Development of a Closed Area in NAFO 0A to protect Narwhal Over-Wintering Grounds, including Deep-sea Corals

Context

This report provides background information on the development of effort restrictions for the Greenland halibut fishery in the southeast area of the Northwest Atlantic Fisheries Organization (NAFO) Div. 0A. The decision to close this area was taken by Fisheries Management in April 2006 and set out in the draft 2006-2008 Fisheries Management Plan for Greenland Halibut in NAFO SA0 that was circulated to stakeholders for comment in September 2006. A summary of narwhal life history and biology is included while more detailed information is available in the publications listed under Sources of Information. DFO policies related to this issue are under development. The material summarized here comes from published scientific literature and as additional research is undertaken, the advice provided in April 2006 may be modified to reflect the results.

Effort restrictions were first established in 1998 following consultation between DFO Fisheries Management, Science and the Nunavut Wildlife Management Board. There were concerns about the concentration of bottom trawl fishing effort in the southern narwhal over-wintering area and potential for habitat destruction and local depletion of Greenland halibut, a significant food resource of narwhal. These restrictions were subsequently included in the 2003-2005 Management Plan. During the consultation meeting for the 2006-2008 Management Plan, held February 7 and 8, 2006 in Iqaluit, there was general agreement that these restrictions would continue. With the introduction of gillnets to the fishery in 2004, the risk of narwhal entanglement in lost gillnets had increased. Gillnets were lost in both the 2004 and 2005 fishery. There was also new information provided in March 2006 on the potential ecosystem effects of the first few fishing events on sensitive habitat. Fisheries Management, following discussion with Science, decided in early April 2006 to close the area rather than continue with fishing effort restrictions. The draft 2006-2008 Management Plan defines the closed area as: Point A) 68^{o} 15' N / 58^{o} 30' W in the Northeast; Point B) 68^{o} 15' N / 60^{o} 30' W in the Northwest; Point C) 67^{o} 15' N / 60^{o} 30' W in the Southwest and Point D) 67^{o} 15' N / 57^{o} 50' W in the Southeast. This area corresponds to the core of the southern narwhal over-wintering ground and includes three of the four locations where deep-sea corals have been found.

Background

Prior to 1996, there had been very little fishing with otter trawl or any other gear in Div. 0A. The Greenland halibut fishery had been concentrated in Davis Strait on the Div. 0B fishing grounds with annual catches of approximately 5,500 t. An exploratory fishery for Greenland halibut began in 1996 with an allocation of effort rather than total allowable catch (TAC). Fishing was carried out by an otter trawl vessel. The effort for 1996 was set at 32 days (catch was 329 t). Div. 0A was also divided into four "sub-zones" with a minimum of six days to be fished in each sub-zone in an attempt to distribute fishing effort. In 1997, a similar approach was used with Div. 0A being further sub-divided into 18 sub-zones and three otter trawl vessels were licensed for a fixed number of days with catches totaling 241 t. These vessels were free to spend time

fishing where they chose but also had to fish a certain amount of time in specific sub-zones in order to distribute effort and allow assessment of Greenland halibut distribution within Div. 0A. In both years, a majority of the tows were conducted in sub-zone 2.1 in the south-east corner of Div. 0A (Appendix 1).

During this same period, marine mammal researchers were analyzing tracking data and dive behaviour data from narwhals tagged in Eclipse Sound, Baffin Island and Melville Bay, Greenland. Narwhals from these summering areas over-wintered in heavy pack ice (Heide-Jørgensen *et al.* 2002 and 2003) in the same area where the Greenland halibut fishery was concentrated in 1996 and 1997 (Appendix 2). The Greenland halibut fishery begins in late July and continues through to the middle of November. Narwhals arrive on their over-wintering grounds in late October or early November and leave the following April. Narwhals do not feed extensively on their summering grounds but are known to rely on Greenland halibut as a major food source during fall and winter (Laidre *et al.* 2004a). It was noted that during the time narwhals were on the southern over-wintering grounds they spent considerable time diving to depths over 800 m which corresponds to the depth where Greenland halibut are most abundant (Laidre *et al.* 2003 and 2004b, Treble *et al.* 2000 and 2001).

The closed area defined above corresponds very closely to the southern narwhal over-wintering grounds as shown in Laidre *et al.* 2004a which is based on satellite tracking data from three narwhals from Eclipse Sound and two from Melville Bay that spent time in the over-wintering area (Dietz *et al.* 2001 and Laidre *et al*. 2003). Additional whales were tagged and information on timing and direction of migration and dive behaviour were collected but the signal was lost before they reached the wintering ground. As new information becomes available the boundaries of the closed area could be adjusted.

Concern was expressed by Fisheries and Oceans Canada (DFO) as well as our co-management partner, the Nunavut Wildlife Management Board (NWMB), that narwhals could be impacted if the bottom habitat were damaged and their food supply depleted in the southern over-wintering area. The Greenland halibut fishery becomes concentrated in the southeast portion of Div. 0A late in the season because of encroaching sea ice. This increase in effort occurs immediately prior to the arrival of the narwhal. In 1998, fishing restrictions were put in place to limit fishing activities in sub-zone 2.1, which was found to correspond very well with the core of the narwhal's over-wintering grounds and later described by the points listed above. Three vessels were restricted to a combined total of 12 days of fishing in this area. This was approximately the level of effort observed in 1996 and 1997. This restriction has been maintained as policy for vessels fishing in the Greenland halibut fishery since 1998, although in some years, it was mistakenly omitted from certain exploratory licenses and compliance may not have been monitored.

Up to 2005, the harvest of Greenland halibut from the restricted area has comprised a relatively small portion of the overall harvest within Div. 0A based on a review of catch data from vessel daily hails and logbook data provided to the Eastern Arctic Area Office. In 2003, for example, 1.3% (55.4 t) of the trawl catch and 6.6% (272 t) of the overall catch came from the restricted area. In 2004, 3.0% (114 t) of the trawl catch and 5.0% (191 t) of the overall catch and in 2005 0.2% (8 t) of the trawl catch and 5.4% (233 t) of the overall catch came from the restricted area. During this period, there were effort restrictions in place but in each year there was at least one vessel that did not comply with these restrictions. Effort displaced by a complete closure of this area should be able to re-locate to other grounds within Div. 0A.

In 1999 and again in 2001, deep-sea coral species (including gorgonian species) were identified at several locations within the narwhal over-wintering grounds during multi-species trawl

surveys conducted by DFO. Division 0A has been surveyed several times (1999, 2001, 2004 and 2006) and gorgonian deep-sea corals have not been found anywhere else within Div. 0A.

Gillnet vessels were first introduced into the Div. 0A fishery late in 2004. In 2005, 26% of the catch came from gillnet vessels and in 2006 their share of the Div. 0A catch had increased to approximately 40%. The use of gillnets in the narwhal over-wintering area increases the risk of narwhals becoming entangled in lost nets. Bio-degradable mesh or similar technology is in development but it has not been used in this fishery. In 2004, there were 174 gillnets lost, approximately 16 km (each net is approximately 50 fathoms by 2 fathoms or 91.5 m by 3.7 m). DFO Science advised against the use of gillnets throughout Div. 0A in a briefing note submitted to the NWMB in March 2005. Rather than restricting their use however, an end date to the gill net season of Nov. 15th was established in an effort to reduce the risk of gear loss due to late season ice conditions. There were 291 (27 km) and 135 (12 km) gillnets reported lost in Div. 0A in 2005 and 2006, respectively.

Restrictions were not placed on vessels fishing for shrimp because they fish in shallow waters (<400 m). Dive behaviour showed that narwhals used depths >800m and deep-sea corals were found at depths >500 m.

The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) re-assessed the status of narwhal in Canada in 2004 and recommended the designation of “Special Concern” for all populations (COSEWIC 2004). COSEWIC cites uncertainty about numbers, trends, life history parameters, and levels of sustainable hunting as reasons for this designation. The developing fishery for Greenland halibut, one of the main prey species of narwhal, and the presence of lost gillnets in the narwhal over-wintering areas could be considered potential risks to the population that were not identified by COSEWIC.

At their April 2006 meeting the Canada/Greenland Joint Commission on the Conservation and Management of Narwhal and Beluga noted that “…under some scenarios of a high loss rate and/or a low rate of population increase, there is a risk that present catch levels are not sustainable in one of the small units (Admiralty Inlet sub-stock.” (JCNB 2006). Admiralty Inlet is one of three sub-populations of narwhals that are known to over-winter in southern Baffin Bay. On the interaction between Greenland halibut (turbot) and narwhal the JCNB noted that “… the Scientific Working Group indicated that turbot, an important commercial species, forms a significant part of the diet of narwhal. The Commission, at their May 2004 meeting noted that interactions between these two species may become a management concern.” (JCNB 2004).

Literature and Policy Review

Narwhal Life History and Biology

Research on narwhal in Baffin Bay beginning in 1997 has continued with tagging programs conducted in Eclipse Sound in 1997, 1998 and 1999, Creswell Bay, Somerset Island in 2000 and 2001 and in Admiralty Inlet, Baffin Island in 2003 and 2004. Narwhals from Eclipse Sound (n=3, Dietz *et al.* 2001, Heide-Jørgensen *et al.* 2002, Laidre *et al.* 2003), and Admiralty Inlet (n=18, unpublished data) off Baffin Island and from Melville Bay (n=2, Dietz *et al.* 2001, Laidre *et al.* 2003) off Greenland were observed to over-winter in the south-east area of Baffin Bay, identified as the “southern narwhal over-wintering area”. Narwhals from Creswell Bay, Baffin Island over-wintered further north, in the “northern narwhal over-wintering area” (Heide-Jørgensen *et al.* 2002, Heide-Jørgensen *et al.* 2003, Laidre *et al.* 2003). The northern over-

wintering area lies completely within Greenland waters, while the southern area lies primarily within Canadian waters (Appendix 2).

An examination of dive behaviour data showed that the number of surface dives (0 to 50 m) and time at the surface declined between summer and winter and clear differences were noted between the two over-wintering areas (Laidre *et al.* 2003) (Appendix 3). In the northern over-wintering area (Somerset sub-populations) narwhal spent most of their time diving to between 200 and 400 m while narwhal in the southern over-wintering area (Eclipse and Melville sub-populations) spent less time at shallow depths and most of their time diving to 800 m or deeper, spending over 3 hours at these depths per day and traveling 13 min. per round trip (Laidre *et al.* 2003) (Appendix 3).

Stomach contents of 94 narwhals harvested in the Eastern Canadian high Arctic and West Greenland were examined to assess feeding activity and prey selection (Laidre and Heide-Jørgensen 2004). Stomachs collected from summer harvests in Eclipse Sound, West Greenland near Inglefield Bredning and Melville Bay (n=21) contained Arctic cod, polar cod and squid but most were found to be empty (Laidre and Heide-Jørgensen 2004). Samples were collected in late fall from Uummannaq, West Greenland (n=51 stomachs from). Winter samples were collected 20 km offshore from Disko Island in approx. 800 m of water (n=22 stomachs) (Laidre and Heide-Jørgensen 2004). Greenland halibut, squid and shrimp were most common prey items in the fall and winter samples with Greenland halibut constituting a significant winter resource. Greenland halibut were found in 64% of the narwhal stomachs collected in winter and were the only prey species found in almost half of all stomachs sampled (Laidre and Heide-Jørgensen 2004 and Laidre 2003). There were no narwhals sampled from the over-wintering ground which is well off-shore with heavy ice conditions making sampling dangerous.

Laidre *et al.* 2004a investigated deep-ocean predation by narwhals using a bio-energetic model, narwhal satellite data and data on fish abundance, density and length frequencies. The bio-energetic model was used to estimate the biomass of Greenland halibut needed to sustain the sub-population(s) of narwhals for the five months that they spend on their winter grounds. The authors noted that energy budget models are not assumption-free and their model was no exception. They developed a “minimum realistic” model with results that compared well with one developed for beluga whale (Welch *et al.* 1993 in Laidre *et al.* 2004a). Estimates were made for varying levels of Greenland halibut in the narwhal diet, 25%, 50% and 75%. Assuming a diet comprised of 50% Greenland halibut Laidre *et al.* (2004a) estimated a daily consumption of 90 t and a mean consumption overall of 13,500 t (95% CI of 5,400 t – 28,300 t) for the southern narwhal over-wintering area that at the time was estimated to support 5,000 narwhal. They also found that the difference in Greenland halibut biomass between an area with high predation by narwhals and a comparable area without whales was approximately 19,000 t and corresponded well with the predicted biomass removed by the narwhal, assuming a diet of 50%-75% Greenland halibut (Laidre *et al.* 2004a).

The current narwhal population estimates for the Melville Bay and Eclipse Sound sub-populations that over-winter in the southern wintering ground is 20,000 and there is now evidence that approx. 5,000 narwhals from Admiralty Inlet also use this over-wintering area. Extrapolating to these new estimates of population size and assuming a diet of 50% Greenland halibut, the three sub-populations of narwhals may consume in the order of 67,500 t of Greenland halibut over the five months spent on their wintering ground. The most recent estimate for Greenland halibut biomass in southern Div. 0A is 86,176 t (S.E. 12,502) (Treble 2005) and for all of Baffin Bay it is 222,336 t (Jørgensen 2005). While the estimate for narwhal consumption on the southern over-wintering ground is higher than what was first reported by Laidre *et al.* (2004a) it still falls within the estimated biomass of Greenland halibut. Laidre *et al.*

(2004a) also found that mean densities and length distributions of Greenland halibut inside and outside of the narwhal wintering grounds correlated well with predicted whale predation levels based on diving behaviour (Appendix 4), which further supported their conclusions that narwhals were targeting Greenland halibut in the southern over-wintering grounds.

The TAC established for the Greenland halibut fishery in Baffin Bay (NAFO Div. 0A and 1A(offshore) and 1B) is lower than that set in other Greenland halibut fisheries. This approach was taken because of the difficulty in monitoring the Baffin Bay Greenland halibut stock, the possibility of reduced growth due to colder oceanographic conditions and predation of a significant amount of Greenland halibut by narwhals.

The northern over-wintering ground supports a larger number of whales (approx. 45,000 in 1996) and was estimated to require 700 t per day with a mean consumption over five months of 110,700 t (95% CI of 53,000 t - 310,300 t). This estimate for the northern over-wintering area was greater than the abundance of Greenland halibut estimated in a 2001 survey (36,416 t (Jørgensen 2005)). Laidre *et al*. 2004a suggest that Greenland halibut likely do not play the same role in the diet of narwhals in the northern area that they do in the southern area. An increase in the number of dives and time spent at mid-water for narwhals in the northern over-winter area compared to those in the southern over-winter area supports this conclusion (Laidre *et al.* 2003) (Appendix 3). Also, pelagic polar cod increase in abundance with increase in latitude (Laidre *et al.* 2004a) (Appendix 5) suggesting that schools of polar cod may be an alternative food source to Greenland halibut in the northern over-wintering ground (Laidre *et al.* 2004a).

Top predators are thought to congregate at predictable sites in response to elevated availability of prey resources driven by physical oceanographic processes (Guinet *et al.* 2001 and Thompson *et al.* 2003 in Laidre *et al.* 2004b). Also, marine trophic interactions are complex and are not easily measured so physical habitat features such as depth or bottom temperature are often used as proxies for the distribution of prey resources. Laidre *et al.* (2004b) found that bottom temperature was the strongest predictor of fall and winter movements and dive behaviour of narwhals. Bottom temperature on the west side of Baffin Bay rarely exceeded 1^{o} C while bottom temperatures were much warmer on the east side, as high as 4.0 to 4.5^{o} C.

Greenland halibut are relatively abundant throughout Baffin Bay and Davis Strait (Appendix 4) so prey distribution alone would not account for the overwintering concentration of narwhals. Winter distribution of narwhals may result from a combination of prey abundance, oceanographic conditions such as sea-ice concentration and predator (killer whale) avoidance, so how readily narwhal would shift their over-wintering area in response to local depletion of prey is unknown.

Deep-sea Coral Locations in Baffin Bay

The distribution of coral in Atlantic Canada based on data from DFO groundfish trawl surveys (including those described below) and fisheries observer reports is reviewed in Gass (2002) and Gass and Willison (2005).

Scientific surveys were conducted using otter trawl gear in Baffin Bay in 1999, 2001, 2004 and 2006. During the 1999 survey, a large mound or reef of gorgonian coral (predominantly comprised of *Keratoisis ornata*) was encountered at 67^{o} 58' N and 59^{o} 30' W. The trawl filled with the heavy coral after only nine minutes and could not be brought back on board. The twine gave out due to the weight and only the doors and rigging lines were retrieved. This location fell within the southern narwhal over-wintering grounds and the restricted fishing zone (2.1)

described above (Appendix 1 and Appendix 6). In 2001, several cold-water coral species including two gorgonian species (*Acanella arbuscula, Paragorgia arborea*) and a *Flabellum* sp. were identified at three locations within the southeastern portion of Baffin Bay and within the narwhal over-wintering grounds (Appendix 6). Two of these locations fell within the restricted fishing zone and at one of these locations three different species were caught in a single 30 minute tow. No hard corals have been found in any other area of Div. 0A.

It could be argued that the entire area surrounding the locations where deep-sea coral were located should be protected from trawl gear. However, this would include most of the southeastern portion of Div. 0A, that area east of 60^{o}W, and would create a significant problem for the fishery. The compromise was to close an area which corresponds to approximately 50% of the total area encompassed by locations where corals have been identified.

The bathymetry in the closed area is characterized by a very steep gradient between the 400 m and 1000 m depth contours, leveling off somewhat between 1000m and 1500 m. Given that coral was found at different randomly selected stations there is a good chance conditions would be suitable for coral growth in other locations as well. With the low level of fishing effort in the early years of the Greenland halibut fishery and the effort restrictions in place since 1998 it may be reasonable to assume that there is still habitat in this area that has not been impacted by bottom trawl gear. However, it is not possible to determine the actual status of any coral areas without conducting video or Remote Operated Vehicle surveys and there are no plans for this type of research in the near future.

In 2003, DFO drafted a national strategy for conserving deep-sea gorgonian corals which identified fishery closures as an interim management tool that could be implemented through fisheries management plans to protect known or newly discovered areas of significance. Since then, DFO conducted a National Advisory Process meeting in March 2006 to review impacts of trawls (DFO 2006) and a Policy for Managing the Impacts of Fishing on Sensitive Benthic Areas is under development (see below).

DFO Draft Policy for Managing the Impacts of Fishing on Sensitive Benthic Areas

DFO is developing policy to guide the management of impacts of fishing on sensitive benthic areas. Restrictions applied to the Greenland halibut fishery in 1998 were also established to minimize gear impacts from trawling on benthic organisms and physical structures that provide habitat for Greenland halibut and their prey. The decision to restrict fishing effort in a significant portion of the southern narwhal over-wintering area is consistent with the intent of the draft policy for protecting sensitive benthic areas. New information suggests the greatest damage to ecosystems that are most vulnerable to fishing activity occurs with the first few fishing events (DFO 2006). The area in question could have been considered a “frontier area” in 1998 (DFO 2006), and a decision to close the area completely to bottom trawl fishing at that time might have been more appropriate. Since then we have new information concerning deep-sea corals and although fishing has occurred in the area effort has been restricted and it is believed that a closure to bottom impacting gears would be in keeping with the precautionary approach to fisheries and ecosystem-based management.

DFO Draft Policy on Fisheries for Forage Species

DFO is developing policy as a guide for fisheries targeting forage species. The management decision taken in 1998 to restrict fishing effort in a significant portion of the southern narwhal

over-wintering area is consistent with the goals of this draft policy for forage species. While Greenland halibut might not be thought of as a typical forage species there are aspects of the policy that could apply. For example, Greenland halibut is a significant component of the diet for three sub-populations of narwhals that over-winter in southern Baffin Bay. Restrictions were also applied to the Greenland halibut fishery in 1998, in part, to ensure that local depletion of the narwhal food supply did not occur in the southern narwhal over-wintering area. In October and November, ice conditions in Baffin Bay force fishing effort to concentrate in the southern area of NAFO Div. 0A. If no restrictions were in place, the increased effort in this area could result in a depletion of Greenland halibut immediately prior to the narwhal's arrival in November. Greenland halibut are not a sedentary species so they would move in to re-occupy depleted areas but the rate at which this would occur is not known. If dispersal takes a number of days or weeks local depletion might not impact the narwhals but if it takes a number of months or up to a year then local depletion could be an important consideration. Given the uncertainties effort restrictions in this area are warranted.

Ecosystem-based Management

The Oceans Act, passed in 1997, requires the consideration of impacts of all human activities on an ecosystem level, not just impacts on a single species or stock. As a result DFO Science and Fisheries Management have been working towards an "ecosystem approach" to fisheries management by developing mechanisms with which to incorporate ecosystem considerations within single species assessment and management. The Fishery Management Plan for Greenland Halibut in NAFO SA0 includes several Biological Objectives one of which is to "Protect critical habitat, ecosystems and other species" (DFO 2006 in prep.). The management measure to restrict fishing in the narwhal over-wintering ground was implemented to help achieve this objective which is further enhanced by the decision to close the area entirely for all fishing gears.

Conclusions

Since 1998, the Greenland halibut fishery in NAFO Div. 0A has expanded to a level of 6,500 t TAC and a combination of otter trawl and gillnets is currently being used in this fishery. Since 1997, new information on narwhal migration, over-wintering areas and diet added further support to continue the 1998 decision to establish fishing effort controls in the southern narwhal over-wintering grounds. The introduction of gillnet gear into the fishery in 2004 and this fleet's concentration in the southern portion of Div. 0A introduced the potential for narwhal entanglement in lost gear. In addition, the identification of deep-sea coral and a greater understanding of fishing gear impacts on sensitive benthic habitat suggested that further steps should be taken to protect the area. In April 2006, DFO Fisheries Management, following discussions with DFO Science, decided that a significant portion of the southern narwhal over-wintering grounds that includes deep-water coral locations should be closed to all Greenland halibut fishing (fixed and mobile gears). A description of the closed area was included in the draft 2006-2008 Fisheries Management Plan for Greenland Halibut in SA0.

In summary, the rationale for closing an area of NAFO Div. 0A to the Greenland halibut fishery :

1) COSEWIC has assessed narwhal, including the high Arctic populations as "Special Concern". Important over-wintering habitat for three sub-populations is located in the southeast corner of NAFO Div. 0A where bottom temperatures are the warmest. The size of the closed area was based on tagging data from five narwhals from two of the sub-populations. The boundaries will be re-examined as more data becomes available.

2) Greenland halibut are an important forage species for narwhal, particularly the three sub-populations, Melville Bay, Eclipse Sound and Admiralty Inlet, that utilize the southern over-wintering area located in the southeast corner of NAFO Div. 0A. Continued research on narwhal diet and bio-energetic requirements is needed to further refine estimates of Greenland halibut consumption.
3) Narwhals feed primarily during the period spent on their over-wintering grounds. By closing a significant portion of the grounds to Greenland halibut fishing, we would ensure this important food resource does not become locally depleted prior to the narwhal's arrival on these grounds.
4) The only deep-sea corals found to date in Division 0A came from by-catch during scientific groundfish surveys conducted in 1999 and 2001 and were located within the southern narwhal over-wintering area. The role deep-sea coral plays in the ecosystem is still being investigated. Using a precautionary approach, measures should be taken to protect these areas from bottom impacting gears in the interim. The closed area covers approximately 50% of the total area encompassed by locations where corals were identified. It was recognized that this does not protect all the known coral locations but was a compromise in recognition of the developing fishery. The size of the closed area to protect coral habitat could be re-examined in the future.
5) While gillnets don't have the same degree of impact on benthic habitat as bottom trawls they can disturb habitat. However, in this case the risk of narwhal entanglement in lost gear, in an area where narwhals aggregate for several months at a time, is a concern and this risk is reduced by excluding gillnet gear in a significant portion of the over-wintering area.

The draft policies discussed above will undergo a consultation process prior to being adopted as policy. The advice provided in April 2006, summarized in this report, may be modified in the future as more information is gathered on benthic habitat, narwhals and coral in Southeast Baffin Bay. In the meantime, DFO is being guided by a broad ecosystem approach provided in part by these draft policies which includes the need to consider the impacts of fishing on forage species and on benthic habitat, with a view to determine ways of mitigating those impacts.

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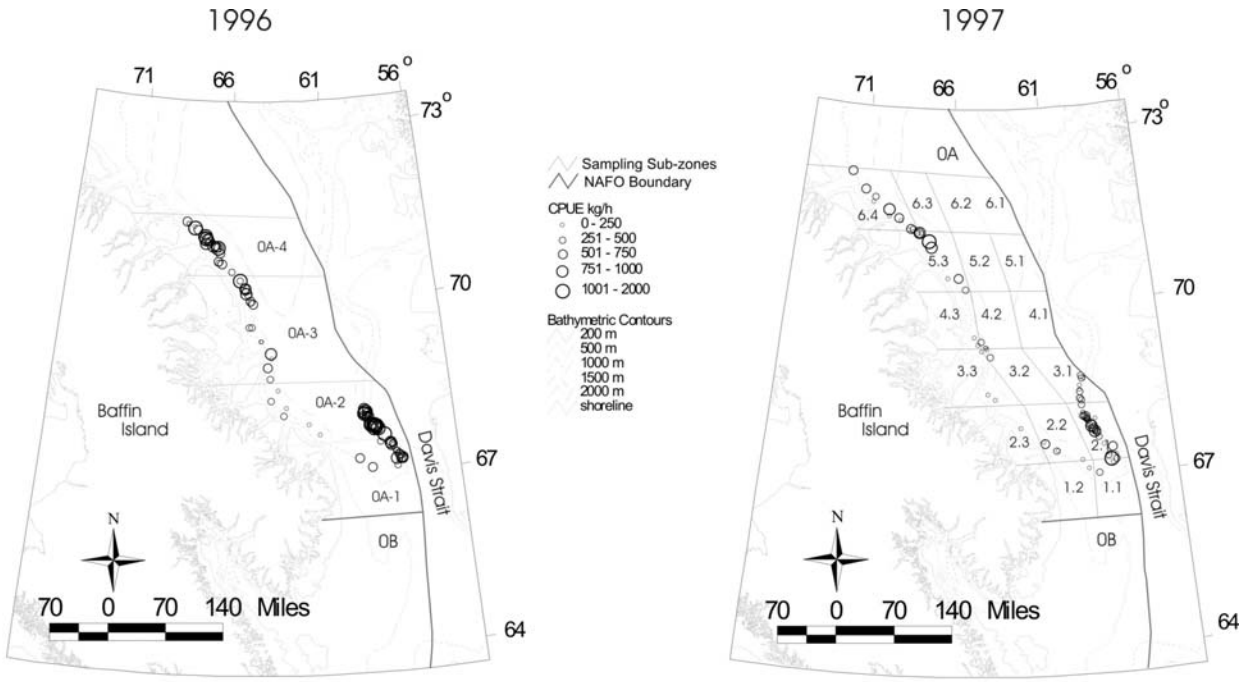
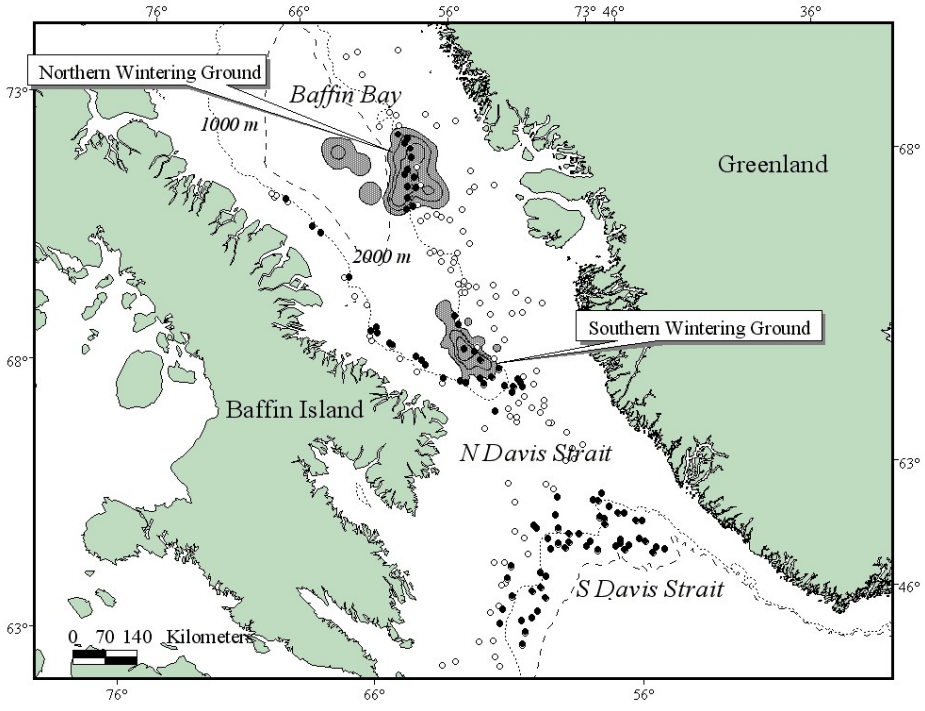
Appendices



Appendix 1. Distribution of fishing effort in NAFO Division 0A for 1996 and 1997 (from Treble 1999).



Appendix 2. Narwhal over-wintering areas and location of trawl tows from the 2001 Greenland halibut survey (from Laidre *et al.* 2004a).

Appendix 3. *Monodon monoceros.* Repeated-measures mixed model parameter estimates (with SE) based on an interaction model between season and locality for each of seven depth categories. A random effect of individual behaviour and an effect of linear temporal autocorrelation between days (without a nugget) were included in the models. Average number of dives per day and absolute time at depth (h) in three seasons for each of three narwhal sub-populations are reported (from Laidre *et al*. 2003).

Depth bin (m)	Summer			Migration			Winter		
	Eclipse	Melville	Somerset	Eclipse	Melville	Somerset	Eclipse	Melville	Somerset
Average number of dives per day									
0–50	159 (28)	167 (63)	149 (25)	147 (27)	165 (61)	101 (25)	116 (28)	151 (61)	59 (26)
50–100	8 (3)	11 (8)	15 (3)	7 (3)	6 (7)	10 (3)	10 (3)	13 (7)	11 (3)
100–200	4 (4)	7 (8)	8 (3)	5 (4)	4 (8)	14 (3)	10 (4)	5 (8)	19 (4)
200–400	11 (3)	14 (6)	9 (2)	7 (3)	12 (6)	20 (2)	5 (3)	3 (6)	25 (3)
400–600	11 (3)	5 (6)	6 (3)	12 (3)	6 (6)	10 (2)	3 (3)	2 (6)	12 (3)
600–800	4 (1)	10 (2)	0 (1)	7 (1)	10 (2)	2 (1)	2 (1)	4 (2)	2 (1)
>800	1 (1)	1 (2)	0 (1)	3 (1)	13 (2)	1 (1)	13 (1)	26 (3)	5 (1)
Average absolute time at depth per day (h)									
0–50	16.8 (0.8)	15.6 (1.9)	19.3 (0.7)	15.8 (0.8)	13.7 (1.8)	15.6 (0.7)	13.9 (0.8)	11.8 (1.8)	12.7 (0.8)
50–100	1.1 (0.2)	1.3 (0.4)	1.4 (0.1)	1.0 (0.2)	0.9 (0.4)	1.5 (0.1)	1.3 (0.2)	1.6 (0.4)	1.9 (0.2)
100–200	1.4 (0.2)	1.8 (0.6)	1.1 (0.2)	1.4 (0.2)	1.5 (0.5)	2.2 (0.2)	1.6 (0.2)	1.4 (0.5)	3.4 (0.2)
200–400	2.6 (0.5)	3.2 (1.3)	1.8 (0.5)	2.5 (0.5)	3.2 (1.2)	3.3 (0.5)	1.7 (0.5)	2.6 (1.2)	3.6 (0.5)
400–600	1.5 (0.2)	1.0 (0.6)	0.3 (0.2)	2.0 (0.2)	1.4 (0.6)	1.0 (0.2)	1.5 (0.3)	1.4 (0.6)	1.3 (0.3)
600–800	0.4 (0.1)	0.9 (0.3)	0 (0.1)	0.9 (0.1)	1.7 (0.2)	0.2 (0.1)	1.0 (0.1)	1.8 (0.2)	0.4 (0.1)
>800	0.1 (0.1)	0.1 (0.3)	0 (0.1)	0.4 (0.1)	1.5 (0.3)	0.1 (0.1)	3.0 (0.1)	3.3 (0.3)	0.7 (0.1)

Appendix 4.

Table 1. Summary information on survey tows for Greenland halibut (GHL) and "other" fish species in Baffin Bay and Davis Strait in 2001 (from Laidre *et al.* 2004a). Note: NWG is the Northern Wintering Ground and SWG is the Southern Wintering Ground.

Region	Number of tows	Number of GHL measured	Range of length categories for GHL (cm)	Mean density of GHL in kg/km^2 (SD)	Mean density of other fish in kg/km^2 (SD)
NWG	13	1,739	13-85	1,295 (667)	108 (77)
SWG	9	616	20-99	667 (974)	371 (454)
Baffin Bay	15	3,912	25-70	2,416 (2283)	130 (111)
North Davis Strait	7	1,255	18-104	1,762 (1085)	66 (32)
South Davis Strait	51	8,486	19-105	2,184 (1113)	436 (232)
TOTAL	95	16,008	13-105	1,664 (702)	302 (261)

Appendix 4 Continued.

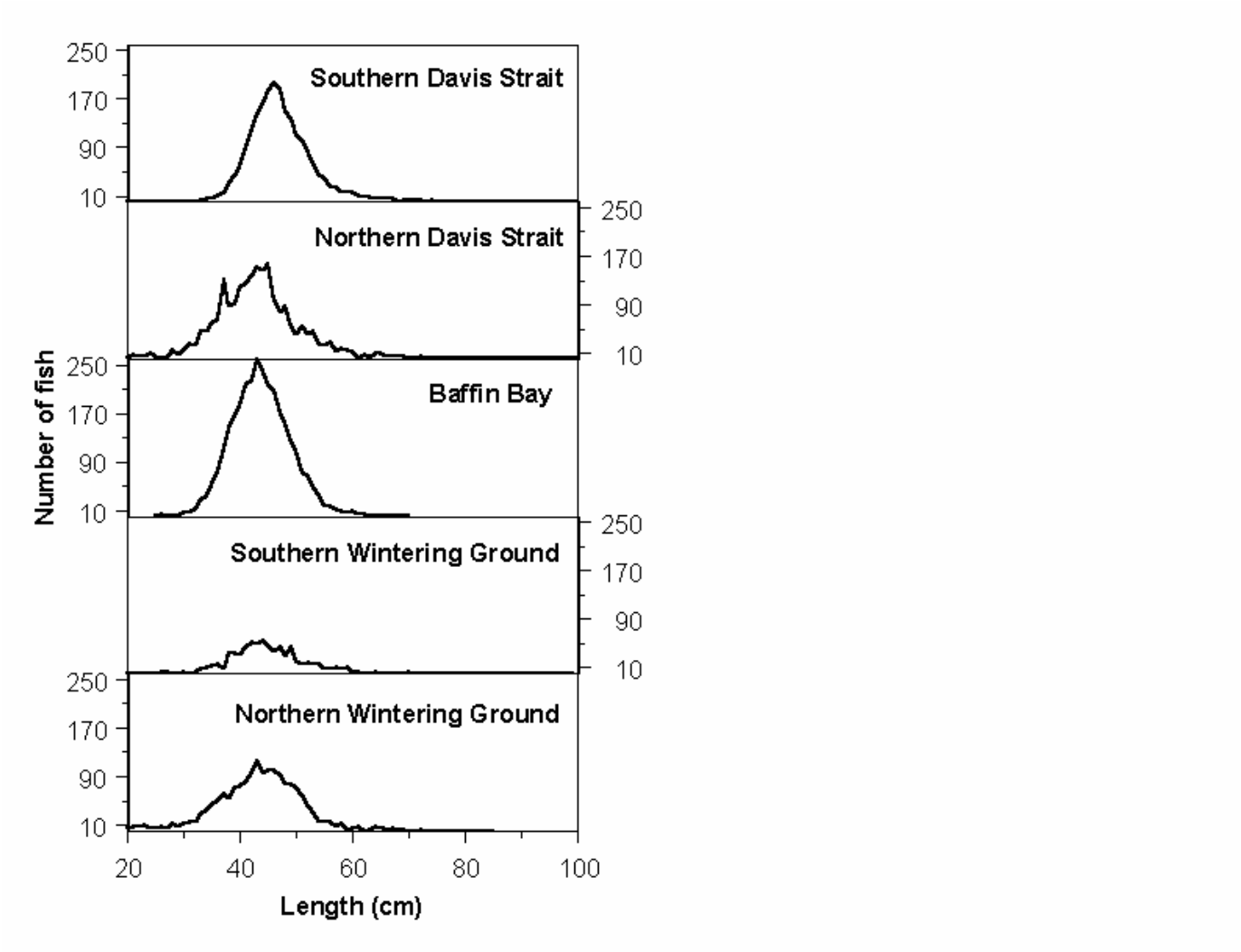
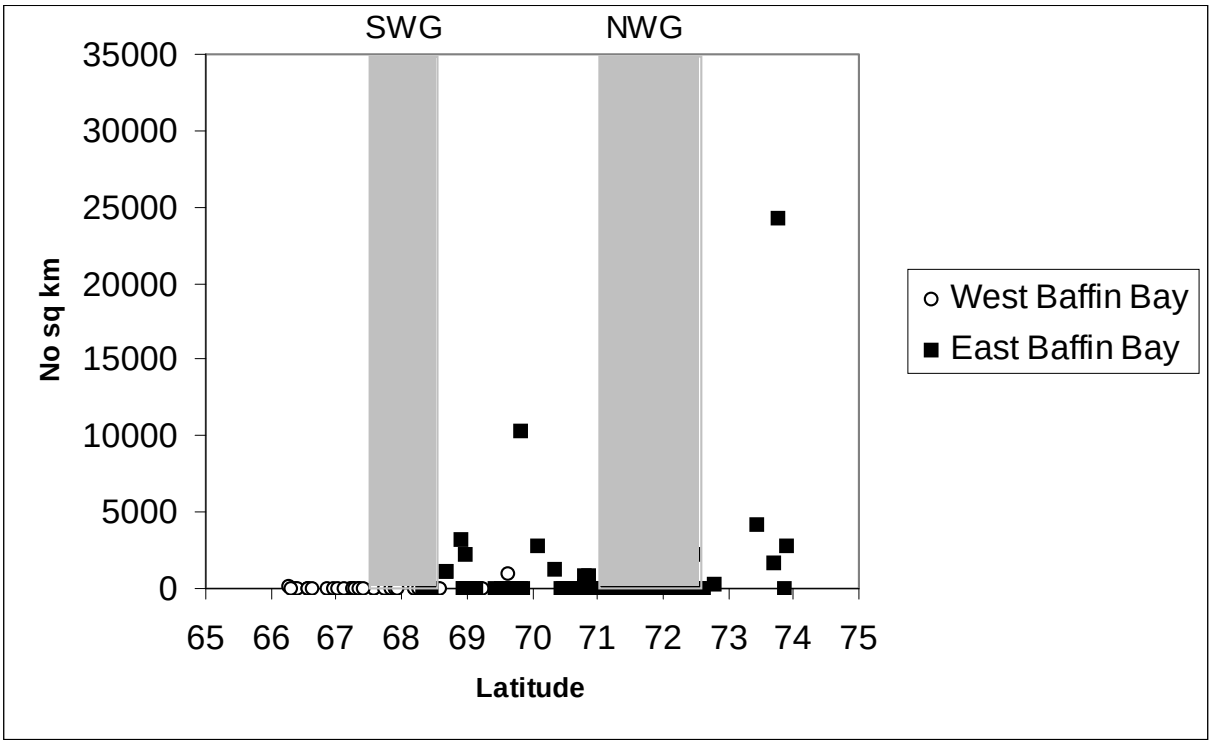


Figure 1. . Distribution of the number of Greenland halibut/km^2 by length class in the five regions. The Southern wintering ground is hypothesized to have high predation levels, Northern wintering ground is hypothesized to have low predation levels, and Northern Davis Strait, South Davis Strait and Baffin Bay are hypothesized to have no predation (from Laidre *et al*. 2004a).

Note: See the figure in Appendix two for location of the regions named in the above table and figure.



Appendix 5. Abundance of polar cod in West and East Baffin Bay, 2001, shown with latitude (degrees N) of each trawl location. The Northern Wintering Ground (NWG) and Southern Wintering Ground (SWG) are shaded. The large number of zero observations is due to the schooling behaviour of the pelagic species (from Laidre *et al*. 2004a).

Appendix 6

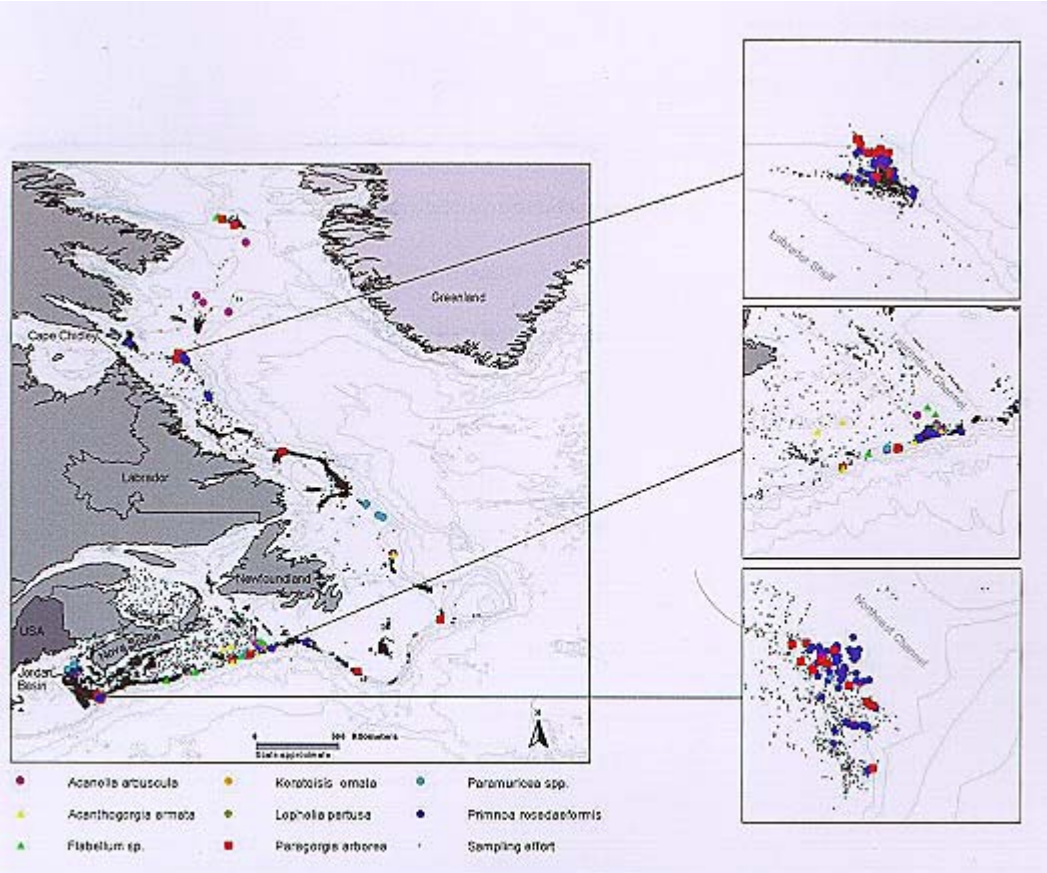


Figure 1. The distribution of deep sea corals based on DFO trawl surveys (1999-2001) and fisheries observer reports (2000 and 2001) (from Gass 2002). Note the cluster of samples that overlap with the southern narwhal over-wintering grounds.

Table 1. Locations of hard, deep-sea coral in NAFO Division 0A taken as by-catch in multi-species surveys (* locations within the restricted fishing zone).

Year	Trip	Set	Date	Start Latitude ˚N	Start Longitude ˚W	Mean Depth (m)	Temperature (˚C)	Species
1999	1	23*	Oct. 11	67 58.5’	59 30.8’	930	0.8	*Keratoisis ornata*
2001	6	7	Sept. 17	66 38.4’	57 50.6’	619	2.3	*Acanella arbusculla*
2001	6	13*	Sept. 18	67 34.2’	58 29.3’	556	3.8	*Paragorgia arborea*
2001	6	16*	Sept. 18	67 52.8’	59 09.9’	516	3.4	*Acanella arbusculla* *Paragorgia arborea* *Flabellum spp.*

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