COSEWIC
Assessment and Update Status Report

on the

Narwhal
Monodon monoceros

in Canada

SPECIAL CONCERN
2004

COSEWIC
COMMITTEE ON THE STATUS OF
ENDANGERED WILDLIFE IN
CANADA

COSEPAC
COMITÉ SUR LA SITUATION DES
ESPÈCES EN PÉRIL
AU CANADA

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Narwhal — Drawing of an adult male narwhal (*Monodon monoceros*). Artist Ray Phillips; © Department of Fisheries and Oceans Canada reproduced with permission.

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COSEWIC
Assessment Summary

Assessment Summary – November 2004

Common name
Narwhal

Scientific name
Monodon monoceros

Status
Special Concern

Reason for designation
The Baffin Bay population appears to be large (~45,000), although there is uncertainty about numbers, trends, life history parameters, and levels of sustainable hunting. There is similar uncertainty about the much smaller Hudson Bay population (~2,100 mature individuals). Hunting for *maktak* and the commercially valuable tusk ivory represents the most consistent threat to narwhals. Potential effects of changes in ice coverage caused by climate trends are unknown. The Hudson Bay population could decline by 30% in 30 years if hunting is not closely regulated. Similarly, the Baffin Bay population could be affected if hunting in Greenland is not effectively managed. Numbers removed by hunting increased during the 1990s. Community-based management is monitoring hunting and is attempting to regulate removals. Reliable information about numbers that are killed and not recovered is difficult to obtain.

Occurrence
Arctic Ocean

Status history
Designated Not at Risk in April 1986 and April 1987. Status re-examined and designated Special Concern in November 2004. Last assessment based on an update status report.

COSEWIC
Executive Summary

Narwhal
Monodon monoceros

Species information

Narwhals (*Monodon monoceros*) are medium-sized toothed whales that lack a dorsal fin. They are about 1.60 m long at birth (80 kg). Males can grow to 5.40 m (~1935 kg) and females to 4.94 m (~1552 kg). Adult narwhals have only two teeth. In most males, the right tooth remains embedded in the skull and the left forms a magnificent spiral tusk that can extend straight forward over 3 m.

Distribution

Two of three recognized populations of narwhals occur in Canada (Baffin Bay and Hudson Bay). The third occurs in East Greenland. The populations are distinguished by their summering distributions, which may not reflect the degree of interchange between them. The East Greenland population is not thought to enter Canadian waters. Narwhals from the Baffin Bay population summer in the waters of West Greenland and the Canadian High Arctic, and winter in Baffin Bay and Davis Strait. They range over an area of at least 1.25 million km². The degree of site fidelity within this shared population is unknown and it may in fact consist of several populations. Narwhals that summer in northwest Hudson Bay are believed to winter in eastern Hudson Strait and range over an area of roughly 250,000 km². The population affinity of animals that summer north of Baffin Bay and along the eastern and southern coasts of Baffin Island is unknown. Biologists have not identified any large-scale changes in the seasonal distribution of narwhals, but Inuit have observed local changes.

Habitat

Narwhals inhabit a vast area of the Arctic, but little is known of their actual habitat requirements. In summer, they prefer coastal areas that offer deep water and shelter from the wind. During their fall migrations, and later while wintering in the pack ice, narwhals prefer deep fjords and the continental slope, where depths range from 1000 to 1500 m and upwellings may increase biological productivity. The quality of the ice habitat, particularly the presence of leads in fast ice and the density of broken pack ice, appears to influence habitat selection.

Biology

The vital rates of narwhals are uncertain because there is no accurate method to determine their ages. Females are believed to mature at 5 to 8 years and produce their first young at 7 to 13 years. Mating peaks in mid-April, and most calves are produced in July and August after a gestation period of 14 to 15.3 months. While more frequent reproduction is possible, mature females produce a single calf about every three years on average until perhaps 23 years of age. Longevity may be about 50 years, but most animals probably do not reach the age of 30. Generation times and net recruitment rates for narwhals are unknown. Rates of mortality from hunting are imprecise because numbers that are struck and losses is uncertain, and rates of predation by killer whales and polar bears are unknown. Little is known of the diseases of narwhals and their response to pathogens. The potential for large-scale mortality due to entrapment by ice or to disease is also unpredictable.

Narwhals generally travel in small groups in summer (<10 individuals), but gather in concentrations of many hundreds of animals during migrations in the spring and fall. Their diving ability enables them to move long distances under water and makes it difficult to obtain accurate population estimates. Narwhals eat a variety of fishes and invertebrates. Little is known about the physiological requirements of narwhals or their ability to adapt to environmental change or shifts in prey availability.

Population sizes and trends

A good estimate of the initial size of the Baffin Bay and Hudson Bay narwhal populations cannot be generated from historical harvest data. Estimates of population size have generally been limited to methods that only estimate a portion of the population. Past surveys based on aerial surveys of areas of aggregation seldom accounted for narwhals that were submerged beyond view, missed by observers because of ice or poor visibility, or were outside the survey area.

In 1996, a systematic aerial survey of Prince Regent Inlet, Barrow Strait and Peel Sound estimated 45,358 narwhals (95% CI = 23,397-87,932). This estimate was corrected for submerged animals and those missed by observers. It compares well with estimates from surveys conducted in the mid-1980s, but the statistical power to detect a trend is low. Between 45,000 and 50,000 narwhals from the Baffin Bay population may summer in Canadian waters.

The narwhal population in Hudson Bay was estimated at 1,355 (90%CI = 1000-1900) animals in 1984 and 1,780 (90%CI = 1212-2492) animals in 2000. Neither estimate corrected for submerged animals or weather conditions, and the latter included northern Lyon Inlet and Foxe Channel. The Hudson Bay population may be about 3,500 animals in summer.

Limiting factors and threats

Narwhal populations in Canada may be limited or threatened by hunting, environmental contaminants, climate change, and industrial activities such as commercial fishing. The effects of climate change on ice habitats used by narwhals are uncertain, as is the species' capacity to adapt. The effects of the other factors are mitigated by the species' deepwater habits and widespread geographical distribution, much of which is outside normal hunting areas in offshore pack ice and in isolated areas of the Arctic. This remote distribution protects many narwhals from hunters as well as isolated oil spills or other events. However, under exceptional circumstances, such as large ice entrapments or when killer whales drive narwhals into shallow water, many animals can be taken at once from a single locality. Hunting probably represents the most consistent limiting factor to narwhal populations in Canada.

Special significance of the species

Narwhals historically provided important staples in the traditional subsistence economy of the eastern Canadian Arctic and Greenland. Hunting and sharing of its proceeds continue to be of great social and cultural significance for some communities. Narwhals are harvested mainly for their *maqtaq* and ivory. The ivory commands high prices and is marketed internationally, while the *maqtaq* is consumed locally or traded to other Inuit communities. It is a highly-valued food and demand often exceeds supply. Ecologically, the narwhal is important as it is the only species in its genus and is an apex predator in the Arctic food chain. It generates avid public interest because of its unique "unicorn" tusk and the remoteness of its habitat, but has not been successfully displayed in captivity.

Existing protection or other status designations

Protection for narwhals in Canada is limited to measures that manage the hunt, live capture, and movement of narwhal products. The Nunavut Wildlife Management Board is the main instrument of wildlife management in Nunavut. The Department of Fisheries and Oceans is a co-management partner who provides scientific advice and regulatory support. Other co-management partners are the Hunters and Trappers organizations and the Regional Wildlife organizations. Only Inuit can hunt narwhals and limits are placed on the number of animals each community can land. The species is listed in Appendix II of the *Convention on International Trade in Endangered Species of Wild Fauna and Flora* (CITES). Canada cooperates with Greenland in the conservation of shared narwhal populations. The Joint Commission on Conservation and Management of Narwhal and Beluga has not been able to determine the status of narwhal populations using the data available and Canada and Greenland are conducting surveys to collect new data.

COSEWIC HISTORY

The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) was created in 1977 as a result of a recommendation at the Federal-Provincial Wildlife Conference held in 1976. It arose from the need for a single, official, scientifically sound, national listing of wildlife species at risk. In 1978, COSEWIC designated its first species and produced its first list of Canadian species at risk. Species designated at meetings of the full committee are added to the list. On June 5th 2003, the *Species at Risk Act* (SARA) was proclaimed. SARA establishes COSEWIC as an advisory body ensuring that species will continue to be assessed under a rigorous and independent scientific process.

COSEWIC MANDATE

The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) assesses the national status of wild species, subspecies, varieties, or other designatable units that are considered to be at risk in Canada. Designations are made on native species for the following taxonomic groups: mammals, birds, reptiles, amphibians, fishes, arthropods, molluscs, vascular plants, mosses, and lichens.

COSEWIC MEMBERSHIP

COSEWIC comprises members from each provincial and territorial government wildlife agency, four federal agencies (Canadian Wildlife Service, Parks Canada Agency, Department of Fisheries and Oceans, and the Federal Biodiversity Information Partnership, chaired by the Canadian Museum of Nature), three non-government members and the co-chairs of the species specialist and the Aboriginal Traditional Knowledge subcommittees. The Committee meets to consider status reports on candidate species.

DEFINITIONS
(NOVEMBER 2004)

Wildlife Species	A species, subspecies, variety, or geographically or genetically distinct population of animal, plant or other organism, other than a bacterium or virus, that is wild by nature and it is either native to Canada or has extended its range into Canada without human intervention and has been present in Canada for atleast 50 years.
Extinct (X)	A wildlife species that no longer exists.
Extirpated (XT)	A wildlife species no longer existing in the wild in Canada, but occurring elsewhere.
Endangered (E)	A wildlife species facing imminent extirpation or extinction.
Threatened (T)	A wildlife species likely to become endangered if limiting factors are not reversed.
Special Concern (SC)*	A wildlife species that may become a threatened or an endangered species because of a combination of biological characteristics and identified threats.
Not at Risk (NAR)**	A wildlife species that has been evaluated and found to be not at risk of extinction given the current circumstances.
Data Deficient (DD)***	A wildlife species for which there is inadequate information to make a direct, or indirect, assessment of its risk of extinction.

* Formerly described as “Vulnerable” from 1990 to 1999, or “Rare” prior to 1990.
** Formerly described as “Not In Any Category”, or “No Designation Required.”
*** Formerly described as “Indeterminate” from 1994 to 1999 or “ISIBD” (insufficient scientific information on which to base a designation) prior to 1994.

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The Canadian Wildlife Service, Environment Canada, provides full administrative and financial support to the COSEWIC Secretariat.

Update
COSEWIC Status Report

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2004

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SPECIES INFORMATION

Name and classification

Narwhals (*Monodon monoceros* Linnaeus, 1758) are mammals belonging to the genus *Monodon* (Linnaeus, 1758), family Monodontidae (Gray, 1821– white whales), suborder (Odontoceti Flower, 1867– toothed whales), and order Cetacea (Brisson, 1762– cetaceans, whales). They are the only species in the genus *Monodon*. No subspecies have been identified. Common names for the species include narwhal, sea unicorn, narwhale, narval (French, Swedish, Spanish), narhval (Danish, Norwegian), itsu-keku (Japanese), rogozub (Russian), and enhorned hortand (Swedish). Inuit use a variety of descriptive words in Inuktitut to identify narwhal (J. Kilabuk, pers. comm. 2002). These include tuugaalik (with tusk), qirniqtaq qilalugaq (black whale), and Allanguaq (with black and white dots). The latter is commonly used in different regions of the Arctic.

Description

Narwhals are medium-sized toothed whales that lack a dorsal fin and have convex-shaped tail flukes (Figure 1). Like their close relatives, the beluga (*Delphinapterus leucas*), the colour of narwhals changes with age. The skin of newborn narwhals is an uneven grey or bluish grey, which changes to a uniform black or bluish black soon after weaning (Arvy 1978; Reeves and Tracey 1980). As the animal matures, white streaks and patches begin to develop around the anus, genital slit and navel, and spread over the entire ventral surface and onto the flanks. Adults are white to creamy yellow on the belly and mottled grey to black on the back. Very old animals, especially males, are almost completely white.

Figure 1. Drawing of an adult male narwhal (*Monodon monoceros*) (Artist Ray Phillips; ©Department of Fisheries and Oceans Canada, reproduced with permission).

Adult narwhals are unique among toothed whales in having only two teeth (Eales 1950). These teeth are embedded horizontally in the maxilla of the upper jaw, one on each side. In most adult males, the left tooth forms a very long straight ivory tusk that

spirals to the left along its long axis (Dow and Hollenberg 1977). Females with a tusk, males without a tusk, and males and females with two tusks are rare (Hay and Sergeant 1976; Reeves and Tracey 1980; Reeves and Mitchell 1981).

Adult male narwhals are larger on average than adult female narwhals. Males taken at Arctic Bay in 1986-89 averaged 4.58 m (range 3.96-5.40 m, SD 0.203 m, n = 56) and females averaged 4.13 m (range 3.56-4.94 m, SD 0.331 m, n = 20) (Roberge and Dunn 1990). These individuals were significantly larger ($P<0.001$) on average than male (mean 4.35 m, range 3.90-4.86 m, SD 0.226 cm, n = 37) and female (mean 3.81 m, range 3.48-4.20 cm, SD 0.216 m, n = 17) narwhals taken at Pond Inlet in 1982-83 (Weaver and Walker 1988). Newborn calves are typically about 1.60 m long (Hay 1984; Neve 1995a).

DISTRIBUTION

Global range

Narwhals inhabit Arctic waters and are seldom seen south of 61°N (Figures 2 and 3). They are common in the waters of Nunavut, west Greenland and the European Arctic but are rare in the East Siberian, Bering, Chukchi and Beaufort seas. This distribution appears to be unchanged from historical reports.

Two populations of narwhals have been recognized for the purpose of hunt management in Canada (Fisheries and Oceans Canada 1998a, 1998b). This tentative separation into Baffin Bay and Hudson Bay populations is based largely on summering distribution and may not reflect the degree of interchange between populations Narwhals from the Baffin Bay population summer in the waters of West Greenland and the Canadian High Arctic and winter in Baffin Bay and Davis Strait (Koski and Davis 1994; Dietz *et al*. 2001; Heide-Jørgensen *et al*. 2003). They range over an area of at least 1.25 million km². The degree of site fidelity within this shared population is unknown and it may in fact consist of several populations (JCNB/NAMMCO 2001). Narwhals that summer in northwest Hudson Bay are believed to winter in eastern Hudson Strait (Richard 1991). They range over an area of roughly 250,000 km². Animals that summer in East Greenland waters are believed to winter in the pack ice between eastern Greenland and Svalbard (Dietz *et al*. 1994). They are not thought to enter Canadian waters.

Physical and behavioural observations suggest that different narwhal populations exist within the Baffin Region. Hunters from Qikiqtarjuaq, Clyde River, and Resolute recognize two different types of narwhals — one that is relatively large and dark with a long tusk and another that is smaller and lighter in colour with a smaller and more twisted tusk (Remnant and Thomas 1992). Narwhals in the Jones Sound area are more likely to seek deep water when threatened by hunters than those in the Pond Inlet area (Reeves 1992a), and are not alarmed by the sight of hunters at the ice edge (Stewart *et al*. 1995).

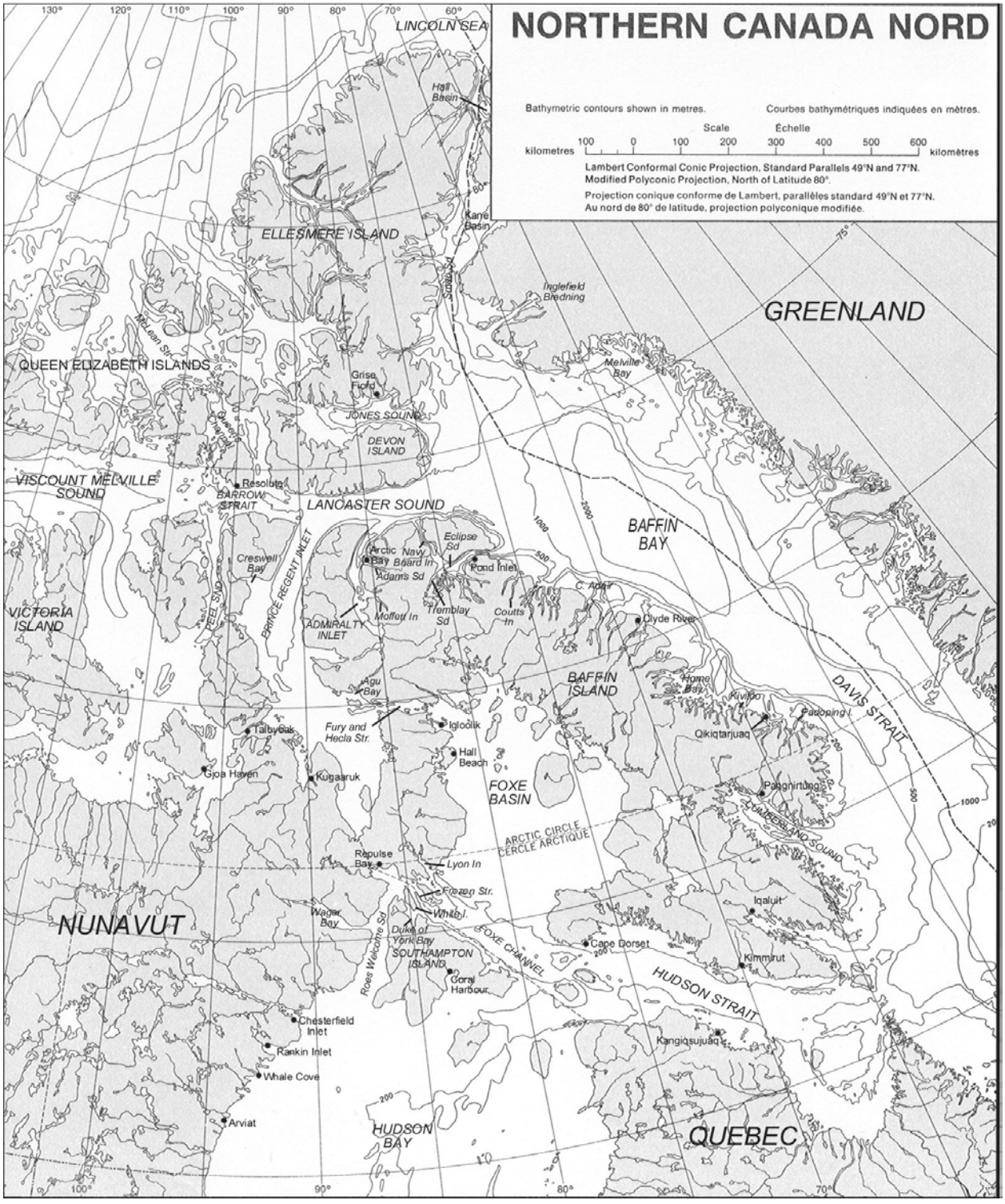

Figure 2. Map referencing the names of locations used within the report.

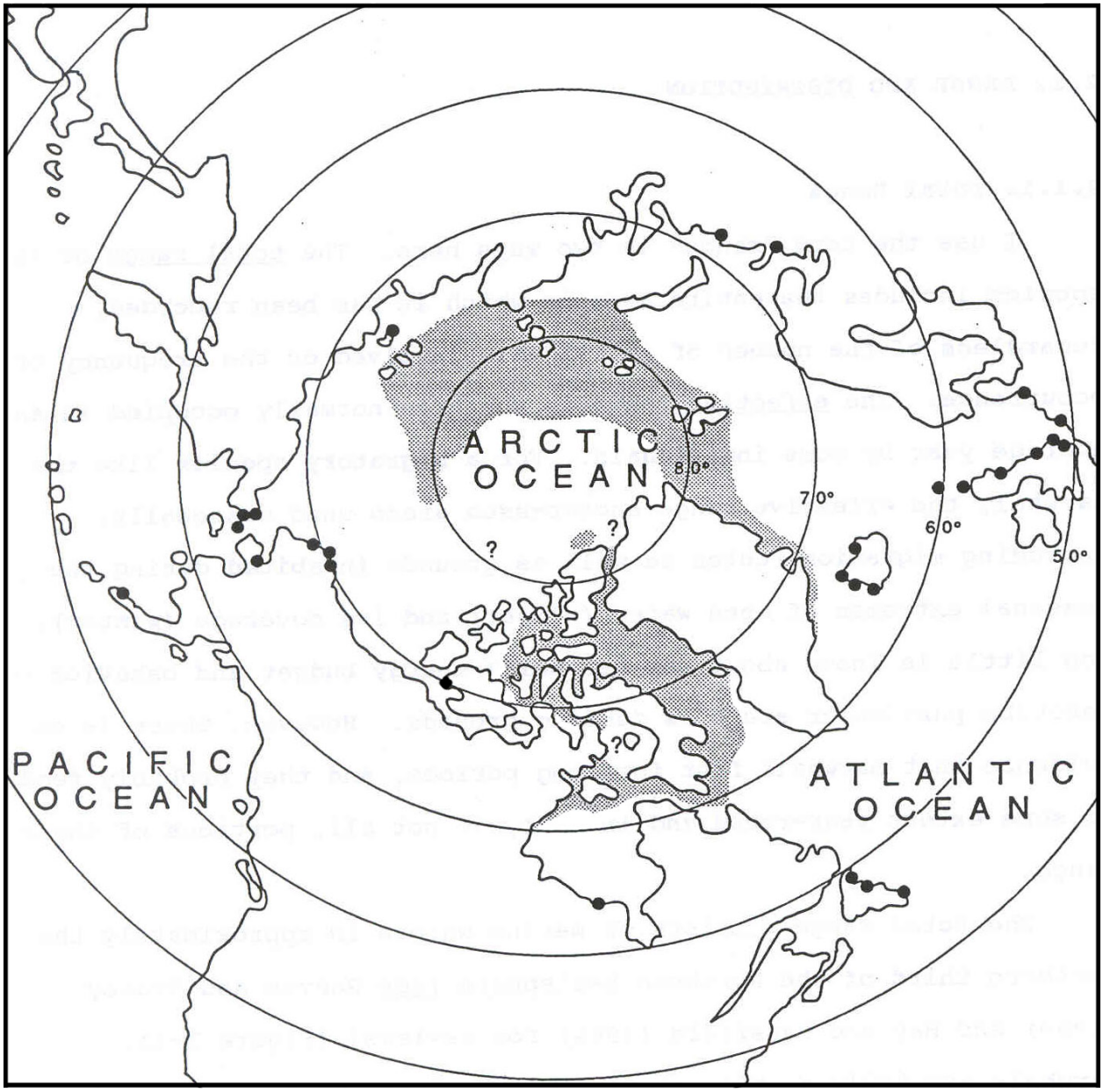

Figure 3. Narwhal distribution as modified from Reeves (1992a) using reference material cited in text. Stippling indicates the species' general distribution and the dots indicate extralimital reports.

Studies of molecular genetics from narwhals taken in Canada and Greenland have yet to find strong, consistent differences that would lead to better population definition (Palsbøll *et al.* 1997; de March *et al.* 2001, 2003). Genetic differences were observed by these studies, but their interpretation is confounded by the fact that samples from a particular area are typically small and non-random. However, narwhals from Repulse

Bay were significantly differentiated from most high Arctic locations for both microsatellite alleles and mitochondrial DNA (de March *et al*. 2003). Comparison of contaminant composition may be more useful for the delineation of narwhal populations (JCNB/NAMMCO 2001; de March *et al*. 2003). Whales taken from the Repulse Bay, Pond Inlet, Grise Fiord, and Broughton Island areas have different organochlorine contaminant profiles, with those from Repulse Bay being the most distinct (de March and Stern 2003).

Canadian range

The seasonal range of narwhals in Canada extends throughout the eastern Canadian Arctic south to northwest Hudson Bay, west to Viscount Melville Sound and north to the northern tip of Ellesmere Island (Figure 4). Animals from the Baffin Bay population occupy the northern portion of this range; those from the Hudson Bay population occupy the south. The population affinity of animals that may summer north of Baffin Bay and along the eastern and southern coasts of Baffin Island is unknown. Inuit have described changes in the species' seasonal distribution.

Baffin Bay Population

In summer, narwhals from the Baffin Bay population probably move into waters of the Canadian Arctic Archipelago as far north and west as ice conditions permit (Figure 4). Their range certainly extends from southern Baffin Island north into Hall Basin (Greeley 1886; Peary 1907; Borup 1911; Vibe 1950), and probably into the Lincoln Sea, and it extends west into Viscount Melville Sound (Strong 1988; Richard *et al*. 2001). Lancaster Sound is an important migration route in the spring and fall for Baffin Bay narwhals moving to and from summering grounds in Barrow Strait, Peel Sound, Prince Regent Inlet, Admiralty Inlet and the Eclipse Sound area (Read and Stephansson 1976; Richard *et al*. 1994). The area of these summering grounds could be close to 300,000 km². Many animals spend the summer in these areas, but some may enter northern Foxe Basin via Fury and Hecla Strait (Stewart *et al*. 1995). Little is known of their distribution in the interior channels of Queen Elizabeth Islands, but narwhals have been seen in Queens Channel and in McLean Strait between King Christian and Lougheed islands (Roe and Stephen 1977). They are rare to the southwest in waters surrounding Victoria and Banks Islands but there are incidental reports of their occurrence in the Beaufort and Bering seas (Huey 1952; Geist *et al*. 1960; Smith 1977) and at Bell Island, Newfoundland (Mercer 1973). In summer, concentrations of narwhals from the Baffin Bay population are also found at Melville and Inglefield bays in West Greenland (Born 1986, Born *et al*. 1994; Heide-Jørgensen 1994).

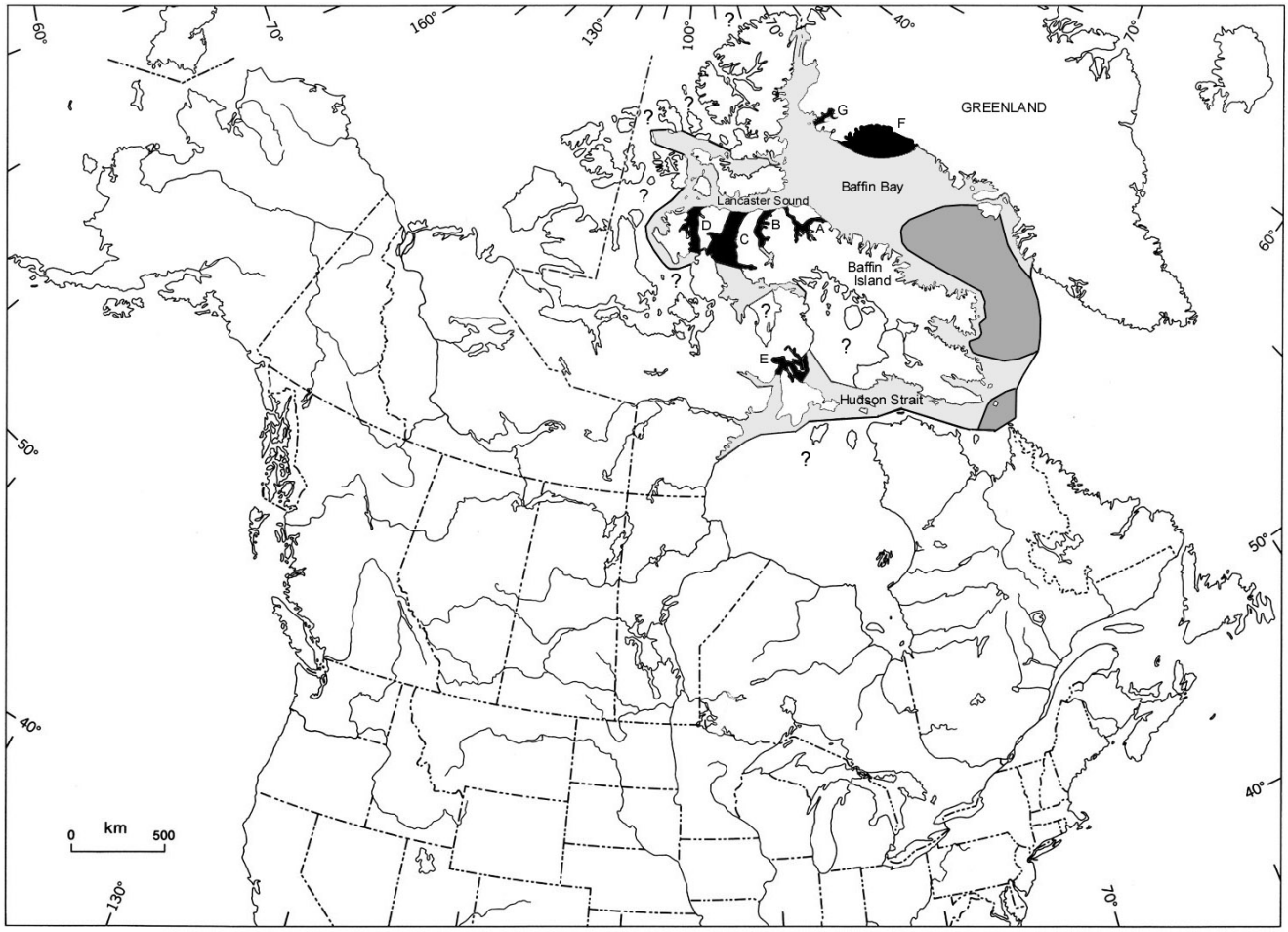

Figure 4. Distribution of narwhals in Canada. Modified from Strong (1988) to include material from literature cited in text. Summer concentrations in solid black include: A. Eclipse Sound/Navy Board Inlet, B. Admiralty Inlet, C. Prince Regent Inlet, D. Peel Sound, E. Foxe Channel, F. Melville Bay, and G. Inglefield Bredning. Wintering concentrations are shown in medium grey and known range in pale grey. Question marks indicate areas where the extent of the narwhal's distribution is uncertain.

Narwhals from the Baffin Bay population that summer in Canada and Greenland winter together in Baffin Bay and Davis Strait (Dietz *et al*. 2001). Observations from aerial surveys in the late winter and early spring (mid-March to late May) suggest that they are distributed throughout the close pack ice in Davis Strait and southern Baffin Bay south to 64°N (Turl 1987; Heide-Jørgensen *et al.* 1993; Koski and Davis 1994). Narwhals are more numerous in winter south of 64°N, and are found at least as far north as Smith Sound in winter. Recent satellite tracking studies suggest that they may tend to concentrate along the edges of the continental shelf near the southern tip of the deep trough that extends down the middle of Baffin Bay and Davis Strait, midway between Canada and Greenland (Dietz *et al.* 2001; Heide-Jørgensen *et al.* 2002). Narwhals also overwinter in leads and polynyas of the "North Water" of Baffin Bay (Finley and Renaud 1980; Richard *et al.* 1998).

Hudson Bay Population

The summer range of the Hudson Bay narwhal population includes the waters surrounding Southampton Island, with the largest aggregations in Repulse Bay, Frozen Strait, western Foxe Channel and Lyon Inlet (Richard 1991; Gaston and Ouellet 1997; DFO 1998a; Gonzalez 2001; P. Richard, pers. comm. 2002). The area of these summering grounds is roughly 17,000 km². Whales from this population also summer, typically in smaller numbers, in Wager Bay or Duke of York Bay. There are no indications of large summer aggregations elsewhere in Hudson Bay or in James Bay, Hudson Strait or southern Foxe Basin. Sightings of narwhals to the south near Arviat and east near Cape Dorset are unusual and have been attributed to the presence of killer whales (*Orcinus orca*) (Higgins 1968; W. Angalik, pers comm. in Stewart *et al*. 1991). Narwhals were not seen in central or eastern Foxe Channel during a visual aerial reconnaissance survey of Foxe Channel on 8 August 2000 (P. Richard, pers. comm. 2002). Thorough searches of the historical literature for the Quebec coast of Hudson Bay and James Bay have not found reports of narwhals (Reeves and Mitchell 1987). Three narwhal carcasses have been found along the Ontario coast of Hudson Bay (Johnston 1961).

Hudson Strait appears to be an important migration route for this population in the spring and fall, but there is no evidence of movement northward into Foxe Basin (Richard 1991; Gonzalez 2001). Most animals follow the east coast of Southampton Island on their way to and from Hudson Strait, but some occasionally visit Coral Harbour. The population is believed to winter mainly in eastern Hudson Strait where hundreds of narwhals were seen during aerial surveys in March 1981 (McLaren and Davis 1982; Richard 1991; Koski and Davis 1994). Some animals also winter in open leads and polynyas of northern Hudson Bay and western Hudson Strait (Sutton and Hamilton 1932; Richard 1991). Narwhals are only seen during late spring or early summer, May or June, in the Kangiqsujuaq area (Fleming 2002).

Narwhals of unknown population affinity

Narwhals may also summer north of Baffin Bay, in the Smith Sound-Kane Basin area, and in the fiords of eastern and southern Baffin Island. The population affinity of these whales is unknown. On 5 July 1979, 1216 narwhals were counted at the ice edge in northern Smith Sound (Koski and Davis 1994) before they dispersed to their summering grounds (Born 1986). The presence of narwhals in Hall Basin (81°30'N, 63°00'W) suggests that these whales may move northward as the ice deteriorates. Studies have not been conducted to confirm their summer destination.

Summer use of the Home Bay area of eastern Baffin Island is supported by the observations of Inuit hunters (Haller 1967; Brody 1976; Remnant and Thomas 1992), and by the sighting of 300 narwhals east of Kekertal Island on 1 August 1985 (68°38'N, 67°36'W; Guinn and Stewart 1988). These animals were moving northward and no correction was made for submerged animals. Narwhals may also summer in the fiords of southern Baffin Island where over 400 animals were seen in Totnes Road (66°22'N, 62°20'W) on 18 July 1985, 50 on 22 July in Sunneshine Fiord (66°34'N, 61°39'W), and

>100 in Totnes Road on 23 July (Guinn and Stewart 1988). On the 23 of July, hunters also harvested 3 narwhals at Delight Harbour (67°02'N, 62°44'W). These sightings are well past the typical entry date of narwhals from the Baffin Bay population into Lancaster Sound (Greendale and Brousseau-Greendale 1976; Koski 1980a) or from the Hudson Bay population into the Repulse Bay area (Gonzalez 2001).

Changes in Seasonal Distribution

Scientific studies have not identified any large-scale changes in the seasonal distribution of narwhals, but Inuit have observed local changes. In the late 1970s, narwhals stopped frequenting the areas around Kivitoo and Padloping Island, but began to appear near Qikiqtarjuaq and Canso Channel (67°15'N, 63°35'W) and in the fiords in between (Remnant and Thomas 1992). Until the 1970s, narwhals in the Clyde River area were mainly transients migrating south in the fall. Since then they have remained in the area from spring to fall. Since the 1970s, narwhals have been seen more often in the sounds and bays south of Eclipse Sound. They have been seen since the 1980s in the Coutts Inlet area and further south towards Clyde River. Since the 1960s, narwhals have become less common near Pond Inlet and tend to travel down the middle of the inlet. Hunters attribute this change to an increase in the number of people hunting and traveling with motorboats and snowmobiles near the community. Hunters at Resolute, Arctic Bay, and Repulse Bay have made similar observations (Remnant and Thomas 1992; Stewart *et al*. 1995; Gonzalez 2001). In the Arctic Bay area, some hunters report that narwhals now make less use of the inlets off Admiralty Inlet and arrive later in the year when the ice is unsafe for travel (Stewart *et al*. 1995).

HABITAT

Habitat requirements

Narwhals inhabit a vast area of the Arctic, but little is known of their actual habitat requirements. In summer, they show preference for coastal areas that offer deep water and shelter from the wind (Finley 1976; Kingsley *et al.* 1994; Richard *et al.* 1994). Remote sensing studies suggest that they may prefer to locate near thermal boundaries that are created by upwellings and frontal areas where water masses meet (Barber 1989). However, blubber loss by female narwhals suggests that their summer habitat selection may be related more to calving requirements than feeding opportunities (Finley and Gibb 1982). During their fall migrations, and later while wintering in the pack, narwhals show preference for deep fjords and the continental slope, where depths range from 1000 to 1500 m and upwellings may increase biological productivity (Dietz and Heide-Jørgensen 1995; Dietz *et al.* 2001). The quality of the ice habitat, particularly the presence of leads in fast ice and the density of broken pack ice, appears to be a key aspect of their habitat selection (Koski and Davis 1994). The ice may also provide refuge from predation by killer whales.

Trends

The potential effects on narwhal populations of changes in ice habitat resulting from climate change have not been evaluated. This is an important question since the species' range and distribution may be directly related to long-term temperature fluctuations and the resultant ice cover (Vibe 1967).

BIOLOGY

General

Age determination of narwhals continues to be a source of debate and a problem for population biologists. Layers of periosteal bone and tooth dentine and cementum are deposited throughout most of the animal's life as it continues to grow. These growth layer groups (GLGs) provide a record of the animal's growth and longevity. Unfortunately, mark-recapture experiments have not been conducted to confirm the rate of layer deposition, which may vary with age (Hay 1980). Young fast-growing animals may deposit three growth layers annually, while adult females may only deposit one in the tooth and mandible annually. As females approach physical maturity, they appear to resorb layers as fast as they deposit them. For population management purposes, narwhals in Canada are assumed to deposit one layer of periosteal bone on the mandible and one dentinal layer on the unerupted tooth annually (Hay 1984). The maximum number of mandibular periosteal growth layers that have been recorded is about 50 in males and 30 in females. Based on aspartic acid racemization in narwhal teeth, this may underestimate the actual age of narwhals (Bada *et al.* 1983). While the species' longevity may be about 50 years, most animals probably do not reach the age of 30 (Bada *et al.* 1983; Hay 1984). Recent studies by Neve (1995b) suggest that two growth layer groups may be deposited annually on the mandible and tooth cementum of male narwhals. The function of the male narwhal's spectacular ivory tusk, which has long been sought after by humans, continues to be a matter for speculation.

Reproduction

Narwhals are seasonal breeders (Best and Fisher 1974; Hay 1984; Hay and Mansfield 1989). The females are polyoestrous and experience up to four consecutive ovulations during the breeding season (Hay 1984).

Conception occurs between 20 March and 19 May, peaking in mid-April (Hay 1984). The gestation period has been estimated at between 14 (Best and Fisher 1974) and 15.3 months (Hay 1984). Two foetal length classes are found in narwhals that are hunted during the summer, one that is very small (10-40 cm) and another that is near term (140-170 cm) (Hay and Mansfield 1989; Stewart *et al.* 1995; Gonzalez 2001). Neonates are typically about 160 cm and 80 kg (Hay 1984; Neve 1995a). Most calves are born in July and August (Mansfield *et al.* 1975; Hay 1984; Hay and Mansfield 1989). However, the presence of newborn narwhals in Lancaster Sound on 27 May, and regularly thereafter during the spring of 1986 (Cosens and Dueck 1990), suggests that the breeding and calving periods are either broader than reported or vary significantly

between years and/or locations. There are few newborn calves at the Repulse Bay ice edge in July (Gonzalez 2001).

Mature females produce a calf about once every three years on average (Hay and Mansfield 1989; Kingsley 1989). About 20% of mature females calve every 2 years (Hay 1984). The proportion of females becoming pregnant in any one year is between 0.30 and 0.38. The crude birth rate is about 0.07 for Lancaster Sound (Hay and Mansfield 1989). Calves are weaned at 1 to 2 years of age (Hay 1984).

Lacking accurate information on the true age of narwhals beyond the age of sexual maturity, population biologists must assume that they live, grow and reproduce much like belugas and have used data from the beluga as estimates for the biological traits of narwhals (JCNB/NAMMCO 2001).

Vital rates for narwhals are uncertain due to the lack of a proven method to estimate age. The available data suggest that females mature at 5 to 8 years (Braham 1984; Kingsley 1989)—possibly 4 to 9 years (Neve 1995a), and produce their first young at 7 to 13 years (Kingsley 1989). Reproductive senescence in females may begin at about 23 years (Hay 1984). Male narwhals are believed to mature at 11 to 13 years (Hay 1984; Kingsley 1989)—possibly 12 to 16 years (Neve 1995a).

Lacking reliable age estimates, generation time cannot be calculated accurately using discrete age classes. Braham (1984) estimated the generation time of narwhals at about 10 years, which seems low. Assuming ages of maturity (α) of 7 y and reproductive senescence (ω) of 23 y, a simplistic calculation of generation time (T), where $T = (\alpha+\omega)/2$, yields an estimate of 15 years. This calculation ignores the fact that many females die before reaching reproductive senescence. However the effect of this omission may be more than offset by uncertainty in the estimate of reproductive longevity, which may be conservative. Instantaneous adult mortality and net recruitment rates for narwhals are unknown.

There is disagreement between biologists and Inuit as to the reproductive rate of narwhals (Remnant and Thomas 1992; Stewart *et al.* 1995; Gonzalez 2001). Scientific reproductive rates are based on examination of the ovaries and uterus. Because the gestation period of narwhals is greater than 12 months, as demonstrated by the presence of two foetal age classes in summer, narwhals cannot breed annually. Based on the proportion of the mature females in the population that are pregnant at any one time, narwhals appear to breed about every three years on average. Many Inuit believe that narwhals give birth more frequently because they have seen females accompanied by more than one calf, sometimes by a neonate, yearling, and two-year-old. Their assumption that the female gave birth to each of these calves has not been tested.

Survival

There are no direct estimates of survival rates for narwhals, only reasonable guesses based on analogies to other odontocetes. In modeling narwhal population

dynamics, Kingsley (1989) found that uncertainty in the values of survival rates of adults and young contributes twice as much to the uncertainty in population growth rates as does uncertainty in reproductive rates. Removal by humans is perhaps the greatest and most consistent cause of mortality among narwhals. The rate of mortality from predation by killer whales and polar bear (*Ursus maritimus*) is unknown and may vary significantly depending on the annual presence of killer whales and ice. The potential for large-scale mortality due to entrapment by ice or disease is unpredictable.

Ice entrapment

Reports of narwhals being entrapped by ice come from a number of sites. Whales from the Baffin Bay population have been trapped by ice in Eclipse Sound (Munn 1932); at Moffet Inlet and near Pond Inlet (Degerbøl and Freuchen 1935); in Adams Sound (Remnant and Thomas 1992; Stewart *et al*. 1995); at Dundee Bight (76°04'N, 100°10'W) of May Inlet, Bathurst Island; in Agu Bay and near Pond Inlet (Mitchell and Reeves 1981); and in the vicinity of Fury and Hecla Strait (Stewart *et al*. 1995). Narwhals from the Hudson Bay population have been trapped by ice in Lyon Inlet (Degerbøl and Freuchen 1935), near White Island, and in Ross Bay (66°52'N, 85°00'W) (Gonzalez 2001). Few large entrapments have been reported from Canadian waters. The largest on record was at Moffet Inlet in March 1924, when at least 600 narwhals were entrapped (Degerbøl and Freuchen 1935; Mitchell and Reeves 1981). About 400 whales were killed, some drowned, and the remainder escaped when a lead formed in the ice.

When these entrapments occur early in the winter the mortality rate is likely high but the survival rate of animals trapped later in the season may be better, provided they are not hunted or found by bears. These catastrophic events are a significant and unpredictable cause of mortality for the species.

Predation

The rate of predation on narwhals by killer whales and polar bears is unknown but may be significant. When killer whales are present narwhals hide in broken pack ice or shallow nearshore waters (Freuchen and Salomonsen 1958; Steltner *et al*. 1984; Campbell *et al*. 1988; Reeves and Mitchell 1988; Gonzalez 2001). They breathe quietly to avoid detection and stop vocalizing instantly when killer whales approach (Ford 1987). Their fear is such that they will ignore humans. Killer whales appear to prefer non-tusked narwhals (Gonzalez 2001).

Hunters in the Repulse Bay area see killer whales more frequently now than in the past and have expressed concern about killer whale predation on narwhals (Gonzalez 2001). The frequency of seasonal visits by killer whales to Hudson Bay, and their effect on the narwhals is unknown (Reeves and Mitchell 1988; DFO 1998a; Stewart *et al*. 1991). Killer whales may have driven narwhals close to Cape Dorset in the 1960s (Higgins 1968), south to Arviat in 1988 (W. Angalik, pers. comm. in Stewart *et al*. 1991), and into shallow water in the Repulse Bay area in 1999 (Gonzalez 2001). The latter resulted in an unusually large harvest of narwhals by Repulse Bay (Tables 1 and 2).

Killer whales also made hunting narwhals easier in the Repulse Bay area in 1998, and in the Lyon Inlet area in 2000.

Polar bears will kill narwhal calves (Kingsley 1990) and prey upon stranded narwhals (Smith and Sjare 1990). Hunters have described parallel claw scars from unsuccessful bear attacks on the backs, sides, and tails of narwhals (Kingsley 1990; Stewart *et al.* 1995). Greenland shark (*Somniosus microcephalus*) scavenge dead narwhals, but it is not known whether they also prey upon narwhals (Beck and Mansfield 1969; Stewart *et al.* 1995). Walrus have been found eating dead narwhals (Gray 1939 in Hay and Mansfield 1989).

Diseases and parasites

Little is known of the diseases of narwhals and their response to pathogens (Murray *et al*. 1995; Nielsen *et al*. 2000).

The skin fold at the base of the tusk and wounds on the body of narwhals are frequently infested by the amphipod whale lice *Cyamus nodosus* Lütken and *C. monodontis* Lütken (Porsild 1922; Hay and Mansfield 1989). Five species of endoparasites have been found in narwhals (Hay and Mansfield 1989).

Physiology

Little is known of the physiological requirements of narwhals or of the species' ability to adapt to changes in its environment.

Movements/dispersal

Narwhals display a pronounced seasonal migratory cycle, the timing of which can vary by a month or more from year to year, depending upon ice conditions. They generally travel in groups (pods) of <10 animals that are dispersed during localized movements in summer, but gather into concentrations of many hundreds of animals during directed migrations in the spring and fall (Silverman 1979; Koski 1980a; Guinn and Stewart 1988; Cosens and Dueck 1991; Koski and Davis 1994; Richard *et al.* 1994). Most travelling to new areas occurs at the surface and their swimming speed averages 5.0 km/h whether they are travelling horizontally or diving vertically (Heide-Jørgensen *et al*. 2001). Narwhals can reach peak speeds of 20 km/hr (Richard 2001).

There is good agreement between scientific (e.g. Finley 1976; Koski and Davis 1994; Richard *et al.* 1994; Dietz *et al.* 2001; Heide-Jørgensen *et al*. 2003) and traditional knowledge (e.g. Remnant and Thomas 1992; Stewart *et al.* 1995) of the general timing and progression of the Baffin Bay populations' migrations. Narwhals from this population move northward along the ice edge offshore the east coast of Baffin Island in April and May (Remnant and Thomas 1992; Stewart *et al.* 1995; Stewart 2001; Heide-Jørgensen *et al*. 2003). They then move westward into the sounds of eastern Baffin Island and into Lancaster Sound and adjoining waters as the ice permits,

following cracks and leads, typically during June and July, to reach their summering habitats in the Eclipse Sound area, Admiralty Inlet, Prince Regent Inlet, Barrow Strait and Peel Sound. Some animals may travel south out of Prince Regent Inlet through Fury and Hecla Strait and into Foxe Basin (Brody 1976; Stewart *et al.* 1995). When landfast ice begins to form, typically in September or October, the whales begin to move out of the sounds and inlets adjoining Lancaster Sound and the sounds of eastern Baffin Island. Some of the animals from the Lancaster Sound region continue eastward, moving offshore from southeastern Devon Island towards Baffin Bay (Koski and Davis 1994). Most of them move eastward out of Lancaster Sound and then south along the east coast of Baffin Island, visiting many of the fiords on their way to wintering areas in southern Baffin Bay and northern Davis Strait. The narwhals that visit Fury and Hecla Strait may retrace their route to exit via Lancaster Sound, or they may continue southward through Foxe Basin and Hudson Strait to complete the circle.

Thirteen narwhals tagged in August at Tremblay Sound remained in Eclipse Sound and its tributaries until they moved south in late September (Dietz et al. 2001; Heide-Jørgensen *et al.* 2002). However, three animals travelled west into southern Admiralty Inlet and to Creswell Bay area of Prince Regent Sound in late August and early September before moving east and south. They visited many fiords along the east coast of Baffin Island on their way, passing Cape Adair in late September or early October and reaching their wintering grounds in the pack ice of southern Baffin Bay and Davis Strait in late October or early November. The speed and range of their movements declined from 85 km/day enroute to the wintering grounds to 29 km/day once the wintering ground was reached. Their late summer and winter kernel home ranges were about 3,417 km² (SD 3,900, range 874-11,275 km²) and about 12,000 km², respectively (Heide-Jørgensen *et al.* 2002). At least three of the animals tagged at Tremblay Sound wintered in the same general area of Davis Strait as narwhals tagged at Melville Bay, Greenland (Dietz and Heide-Jørgensen 1995).

Sixteen female narwhals tagged at Creswell Bay (72°45'N, 94°05'W) in August 2000 and 2001 were also tracked by satellite (Heide-Jørgensen *et al*. 2003). They remained within <200 km of the tagging site during August and followed specific migration corridors east and south in the fall to their wintering grounds in the consolidated pack ice of Baffin Bay. They remained there from November through April but in a different area than the animals from Tremblay Sound. In May through July they followed the receding ice edge back into Lancaster Sound. The areas of their summering and wintering grounds were 9,464 km² (7 whales, 95% common kernel range, SD = 4718) and about 25,846 km² (3 whales), respectively. Two of the animals were followed for a complete migratory cycle and returned to the summering grounds they occupied in Peel Sound the previous year.

The degree of site fidelity shown by narwhals, particularly those of the Baffin Bay population, is an important unanswered question. Only two narwhals have been followed for an entire migratory cycle and both returned to Peel Sound in two consecutive years (Heide-Jørgensen *et al*. 2003). This demonstrates strong site fidelity on the part of at least some female narwhals. It does not confirm whether this behaviour is widespread

among narwhals or consistent over the life of individual animals. Likewise, while none of the Tremblay Sound and Melville Bay narwhals traveled to another area of aggregation after they were tagged, it is not known whether there was exchange between the summering aggregations earlier in the season or between years (Dietz *et al.* 2001). Narwhals that summer in Eclipse Sound are vulnerable to being killed by hunters from Pond Inlet in the summer and by hunters from Clyde River in the fall. It is not known whether other animals that summer in Canadian waters are also vulnerable to hunting by hunters from several Canadian communities (JCNB/NAMMCO 2001).

The seasonal movement patterns of the Hudson Bay narwhals are not well known. In the spring, they likely migrate westward from putative wintering grounds in eastern Hudson Strait (Richard 1991; Koski and Davis 1994), traveling offshore through Hudson Strait and Foxe Channel until they reach the floe edge east of Repulse Bay in late June (Gonzalez 2001). They move into their summering grounds in western Foxe Channel, Frozen Strait, Lyon Inlet and Repulse Bay as ice conditions permit and typically remain until late August or early September, when they travel southeastward out of the area through Frozen Strait, following the east coast of Southampton Island. Narwhals are seldom seen west of Southampton Island or along the west coast of Hudson Bay unless killer whales are present, but they are seen on occasion at the floe edge near Coral Harbour in late June or early July, and in late August or early September.

Narwhals from the Hudson Bay population are not known to move north of Lyon Inlet (Richard 1991; Gonzalez 2001), but observations of whales passing east of Igloolik Island on their way north to Fury and Hecla Strait (Stewart *et al.* 1995) suggest that there may be some northward movement of narwhals into the region. It is also possible that these whales are resident in the region or are members of the Baffin Bay population returning northward. Tagging studies have not followed whales from the Hudson Bay population between their summer and winter habitats or whales from the Igloolik area to their wintering habitat.

Nutrition and interspecific interactions

Narwhals eat a small variety of fishes and invertebrates. The composition of their diet varies with season and location, likely in response to dietary preferences and the seasonal or geographical availability of prey species (Neve 1995a). They appear to feed year-round but may increase their food intake prior to migration (Remnant and Thomas 1992; Stewart *et al.* 1995). Tomilin (1957) described them as “teuthophages” or squid eaters, citing their reduction in teeth, wide rostrum, coarse palatal surfaces, and deep-diving ability as adaptations for feeding on squids.

The diet of narwhals hunted from mid-June through August in the Pond Inlet area consists mostly of fish and squid (Finley and Gibb 1982). Stomach samples (n=93) pooled over two years contained: Arctic cod *B. saida* (51% wet wt.), turbot *Reinhardtius hippoglossoides* (37%), squid *Gonatus fabricii* (7%), and polar cod *Arctogadus glacialis* (6%). Small amounts (<1% wet wt.) of other fishes (dark belly skate *Raja hyperborea,* snailfish *Liparis* spp., redfish *Sebastes marinus*, eelpouts *Lycodes* spp. and sculpin

Cottidae) and invertebrates (octopus *Bathypolypus arcticus*, and crustaceans *Boreomysis* spp.) were also present. Most (61%) of these samples were taken from adult male narwhals. Narwhals had more food in their stomachs when they were taken at the ice edge or from ice cracks than from open water. The largest item found was a whole turbot weighing 2.4 kg. [Note: in Greenland *B. saida* is known as polar cod and *A. glacialis* as Arctic cod; turbot are also known as Greenland halibut].

Other scientific studies of the diet of narwhals in Canada and West Greenland have found the same prey species but in different proportions (e.g. Vibe 1950; Bruemmer 1971; Hay 1984; Hay and Mansfield 1989; Roberge and Dunn 1990; Heide-Jørgensen *et al.* 1994; Neve 1995a). Inuit hunters have made similar observations (Remnant and Thomas 1992; Thomsen 1993; Stewart *et al.* 1995). Arctic and polar cod, turbot and squid are all eaten in quantity during the open water season, and narwhals feed heavily on shrimps (*Pasiphaea tarda*) as they migrate through breaking fast ice of Pond Inlet, Eclipse Sound, and Admiralty Inlet in late June and July (Hay and Mansfield 1989). Inuit hunters have also found Greenland cod (*Gadus ogac*) in narwhal stomachs (Stewart *et al.* 1995) as well as Arctic charr (*Salvelinus alpinus*) (Remnant and Thomas 1992). Arctic cod are abundant under the ice edge of Admiralty Inlet in June, coincident with the presence of narwhals (Crawford and Jorgenson 1990).

Little is known of the narwhal diet from late autumn to spring. Neve (1995a) found mainly squid *G. fabricii* in the October-November diet of narwhals taken in West Greenland (Uummannaq) and shrimp *Pandalus* spp. in March-April samples from the Disko Bay area.

Little is known about the interactions between narwhals and other species for food and habitat. Their preference for deepwater habitat effectively separates them from belugas for much of the summer. They do participate with belugas, harp seals (*Phoca groenlandica*) and seabirds in mass feeding frenzies on Arctic cod, which they occasionally drive into shallow water in late summer (Finley and Gibb 1982; Welch *et al.* 1993).

Commercial fisheries in Baffin Bay, Davis Strait, and Cumberland Sound may increasingly compete with narwhals for turbot, redfish and other species (Topolniski 1993; Treble and Bowering 2002; M. Treble, pers. comm. 2002). These fisheries take place in open water or through landfast ice and are rarely, if ever, coincident with the presence of narwhals.

The question of whether food availability is a limiting factor for narwhal abundance has not been examined. While narwhals feed heavily on cod and turbot, the extent of their dependence on these species for food is unknown. A significant change in the abundance or distribution of these fishes might adversely affect narwhals.

Behaviour/adaptability

Key aspects of narwhal behaviour that may affect their population numbers and assessment include their sensitivity to noise, affinity for heavy ice cover, fear of the killer whale, and ability to dive deeply and remain under water for long periods.

Noise sensitivity

Narwhals make a variety of sounds and are sensitive to underwater noise. They appear to use click-sounds for orientation and echolocation of prey and squealing, growling, and whistling sounds for communication (Reeves 1977; Ford and Fisher 1978; Ford 1987; Miller *et al*. 1995). Narwhals can detect approaching ships at a distance of 80 km and show behavioural responses at distances of 55-40 km (Finley *et al.* 1984, 1990; Miller and Davis 1984; Cosens and Dueck 1988, 1993). Unlike beluga, which show a "flight" response by aggregating into large herds and moving rapidly away from approaching ships, narwhals show a "freeze" response similar to that seen when killer whales are present (Finley *et al.* 1983, 1984, 1990; Miller and Davis 1984). They return to disturbed areas and resume normal activities faster than beluga, when the noise level from ice-breaking operations is up to 120 dB. Cosens and Dueck (1988) did not observe this "freeze" reaction, perhaps due to the lack of an ice edge in the survey area or habituation to ship traffic. They did observe an increase in slow directed movements. Inuit hunters have observed that narwhals are sensitive to, and avoid, noise from machines and explosions (Remnant and Thomas 1992; Stewart *et al.* 1995; Gonzalez 2001).

Diving behaviour

The narwhal's ability to dive deeply and hold their breaths for long periods enables them to move long distances under water to avoid hunters and to locate areas where they can surface to breathe. In the deep waters of Baffin Bay, narwhals dive to at least 1500 m and daily make dives to depths of over 500 m (Heide-Jørgensen and Dietz 1995; Heide-Jørgensen *et al.* 2002). They can remain under water for at least 26.2 minutes when foraging (Laidre *et al.* 2002) and up to 30 minutes when pursued by Inuit (Gonzalez 2001). Their diving ability makes it difficult to obtain accurate population estimates. Variations in narwhal diving behaviour related to season, location, and sex of the animal complicate the correction of population survey data for animals that were submerged deeply enough to be invisible to the survey. Instead of using a single general correction factor, specific values may have to be determined for each locale and season (Heide-Jørgensen *et al.* 2001).

Ice

Narwhals frequent heavy pack ice for much of the year and follow leads in the ice to their summering grounds. They can be entraped in the ice, and their use of narrow leads also makes them vulnerable to hunting. Narwhals will explore tracks in the ice created by icebreakers (Finley *et al*. 1984; P. Richard, pers. comm. 2002). The effects on narwhals of shipping activities that alter ice habitats are unknown.

Avoidance of killer whale

Narwhals normally avoid people but will ignore them in the presence of killer whale (DFO 1998a; Gonzalez 2001). They seek shallow water and remain immobile, making them easy targets for Inuit who take advantage of this behaviour to hunt the frightened

whales. This behaviour contributed to the unusually large number of narwhals killed by Repulse Bay hunters in 1999 (Table 2) and made hunting easier in 1998 and in the Lyon Inlet area in 2000.

Table 2. Landed harvest and loss and mortality estimates from communities with Community-Based management of the narwhal harvest in 1999-2001 (DFO unpubl. data).

Community	Year	Narwhals landed (#)	Loss estimate (# of animals)		Mortality estimate (# of animals)		Loss rate (% of landed harvest)	
			Killed and lost	Wounded and escaped	minimum	maximum	minimum	maximum
BAFFIN BAY NARWHAL								
Arctic Bay (Tununirusiq)	2001	134	12	12	146	158	9	18
Pelly Bay (Kugaaruk)	2001	37	8	18	45	63	22	70
Pond Inlet (Mittimatalik)	1999	130	16	14	146	160	12	23
	2000	166	10	21	176	197	6	19
	2001	63	27	5	90	95	43	51
Qikiqtarjuaq (Broughton Island)	1999	81	25	30	106	136	31	68
	2000	137	40	79	177	256	29	87
	2001	87	10	9	97	106	11	22
HUDSON BAY NARWHAL								
Repulse Bay (Naujaat)	1999	156	30	68	186	254	19	63
	2000	49	5	9	54	63	10	29
	2001	100	21	38	121	159	21	59

Adaptation to captivity

Narwhals have not been held successfully in captivity. Six whales were captured in 1969-70 for exhibit in public aquaria and all died within four months, likely of pneumonia (Newman 1970; Reeves 1977). In 1987, an attempt to capture narwhals at Pond Inlet for on-site assessment in a large holding tank was unsuccessful (P. Hall, pers. comm. 2002). Animals that are captured for tagging are restrained in the water and released immediately after the tag has been attached (Dietz *et al.* 2001; Laidre *et al.* 2002; Heide-Jørgensen *et al.* 2002).

POPULATION SIZES AND TRENDS

A good estimate of the initial size of the Baffin Bay and Hudson Bay narwhal populations cannot be generated from historical harvest data (Mitchell and Reeves 1981; Reeves 1992a). Consequently, it is not possible to assess whether historical hunting activities have depleted population sizes, and estimates or indices of

abundance from surveys after 1975 are the only benchmarks for future population assessments.

Until 1996, estimates of population size were limited to methods that only estimated a portion of the population (Innes *et al.* 1996). They were based on aerial surveys of areas of aggregation and seldom accounted for narwhals that were submerged beyond view (availability bias), missed by observers because of ice or poor visibility (perception bias), or simply outside the survey area (DFO 1998a, 1998b). They also did not distinguish between mature and immature animals, so changes in the population structure cannot be assessed, and may significantly underestimate young-of-the-year which are more difficult to see and identify from the air (Richard *et al*. 1994). Estimates from the aerial photographic surveys are typically higher than those obtained from simultaneous visual observations (Innes *et al*. 2002; P. Richard, pers. comm. 2002).

More data are required before survey estimates can be accurately corrected for diving animals. Recently, Heide-Jørgensen *et al*. (2001) and Innes *et al.* (2002) applied correction factors for availability and perception bias but noted the need to develop more precise correction factors for availability bias. Land-based observations (Born *et al*. 1994) and dive data from small samples of tagged whales suggest that less than 50% of the animals in a population may be visible at the surface at any one time (Heide-Jørgensen and Dietz 1995; Heide-Jørgensen *et al*. 2001; Laidre *et al*. 2002). Survey estimates are sensitive to violation of the assumption that narwhals are visible and recognizable to a particular depth, typically 5 m.

Baffin Bay Population

Aerial surveys of the pack ice of western Baffin Bay in May 1979 estimated that there were 34,363 (±SE 8282) narwhals at the surface (Koski and Davis 1994). This survey covered about 2/3 of Baffin Bay but missed West Greenland waters and Smith Sound where narwhals also occur in May. The population estimate did not correct for perception bias. If narwhal wintering in Baffin Bay show preference for the edge of the coastal shelf, as recent work by Dietz *et al.* (2001) suggests, it may be worthwhile to revisit these data and recalculate these estimates.

In August 1984, an aerial photographic survey of Eclipse Sound, Admiralty Inlet, Prince Regent Inlet and Peel Sound estimated that there were 17,991 (90%CI 14,724-21,258) narwhals at the surface (Richard *et al.* 1994). This survey covered important areas of summer aggregation for narwhals, but did not cover the entire known summer range of the Baffin Bay population in Canadian waters (Figure 4). The number of Baffin Bay narwhals that summered in the waters of West Greenland in 1984 is unknown, but land-based observers counted 4,043 narwhals passing their observation point in Inglefield Bay on 18 August (Born 1986).

A systematic aerial survey of belugas in Prince Regent Inlet, Barrow Strait and Peel Sound was conducted from 31 July to 3 August 1996 (Innes *et al.* 2002). Visual observations were made in the offshore areas and aerial photographs were taken in the

concentration areas. Narwhals were also counted during the same survey. The visual estimates were corrected for animals missed by the observers, sightings without distance estimates, and for submerged animals to produce an estimate of 45,358 narwhals (95% CI = 23,397-87,932). The submergence correction was obtained from retrievable time-depth-recorders deployed on four narwhals in Creswell Bay and Tremblay Sound (Laidre *et al.* 2002) and assumed that narwhals were visible to a depth of 5 m.

Estimates by Innes *et al.* (2002) of the number of narwhals at the surface of Barrow Strait and Prince Regent Inlet (14,474, CV = 0.24) compare well with those obtained by Smith *et al.* (1985) (11,142, CV = 0.09), considering that the latter was not corrected for animals missed by the observers (perception bias). Likewise, estimates of the number of narwhals at the surface of Prince Regent Inlet (12,324, CV = 0.25) and central Peel Sound (1,891, CV = 0.55) compare well with those obtained by Richard *et al.* (1994) (Prince Regent Inlet 9,754, CV = 0.18; Peel Sound 1,701, CV = 0.17; CV from Innes *et al.* 2002), considering that the latter was not corrected for perception bias. Nevertheless, the statistical power to detect a trend, if there is one, is low given the large variance in the estimates.

Several other systematic surveys have covered smaller portions of the summer aggregation areas (Fallis *et al.* 1983; Smith *et al.* 1985; Dueck and Riewe 1986; Dueck 1989) but these data are not useful for estimating the overall population size or trend (DFO 1998a). The same is true for a number of systematic aerial surveys of migrants in the spring (Finley 1976; Johnson *et al.* 1976; Davis *et al.* 1978; Koski 1980a, 1980b), fall (Stepney and Wooley 1976; Koski 1980b; Koski and Davis 1980), and winter (Heide-Jørgensen *et al.* 2002); of non-systematic surveys (Hay and McLung 1976); and of land-based observations in the spring (Tuck 1957; Greendale and Brousseau-Greendale 1976).

Without recent and complete survey information, and with uncertainty about hunting mortality and natural mortality, it is not possible to provide a quantitative estimate of the size of the Baffin Bay narwhal population, or of that portion of the population that enters Canadian waters. Earlier reports concluded that there was no evidence of population decline (Strong 1988; Remnant and Thomas 1992; Thomsen 1993) and that the “narwhal hunt may be sustainable” (SWG 1997). In fact, although the Canadian population is obviously still large as evidenced by the 1996 survey (Innes *et al.* 2002), the true size and trend of the Baffin Bay narwhal population are unknown. There has been concern about the summering grounds of narwhals hunted in the fall in West Greenland, but recent information suggests that they are not from Canada. Removals due to hunting appear to have risen in recent years (Table 1; Figures 5 and 6), and have increased the urgency of improving knowledge of the Baffin Bay population (JCNB/NAMMCO 2001). To address this need, DFO undertook surveys of the population’s summering grounds in Arctic Canada in August 2002 and 2003 (P. Richard pers. comm. 2004).

There is no clear consensus among Inuit hunters of a population trend in the Baffin Bay population (Stewart 2001). In 1992, most hunters from Qikiqtarjuaq and Clyde River believed that, despite year-to-year variation, the narwhal population in their area

had increased since the 1960s or 1970s (Remnant and Thomas 1992). Most hunters from Pond Inlet, Arctic Bay, Resolute, Igloolik, Hall Beach, and Grise Fiord believed the narwhal population in their area to be stable despite year-to-year variations and changes in local seasonal distributions (Remnant and Thomas 1992; Stewart *et al.* 1995). However, interpretation of this information is confounded by changes in the local seasonal distribution of narwhals.

Hudson Bay Population

Richard (1991) conducted systematic visual and photographic aerial surveys of narwhals in the Repulse Bay area between Roes Welcome Sound and Lyon Inlet, north of Southampton Island in March 1983 and July of 1982, 1983, and 1984. These surveys included the major known summering concentrations of the Hudson Bay narwhal population. The July 1984 photographic survey was repeated in August 2000, with the addition of northern Lyon Inlet and Foxe Channel (P. Richard, pers. comm. 2002). Without correcting the results of either survey for submerged animals, or the latter survey for persistent fog or animals that may have occupied Wager Bay (Gonzalez 2001), the narwhal population was estimated at 1355 (90%CI = 1000-1900) animals in 1984 and 1780 (90%CI = 1212-2492) animals in 2000.

At least 50% of the whales seen in Hudson Bay are believed to be submerged when surveyed. In North Baffin Bay the correction factor may be 2.6 times the number counted based on the proportion seen at the surface (38%, SE = 9%, Innes *et al.* 2002). The current Hudson Bay population likely numbers about 3,500 animals in summer after correcting for submerged individuals. While the 2000 survey result is preliminary, it suggests that the population has not decreased between surveys (1984 and 2000), despite concern over heavy exploitation of the population in 1999 (Table 2; Figure 6). These hunting levels are not believed to reflect ongoing harvest levels, and should not be interpreted to have been sustainable.

LIMITING FACTORS AND THREATS

Narwhal populations in Canada may be limited or threatened by hunting activities, environmental contaminants, industrial activities such as commercial fishing, and climate change. The effects of these factors are mitigated by the species' deepwater habits and widespread geographical distribution, much of which is outside normal hunting areas in offshore pack ice and in isolated areas of the Arctic. This remote distribution protects large numbers of narwhals from hunters as well as isolated oil spills or other events. However, under exceptional circumstances, such as large ice entrapments or when killer whales drive narwhals into shallow water, many animals can be hunted at once from a single locality. The question of whether narwhals that summer in isolated areas serve as a reserve for those in more accessible areas, where they are more vulnerable to extirpation, remains unanswered. Narwhals are not seen as direct competitors with humans for resources, or as a physical threat.

Table 1. Landed harvests of narwhals from communities* in Canada and from Greenland, 1977-2001.

	Historical Quota	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	Total	Average
BAFFIN BAY NARWHAL																												
Arctic Bay	**100****	42	65	33	100	100	90	100	93	100	100	25	86	99	67	114	102	85	99	46	99	66	103	101	101	134	**2150**	**86**
Qikiqtarjuaq (Broughton I.)*	**50****	35	26	21	49	50	50	20	36	49	7	47	26	46	50	50	40	52	50	50	23	50	50	81	135	87	**1180**	**47**
Clyde River	**50**	42	4	9	35	37	19	46	49	5	5	19	44	36	26	35	33	34	25	26	10	15	27	4	48	28	**661**	**26**
Gjoa Haven	**10**	0	0	0	0	0	0	22	0	2	0	0	2	0	0	0	0	0	0	0	0	0	nr	0	0	1	**27**	**1**
Grise Fiord	**20**	0	0	12	0	0	28	3	2	8	2	2	7	5	19	20	1	9	12	9	1	1	10	16		24	**191**	**8**
Hall Beach	**10**	13	0	2	11	17	7	1	0	2	0	0	0	3	0	0	1	0	6	0	1	2	10	0	0	7	**83**	**3**
Igloolik	**25**	0	0	108	14	36	25	18	0	4	1	0	0	0	0	0	25	27	25	18	5	3	29	4	2	6	**350**	**14**
Iqaluit (Frobisher Bay)	**10**	0	0	0	0	0	0	1	1	0	0	0	0	0	3	0	0	0	0	0	0	0	1	0	0		**6**	**0**
Pangnirtung	**40**	3	2	28	19	44	49	2	32	18	31	0	2	40	2	8	4	24	33	6	19	2	2	41	50		**461**	**19**
Kugaaruk (Pelly Bay)	**10****	nr	0	0	0	0	0	0	0	10	0	0	1	1	0	0	0	0	0	5	7	15	8	0	30	41	**118**	**5**
Pond Inlet	**100****	107	150	94	96	82	100	104	45	98	100	52	53	77	69	100	99	79	91	73	100	75	108	130	166	63	**2311**	**92**
Resolute and Creswell Bay	**32**	3	14	2	nr	nr	14	11	0	2	1	0	12	19	22	21	0	8	3	4	2	7	9	1	12	11	**178**	**8**
Taloyoak (Spence Bay)	**10**	nr	0	0	0	0	0	5	0	0	0	0	1	0	0	7	0	0	0	0	0	0	nr	0	3	13	**29**	**1**
Canada	**207**	**245**	**261**	**309**	**324**	**366**	**382**	**333**	**258**	**298**	**247**	**145**	**234**	**326**	**258**	**355**	**305**	**318**	**344**	**237**	**267**	**236**	**357**	**378**	**547**	**415**	**7745**	**310**
Greenland		387	612	377	462	609	461	439	666	256	237	505	500	312	1057	?	?	614	995	485	691	745	775	372	?	?	13340	***550***
BAFFIN BAY TOTAL		**632**	**873**	**686**	**786**	**975**	**843**	**772**	**924**	**554**	**484**	**650**	**734**	**638**	**1315**	**?**	**?**	**932**	**1339**	**722**	**958**	**981**	**1132**	**750**	**?**	**?**	**21085**	**842**
HUDSON BAY (HB) NARWHAL																												
Cape Dorset	**10**	0	2	1	1	0	0	0	nr	0	0	0	1	0	0	16	0	0	1	0	0	0	0	0	0	1	**23**	**1**
Chesterfield In.	**5**	nr	nr	nr	nr	nr	nr	nr	nr	nr	nr	nr	0	0	0	0	0	0	0	0	0	0	3	5	3	2	**13**	**1**
Coral Harbour	**10**	0	0	0	0	0	0	0	0	0	0	12	0	0	0	0	0	1	0	10	10	9	4	0	0	0	**46**	**2**
Kimmirut (Lake Harbour)	**10**	0	0	0	0	0	0	nr	0	0	0	7	0	0	0	0	0	0	0	0	0	0	0	0	0		**7**	**0**
Repulse Bay	**25****	nr	4	30	25	29	21	11	25	15	7	16	25	16	17	3	20	13	5	4	10	35	18	156	49	100	**654**	**27**
Rankin Inlet	**10**	0	0	0	0	5	0	0	2	1	0	0	0	0	0	0	0	0	0	6	7	0			7	3	**31**	**1**
Whale Cove	**5**	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1				2	**4**	**0**
HB TOTAL	**50**	**0**	**6**	**31**	**26**	**34**	**22**	**11**	**27**	**16**	**7**	**35**	**26**	**16**	**17**	**19**	**20**	**14**	**6**	**20**	**27**	**45**	**25**	**161**	**59**	**108**	**778**	**31**
CANADIAN HARVEST		**245**	**273**	**371**	**376**	**434**	**426**	**355**	**312**	**330**	**261**	**215**	**286**	**358**	**292**	**393**	**345**	**346**	**356**	**277**	**321**	**326**	**407**	**700**	**665**	**631**	**9301**	**372**

Source material: Canadian harvests 1977-87 (Strong 1989), 1988 (DFO1991), 1989 (DFO1992a), 1990 (DFO 1992b), 1991 (DFO 1993), 1992 (DFO 1994), 1993 (DFO 1995), 1994 DFO1996), 1995 (DFO 1997), 1996 (DFO 1999), 1997-2001 (DFO unpubl. data); Greenland harvests (JCNB/NAMMCO 2001).

*Community names that were used in the past are enclosed in brackets.

**Harvest limits in these communities are now set by pilot community-based management programs. In 2002, hunters from Arctic Bay were permitted to take 101 narwhals, Kugaaruk 17, Pond Inlet 108, Qikiqtarjuaq 50, and Repulse Bay 72. nr = no report, blank space= report may be forthcoming.

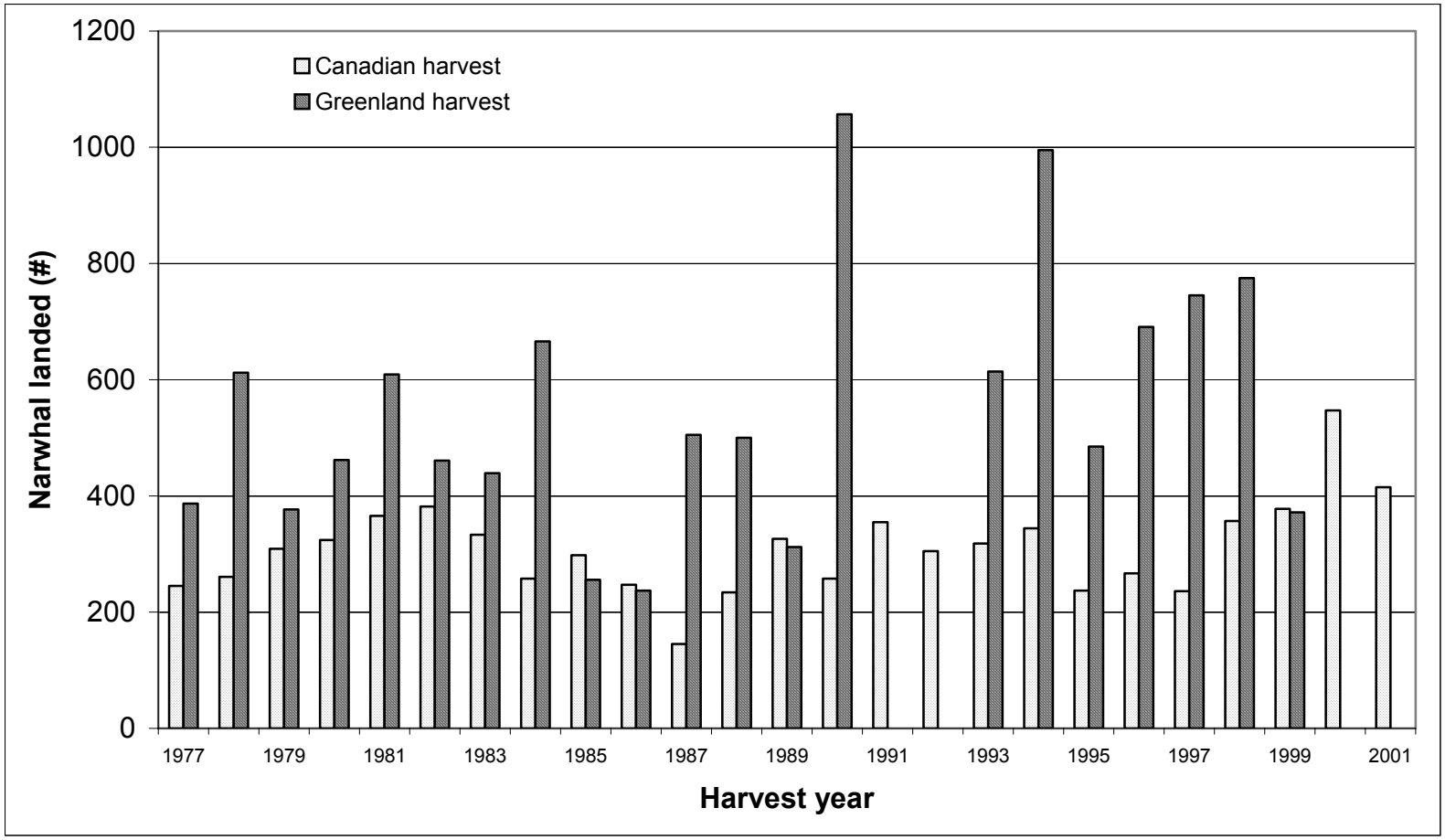

Figure 5. Landed harvests of Baffin Bay narwhals by Canada and Greenland from 1977 to 2001. Source material for the data is provided in Table 1.

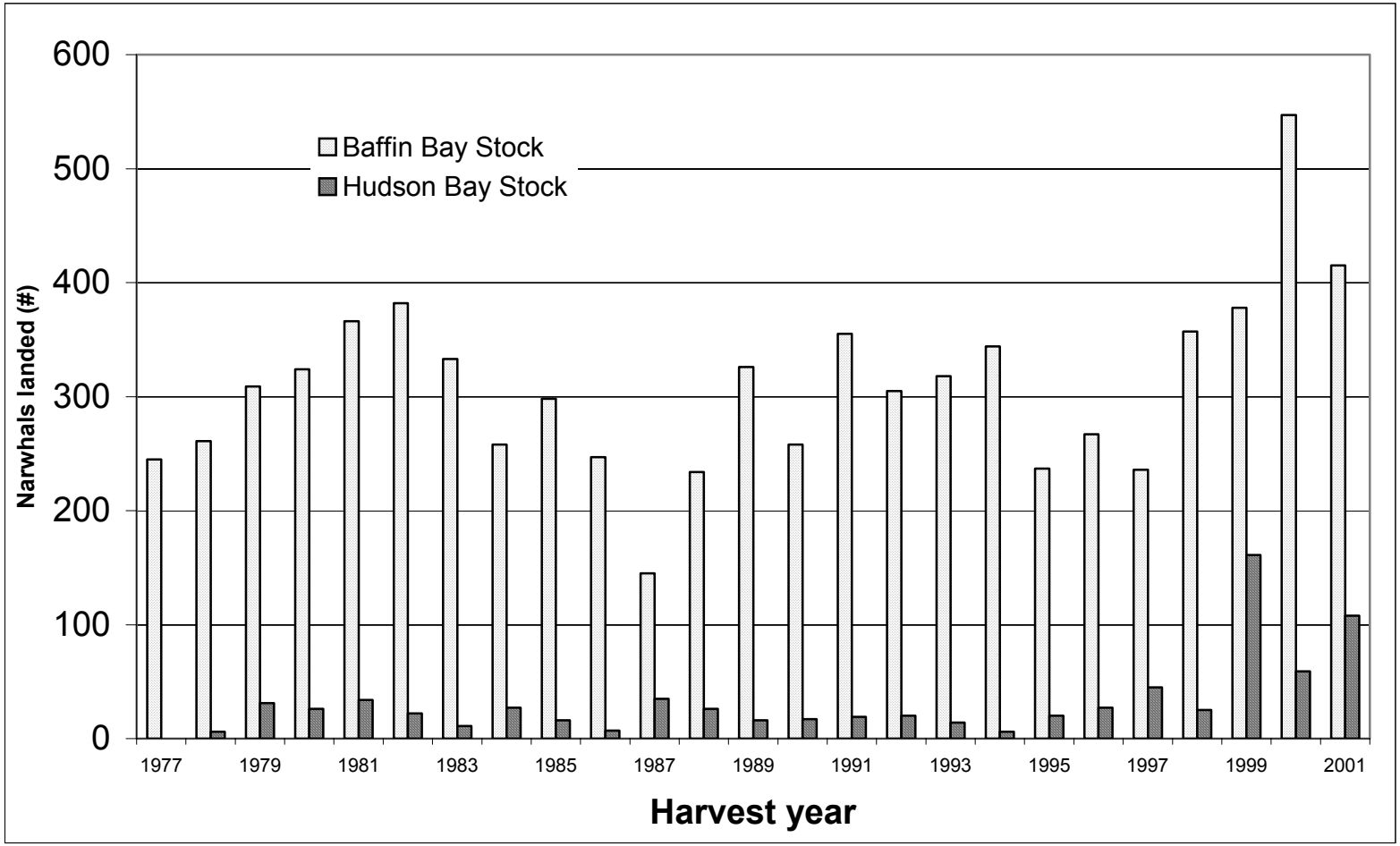

Figure 6. Canadian landed harvests of narwhals from the Hudson Bay and Baffin Bay populations, 1977 to 2001. Source materials for the data are provided in Table 1.

Hunting

Hunting activities probably represent the most consistent limiting factor and threat to narwhal populations in Canada. Inuit residents of 13 communities hunt animals from the Baffin Bay population, while the Hudson Bay narwhals are hunted mainly by residents of Repulse Bay and sometimes by residents of 6 other communities (Table 1). Narwhal are also hunted by the Kugaaruk community following the community-based management system, while Taloyoak and Gjoa Haven have a yearly limit of 10 narwhals each.

Most narwhals are harvested in July and August (Donaldson 1988; Gamble 1988; Guin and Stewart 1988; J. Pattimore, pers. comm. 1986). The hunts begin earlier in the year in Pangnirtung (April), Pond Inlet and Arctic Bay (May) and end later in the year in Clyde River and Qikiqtardjuak (October). The actual number of narwhals killed during these hunts is higher than the number landed, but unknown because few data were collected on the number of animals that were killed and lost. These losses vary depending upon the location, weather, hunter experience, and type of hunt (e.g. floe edge, ice crack, open water). They also vary from year to year. Thus loss rates cannot be extrapolated from one season to another or from one community to another (Weaver and Walker 1988; Roberge and Dunn 1990).

Loss rates are typically highest at the floe edge and lowest during the open water hunt (Roberge and Dunn 1990). Comparison of these rates between studies is confounded by the fact that some studies considered only whales killed and lost, while others also considered whales that were wounded and escaped. The former method tends to underestimate the total kill, and the latter to overestimate it. These two extremes provide a range within which the actual loss rates should lie. Loss estimates from the community-based management hunts in 2001 suggest that on average at least 19 (SD 11; killed and lost only) and perhaps as many as 46 (SD 5; killed and lost plus struck and escaped) animals are lost for every 100 landed (Table 2). These crude annual loss rate estimates are comparable to those from earlier studies, most of which were for portions of the annual hunt (e.g. Hay and Sergeant 1976; Finley *et al*. 1980; Kemper 1980; Finley and Miller 1982; Weaver and Walker 1988; Roberge and Dunn 1990). The collection of struck and lost data is a key contribution of the community-based management program to improving estimates of hunting mortality.

Losses result in part from the fact that narwhals are often shot before they are harpooned (Bruemmer 1971; Stewart et al. 1995). Loss rates are greater among animals that are not harpooned (Gonzalez 2001). In 1979, Pond Inlet hunters tried using harpoon guns to reduce loss rates. This technology proved to be much less practical than .303 calibre rifles and hand-thrown harpoons for killing and securing narwhals (Finley and Miller 1982). In the Pond Inlet area, a high proportion of harvested animals have old bullet wounds (42% Finley *et al*. 1980; 23% Finley and Miller 1982). Many of the communities participating in community-based management require hunters to use harpoons as a means of reducing the number of whales that are struck and lost (M. Wheatley, pers. comm. 2003).

There is strong economic pressure to land tusked males despite a preference for the *maqtaq* of juvenile narwhals (Reeves 1992a). This selection is more successful during on-ice hunts in the spring when the narwhals are shot at close range and the tusk is clearly visible, than during open-water hunts (Reeves 1976). Hunter preference for large-tusked males likely leads to underestimates of numbers of females killed, given that hunters may expend more effort to retrieve male carcasses (Weaver and Walker 1988; Roberge and Dunn 1990).

Lack of reliable age data for narwhals prevents accurate prediction of reproductive and survival rates and thereby sustainable hunts. Sergeant (1981) assumed the sustainable annual hunting rate for narwhals was 5% based on studies of beluga. A more reasonable estimate is probably 3-4% given that the 5% estimate did not incorporate natural mortality (Kingsley 1989). The latter assumes that an equal proportion of male and female narwhals are killed. A bias towards males as seen at Pond Inlet (2:1 Weaver and Walker 1988) and Arctic Bay (3:1 Roberge and Dunn 1990), might increase the sustainable hunting rate, but a bias towards females should reduce it. The extent or direction of this bias over time will likely reflect trends in the price of tusk ivory and, to a lesser extent, maqtaq. Given the uncertainties related to reproductive and survival rates, and the species' vulnerability to unpredictable mass mortality from entrapment in the ice, a more precautionary hunting rate would be 2% (DFO 1998a).

Over the period 1988 through 2001, Canadians landed an average of 327 (SD 85; range 234-547) narwhals annually from the Baffin Bay population, and 40 (SD 43; range 6-161) from the Hudson Bay population. The number of narwhals landed annually from the Baffin Bay population fluctuates widely each year, but removals due to hunting have likely increased recently in both Canada and Greenland (Figure 5; JCNB/NAMMCO 2001). However, Greenland kills may not be relevant based on recent information that suggests that Canadian populations of narwhal do travel to Greenland.

Landings from the Hudson Bay population increased from an average of 22 (SD 9.7) whales per year over the period 1979-1998 to an average of 109 (SD 51) whales per year over the period 1999-2001(Table 1). Unusually large numbers killed by Repulse Bay hunters are responsible for this increase. Repulse Bay may have removed between 5.2 and 6.9% of the Hudson Bay narwhal population in 1999 based on the 2000 survey estimate of 1780 narwhals in the Hudson Bay population (P. Richard, pers. comm. 2002), assuming that at least 50% of the whales may have been submerged and therefore missed by the survey, assuming an annual rate of increase of 4%, and using the community-based mortality estimates (186-254 narwhals; Table 2). Indeed, population mortality in 1999 may have been higher given that predation by killer whales contributed to the hunters' success. The effects on population structure of this simultaneous removal by hunters, who prefer tusked males, and killer whales, that appear to prefer non-tusked narwhals, are unknown. Hunters from the community may also have removed between 3.6 and 4.7% of the population in 2001, when they filled the community-based management hunting limit of 100 narwhals.

The Hudson Bay narwhal population is unlikely to support the rates of removal seen in 1999 and 2001 over the long term, unless the natural rate of increase is greater than 5% per year. In 2002, the community-based management program responded to this concern by reducing the annual harvest limit for Repulse Bay from 100 to 72 narwhals. If the population is smaller than the estimate (i.e. including a correction for submerged animals), or if the natural rate of increase is less than 4%, then the population would be at risk if communities that hunt narwhals from the Hudson Bay population approach their annual limits on a regular basis. Past experience suggests this is unlikely to occur, but it must be monitored (Table 1). Evidence of unusually high mortality from causes other than hunting, such as killer whale predation or ice entrapment, must also be considered when hunting limits are adjusted.

Contaminants

Elevated concentrations of cadmium and mercury have been found in the tissues of narwhals taken in Canada and Greenland (Wagemann *et al*. 1983, 1996, 1998; Hansen *et al*. 1990). These metals accumulate in soft tissue as the animal grows but the lack of age data and small sample sizes make it difficult to identify trends in their accumulation over time and space. Within these limitations, the tissue concentrations of cadmium in narwhals taken at Pond Inlet do not appear to have changed over the period 1978-79 to 1992-94, but total mercury concentrations in the muscle, liver, and kidney may have increased (Wagemann *et al*. 1996). The effects of age and dietary differences and the contribution of anthropogenic mercury could not be quantified. Concern has been raised about the potential for kidney damage in narwhals from elevated cadmium levels and about the risk to human health from consuming narwhal *maqtaq* and meat containing elevated mercury concentrations (Wagemann et al. 1996; 1998).

In 1982-83, the blubber and liver of narwhals collected at Pond Inlet were analyzed for organochlorine pesticides (DDT, chlordane, polychlorinated camphenes [PCCs], dieldrin, hexachlorocyclohexanes [∑HCH], mirex), polychlorinated biphenyl congeners (PCBs), and chlorobenzenes (∑CBz) (Muir *et al*. 1992). Their mean ∑PCB concentrations were 6- to 15- fold lower than in dolphins from the Canadian east coast and belugas from the St. Lawrence River estuary, respectively, while PCC levels were from 4- to 2- fold lower, and ∑HCH, dieldrin and ∑CBz differed by <2-fold. The pattern of these contaminants in their tissues suggests that narwhals are exposed to proportionally more volatile compounds, likely by long range transport, and may have less capacity to metabolize some of these compounds than do odontocetes living nearer sources of these contaminants. No temporal trends have been identified in the accumulation of organochlorine contaminants in narwhal.

Industrial development

Recent development of the turbot (Greenland halibut) fishery in Baffin Bay has raised concern among narwhal researchers (Heide-Jørgensen *et al*. 2002). This fishery takes place during the open water season in the same area where narwhals winter.

While it is not coincident with narwhal occupation, it is targeting fish that narwhals eat at depths of 1000 to 1300 m where they feed. The total allowable catch (TAC) rose from 300 tonnes annually from NAFO Div. OA in 1996 to 2000 (Treble 1999), to 4,000 tonnes for NAFO Div. OA and 1A (offshore) in 2001 (Treble and Bowering 2002), and is expected to increase to 8,000 tonnes in 2003 (M. Treble, pers. comm. 2002). The effects of this new competition for food resources on wintering narwhals are unknown and worthy of study. Narwhals have been captured in fishing nets (Mitchell 1981), but this is not common and of lesser concern than the effects of competition for food.

Large quantities of turbot are also caught in the spring through the landfast ice in Cumberland Sound (Topolniski 1993; Stewart 1994) when narwhals are on their wintering grounds. This longline fishery began in 1986 and targets fish at depths of 600 to 1125 m. Catches have exceeded 430 tonnes but have been in the 250 tonne range in recent years (M. Treble, pers. comm. 2002). Their effect on narwhals is unknown. Exploratory turbot fisheries have been conducted by a number of other communities in the Baffin region but they have not identified populations that will support a commercial harvest (Stewart 1994).

Threats posed to narwhals in Canadian waters by hydrocarbon and mineral development and exploration are low at present. Indeed, there is less hydrocarbon exploration ongoing in the High Arctic today than there was in the 1970s and 1980s (D.G. Wright, pers. comm. 2002), and both of Canada's High Arctic metal mines closed in September 2002 (M. Wheatley, pers. comm. 2003). This will reduce the effects of ice breaking activities on narwhals entering Lancaster Sound in the spring. It will also reduce seismic and noise disturbances related to mining activities and the risk of hydrocarbon and heavy metal pollution. Future developments could reverse this trend.

Climate change

The potential effects of climate change on the narwhal have not been examined in detail but given the species' close association with consolidated pack ice and dependence on small leads and cracks, such analysis should be a priority. Climate change has the potential to alter the distribution, duration, and quality of seasonal ice cover in the Arctic and thereby the density of ice-associated prey species of marine mammals, such as Arctic cod and sympagic (with ice) amphipods (Tynan and DeMaster 1997).

In the long term, global warming may result in increased visitor numbers and activities in the Arctic (such as whale watching) that may disturb and affect narwhals. It is also possible that reduced ice coverage may make narwhals more susceptible to predation by killer whales. Overall, the effects of climate change on sea ice in areas presently inhabited by narwhals are uncertain (Maxwell 1999). Indeed, the duration of ice cover in Baffin Bay and Davis Strait increased between 1979 and 1996 (Parkinson 2000). The capacity of the narwhal to adapt to changes in pack ice is also unknown (Heide-Jørgensen *et al*. 2002). Given this uncertainty and the fact that changes in ice cover and dynamics might alter the species' seasonal distribution, geographical range,

migration patterns, nutritional status, reproductive success, and ultimately the abundance and stock structure, the narwhal's vulnerability to climate change deserves attention.

SPECIAL SIGNIFICANCE OF THE SPECIES

Narwhals historically provided important staples in the traditional subsistence economy of the eastern Canadian Arctic and Greenland, and the hunt itself and the sharing of its proceeds continue to be of great nutritional, social and cultural significance for some communities (Brody 1976; Reeves 1992a, 1992b, 1993a; Remnant and Thomas 1992; Thomsen 1993; Reeves and Heide-Jørgensen 1994; Stewart *et al*. 1995; Gonzalez 2001; Richard 2001). The large quantities of edible skin (10%), meat (25%), and oil (30-35% blubber) could sustain people and dogs in good health for a relatively long period (Mansfield *et al*. 1975; Reeves 1992a, 1992b, 1993a). Sinews were used for sewing thread, skin for laces, and tusks for tent poles, walking sticks, and the manufacture of hunting implements.

Today narwhals are hunted mainly for their ivory and skin (known variously as *maqtaq*, *maktaq*, *muktaaq*, and *muktuk*); the meat is seldom eaten if other meat is available, but is fed to dogs (Reeves 1992a, 1992b, 1993a, 1993b; Stewart *et al.* 1995; Gonzalez 2001; Richard 2001). *Maqtaq* is a highly valued food that in addition to its protein and caloric value is rich in vitamin C, zinc, retinol, and other essential nutrients (Geraci and Smith 1979; Kinloch *et al.* 1992; Wagemann *et al.* 1996). It is consumed locally or traded to other Inuit communities (Reeves 1993a, 1993b). Inuit prefer the *maqtaq* from young (black) narwhals, but all *maqtaq* is eaten (Reeves 1992a).

The ivory tusk of males is a valuable economic commodity and an important source of cash income for some coastal communities (Reeves 1992a, 1992b; Gonzalez 2001). The international value of the tusk gives hunters a strong incentive to hunt males with large tusks. This can strongly influence the nature and intensity of the hunt. A ban on the importation of narwhal ivory by the European Economic Community (EEC) caused the price of narwhal ivory to plummet in 1983/84, but it has since recovered due to the strong demand for narwhal ivory in Japan. Market interventions and price instability have had serious ramifications for Inuit communities in the past and are likely to affect the cost and rewards of narwhal hunting in the future as well (Reeves 1992b).

Prices paid to Arctic Bay hunters for both *maqtaq* and ivory approximately doubled between 1975 and 1990 (Reeves 1992a, 1993a). This price surge appears to have been driven by export demand in Iqaluit, where local hunting cannot satisfy the demand for *maqtaq*, and by the willingness of Arctic Bay residents to buy *maqtaq* rather than rely on traditional caching and sharing arrangements. If it is correct to assume, as the Government of Canada has done, that narwhal hunting is primarily a food quest and that ivory is only a by-product (Yaremchuk and Wong 1989), then the demand for *maqtaq* may ultimately be a more critical factor when considering narwhal conservation (Reeves 1993b).

The narwhal also has special significance to the broader world community. Ecologically it is important as the only species in its' genus, as a key link in the Arctic food chain between Arctic cod and humans or killer whales, and for its ability to inhabit frigid Arctic waters and dive to great depths. It generates avid public interest because of its unique "unicorn" tusk and remote habit, particularly as it has not been successfully displayed in captivity. Its tusk has also been used to make handicrafts and, in the orient, for traditional medicine.

EXISTING PROTECTION OR OTHER STATUS

Protection for narwhal in Canada is limited to measures that manage the hunt, live capture, and movement of narwhal products. As yet there are no Arctic marine parks or protected areas that protect narwhals in Canadian waters from hunting or other activities (F. Mercier, pers. comm. 2002). However, there are protected marine areas within the Nunavut National Parks, although they are not National Marine Conservation Areas. No protection exists outside of the parks, and no protected area (terrestrial or marine) prevents harvest by Inuit in the Nunavut Settlement area — where restrictions and quotas are established the Nunavut Wildlife Management Board under the Nunavut Land Claims Act. Visitor use of the National Parks is minimal, and there is no evidence that they are a threat to narwhal populations.

International trade in narwhal products is regulated by a number of laws and conventions. These include the *Convention on International Trade in Endangered Species of Wild Fauna and Flora* (CITES), which is embodied in Canadian legislation (*Bill C-42,* the *Wild Animal and Plant Protection and Regulation of International and Interprovincial Trade Act* — WAPPRITA); the *Marine Mammal Protection Act* in the United States; and *Council Regulation EC 338/97* in the European Union.

International organizations have been unable to determine the status of the narwhal using the data available.

Canadian harvest quotas and protection

Narwhal hunting in Canada is managed by the Nunavut Wildlife Management Board (NWMB), which is charged under Bill C-133 with making all decisions about wildlife management in Nunavut. The board consists of four Inuit and four Government representatives, plus a Chairperson. Canada's Department of Fisheries and Oceans (DFO), and the Hunters and Trappers organizations and the Regional Wildlife organizations are co-management partners. DFO advises the NWMB and hunting communities on sustainable hunting levels, who in turn use this information to manage community hunts (Richard and Pike 1993; DFO 1998a, 1998b).

Hunting regulations are implemented under the *Fisheries Act* and the Marine Mammal Protection Regulations by DFO. Under these regulations, only Inuit can hunt narwhals and there is a quota on the number of animals that can be harvested by each

community. These quotas were originally set through negotiation with the communities and based on historic harvesting levels (Strong 1988). Tags were allocated to hunters from the settlement quota to be attached to harvested animals. For many years, the hunters have requested changes to the management system for narwhals, with the result that community-based management of the hunt is now being tried at Repulse Bay, Pond Inlet, Qikiqtarjuaq (formerly Broughton Island), Arctic Bay and Kugaaruk (formerly Pelly Bay) (Table 2) (DFO1998a, 1998b; Gonzalez 2001).

Under the community-based management system, the quota has been lifted and the local Hunters and Trappers Organizations (HTOs) manage the hunt and have placed harvest limits in communities using a set of rules or by-laws (Gonzalez 2001). These rules are developed by the local HTO and address the conservation and management of the narwhal population, the reduction of waste, hunter education, and safety. The HTOs have also agreed to collect information on the number of narwhals wounded, killed, and not landed. In 1999, an unusually large harvest of 158 narwhals by Repulse Bay raised concerns about the effectiveness of community-based management. In 2002, the NWMB reduced the annual community harvest limit by Repulse Bay from 100 to 72 narwhals. While this limit is not likely to be taken every year, the potential remains for Repulse Bay to significantly increase its harvest from an average of 17.3 (range 3-35; SD 9.1) narwhals per year in the 20 years (1979-98) prior to the community-based management program (Table 1). This 3-year pilot program was reviewed in 2003 and and found to have not been long enough for assessment. It has been extended with a revised approach for a further 5 years, and an integrated management plan is being developed (M. Wheatley, pers. comm. 2003).

Protection for live-captured narwhals is afforded on largely moral rather than legal grounds unlike narwhal hunts and the trade in narwhal products, which are controlled by laws and conventions (Lien 1999). Notwithstanding the Marine Mammal Protection Regulations, the Nunavut Wildlife Management Board has the authority to approve or not approve live captures. Under the Marine Mammal Protection Regulations of the Fisheries Act, DFO has the authority to issue live capture permits. In practice, the department has not issued such a permit since 1987 (P. Hall, pers. comm. 2002). DFO can attach conditions to live-capture permits but it does not have enforcement authority for animals maintained in captivity (Lien 1999). Animal welfare is governed in Canada under Section 446 of the Criminal Code, which forbids imposing unnecessary suffering for animals and provides penalties for abuses. It does not provide for routine inspections of animal care or enforcement of maintenance standards. To fill these regulatory gaps, additions have been proposed to the Marine Mammal Regulations (Lien 1999). They include authorizations for clinical interventions and would require a holding permit for captive maintenance to be issued on an annual basis.

International trade and cooperation

Regulation of international trade in narwhal products began in 1972, when the US *Marine Mammal Protection Act* banned the importation of marine mammal products, including narwhal ivory, into the United States (Reeves 1992a, 1992b). In 1979, the

narwhal was listed in Appendix II of the *Convention on International Trade in Endangered Species of Wild Fauna and Flora* (CITES). This designation is reserved for species that could be threatened with extinction if trade is not controlled and monitored. It means that a CITES export permit is required for narwhal products that cross international boundaries. In Canada, these permits are administered by DFO, which manages narwhal under the *Fisheries Act*. CITES is embodied in Canadian legislation in *Bill C-42* (1992), the Wild Animal and Plant Protection and Regulation of International and Interprovincial Trade Act (WAPPRITA) (Lien 1999).

In 1985, a proposal to list the narwhal in CITES Appendix I was defeated (Kingsley 1989; Yaremchuk and Wong 1989; Reeves 1992a, 1992b). Had it passed, the narwhal would have been designated as a species threatened with extinction and special permits would have been required from both the importing and exporting country. In 1984, the European Economic Community (EEC; Regulation 3626/82) required member countries to control commerce as if all cetaceans, including the narwhal, were on CITES Appendix I - despite the fact that they are not. This regulation, which effectively bans the importation of narwhal ivory, does not apply to products originating in Greenland (Reeves and Heide-Jørgensen 1994). In 1997, the European Union replaced it with Council Regulation EC 338/97, which maintains this stricter control of Canadian narwhal exports.

The narwhal is also listed under Appendix II of the *Convention on the Conservation of Migratory Species of Wild Animals* (CMS or Bonn Convention), which promotes international cooperation in the management of migratory species. Appendix II lists migratory species that require or would benefit significantly from international cooperative agreements under CMS. Canada cooperates with Greenland in the conservation of shared narwhal populations through participation in the Canada/Greenland Joint Commission on Conservation and Management of Narwhal and Beluga (JCNB).

Status designations

In 1996, the International Union for the Conservation of Nature and Natural Resources (IUCN) assessed the population status of the narwhal (Hilton-Taylor 2000). It concluded that the threat of extinction could not be adequately assessed with the data available and listed narwhal in the data deficient (DD) category in *The 2000 IUCN Red List of Threatened Species.*

In 2001, a joint meeting of scientific working groups from the JCNB and NAMMCO also concluded that existing information was insufficient to assess the status of narwhals in the Baffin Bay area (JCNB/NAMMCO 2001). While the overall population was not believed to face an immediate threat from unsustainable hunting, concern was expressed that some population units may be over-hunted. Focussed and intensive research efforts were recommended to improve knowledge of narwhals and thereby strengthen the basis for advice on the conservation and management of the species.

SUMMARY OF STATUS REPORT

Without recent and complete survey information, and with uncertainty about hunting mortality and natural mortality, it is not possible to provide a quantitative estimate of the size of the Baffin Bay narwhal population, or of that portion of the population that enters Canadian waters, or to detect a trend. There is also no clear consensus among Inuit hunters of a population trend. While tens of thousands of narwhals from this population summer in Canadian waters, and the apparent increase in hunting mortality since 1977 increase the urgency of improving knowledge of the Baffin Bay population (JCNB/NAMMCO 2001).

Similar uncertainties exist for the Hudson Bay population, which likely numbers several thousand animals. Hunters from Repulse Bay may have removed between 5.2 and 6.7% of the Hudson Bay narwhal population in 1999, and 3.6 to 4.7% in 2001. This population is unlikely to support these rates of removal over the long term. Consequently, the annual harvesting limit for Repulse Bay was reduced in 2002 from 100 to 72 narwhals. An integrated management plan is being developed for the Hudson Bay population.

TECHNICAL SUMMARY

Monodon monoceros
Narwhal Narval
Baffin Bay & Hudson Bay Populations
Range of Occurrence in Canada: Eastern Arctic

Extent and Area Information	
• *Extent of occurrence (EO)(km²)*	Baffin Bay ~1,250,000 km² Hudson Bay ~250,000 km²
• *Specify trend in EO*	unknown
• *Are there extreme fluctuations in EO?*	unknown
• *Area of occupancy (AO) (km²)* summer aggregations Likely smaller more concentrated home ranges in summer	Baffin Bay ~60,000 km² Hudson Bay ~17,000 km²
• *Specify trend in AO*	unknown
• *Are there extreme fluctuations in AO?*	unknown
• *Number of known or inferred locations:* ***are migratory & widespread***	many
• *Specify trend in #*	unknown
• *Are there extreme fluctuations in number of locations?*	no
• *Specify trend in area, extent or quality of habitat*	unknown
Population Information	
• *Generation time (average age of parents in the population)*	~15 y
• *Number of mature individuals* (~60% of total population)	Baffin Bay 27,000 Hudson Bay 2,100
• *Total population trend:*	unknown
• *% decline over last/next 10 years or 3 generations.*	–
• *Are there extreme fluctuations in number of mature individuals?*	no
• *Is the total population severely fragmented?*	no
• *Specify trend in number of populations*	–
• *Are there extreme fluctuations in number of populations?*	–
• *List populations with number of mature individuals in each*	–
Threats (actual or imminent threats to populations or habitats)	
- **Hunting:** Numbers removed by hunting appear to have increased over the past decade from the Baffin Bay population, and since 1977 from the Hudson Bay population. Reliable information is not available for numbers that are killed and not landed. The ability of the population to sustain hunting is uncertain. Better knowledge of population size, movements and vital rates are needed. - **Climate change:** potential effects of reduced ice coverage are unknown, but may make narwhals more vulnerable to hunting and predation by killer whales.	
Rescue Effect (immigration from an outside source)	
• *Status of outside population(s)?*	**Greenland:** unknown
• *Is immigration known or possible?*	possible
• *Would immigrants be adapted to survive in Canada?*	likely
• *Is there sufficient habitat for immigrants in Canada?*	likely
• *Is rescue from outside populations likely?*	unknown
Quantitative Analysis	None undertaken
Current Status: Narwhal Not at Risk (COSEWIC, April 1987)	

Status and Reasons for Designation

Status: Special Concern	**Alpha-numeric code:** N/A

Reasons for Designation:

The Baffin Bay population appears to be large (~45,000), although there is uncertainty about numbers, trends, life history parameters, and levels of sustainable hunting. There is similar uncertainty about the much smaller Hudson Bay population (~2,100 mature individuals). Hunting for *maktak* and the commercially valuable tusk ivory represents the most consistent threat to narwhals. Potential effects of changes in ice coverage caused by climate trends are unknown. The Hudson Bay population could decline by 30% in 30 years if hunting is not closely regulated. Similarly, the Baffin Bay population could be affected if hunting in Greenland is not effectively managed. Numbers removed by hunting increased during the 1990s. Community-based management is monitoring hunting and is attempting to regulate removals. Reliable information about numbers that are killed and not recovered is difficult to obtain.

Applicability of Criteria

Criterion A (Declining Total Population): The Baffin Bay population is large (~45,000 all ages), although the trend is not known. The Hudson Bay population numbers about 2,100 mature individuals, but there is considerable uncertainty about its trend, and levels of sustainable hunting are not known. The Hudson Bay population could decline by 30% over the next 30 years if hunting is not closely monitored and effectively regulated

Criterion B (Small Distribution, and Decline or Fluctuation): Does not apply as the extent of occurrence for both populations is >20,000 km^2

Criterion C (Small Total Population Size and Decline): Does not apply given that the number of mature individuals in the Baffin Bay population is >10,000. However, continued hunting at the 2002 level would cause the small Hudson Bay population to decline (Criterion C1, Threatened). Community-based management is monitoring the hunt and appears to be regulating removal levels in Canada. The Baffin Bay population, however, is also hunted in Greenland at levels that may not be sustainable.

Criterion D (Very Small Population or Restricted Distribution): Both populations are >1,000, and their distributions are not restricted.

Criterion E (Quantitative Analysis): No quantitative analysis has been undertaken.

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