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ASSESSMENT OF RISK FROM SHRIMP FISHING TO THE CONSERVATION OBJECTIVES OF THE NARWHAL OVERWINTERING AND COLDWATER CORAL ZONE

Context

Canada has agreed to a suite of international biodiversity conservation goals and targets (the Convention on Biological Diversity 2011–2020 Strategic Plan for Biodiversity's Aichi Targets) and adopted complementary domestic biodiversity goals and targets. Both international and domestic targets call for the conservation of 10 % of coastal and marine areas by 2020 (Canada's Target 1 and Aichi Target 11). In addition, Canada has committed to increasing the proportion of Canada's marine and coastal areas that are protected to 5 % by 2017.

To achieve the 2017 target, "other effective area-based conservation measures" that are not protected areas, but still contribute to the objectives of the targets are being considered. These include fisheries closure areas to achieve one or more objectives (e.g., conservation) and that demonstrate or infer biodiversity conservation benefit(s) (DFO 2016).

The Narwhal Overwintering and Coldwater Coral Zone is currently closed to the Greenland Halibut (*Reinhardtius hippoglossoides*) fishery, but the Northern Shrimp (*Pandalus borealis*) fishery operates within the closure area. The conservation objectives for the closure area, identified in the Subarea 0 Greenland Halibut Integrated Fishery Management Plan, is to minimize impacts on the winter food source and overwintering habitat for Narwhal (*Monodon monoceros*), and conserve coldwater coral concentrations.

DFO Fisheries Management has requested advice from DFO Science on the levels of risk from shrimp fishing to narwhal overwintering habitat, narwhal food sources and coldwater coral within the existing Narwhal Overwintering and Coldwater Coral Zone.

This Science Response resulted from the Science Response Process of March 2017 on the Assessment of risk from shrimp fishing to the conservation objectives of the Narwhal Overwintering and Coldwater Coral Zone.

Background

The current Narwhal Overwintering and Coldwater Coral Zone is enclosed by lines between the following coordinates:

1. 68°15' N 58°33' 4.7" W
2. 68°15' N 60°30' 00" W
3. 67°15' N 60°30' 00" W
4. 67°15' N 57°50' 33" W

Points are connected by straight lines except between points 1 and 4 which follow the boundary of the Canadian Exclusive Economic Zone (EEZ). This also follows the eastern boundary of the Northwest Atlantic Fisheries Organization (NAFO) Division 0A. The Narwhal Overwintering and

Coldwater Coral Zone is closed to the Greenland Halibut fishery; this closure area is 10,964 km^2.The closure area is located within the NAFO Div. 0A fishing area for the Greenland Halibut fishery and within Shrimp Fishing Area (SFA) 1 for the Northern Shrimp fishery. SFA 1 is 28,741 km^2 but most of the shrimp fishing effort is concentrated within the closure area (Figure 1).

The area is currently closed to the Greenland Halibut fishery but shrimp fishing occurs within the area. The closure targets an area where several stocks of Narwhal overlap in winter and where concentrations of coldwater Gorgonian corals are found.

The Greenland Halibut fishery has operated in Div. 0A since 1996. Effort restrictions were first established in 1998 in the Greenland Halibut bottom trawl fishery as there were concerns about the concentration of bottom trawl fishing effort in an area where Narwhal overwinter. In addition, there was the potential for habitat destruction and local depletion of Greenland Halibut, a significant component of Narwhal diet. With the introduction of bottom-set gillnets to the fishery in 2004, the additional risk of Narwhal entanglement in lost gillnets increased. In 2008, the area was closed to the Greenland Halibut fishery which now uses primarily bottom trawls or gillnets (longline gear is permitted but rarely used) outside of the closed area in Div. 0A (Jørgensen and Treble 2015).

Narwhal leave the fiords and inlets of northern Baffin Island in November and migrate to Davis Strait where they spend the winter (Watt et al. 2012). Tracking studies of the Baffin Bay Narwhal population were used to define two winter home ranges in Baffin Bay and Davis Strait (DFO 2014a). The southern wintering area (Figure 2) is used by Narwhal from Admiralty Inlet, Eclipse Sound and Melville Bay summering stocks of Baffin Bay Narwhal (DFO 2014a). Stomach contents from Baffin Bay Narwhal in summer identified the primary prey as Arctic Cod (*Boreogadus saida*), Greenland Halibut, redfishes (*Sebastes* spp.), Polar Cod (*Arctogadus glacialis*), Arctic Squid (*Gonatus fabricii*) and octopus (Finley and Gibb 1982, Laidre and Heide-Jørgensen 2005, Richard 2009). Laidre and Heide-Jørgensen (2005) also identified the Northern Shrimp and Arctic Squid as being abundant in Narwhal stomachs in winter. Animals in the southern wintering area forage at depths over 800 m and a large part of their diet is likely composed of Greenland Halibut at those depths. Using stable isotope analysis, Watt et al. (2013) estimated that shrimp contributed the most to Baffin Bay Narwhal diet (38–43 % of the diet versus 2–14 % Greenland Halibut). It is estimated that over a five-month period the stocks of Narwhal occupying the southern wintering area (32,000 Narwhal) would consume about 86,000 t of Greenland Halibut (Richard et al. 2014). More recent abundance estimates for Baffin Bay Narwhal stocks would likely increase the estimated total consumption of Greenland Halibut by Narwhal (DFO 2015).

The bathymetry in the closed area is characterized by a very steep gradient between the 400 and 1,000 m depth contours, leveling off somewhat between 1,000 and 1,500 m (Figure 3). Kenchington et al. (2016a) identified Significant Benthic Areas within the closure area based on kernel density analysis of survey catches of corals, primarily large catches of gorgonian coral *Keratoisis ornata* (Figure 3).

The Northern Shrimp stock off west Greenland is distributed mainly in Greenland waters in NAFO Subarea 1, but a small part of the habitat is found on the eastern edge of Div. 0A in Canadian waters (NAFO and ICES 2016). This shrimp stock is assessed as a single population. Canada has defined SFA 1 as the part of Div. 0A lying east of 60°30' W (Figure 1; NAFO and ICES 2016). The NAFO Scientific Council recommends the total allowable catch (TAC). Canada claims 17 % of the offshore portion which is fished in SFA 1 (NAFO and ICES 2016). The Canadian Northern Shrimp fishery in SFA 1 began in the late 1970s. The fishery uses bottom trawls (single, double or triple) with a Nordmore separator grate with bar spacing of 28 mm which was made mandatory in 1997 to minimize bycatch of non-target species. The grate filters the catch entering the trawl allowing animals larger than the grate size to escape through an opening in the top of the net (Siferd 2010). Table 1 summarizes the TAC and harvest data for this fishery. The fishery in SFA 1 has never come close to obtaining the TAC (Table 1).

Table 1. Total allowable catch (TAC) and harvest data in tonnes for the Canadian SFA 1 Northern Shrimp fishery. Harvest is from Siferd (2010) from 1996–2003 At-sea Observer data and reporting from NAFO and ICES (2016) for 2004–2016. % Harvest is the percentage of the TAC taken in a given year.

Year	TAC (t)	Harvest (t)	% harvest
1996	8,500	2,683	32
1997	8,500	520	6
1998	7,650	873	11
1999	9,350	2,098	22
2000	9,350	1,676	18
2001	9,350	3,540	38
2002	12,040	6,472	54
2003	14,167	6,983	49
2004	18,417	6,369	35
2005	18,417	6,921	38
2006	18,417	4,127	22
2007	18,417	1,945	11
2008	18,417	0	0
2009	15,583	429	3
2010	15,583	5,882	38
2011	15,583	1,330	9
2012	12,750	12	0
2013	11,333	2	0
2014	11,333	0	0
2015	8,500	0	0
2016	10,625	1,225	12
2017	12,750		

Dive behaviour from Narwhal tagged with depth-recording satellite tags showed that Narwhal tended to make deep dives to depths > 800 m (Richard et al. 2014) and coldwater corals were found at depth > 500 m (DFO 2007); therefore when the closure came into effect restrictions were only placed on vessels fishing for Greenland Halibut which fish below 500 m, not on those vessels fishing for shrimp, which fish in shallower waters. The intent of the closure was to protect the core of the southern Narwhal over-wintering ground and three of the four locations where coldwater corals had been found (DFO 2007). The eastern boundary was set at the Canada-Greenland boundary for ease of communication to the Greenland Halibut fishery fleets.

Analysis and Response

Marine Mammals

Narwhal use the closure area from November to around late March or late April (Watt et al. 2012) and are found throughout the area, using both deep and shallow waters. A large part of their diet is assumed to be composed of Greenland Halibut which is found in the deeper waters of this area (DFO 2014a), although shrimp are estimated to contribute a greater proportion of Narwhal diet, particularly males, based on stable isotope analysis (Watt et al. 2013).

Other marine mammals also use the closure area including Sperm Whale (*Physeter macrocephalus*) and Northern Bottlenose Whale (*Hyperoodon ampullatus*) (Davidson 2016). Northern Bottlenose Whale feed mostly on squid but also take herring and bottom fish like redfish and Greenland Halibut (Richard 2009).

Coral

Arctic coldwater corals and sponges are long-lived species with slow growth rates and low recruitment (Boutillier et al. 2010, CAFF 2010). They are important to ecosystem function and biodiversity in polar environment and are considered ecosystem engineers (Kenchington et al. 2012). These corals provide structure on the sea floor providing habitat for fishes and invertebrates and potentially altering bottom currents. Areas with dense coral aggregations tend to have greater biodiversity compared with surrounding areas (Boutillier et al. 2010, Kenchington et al. 2012). However, corals are vulnerable to impacts from anthropogenic activities, particularly bottom-contact fisheries and significant impacts can be observed after only a few fishing events (DFO 2006).

Fishing Impacts

Bottom contacting gears (e.g., trawl, bottom-set gill nets and longlines), have been and are currently being used in the closure area. Physical destruction of benthic species and habitats can occur with bottom contact gear (Groenewold and Fonds 2000, Kaiser et al. 2001, DFO 2006, 2010). The impact of a fishery on benthic species and habitats is related to the extent of overlap between the fishing footprint of bottom-contact gear and the species and habitats of concern. Fishing gear can cause resuspension and entrainment of sediments. Concerns about the remobilization of sediments by fishing have been expressed in studies for decades. Remobilized sediments can have a variety of effects depending on the extent and duration of remobilization. These potential effects include altering nutrient recycling, eutrophication of shallow water areas due to excess nutrient loading from trawling (Dounas et al. 2007). Remobilization of sediment can also cause resuspension of phytoplankton cysts and copepod eggs and smothering of feeding and respiratory organs of some benthic species (O'Neill and Summerbell 2011 cited in Boutillier et al. 2013). Bottom contact fishing gear can directly damage and kill benthos (Groenewold and Fonds 2000, Kaiser et al. 2001, DFO 2006, 2010).

Impacts from the shrimp trawl fishery occur in depths < 500 m and include damage or destruction of corals, habitat loss and/or degradation, and competition with Narwhal for winter food. Most fisheries catch species other than the targeted species and the proportion of bycatch landed tends to increase when shrimp catch rates decrease (Gillett 2008). Bycatch may impact stocks that are already exploited and may result in ecosystem changes in the overall structure of trophic webs and habitats (Harrington et al. 2005).

The Greenland Halibut fishery closure reduces environmental impacts from the Greenland Halibut fishery (e.g., marine mammal entanglement, ghost fishing, damage or destruction of corals, habitat loss and/or degradation, and competition with Narwhal for winter food) within the closure area at depths between 500 and 1,500 m. Fishing for Greenland Halibut has occurred historically (1996–2006) within the closed area but has never occurred at depths shallower than 500 m (Figure 1).

The fishing closure area includes waters deeper than 1,500 m which are not currently subject to fishing (Figure 2). However, this portion of the closure area is used by Narwhal as winter habitat due to the presence of pack ice (DFO 2007, 2014a).

Appendix 2 includes the fish and invertebrate species caught in the closure area during DFO multi-species surveys which included species consumed by Narwhal: *Pandalus* shrimp, Greenland Halibut, Arctic Cod, Arctic Squid and octopus. *Keratoisis* species (*K. ornata* and *K. grayi*) and other corals (*Paragorgia arborea, Acanella arbuscula*, *Stauropathes arctica, Flabellum spp.*) have been collected in the closure area at depths from 448 to 930 m (DFO 2007, Kenchington et al. 2016b, DFO unpubl. data).

Risk Assessment

Threats associated with commercial fishing operations could include biota removal (target species, bycatch species), habitat alteration and destruction (seafloor changes, water column changes), gear loss, ship strikes, noise, contaminants and invasive species (DFO 2014b). To assess threats to the closed area from bottom contact gear, this assessment focused on direct or indirect morality of benthos, damage or destruction of coral, habitat loss and/or degradation (e.g., sedimentation), and competition with Narwhal for winter food (i.e., removals of *Pandalus* shrimp, Greenland Halibut, squid and octopus, and Arctic Cod).

Risk is expressed as the product of threat likelihood and threat impact. Certainty is identified for the threat impact. The two categories are evaluated independently and are describe in Appendix 3. The closure area was divided into three depth ranges to evaluate risk from bottom contact fishing gear: < 500 m, 500–1,500 m, and >1,500 m. Table 2 summarizes the results of the assessment.

Threat likelihood was evaluated based on historical and current bottom contact fishing in the closure area. Shrimp fishing with bottom trawls currently occurs in the < 500 m depth range. Greenland Halibut fishing with bottom-set longlines, gillnets and trawls occurred within the 500–1,500 m depth range between 1996–2006. Fishing has been prohibited in this depth range since 2006. Fishing with bottom contact gear has never occurred below 1,500 m in the closure area. If fishing were to occur in these depth ranges, threat impact and threat likelihood would increase.

Benthic species play a crucial role in ecosystem structure and function. For example, coral species can create important habitat for other invertebrate and fish species. Bottom contact gears can have direct impact to the benthos after a single fishing event (e.g., species that are slow to recover) and or through cumulative effects through multiple or repeated fishing events (e.g., sponge or soft coral dominated habitats) (DFO 2006). Gorgonian corals are particularly important habitat forming corals that can be found in cold deep-sea environments. Within the closure area, gorgonian corals have been primarily observed in the 500–1,500 m depth range. However, Kenchington et al. (2016a) identified a Significant Benthic Area that extended from the 500–1,500 m into the < 500 m depth area (Figure 3). As a result of the limited geographic extent, the threat likelihood was evaluated as Occasional in the < 500 m depth range. Gorgonian corals are readily damaged or removed by bottom contact gear and recolonization, if it occurs, is very slow.

In 2010, DFO conducted a survey within the closure area and identified the presence of Black Coral, sea pens and *K. ornata*. In 2013 and 2016, Remotely Operated Vehicle surveys were conducted within the closure area. In 2013, large tracts of 1 m high dense bamboo corals (*K. ornata*) were found at depths of 900–947 m in muddy appearing bottom (Neves et al. 2014). Part of the ROV sample track was designed to travel across the bottom trawl track from a DFO multi-species scientific survey conducted in 1999 during which extremely high concentrations of corals and sponges were caught. The sea bed in this area was still devoid of corals, based on macroscopic evidence, demonstrating the slow replacement of these corals following perturbation (Neves et al. 2014). Certainty scores reflect availability of data on coral distribution and abundance within the closure area. Certainty is low in waters > 1,500 m due to the lack of sampling.

Sediment remobilization is a component of habitat loss and/or degradation is expected to occur with any bottom contact fishing. The degree of remobilization will depend on substrate type. There is visual evidence indicating the presence of mud substrates in portions of the 500–1,500 m depth range. Consequently the threat impact and certainty are higher for this depth range. Data for the other depth ranges are not available.

Narwhal winter prey includes *Pandalus* shrimp, Greenland Halibut, squid and octopus, and Arctic Cod; their abundance and distribution varies among the depth ranges. Shrimp are most abundant in the < 500 m depth range where they are targeted by the shrimp fishery. On average, about 3,600 t of *Pandalus* shrimp were harvest annually in SFA 1 from 1997 to 2007 based on At-sea Observer records. On average, 12 % of the TAC was harvested between 2005 and 2014. Landing of the full TAC would dramatically increase the threat impact. The current harvest of shrimp results in a Moderate risk of impact in this depth range; risk of impact declines with depth. However, fishing gear used in surveys changes with depth and as a result shrimp catchability also declines resulting in lower certainty.

Greenland Halibut demonstrate size segregation by depth, with juveniles occurring in the < 500 m depth range where they are susceptible to the shrimp fishery (Jørgensen 2013). In SFA 1, total weight of Greenland Halibut bycatch averaged 6 $t \cdot y^{-1}$ from 2005–2014 with 95 % of the catch being fish with fork lengths of 5–38 cm based on At-sea Observer data (DFO unpubl. data). The fishery has 100 % At-sea Observer coverage. Although the threat impact was considered Moderate in all depth ranges, immature fish are impacted in the < 500 m depth range while larger fish would be impacted in deeper water (Jørgensen 2013). Certainty is lower in the > 1,500 depth range because of a lack of sampling. Over the last ten years, the shrimp fishery caught on average only 12 % of the TAC (Table 1). Landings closer to the TAC would be expected to have higher bycatch of juvenile Greenland Halibut and other Narwhal prey items.

Arctic Squid and octopus occur at all depths throughout the closure area. However, they are poorly sampled by bottom contact fishing gear therefore limited data are available so certainty scored Low or Very Low. Their occurrence in the bycatch is also expected to be low resulting in a Low threat impact across all depth ranges.

Based on At-sea Observer records, about 22 t of Arctic Cod were taken as bycatch annually in the shrimp fishery in SFA 1 from 1997 to 2007. Arctic Cod are not a benthic species and have poor catchability in bottom contact fishing gear; therefore, limited data are available, so certainty scored Low. Threat impact was scored Low in the < 500 m depth range and Very Low in waters deeper than 500 m.

Table 2. Threat Likelihood (TLH), Threat Impact (TI), Certainty (C) and Threat Level (TL) from bottom contact gear to the winter food source and overwintering habitat for Narwhal, and coldwater coral concentrations based on the best available data. The TLH, TI, C and TL scores were assigned based on the definitions in Tables Appendix 2. The threat level follows the matrix in Table A2-4 (Appendix 2).

Water depth < 500 m

THREAT	TLH	TI	C	TL
Damage or destruction of Coral				
Gorgonian Corals	Occasional	High	High	High
Habitat Loss and/or Degradation				
Remobilized sediments	Regular	Low	Low	Medium
Competition with Narwhal winter food				
Shrimp	Regular	Moderate	High	High
Greenland Halibut	Regular	Moderate	High	High
Squid and Octopus	Regular	Low	Low	Medium
Arctic Cod	Regular	Low	Low	Medium

Water depth 500–1,500 m

THREAT	TLH	TI	C	TL
Damage or destruction of Coral				
Gorgonian Corals	Occasional	High	High	High
Habitat Loss and/or Degradation				
Remobilized sediments	Occasional	Moderate	Moderate	Medium
Competition with Narwhal winter food				
Shrimp	Occasional	Low	Moderate	Low
Greenland Halibut	Occasional	Moderate	High	Medium
Squid and Octopus	Occasional	Low	Low	Low
Arctic Cod	Occasional	Very Low	Low	Low

Water depth > 1,500 m

THREAT	TLH	TI	C	TL
Damage or destruction of Coral				
Gorgonian Corals	Never	High	Very Low	Low
Habitat Loss and/or Degradation				
Remobilized sediments	Never	Low	Very Low	Low
Competition with Narwhal winter food				
Shrimp	Never	Very Low	Low	Low
Greenland Halibut	Never	Moderate	Low	Low
Squid and Octopus	Never	Low	Very Low	Low
Arctic Cod	Never	Very Low	Low	Low

Conclusions

The conservation objectives for the closure area are to minimize impacts on the winter food source and overwintering habitat for Narwhal, and to conserve coldwater coral concentrations. The current risk assessment examined the levels of risk from bottom contact gear to narwhal overwintering habitat, narwhal food sources and coldwater coral within the existing Narwhal Overwintering and Coldwater Coral Zone.

Temporal overlap in use of the area by narwhal and the fishery has been limited over the past ten years to generally between October and December, dependent on ice concentration. One important winter habitat feature for Narwhal is the presence of pack ice, the development of which forces the end of the fishing season. Therefore, the direct effect of bottom contact fisheries on the Narwhal winter habitat generally occurs prior to their arrival on the winter grounds. A full ecological risk assessment would be required to fully evaluate the winter habitat aspect of the conservation objectives.

Our understanding of narwhal forage in the winter has changed since the original closure of the area in 2008. Therefore, our assessment was broadened to include not only Greenland Halibut but also shrimp, squid and octopus, and Arctic Cod.

The overall threat level from bottom contacting gear is greatest in the < 500 m depth range. Threat levels are High for damage or destruction of coral and for competition with Narwhal winter food. The threat level in the > 1,500 m depth range, where no fishing occurs, is Low for all threats considered in this assessment.

There is a High threat level to gorgonian corals, as identified by the Significant Benthic Area (Figure 3).

High to Medium threat levels to Narwhal forage, at the current fishing levels, occur in the < 500 m depth range. Risk would increase if fishing effort increased, which is possible, given the low percentage of the shrimp TAC that has been taken in the last ten years.

For the 500–1,500 m depth range, threat levels are lower compared to the shallow depth range primarily because fishing no longer occurs in the closure area at these depths.

Certainty was highly dependent on data availability. There is no data collection in waters deeper than 1,500 m. In shallower water, there is good coverage of benthic species and habitats through trawl and photographic surveys. However, catchability for non-benthic species (e.g., Arctic Cod, Arctic Squid and octopus) is poor.

A full ecological risk assessment, considering all activities, stressors and threats could not be undertaken within the allotted timeframe but would better inform decision making.

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Appendix 1: Figures

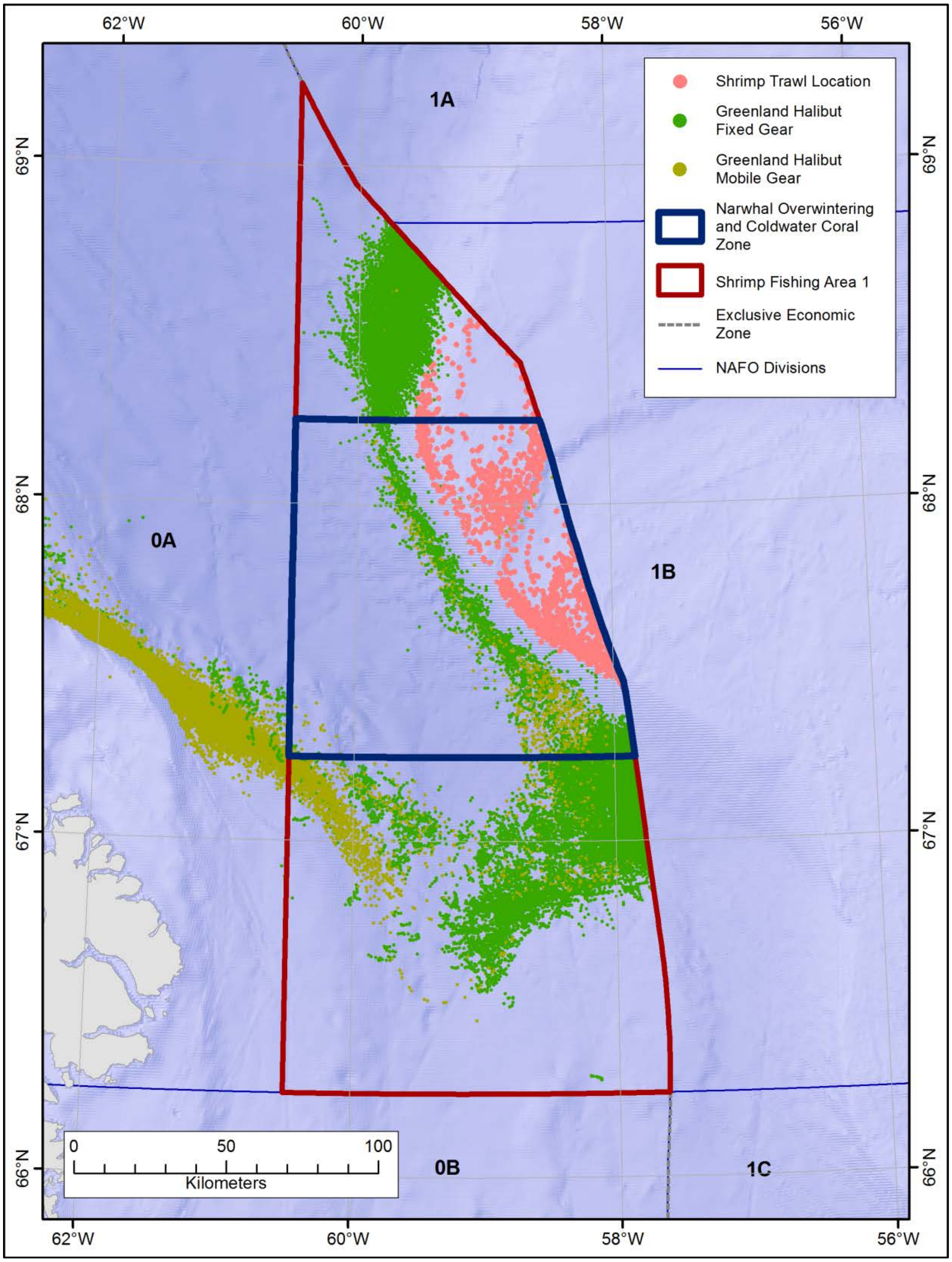

Figure 1. Narwhal Overwintering and Coldwater Coral Zone, Shrimp Fishing Area (SFA 1), Northwest Atlantic Fisheries Organization (NAFO) area boundaries and the fishing footprint from bottom contact gears for 2005–2014. (DFO, Central and Arctic Region, unpubl. data)

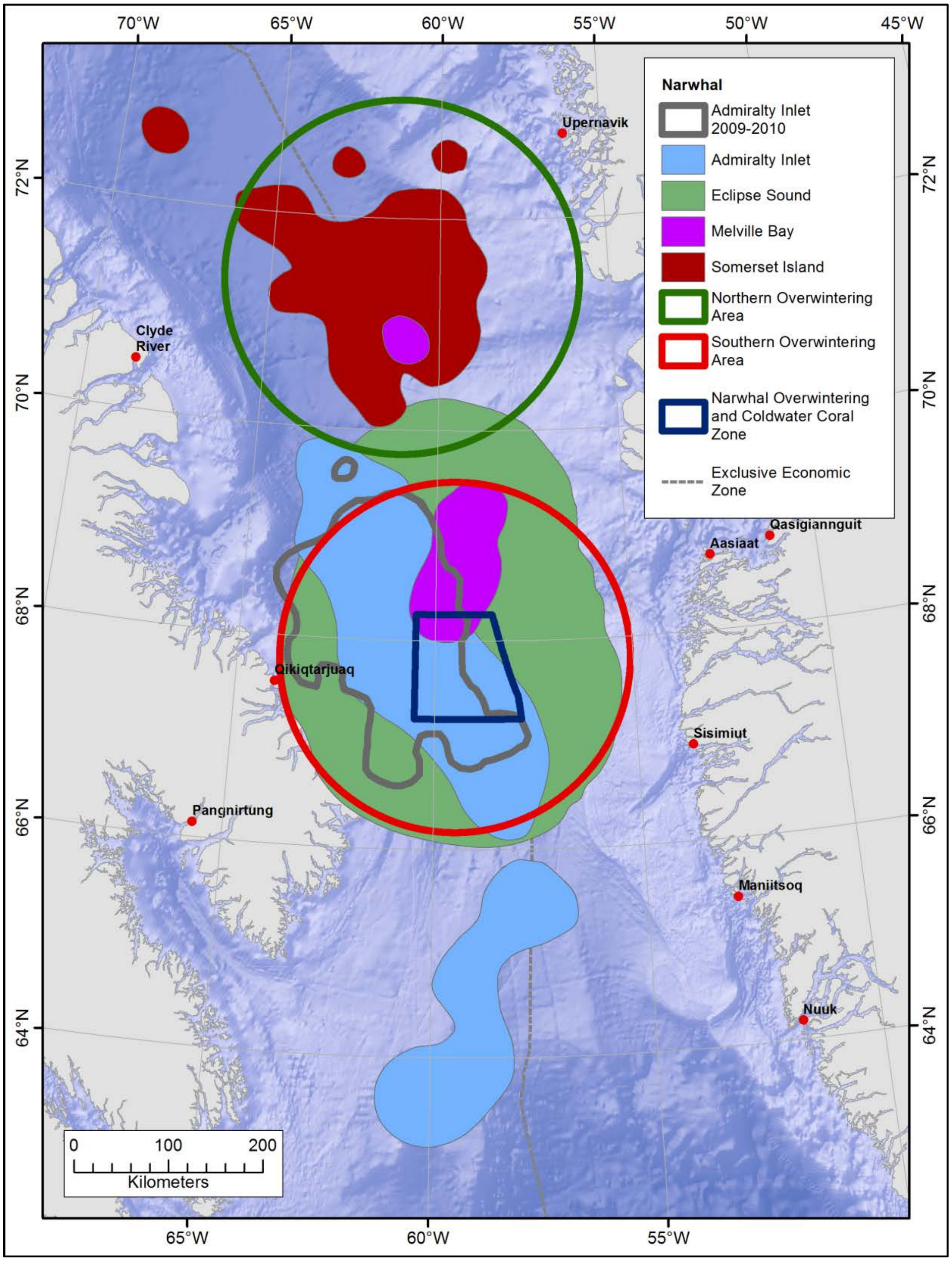

Figure 2. Winter home ranges of Baffin Bay Narwhal (modified from DFO 2014a). Admiralty Inlet 2009–2010 home range (open grey polygon) is overlaid on past winter home ranges for Somerset Island (red), Admiralty Inlet (light blue), Eclipse Sound (green), Melville Bay (purple) summering stocks. The green and red circles identify the northern and southern narwhal over-wintering areas, respectively. The thick blue polygon represents the area closed to Greenland Halibut fishing in NAFO Division 0A and the dashed line is the exclusive economic zone boundary between Canada and Greenland.

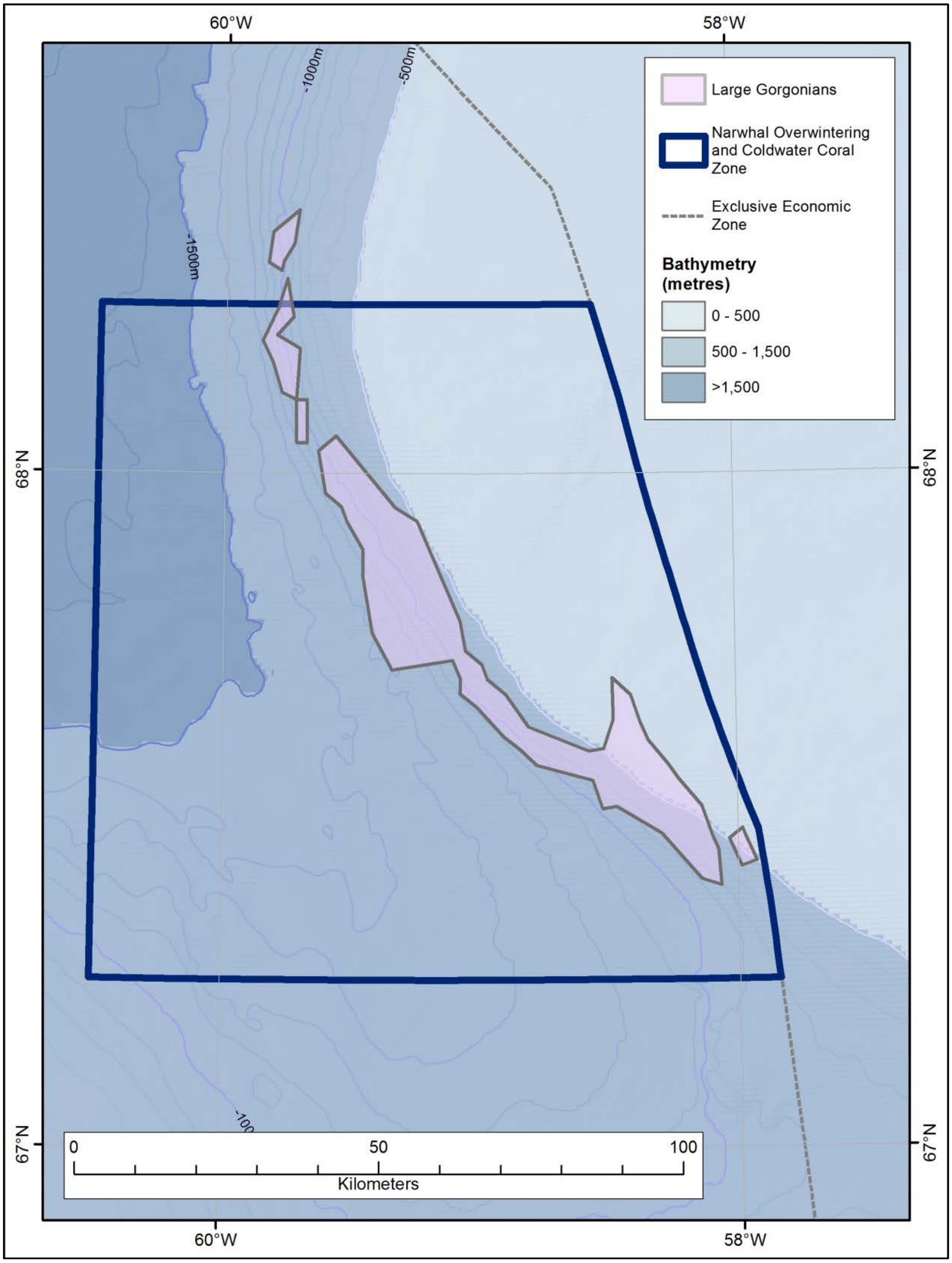

Figure 3. Significant Benthic Area (SBA; pink area with grey outline) for large gorgonian corals delineated from the random forest presence-absence species distribution modelling based on data to 2015 (from Kenchington et al. 2016a). A very large catch of gorgonian corals from the Fisheries At-sea Observer Program was positioned in this area and provided independent confirmation of the SBA.

Appendix 2: Fishes within the Closure Area

Table A3-1. Fishes for all sets conducted by DFO Science in the multi-species survey aboard the Greenland Institute vessel Paamiut *in the closure area (DFO unpubl. data). Catch data are from 2006, 2008, 2010, 2012, 2015, and 2016 using an Alfredo trawl or Cosmos trawl. Data are presented for depths up to 427 m and between 620 m and 1,500 m. Number of species should be considered a minimum as some fish were not identified to species.*

Fish from depths ≤ 427 m

Family name	Common name	Number of Species
Agonidae	poachers	1
Anarhichadidae	wolffishes	3
Argentinidae	argentines	1
Cottidae	sculpins	4
Gadidae	cods	5
Liparidae	snailfishes	2
Muraenidae	morays	1
Myctophidae	lanternfishes	3
Paralepididae	barracudinas	1
Pleuronectidae	righteye flounders	2
Rajidae	skates	3
Scorpaenidae	scorpionfishes	2
Stichaeidae	pricklebacks	2
Zoarcidae	eelpouts	5

Fish from depths between 620–1,500 m

Family name	Common name	Number of Species
Anarhichadidae	wolffishes	1
Bathylagidae	deep-sea smelts	1
Cottidae	sculpins	3
Gadidae	cods	3
Liparidae	snailfishes	5
Macrouridae	grenadiers	1
Myctophidae	lanternfishes	1
Notacanthidae	deep-sea spiny eels	1
Phosichthyidae	lightfishes	1
Pleuronectidae	righteye flounders	2
Psychrolutidae	fathead sculpins	2
Rajidae	skates	3
Scorpaenidae	scorpionfishes	2
Synaphobranchidae	cutthroat eels	1

Table A3-2. Invertebrates for all sets conducted by DFO Science in the multi-species survey aboard the Greenland Institute vessel Paamiut *in the closure area (DFO unpubl. data). Catch data are from 2006, 2008, 2010, 2012, 2015, and 2016 using an Alfredo trawl or Cosmos trawl. Data are presented for depths up to 427 m and between 620 m and 1,500 m. Invertebrates were identified to the lowest taxonomic level possible.*

Invertebrates from depths ≤ 427 m

Common name	Scientific name	Number of Species
Amphipod	Amphipoda	4
Arctic Squid	*Gonatus fabricii*	1
Goldbanded Bamboo Coral	*Keratoisis grayi*	
Hydrozoa	Hydrozoa	
Isopod	Isopoda	
Octopus	Octopoda	1
Polychaete	Polychaeta	
Sea anemone	Actiniaria	
Sea pen	Pennatulacea	
Sea spider	Pycnogonida	
Sea star	Asteroidea	3
Shrimp	*Pandalus borealis*	1
Shrimp - other	Dendrobranchiata or Caridea	9
Soft coral	Anthozoa	1
Spiny Crab	*Lithodes maja*	1
Sponge	Porifera	4

Invertebrates from depths between 620–1,500 m

Common name	Scientific name	Number of Species
Amphipod	Amphipoda	10
Arctic Squid	*Gonatus fabricii*	1
Basket star	*Gorgonocephalus arcticus*	1
Bonsai Coral	*Acanella arbuscula*	
Brittle star	Ophiuroidea	
Gastropod	Gastropoda	
Isopod	Isopoda	
Mysid	*Boreomysis*	1
Nudibranchs	Nudibranchia	
Octopus	Octopoda	3
Polychaete	Polychaeta	
Sea anemone	Actiniaria	
Sea cucumber	Holothuroidea	2
Sea pen	Pennatulacea	
Sea spider	Pycnogonida	
Sea star	Asteroidea	10
Sea urchin	Echinoidea	
Shrimp	*Pandalus borealis*	1
Shrimp - other	Dendrobranchiata or Caridea	12
Sipunculid worm	Sipuncula	
Soft coral	Anthozoa	3
Sponge	Porifera	9
Spoonworm	Echiurid	
True Blackwire Coral	*Stauropathes arctica*	1

Appendix 3: Risk Assessment

Table A2-1. Definition of terms used to describe threat likelihood. The threat likelihood can also be unknown.

	Never	Occasional	Regular
Threat Likelihood	The stressor has never occurred in the assessment area.	The stressor occurs infrequently in the assessment area May have occurred historically and could occur infrequently (e.g., illegal fishing)	The stressor occurs in the assessment area frequently (i.e., annually for weeks or months at a time)

Table A2-2. Definition of terms used to describe threat impacts. The threat impact can also be unknown.

	Very Low	Low	Moderate	High
Threat Impact	Magnitude of the stressor is very low. The stressor occurs at low density or intensity and is ephemeral (i.e., lasting for a short time)	Magnitude of the stressor is low. The stressor occurs at low to moderate density or intensity and is ephemeral (i.e., lasting for a short time)	Magnitude of the stressor is moderate. The stressor occurs at low to moderate density or intensity and is chronic (i.e., lasting for years)	Magnitude of the stressor is high. The stressor occurs at high density or intensity and is chronic (i.e., lasting for a decades)

Table A2-3. Certainty categories, their associated scoring and descriptions (modified from O et al. 2015).

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

Table A2-4. The Threat Level Matrix combines the Threat Likelihood and Threat Impact rankings to establish the Threat Level and has been categorized as Low, Medium, High, or Unknown.

		Threat Impact				
		Very Low	**Low**	**Moderate**	**High**	**Unknown**
Threat Likelihood	**Occurs Regularly**	Low	Medium	High	High	Unknown
	Occurs Occasionally	Low	Low	Medium	High	Unknown
	Never occurs	Low	Low	Low	Low	Unknown
	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown

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