Aug-2018			Kugluktuk Coastal Research (DFO)		-	523	1100	M	-
						Kugluktuk Coastal Research (DFO)		-	446	652	-	-
						Kugluktuk Coastal Research (DFO)		-	575	1726	M	-
Greenland Shark	<i>Somniosus microcephalus</i> (Bloch and Schneider, 1801)	Iqalukuak (Inuktitut)	22-Jul-2019	Darnley Bay, NT (Argo Bay)	69.3910 -124.4546	Arctic Coast (DFO)		Figure A5	501	1441	M	Mature
			01-Oct-2018	Coral Harbour, NU	64.1893 -83.3557	Local News	Unknown	Figure A6	3100	27700	-	-
Broad Whitefish	<i>Coregonus nasus</i> (Pallas, 1776)	Aanaak-sliq; Anaakliq (Inuktitut)	12-Jul-2018	Cambridge Bay, NU (Lauchlan River)	68.9427 -108.5275	Cambridge Bay Stock Assessment (DFO)	Expansion	Figure A7	600	3950	M	Mature
Banded Gunnel	<i>Pholis fasciata</i> (Bloch and Schneider, 1801)	N/A	27-Jul-2019	Darnley Bay, NT (Bennett Point)	69.6785 -124.0392	Arctic Coast (DFO)	Rare	Figure A8	144	8	M	Mature
Salmon Shark	<i>Lamna ditropis</i> Hubbs and Follett, 1947	N/A	18-Sept-2019	Kugluktuk, NU	67.8250 -115.1570	NU Conservation Officers / Arctic Salmon (DFO)	Vagrant	Figure A9	1860	-	M	Mature

first known observation of this species in the Canadian Arctic [20]. The shark observation was first reported by the harvester to conservation officers, who then reached out to their contacts at DFO. The local harvester caught this individual in a seal net and worked with local conservation officers to provide a photo (Fig. A9), length, and samples to the Arctic Salmon program for follow-on analyses. The story was reported shortly after on local news (<https://nunatsiaq.com/stories/article/western-nunavut-fisherman-nets-north-atlantic-shark/>).

## 4 Discussion

Six species found outside of their known distributions across the Canadian Arctic are summarized here, with information obtained from three different approaches. The majority of novel occurrences, were reported opportunistically through community networks consisting of harvesters, researchers, and northern partners, or through local media. Individually, documenting each occurrence is important to better understand the contemporary distribution of each species and potential responses to changing environmental conditions. Together, this information not only highlights the importance of recording and communicating observations of unusual fishes (as well as other taxa) across collection methods, it also contributes to filling in knowledge gaps regarding basic species' distribution information in the Arctic, and documents broad-scale biodiversity changes across a range of species and areas that may not be observed by isolated records alone. The occurrence of new or unusual species in the Canadian Arctic can be interpreted as an expected spatial expansion based upon information from recent years or from predictive models, vagrants found well outside their normal distributions, or rare endemic species that lacked previous baseline information of their true distributions.

Among Pink Salmon, we documented three occurrences beyond their currently known distribution and interpreted these observations as expansion. The expansion of Pacific salmon, including Pink Salmon, to higher latitudes has been previously documented for the Alaskan North Slope [14, 26] and throughout the western Canadian Arctic [13]. More recent evidence is consistent with further expansion of Pink Salmon to Kugluktuk, NU [11] and in Greenland [13, 27]. The occurrence of Pink Salmon in Clyde River reported here is a noteworthy continuation of this geographic pattern as a further expansion of Pink Salmon in Nunavut. The gradual expansion of aquatic species into the Canadian Arctic has been linked to envi-

ronmental ecological drivers such as warming temperatures, shifts in prey availabilities, and reduction in sea ice that once limited dispersal [4, 8, 28].

The Bering Wolffish captured in Kugluktuk and Darnley Bay are representative of rare occurrences. This species has likely been under-represented in previous sampling efforts given biases in sampling gear and association with specialised habitats. Bering Wolffish are associated with shallower depths (<100 m) and are typically found in nearshore soft-bottomed habitats. The presence of wolffish in Coronation Gulf, NU, has been documented in a previous Nunavut Coastal Resource Inventory report [29], and a previous survey conducted in the region [23]. The Bering Wolffish collected by DFO-led coastal surveys and reported here contribute to evidence that this species is rare and studies are ongoing to better understand the life history characteristics of this species for the region. Bering Wolffish are listed as "Special Concern" under the Canadian Species at Risk Act (SARA).

The sole observation of a Greenland Shark in Coral Harbour, NU, is consistent with either a rare or vagrant occurrence. Greenland Shark are endemic to the eastern Canadian Arctic, namely off the coast of Baffin Island found in cold temperatures (0.5° to 1.2°C; [20]) to depths of over 1200 m [30]. This species displays eurythaline characteristics and may be found in inshore habitats such as fiords and estuaries [31], particularly during the winter when the individual reported in Coral Harbour was caught. There is limited information on the movement of Greenland Shark in Canadian Waters [31], and it is unknown to what extent this includes Hudson Bay. Given the elusive nature of this species and the knowledge gaps that exist with respect its habitat use and life history in Hudson Bay, it is uncertain if this individual is rare but present in this region, or if it is a vagrant from the Atlantic Ocean, perhaps appearing due to environmental changes.

The Broad Whitefish reported here is the first confirmed occurrence of this species on Victoria Island. Similar to the salmon, changing environmental conditions may be influencing the current distributions of Arctic fishes such as whitefishes. Broad Whitefish are common in the Mackenzie Delta estuary and coastal Beaufort Sea and occur as small populations in suitable habitats eastwards along the mainland coast [32, 33]. There is a reported occurrence of Broad Whitefish on western Victoria Island [20]; however, upon further investigation of the original report from which this occurrence is based [34], this species was not correctly recorded on Victoria Island. This was most likely a "Lake Whitefish" (*C. clupeaformis*), which is not uncommon to the area [35, 36], that presumably was accidentally recorded as a Broad Whitefish. With a situation

such as this, it is difficult to discern if this Broad Whitefish moved outside of their known habitat within the Arctic in response to changing conditions or if this species has been present in the past but not documented. The former is more likely given the regular and extensive local harvesting occurring in the area. It is in these circumstances that the communication networks among researchers and harvesters becomes so critical for interpreting the nature of the observation.

Banded Gunnel are found in the North Pacific and have also been recorded in Coronation Gulf, therefore the individual in this report is considered a rare occurrence within its potential distribution [20]. This small, eel-like species is most commonly found inshore among seaweed beds [19], and is unlikely to be observed by local fishers given the gear they typically use (gill nets) or by larger research vessels that do not sample inshore. It is doubtful this species is expanding its distribution, given that they have been documented in other locations of the Canadian Arctic [20], but not Darnley Bay specifically.

The Salmon Shark is representative of a vagrant occurrence given that it was found far outside its known geographic distribution and there is no local knowledge record of this species in the region [20, 29]. Salmon Sharks are capable of undertaking large migrations in the north-eastern Pacific, and although they are generally found south of the Bering Strait, individuals have been found in the sub-Arctic Gyre of the Bering Sea [37]. This species is eurythermal and prefers habitats that are high in primary production measured through chlorophyll *a* where substantive downwelling and mixing occurs, rather than preferring a specific thermal range [37, 38]. The conditions that caused an individual of this species to occur in Kugluktuk are uncertain; however, a combination of warming oceanographic conditions in 2019 [4] or a change in prey availability may have caused this individual to stray from the Bering Sea into Canadian waters.

The networks among researchers and communities highlight the importance of communication among multiple observational methods (e.g., scientific surveys, local knowledge, and social media) in order to document unusual occurrences. The input from community-based monitors into these programs provides a substantive perspective on new or unusual species, and their local knowledge can help delineate the nature of such occurrences (rare, vagrant, or expansion) beyond the efforts of a discrete sampling season. Social media can be a valuable tool for connecting local harvesters and researchers because it allows for reporting of unusual observations in real time, unlike any reporting network in previous years [12, 27]. The contribution of local knowledge supplements

the knowledge gaps that exist among scientific surveys, which are conducted over finite periods of time in focal areas, by incorporating occurrences over a wider geographic network and longer temporal scale.

The network presented here may be incorporated into a larger monitoring program, such as Conservation of Arctic Flora and Fauna Circumpolar Biodiversity Programme (CAFF), or the Local Environmental Observer (LEO) Network, and become applicable to other circumpolar nations. The process for documenting biodiversity that is presented in this report is an example of a unique collaboration formed between science and local observers, and like the LEO Network, it highlights the importance of engagement at the community level. Integration of these locally-based networks are critical for developing policy at the national and circumpolar scale. The observations included here, as well as the process to document them, assist in addressing the knowledge gaps in Arctic biodiversity and provide a linkage between community observations and larger circumpolar network.

As noted, shifts in knowledge of local biodiversity can be due to first-time documentation of a rare species that occurs regularly in the area, occurrence of a vagrant, likely non-reproducing individual, and/or occurrence of a species in the process of colonizing the area. While all types of observations increment knowledge of biodiversity for an area, it is the latter two that are most significant in contributing to understanding of the consequences of change in the ecosystems. That is, an initial step in the process to establish a new population in a new area likely includes ‘explorations’ of an area by vagile individuals; where suitable numbers of vagrant individuals, relaxed limiting factors for life history parameters, and ecological conditions co-exist, follow-on establishment of a population may occur. Shifts of local environmental conditions towards optimal physiological needs of some sub-arctic or boreal species, as now appears to be occurring in the Canadian Arctic, provide the basis for potential establishment by those species and permanent shifts in biodiversity. Accordingly, continued monitoring of habitat and species’ distributions is required in order to interpret changes to biodiversity in the Canadian Arctic and the associated ecosystem impacts. This is a challenge in a region where biodiversity data are limited and the distributions of native species is still being developed. Thus, continued monitoring and communication among researchers and communities is required in order to determine which species are new and which ones are expanding, the results of which will be valuable indicators of rapid ecological change. As the cumulative impacts of climate change drive biodiversity shifts, understanding the nature of unusual occur-



rences will be necessary for preservation of species in an already stressed system.

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