Distribution, exploitation and population status of white whales (*Delphinapterus leucas*) and narwhals (*Monodon monoceros*) in West Greenland

MADS P. HEIDE-JØRGENSEN

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Historic and present distribution of narwhals (*Monodon monoceros*) and white whales (*Delphinapterus leucas*) in West Greenland is reviewed. The distribution of white whales changed early in this century. They initially disappeared from Nuuk District and later, during the 1920s, from Maniitsoq District. Southwest Greenland (south of 65°N) is no longer a part of the winter or spring distribution of Baffin Bay white whales. Possible reasons for this change are discussed. No large-scale changes in distribution of narwhals have been detected. The major products from narwhals and white whales traded in Greenland are mattak (= whale skin) and narwhal tusks. The mean yield of mattak per whale is estimated to be about 67 and 133 kg per white whale in the municipalities of Upernavik and Qeqertarsuaq, respectively, and 89 kg per narwhal in the municipality of Avanersuaq. Annual reported catches were approximately 900 white whales and 300 narwhals in West Greenland during 1970–1980. After 1980 the catch reporting system became less reliable and it had virtually collapsed by 1991. However, some statistics of catches during the 1980s are reliable, some are available from other sources and others can be calculated from purchases of mattak. The estimated catches of white whales during the 1980s indicate one of two scenarios: either 1) the population estimates from 1981 seriously underestimated the actual population size, or 2) the population has been declining during the 1980s. For narwhals the catches are smaller and the population estimates higher, albeit subject to large variability.

Key words:
White whale, beluga, *Delphinapterus leucas*, narwhal, *Monodon monoceros*, Greenland.

Heide-Jørgensen, Mads P., Marine Mammal Section, Greenland Fisheries Research Institute, Tagensvej 135, DK-2200 Copenhagen N, Denmark.

Introduction

Narwhals (*Monodon monoceros*) and white whales (*Delphinapterus leucas*) have been exploited for centuries by Inuit. Although the evidence from archaeological excavations is still meagre (*cf.* Savelle 1994), these small whales have probably been hunted in Greenland since the earliest settlement by Inuit. The abundance, coastal habits and nutritional value of white whales and narwhals make them attractive game animals for "subsistence" hunters. The colonisation of the Arctic by Europeans and Americans during the 18th, 19th and first half of the 20th centuries also introduced the commercial exploitation of whales, including white whales and to some extent narwhals. This had detrimental effects on some stocks of white whales in Canada and Greenland (Mitchell & Reeves 1981). Catches of monodontids used to be optional, but with the increased dependency on a monetary economy catches of narwhals and white whales have become critically important to some Inuit hunting communities in northwestern Greenland (Born 1987a, Dahl 1990). Trade with products from these whales provides the most important cash income in some of these communities. The combined value of mattak (= whale skin) from narwhals and white whales exceeds the total revenue obtained from the sale of all other edible hunting products in Greenland today. The cash income from the sale of mattak and narwhal tusks enables hunters to buy boats, hunting gear, kerosene and other imported articles. Also

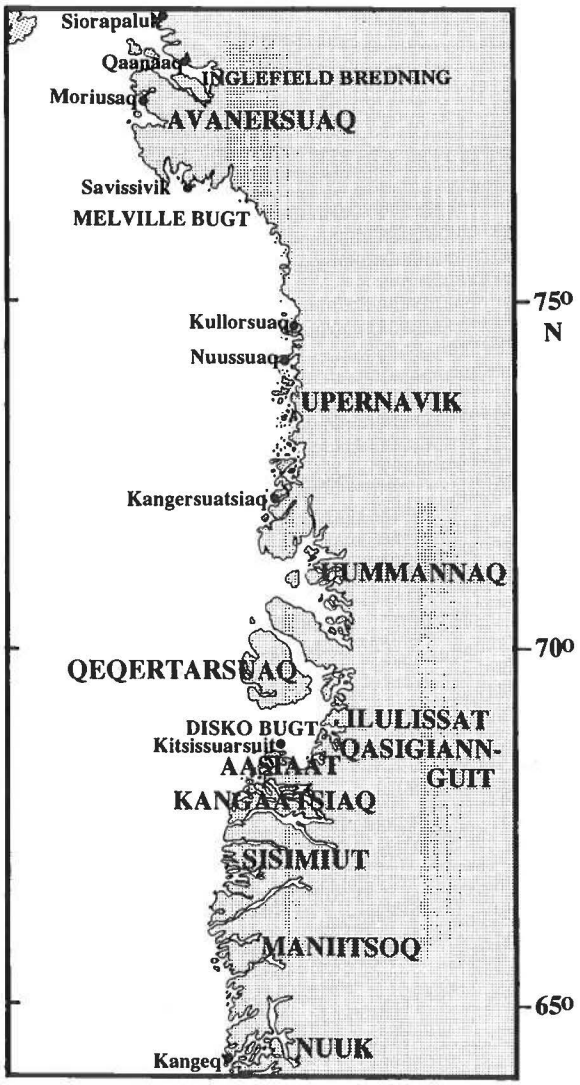

Fig. 1. Municipalities, settlements and bays in West Greenland mentioned in the text.

of major importance is the contribution of whale meat and mattak to the basic food supplies for humans and dogs.

In this paper I consider the white whales and narwhals that spend the summer in the Canadian High Arctic and in Northwest Greenland to belong to Baffin Bay populations. The whales in these populations overwinter primarily in northern Baffin Bay, southward along the west coast of Greenland and in Davis Strait.

I describe current and past distribution of narwhals and white whales in West Greenland and examine the recent harvesting regime in detail. The possible impacts of recent hunting on the population development of both species in West Greenland and the Canadian High Arctic are examined.

Materials and methods

Data on recent and historic distribution and catches

Official catch statistics are available for some years and areas from the annual description of the situation in Greenland (Anon. 1896–1908, Anon. 1909–1931) and from the Hunters' List of Game (HLG, Anon. 1953–1988). Statistics on trade in mattak were obtained from the Greenland Statistical Yearbook for the period 1966–1986 (Anon. 1953–1988). Data on deliveries of mattak for processing at fish factories after 1986 were obtained by sending questionnaires to 19 landing sites, to the central administration of the fish industry, Royal Greenland Production, and to the Greenland Statistical Office. The official statistics from Royal Greenland and the Greenland Statistical Office did not distinguish between mattak from narwhals and white whales until 1991, but some information about the species landed was obtained from the questionnaires or by asking factory employees. Information about the purchases of narwhal tusks by the Greenland Trade Department (KNI; earlier referred to as KGH = Royal Greenland Trade Department) was presented in Reeves & Heide-Jørgensen (1994).

Between 1989 and 1992 I interviewed hunters and other residents of hunting communities to obtain data on catches of white whales and narwhals. I also compiled newspaper articles mentioning large catches. Furthermore, biologists from the Greenland Fisheries Research Institute (GFRI) witnessed some hunting events and flensing situations.

Information about Canadian removals of white whales and narwhals in the Baffin Bay region before 1988 was extracted from Strong (1989) and from Anon. (1991, 1992a, 1992b, 1993) for catches between 1988 and 1991.

Weight of mattak

In September-October 1991 the mattak from 28 white whales killed at Kullorsuaq in the municipality of Upernavik (Fig. 1) was weighed. Additionally, mattak was weighed from four white whales taken at Qeqertarsuaq (Godhavn) in May 1992. In both cases the hunters were asked to flense the white whales in the same manner as they normally do when they sell the mattak. The mattak from the body, excluding the flukes, flippers, and head region, was lifted using a crane aboard the research vessel *Adolf Jensen*. It was then weighed to the nearest kg with a Salter DC-2 digital scale. The total weight and the body length (in a straight line, tip of snout to fluke notch) of the whales were measured before flensing started (see also Heide-Jørgensen & Teilmann 1994).

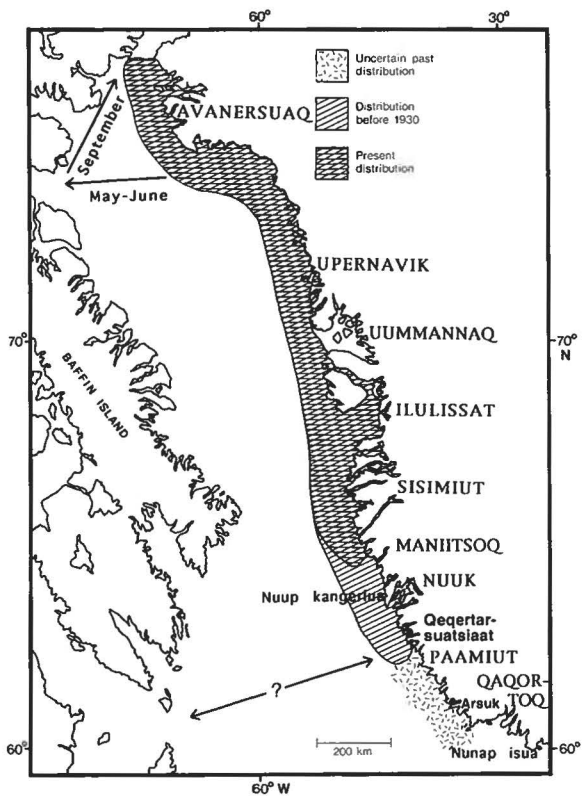

Fig. 2. Historic and present distribution of white whales in West Greenland with likely routes of migrations indicated with arrows.

Trends in population size

The size of the "Baffin Bay population" of white whales was estimated in 1981 at the summer concentration areas in Canada (Smith *et al.* 1985). The number of narwhals in Baffin Bay and Davis Strait was estimated in spring 1979 (Koski & Davis 1994) and the summer concentrations of narwhals in the Canadian High Arctic and in Northwest Greenland were estimated in 1984 (Born 1986, Richard *et al.* 1994). Estimated net recruitment rates were used for simulating the effects on the populations of the documented catch levels.

Plausible population trends can be calculated by adding the net recruitment to an estimate of the population size and subtracting the annual mortality due to hunting:

$$(1)\quad N_{t+1} = N_t - K_t + R_t\,(N_t - FK_t) \qquad \text{(Smith 1983)}$$

where population size (N) in year t + 1 is calculated from population size in year t (N_t), minus the mortality caused by hunting (K_t), plus the net recruitment rate of the population at time t (R_t) multiplied by N_t minus F times the hunting mortality (K_t). The factor F is incorporated because it is assumed that some proportion of the whales killed in year t would have reproduced during the year of the kill (Smith 1983). Most of the catch of white whales and narwhals in West Greenland is made after the peak season of reproduction (April-May), hence a crude estimate of 0.25 was used for F.

Results

Distribution and catches of white whales until 1930

Winge (1902) made an extensive review of 18th and 19th century literature on marine mammals in Greenland. According to his sources white whales migrated south along the west coast in October and arrived at Qeqertarsuaq (Godhavn; Fig. 1) in October or later, and at Nuuk (Godthåb) in December. The southward movement of white whales in the autumn rarely extended past Qeqertarsuatsiaat (Fiskenæsset, Fig. 2). However, reports of white whales as frequent visitors at Arsuk and the catch statistics from Paamiut (Frederikshåb) and Qaqortoq (Julianehåb) districts (Table 1) both show that white whales occurred frequently and in relatively large numbers in South Greenland in the 19th century (Winge 1902). The

Table 1. Catches of white whales in districts and (after 1952) municipalities in southwestern Greenland during 1874–1891 and 1971–1987. Data for 1874–1891 from Winge (1902) and data from 1971–1987 from present study.

District/municipality	1874–1891			1971–1987		
	Years with reported catches	Mean of catches	Range of catches	Years with reported catches	Mean of catches	Range of catches
Qaqortoq	12	5	1–13	0	0	0
Paamiut	17	9	2–15	2	2	1–2
Nuuk	17	203	77–336	15	28	1–78
Maniitsoq	17	283	163–525	15	12	2–45
Sisimiut	17	140	71–240	15	86	25–135

Table 2. Catches of white whales in seven areas during 1894–1951 (Anon. 1896–1908, 1909–1931, 1938, 1944, 1948). The catches are given per district except for the towns and settlements in Disko Bugt that are lumped together, and the drive fishery station at Kangersuatsiaq in Upernavik District that is shown separately.

Year	Nuuk	Maniitsoq	Sisimiut	Disko Bugt	Uummannaq	Kanger-suatsiaq	Upernavik	TOTAL
1894–95	>200							>200
1896–97				'poor catch in all areas'				
1897–98				'generally good catches'				
1898–99		'varying catches; in Uummannaq poor catches but large catches in Upernavik'						
1906–07	ca. 400							400
1907–08		90		150				240
1908–09	109							109
1909–10	161							161
1910–11	98							98
1911–12	300							300
1912–13		'good catch'						
1913–14	530	66						596
1914–15	ca. 670							670
1915–16	200	300			100			600
1916–17	300	150						450
1917–18		150			60			210
1918		'a few'						
1919		'good catch'						
1919–20	400	700		40				1140
1920–21	200	'very good catch'						200
1922	380	1000		50	25			1455
1923		874						874
1924		950			100			1050
1925		950			50		50	1050
1926		1500					25	1525
1927		700			100	150	100	1050
1928		100						100
1929		76			Uummannaq and Upernavik		>1000	>1076
1926–29						1744		
1930		33				311		344
1931				40	200	268	107	615
1932				183	108	610	105	1006
1933						90	106	196
1934–35	1	24	13			240	12	290
1935–36	1	8	47					56
1936–37	4	2	65	20		48		139
1937–38		4	41	49		22		116
1938–39	1	7	8	19		127		162
1939–40	4	2	34	178	83		351	652
1940–41	2	3	99	186	139		351	780
1941–42	1	1	78	326	133		120	659
1942–43		1	36	380	146		127	690
1943–44		3	27	146	63		28	267
1944–45		1	20	324	27		328	700
1945–46	1	1	56	238	13		28	337
1946–47		5	11	207	63	57	70	413
1947–48			9	189	8	54	36	296
1948						122		122
1949						no catch		
1950						24		24
1951						17		17

mean of the annual catches during 1874–1891 in West Greenland south of 66°N was 638 (range 648–1010, sum 10 851). The largest numbers were taken in Maniitsoq (Sukkertoppen) District, but even Nuuk District had large catches (Table 1).

Large numbers of white whales were frequently seen in fjords in West Greenland between 61°N and 63°N during the winter, although their main distribution was farther north, particularly in the fjords of Nuuk and Maniitsoq districts (Fig. 2, Bendixen 1921). The whales were reported to start their northward migration from February until early April. Most whales left the fjords in May, but some remained until June-July (Winge 1902, Degerbøl & Nielsen 1930). Møller (1928, 1964) stated that white

Fig. 3. Flensing of white whales caught in the drive fishery in Nuup kangerlua (Godthåb Fjord) around 1920 (above, Copyright: Arktisk Institut) and at Nuussuaq, Upernavik, in October 1990 (below, Photo: M. P. Heide-Jørgensen).

whales arrived in Nuuk in late October, wintered in Nuup kangerlua (Godthåb Fjord, Fig. 2), and usually left the fjord in April, May or June. This is confirmed by observations of several white whales in leads in the ice during the latter half of November 1914, daily catches of white whales in Nuup kangerlua in January 1915, catches of 42 during 16–20 February and frequent observations and catches between 20 April and 1 May 1914 (J. Noe-Nygård *in litt.*). The season of the catches in Nuuk is known for 12 of the years between 1894 and 1922 (Table 2). In 11 of the years (2769 white whales in total) the catches took place during spring and early summer, usually during May-June. Only once (70 white whales in 1914–15) was the catch reported to have taken place in winter.

Møller (1928) stated that the occurrence of white whales in Nuup kangerlua changed dramatically. After perhaps 1920 they began to leave the fjord earlier in the

spring and were caught only occasionally. No catches were reported in Nuuk between 1922 and 1934 and low numbers (< 5 per year) have been reported since 1934 (Table 2).

Degerbøl & Nielsen (1930) confirmed the southward movement of white whales in the autumn (October) described by Winge (1902), but they mentioned another pulse of migrating white whales that arrived in South Greenland in December. These animals were said to be fatter and in better condition than the autumn arrivals, and they often carried fresh bullet wounds and shells said to have been of Canadian origin (Degerbøl & Nielsen 1930).

White whales were hunted in Nuuk District (and perhaps throughout Greenland) exclusively by kayak and hand harpoon until the mid 19th century (Møller 1928). During the late 1800s rifles, and after 1900 motorboats, became increasingly used for chasing and killing white whales. With motorboats white whales could be driven in Nuup kangerlua and chased into a shallow bay to be killed (Fig. 3; Møller 1964).

Large-scale netting and driving of white whales was introduced in South Greenland at the beginning of the 20th century. In 1923 it was decided to limit the netting of white whales at Nuuk to the inhabitants of Nuuk and the nearby settlement Kangeq (Fig. 1), but by that time the groups of white whales were already reported to be small (Anon. 1924). A drive-net fishery was started in Maniitsoq District in 1917 and particularly large catches were made during 1917–1930 (Table 2). In one year the catch in this fishery reached 1488 whales (Degerbøl & Nielsen 1930), and the cumulative catch during 1917–1930 was in the magnitude of 8000–10 000 (Table 2). A decline in catches was evident during the late 1920s. Before 1917 catches in three of four years were reported to have been in the spring (Anon. 1896–1908, Anon. 1909–1931). After 1917 the whales were mainly taken in Maniitsoq District on their southward migration from mid October till early December (Degerbøl & Nielsen 1930).

Netting of white whales was initiated at Kangersuatsiaq (Sydprøven, Upernavik District, Fig. 1) in 1925. In 1930 the overall impact of the netting and driving activities stirred a heated debate in the Greenland Council (Nordgrønlands Landsraad) between hunters, especially those from the districts north of Disko Bugt, and the Royal Greenland Trade Department (KGH) that oversaw the white whale fishery (Anon. 1933, 1944). Several representatives from the northern districts claimed that the timing of migrations of white whales had changed significantly in Uummannaq and Upernavik districts. It was claimed that after the introduction of motorboats and netting at Kangersuatsiaq, white whales arrived later and stayed for a shorter period, especially during the summer. On the other hand, it was claimed by KGH that the white whales changed their routes of migrations and that their disappearance in Nuuk and Maniitsoq districts was caused by the increased sea temperature after 1926. The decision to abandon the net fishery at Kangersuatsiaq, stated in the summary of the negotiations in the Greenland Council (Anon. 1933), was never implemented (Anon. 1947, Table 2).

Distribution and catches of white whales after 1930

Since 1930 white whales have rarely been seen south of Sisimiut (Holsteinsborg), although they are sometimes listed in the HLG from Maniitsoq, Nuuk and Paamiut (Table 1). The white whale catches reported from these towns have probably been made further north by hunters who pursue white whales from fishing vessels (Kapel 1977). Vibe (1967) stated that white whales were rarely seen in Nuuk around 1940 and that only five were caught in Maniitsoq during 1935–38. However, pods of white whales were occasionally seen in Nuup kangerlua in winter and spring 1993 (Bjørn Rosing, Greenland Home Rule, *in litt.*).

The major wintering ground for white whales off West Greenland at present seems to be along the coast from 67°N to 69°N, as documented by recent aerial surveys (Heide-Jørgensen *et al.* 1993). The timing of the autumn and spring movements of white whales along West Greenland seems identical to that documented by Winge (1902) and Degerbøl & Nielsen (1930), except that the movements no longer extend as far south as they did before 1930 and that white whales are rarely seen in June south of Uummannaq.

White whales were abundant in Avanersuaq (Thule) District in the summers of 1939–41 and small numbers winter in open water in the northern part of Baffin Bay (the "North Water") where they were sometimes caught along the ice edge in Avanersuaq as early as February (Vibe 1950). A few hundred white whales were observed during aerial surveys of leads and cracks in the North Water in March-April 1978 and March 1979 (Finley & Renaud 1980). One adult white whale was seen from the ice edge in Avanersuaq on 26 April 1985 (Heide-Jørgensen unpubl. data).

Summer observations of white whales in West Greenland are rare, but small pods are occasionally seen in the municipalities of Uummannaq and Upernavik in July-August. One observation of a white whale near Nunap isua (Kap Farvel, Fig. 2) in August 1988 (Reeves 1990) must be considered a straggler of unknown origin. In Nuup kangerlua two pods, both of 12–15 white whales, were seen on 30 June 1993 (B. Rosing, *in litt.*). On 9 September 1987, 25–30 white whales were observed in Uummannaq (Heide-Jørgensen & Leatherwood 1987).

In Avanersuaq a few white whales (< 10 per year) are taken in July-August but the largest catches are now taken in September-October just prior to the catches in the municipality of Upernavik. For instance on 3 October

Table 3. Catches of narwhals and white whales in the Baffin Bay region, 1954–1992.

Year	Narwhals				White whales			
	West Greenland (1)	Estimates W. Grl. (2)	Canada (3)	Total Baffin Bay (1+2+3)	West Greenland (1)	Estimates W. Grl. (2)	Canada (3)	Total Baffin Bay (1+2+3)
1954	47			47	1874		0	1874
1955	195		48	243	300		14	314
1956	318		113	431	424		85	509
1957	74		215	289	503		109	612
1958	73		282	355	225		97	322
1959	57		77	134	309		149	458
1960	332		234	566	216		81	297
1961*	203		197	400	345		36	381
1962*	213		198	411	329		78	407
1963*	317		85	402	229		86	315
1964*	319		90	409	207		53	260
1965	99		78	177	429		49	478
1966	110		168	278	561		125	686
1967	140			140	594		1	595
1968	472			472	1250		0	1250
1969	204			204	978		0	978
1970	322			322	1509		0	1509
1971	186			186	737		36	773
1972	107		26	133	823		0	823
1973	199		372	571	1067		136	1203
1974	147		152	299	917		144	1061
1975	117	149	271	537	607	47	55	709
1976	115	141	297	553	1175	37	58	1270
1977	253	134	255	642	804	36	61	901
1978	612		261	873	719		48	767
1979	377		288	665	741		86	827
1980	462		324	786	889		16	905
1981	609		366	975	1017		158	1175
1982	461		382	843	894		101	995
1983	439		333	772	601		106	707
1984	666		258	924	763		123	886
1985	256		298	554	611		120	731
1986	237		256	643	360	75	75	510
1987	505	50	157	812	606	90	58	754
1988		500	228	728		275	91	366
1989		600	285	885		457	52	509
1990	1046	150	253	1449		1000	47	1047
1991			340	340		550	54	604
1992		250		250		750		750

* indicates that a report was received from the municipality of Avanersuaq.
Greenlandic data from 1954–1974 from Hunters' List of Game with estimates from Kapel (1977). Data and estimates from 1975–1977 from Kapel (1983), 1978–79 from Kapel & Larsen (1984), 1980–82 (Kapel 1985), 1983–84 (Born & Kapel 1986), 1985 (Born 1987b), 1986–87 from Greenland Home Rule Authority and 1988–90 from estimates made by biologists from Greenland Fisheries Research Institute. Data from Canada from Strong (1989) and Anon. (1991, 1992a, 1992b, 1993). For white whales Canadian catches include the settlements of Clyde River, Pond Inlet, Arctic Bay, Grise Fiord, Resolute, Creswell Bay, Spence Bay, Hall Beach, Igloolik and Pelly Bay. For narwhals Canadian catches also include the settlements of Broughton Island, Pangnirtung, Iqaluit, and Gjoa Haven. Canadian catches were reported from 1 April to 31 March but all catches were assumed to occur in the first calendar year. Total catches for Baffin Bay include catches from West Greenland, "estimates" and Canada.

1985, 39 white whales were taken in Siorapaluk, two days later 20 were shot in Qaanaaq, and the following day another 50 were taken in Moriusaq (Fig. 1). The first white whales of the season were taken in the municipality of Upernavik on 9 October (R. Dietz, Greenland Environmental Research Institute, *in litt.*). Again in 1991 approximately 50 white whales were taken in Qaanaaq on 20 September and the catches at Kullorsuaq began on 30 September (Heide-Jørgensen unpubl. data).

After 1930 reported catches in West Greenland south of 68°N vanished in Nuuk and Maniitsoq districts (Table 2). The reported catches south of Aasiaat (Egedesminde) District (Fig. 1) remained low (1934–1947: annual average less than 50, Table 2), and most were probably caught in the municipality of Sisimiut north of their previous autumn and winter occurrence (Fig. 2). The drive-net fishery at Kangersuatsiaq in Upernavik was maintained

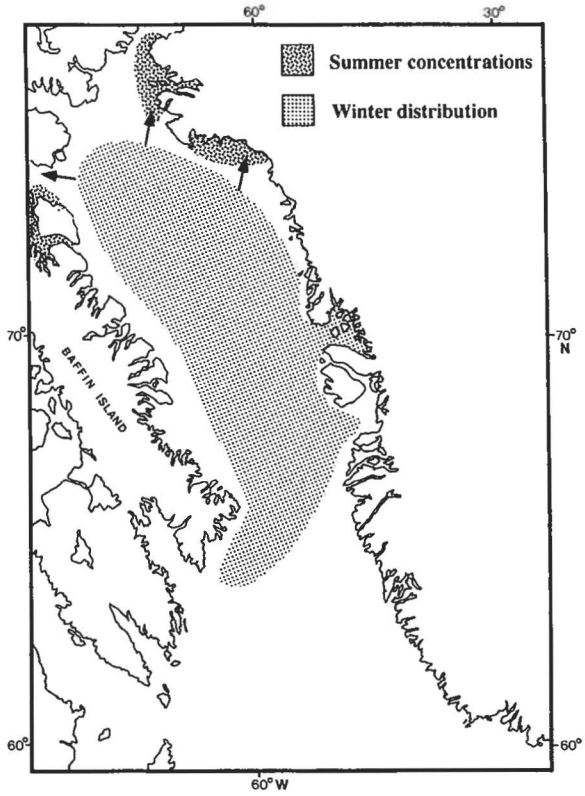

Fig. 4. Distribution of narwhals in West Greenland. Dotted areas indicate major summering grounds, hatched areas indicate wintering grounds.

with varying success until 1951 with a pause during World War II (Table 2).

The reported catch of white whales in West Greenland during 1970–1980 was about 900 whales per year (Table 3). After approximately 1980 the reporting system became progressively less reliable, as several settlements did not report their catches and known catches did not appear in the statistics (Table 3). A contributing factor to this development was the change in hunting methods. During the 1980s more large cutters became involved in catches in "foreign municipalities" and more white whales were caught by co-operative hunting (drive fishery; Fig. 3) involving many hunters, perhaps from several settlements (this study). These changes created uncertainty about who should be responsible for reporting catches.

Distribution and catches of narwhals

Narwhals are present in the offshore pack ice of central Davis Strait and southern Baffin Bay during March (Koski & Davis 1994; Fig. 4). They are also seen and caught during winter and spring along the West Greenland coast where they are particularly abundant at the southern entrance to Disko Bugt. Narwhals are rarely seen or caught south of Aasiaat (Fig. 1). This is also evident from the statistics on trade in narwhal tusks: none were purchased by KGH in districts south of Aasiaat during 1908–1957 (Reeves & Heide-Jørgensen 1994).

Some narwhals winter in the "North Water" polynia and they are sometimes seen and caught along the ice edge in the municipality of Avanersuaq as early as February (Vibe 1950, Finley & Renaud 1980, J. Danielsen pers. comm.). Narwhals are particularly abundant in July through September in Inglefield Bredning (Kangerlussuaq) in Avanersuaq and in Melville Bugt (Qimusseriarsuaq) north of Upernavik (Meldgaard & Kapel 1981, Born 1986, 1987b). During October and November narwhals are frequently seen in Upernavik municipality and particularly in Uummannaq municipality where large catches have been made in recent years. No conspicuous changes in the overall distribution of narwhals have been observed during the last 100–200 years (Winge 1902, Oldendow 1935). Some hunters claimed in 1930 that narwhals had changed their migration routes during the 1920s (?) such that they were no longer abundant in Disko Bugt, but in the northern part of Upernavik the occurrence and relative abundance remained unchanged (Anon. 1933).

The average reported catch of narwhals during 1970–1980 was approximately 270 per year for West Greenland (Table 2). As in the case of white whales the reliability of the narwhal catch statistics declined during the 1980s and no complete catch statistics have been received from Avanersuaq since the 1960s (Table 2).

During one week in November 1989 about 400–450 narwhals were killed in the municipality of Uummannaq according to local sources (Arne Niemann pers. comm., Grønlandsposten 1989), and about 25 tons of mattak was sold (Kjeld L. Rasmussen, Royal Greenland, Uummannaq *in litt.*). In the official catch statistics 275 narwhals were reported for November and 57 for December in Uummannaq. In 1990 1046 narwhals were reported in the catch statistics and of these, 1019 were taken in Uummannaq during an extraordinarily large catch beginning on 29 October and continuing throughout November 1990 (Greenland Statistical Office *in litt.*). From this catch 306 narwhal tusks were sold to KNI (Rudolf Fleischer, KNI Uummannaq, *in litt.*) and 81.5 tons of narwhal mattak and 46.6 tons of narwhal meat were purchased by Royal Greenland during November to January (K. L. Rasmussen *in litt.*). Additionally some narwhals were caught in January and February 1991 in small sassat (ice entrapments) and 9.0 tons of mattak was purchased (*ibid.*). In the autumn of 1991 4.2 tons of mattak was purchased in Uummannaq and low numbers of narwhals were reported to have been caught.

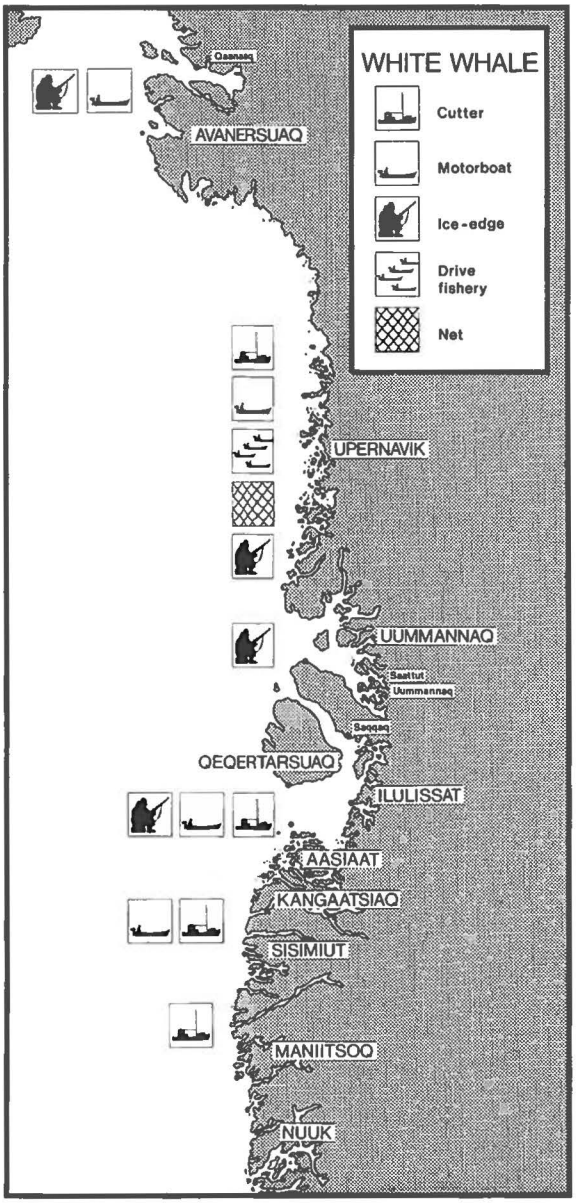

Fig. 5. Most important methods of hunting white whales in the municipalities along West Greenland.

Present methods for catching white whales and narwhals

A variety of methods for catching white whales and narwhals are used by hunters in Greenland. The following is a compilation of information on present hunting methods that I have collected during visits to the hunting areas (also see Thomsen 1993):

White whales are caught in nets, in a drive fishery in the autumn, from the fast ice edge and from cutters in open water (Fig. 5). Harpooning from kayak is rare as most hunters consider it too difficult to approach white whales from kayak. Netting with 80 m-long nets with mesh diameters of 40×40 cm and a depth of 3–6 m is responsible for small and infrequent catches in the municipalities from Qeqertarsuaq to Avanersuaq. The nets are set either in open water in the autumn or in the leads and cracks in the fast ice in late spring in Disko Bugt. During the 1980s the drive fishery for white whales in the municipality of Upernavik provided the largest catches of white whales. There are a number of shallow bays and inlets in

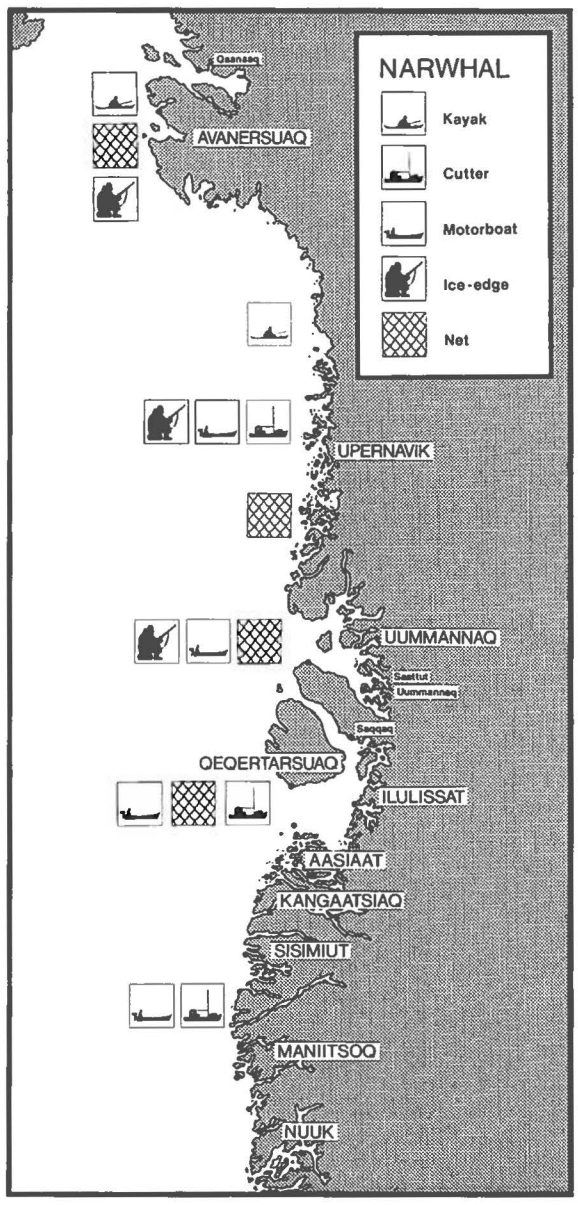

Fig. 6. Most important methods of hunting narwhals in the municipalities along West Greenland.

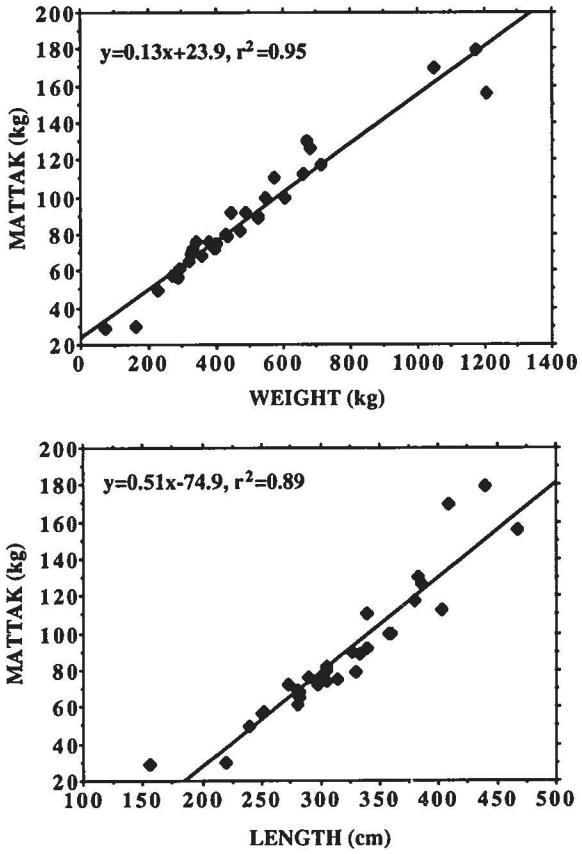

Fig. 7. Yield of mattak for white whales of different length and weight (N = 28). The data are from catches of white whales at Kullorsuaq, Upernavik, in September-October 1991.

the archipelago of Upernavik that are frequently used for this hunt, especially between 73°N and 74°30'N (Fig. 5). The present technique of driving the whales with outboard-powered dinghies is of relatively recent origin as these boats have only been available in Upernavik since the early 1970s. However, the driving of whales with slower motorboats was also practised at Nuuk and Maniitsoq in the first three decades of this century (Fig. 3). Catches from cutters are made primarily in the Disko Bugt area and in the municipality of Sisimiut although white whales are also sometimes taken from cutters in the Upernavik area (Fig. 5).

During the open-water season narwhals are taken from kayaks in the municipality of Avanersuaq and the northern part of the municipality of Upernavik (Fig. 6). Netting of narwhals is also allowed in Avanersuaq after 1 September, but weather and ice conditions often make such netting of narwhals difficult. Netting of narwhals is also practised in Upernavik and Uummannaq especially during November before new ice forms. Large catches of narwhals have recently been made in Uummannaq during November when most narwhals are taken by shooting and harpooning from dinghies. In spring narwhals are chased from dinghies in the loose packice in the entrance to Disko Bugt, especially at Kitsissuarsuit (Hunde Ejland, Fig. 1) and Qeqertarsuaq. In Uummannaq, Upernavik and Avanersuaq narwhals are taken from kayaks along the fast-ice edge during spring.

Sassat or ice entrapments of both narwhals and white whales frequently occur in Disko Bugt and an entrapment in January 1990 resulted in a catch of an estimated 500 white whales (Siegstad & Heide-Jørgensen 1994).

Yield of mattak per whale

The amount of mattak per white whale is linearly related to both the standard body length and the total body mass of the whale (Fig. 7). The mean amount of mattak per whale landed during an autumn catch in Upernavik in 1991 was 79 kg/whale (95% CI 70–88). However this is an overestimate as some of the blubber attached to the skin is removed before the mattak is sold. When the mattak is sold for processing at the fish factories it is required that about 1 cm of blubber be attached to the skin. Simple tests in the field showed that this may reduce the amount of mattak by 10–20% of the values measured in this study. Thus the mean amount of landed mattak per whale during the drive fishery in Upernavik in the autumn is probably closer to 70 kg/whale. The weights of the tails of 9 whales averaged 12 kg.

Three males and one female measured in May at Qeqertarsuaq produced a mean of 156 kg of mattak. Approximately 15% should be subtracted to estimate the mean yield: 133 kg of mattak. White whales taken in Qeqertarsuaq in the spring include animals of a much larger size than those taken in the drive fishery in Upernavik in the autumn (Heide-Jørgensen & Teilmann 1994).

Narwhals reach larger asymptotic lengths and weights at physical maturity than white whales (Hay & Mansfield 1989). It is therefore expected that narwhals generally provide more mattak than white whales. The mean length of 41 narwhals killed in Avanersuaq in 1984 and 1985 was 365 cm (SD = 105, Greenland Environmental Research Institute, unpubl. data). Following the regression in Fig. 7 this corresponds to 105 kg of mattak per whale, from which about 15% should be subtracted to account for blubber that is removed before the mattak is sold. Hence my best estimate of the amount of mattak landed per narwhal in Avanersuaq is about 90 kg. Similarly, Reeves (1993) estimated that 89 kg was landed per narwhal in Arctic Bay.

Utilisation of hunting products

Blubber and skins of white whales were sold to KGH for export to Denmark until 1962 (Reeves & Heide-Jørgensen 1994). In the official statistics only blubber and skins

Table 4. Amounts of mattak from narwhals and white whales sold in West Greenland (1965–1992).

Year	Mattak sold in tons					Total
	ILU	QEQ	UUM	UPV	AVAN	
1965					1.5	1.5
1966				0.1	5.3	5.4
1967				0.1	3.9	4.0
1976					11	
1977					14	
1978					6	
1979					14	
1980					14	
1981				25.0	26.5	51.5
1982				21.2	24.0	45.2
1983				21.1	12.8	33.9
1984				20.7	21.9	42.6
1985				5.8		
1986				1.7		
1987	0	0	4.4	32.6	?	37.0
1988	0	4.9	7.3	27.3	2.4	41.9
1989	0	0.8	31.0	19.3	?	51.1
1990	16.4	2.3	63.6	18.5	9.2	110.0
1991	0	1.4	29.4	26.1	15.1	72.0
1992	0.8	6.7	13.3	46.3	12.2	79.3

Data from Anon. (1967, 1968a, 1968b), Greenland Statistical Office, Royal Greenland Production, Valdemar A.m.b.a. (Adam Kristensen, Innarsuit, pers. comm.) and Born (1987a). The municipalities are abbreviated as follows: ILU = Ilulissat, QEQ = Qeqertarsuaq, UUM = Uummannaq, UPV = Upernavik, AVAN = Avanersuaq.

of white whales are listed, but it is possible that the figures include some blubber and skins from narwhals. Since the 1960s mattak, tusks and to some extent meat have been the primary trade items from the white whale and narwhal hunting in Greenland. Mattak was first purchased by KGH in Avanersuaq in 1965 (Table 4). Although the statistics on the mattak trade are incomplete, it appears that the importance of this trade has increased in parallel with the increase in prices paid for mattak. The price paid to the hunters for mattak was 50 Dkr/kg in 1993 (Royal Greenland Production *in litt.*).

A portion of the mattak obtained from narwhals and white whales is sold to local fish factories, where it is packed, frozen and shipped to the larger towns in South Greenland. The number of white whales killed (observed or reported) and the amount of mattak sold are linearly correlated (Fig. 8), with a mean corresponding to a rate of about 65% of the mattak obtained from white whales in Upernavik being purchased (Fig. 8). This correlation can be used to calculate a rough estimate of the catches from the statistics on purchases of mattak, which are usually more reliable than the catch statistics *per se*.

There have been no purchases of mattak at Royal Greenland plants in Qasigiannguit (Christianshåb), Maniitsoq, Kangaatsiaq, Sisimiut or Aasiaat during the 1980s. Almost all mattak purchased in Qeqertarsuaq, Ilulissat (Jakobshavn) and Upernavik is from white whales, whereas narwhal mattak is traded primarily in Avanersuaq and Uummannaq.

Most of the tusks from narwhals are sold privately or to the KNI for export to Denmark (see Reeves & Heide-Jørgensen 1994).

Catches calculated from the purchase of mattak

The mean weight of mattak (narwhals and white whales, combined) purchased in Avanersuaq during 1976–1981 was 14 tons per year. The catch of white whales in Avanersuaq (excl. Moriussaq and Savissivik) in 1985, 1986 and 1987 was 70–80 white whales per year (Jörn Byrsing and Navarana Qaviaq pers. comm.) and mattak from these would amount to about 5 tons. Subtracting this amount from the total mattak purchased gives an estimate of about 100 narwhals caught, assuming a mean mattak yield of 90 kg per whale and that all of the mattak obtained was sold. It is more likely that only a portion of the mattak was sold and that the rest was consumed locally. If the proportion sold follows the prediction in Fig. 8, then the total catch of narwhals has been about 195 per year in Avanersuaq during 1976–1987.

Trends in population status estimated from the catch statistics and population size estimates

Catch reporting is incomplete in West Greenland. In particular, the municipality of Avanersuaq only infrequently report catches. For proper population assessment precise numbers of removals are mandatory. To correct the reported catches 75 white whales can be added for

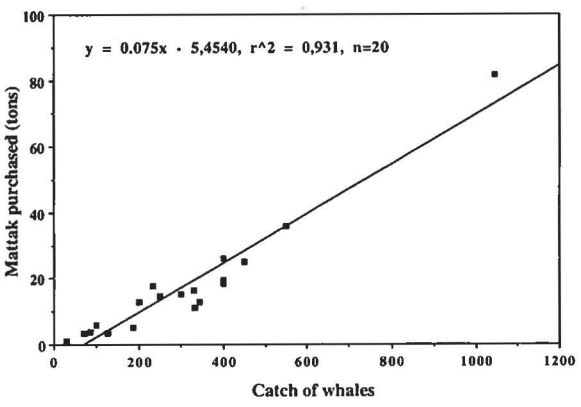

Fig. 8. Correlation between catches of white whales and narwhals and the amount of mattak sold to fish factories per catch.

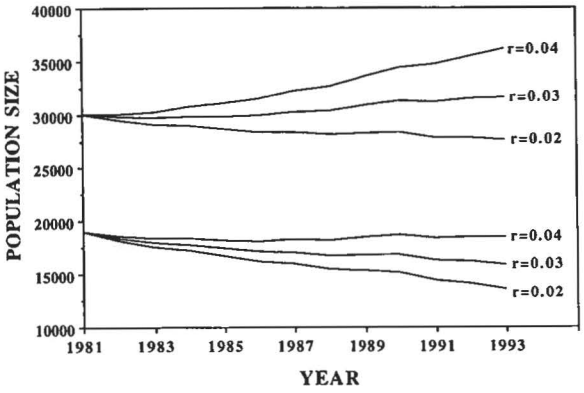

Fig. 9. Trends in the size of the Baffin Bay population of white whales during the 1980s with removals as revealed by the hunting statistics (Canada and Greenland combined), net recruitment rates (r) of 0.02, 0.03 and 0.04 and population estimates in 1981 of 18 600 white whales (Smith *et al.* 1985) or 30 000.

1985 through 1987 for Avanersuaq (see above). Furthermore, 195 narwhals (as calculated above) can be added annually for the 1980s and 1990s, again to account for unreported catches in Avanersuaq. For 1961 through 1964, which are the only years with complete reporting, Avanersuaq reported an average catch of 217 narwhals per year (Kapel 1977).

During the summer of 1981 Smith *et al.* (1985) conducted an aerial "strip-census" of white whales in the Canadian High Arctic where most of the Baffin Bay population of white whales is believed to summer. They estimated 12 000 (95% CI 6 300–18 600) white whales in this area at the time of the survey but made no corrections for submerged whales.

Vital population parameters have been estimated for white whales from Alaska (Burns & Seaman 1986), the Saint Lawrence River (Béland *et al.* 1988), Hudson Strait and Hudson Bay (Sergeant 1981, Doidge 1990) and West Greenland (Heide-Jørgensen & Teilmann 1994). The estimates of net recruitment are generally within the range 0.02–0.04; some of the authors have claimed that the true value is in the upper end of this range. Sergeant (1981) calculated the net recruitment as 0.05 on the basis of 17 years with constant catches of white whales in western Hudson Bay. However the critical assumption of a closed population was not met in his study.

Combining the current estimates of population size with the combined catch statistics for Baffin Bay (Table 3) and the values for the net recruitment reveals a declining trend in the population if this was smaller than about 20 000 white whales in 1981 (Fig. 9). Only a Baffin Bay population of more than 30 000 white whales, with a net recruitment rate of at least 0.03, could have sustained the reported catches without declining.

Visual aerial surveys of Baffin Bay and Davis Strait showed that narwhals are widely dispersed in the heavy pack ice during March through July (Koski & Davis 1994). Based on surveys in May-July 1979 Koski & Davis (1994) estimated that some 34 363 narwhals (SE 8 282) were present in the Baffin Bay pack ice. To this should be added narwhals in areas east and north of the surveyed area, plus whales that were submerged during the passage of the airplane.

Aerial photographic surveys of the Canadian High Arctic summering grounds carried out in 1984 revealed an estimate of 18 000 (90% CI 15 000–21 000) narwhals present at the surface during the survey (Richard *et al.* 1994). At the same time land-based counts of narwhals in Inglefield Bredning in northwestern Greenland produced a figure of about 4 000 narwhals (Born 1986). The sum of these two estimates provides a minimal figure of 18 000 narwhals in northern Baffin Bay and the high Arctic archipelago of Canada. To this estimate should be added figures for unsurveyed areas of Melville Bugt and Smith Sound and a correction factor for whales that did not appear on the photographs due to submergence.

The net recruitment rate of narwhals was recently estimated as no larger than 0.03–0.04 (Kingsley 1989). Narwhals are believed to have vital parameters that resemble those of white whales. It therefore would not be surprising if the net recruitment rates were found to be similar as well.

By applying the range of values for net recruitment, catches after 1979 and a combined estimate of 22 000 in 1984 to equation 1, it appears that the narwhal population could sustain recent catch levels only if it was larger than 22 000 in 1984. For the point estimate of 34 000 narwhals in 1979 (Koski & Davis 1994) the catches can be sustained if the net recruitment exceeds 0.03 (Fig. 10).

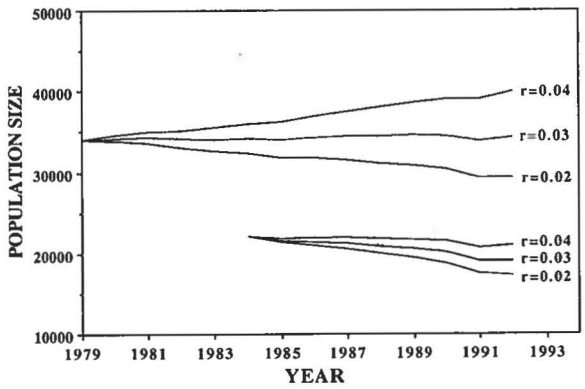

Fig. 10. Trends in the size of the Baffin Bay population of narwhals during the 1980s with removals as revealed by the hunting statistics (Canada and Greenland combined), net recruitment rates (r) of 0.02, 0.03 and 0.04 and point estimates of 22 000 narwhals in 1984 (Born 1986, Richard *et al.* 1994) or 34 000 in 1979 (Koski & Davis 1994).

Discussion

Changes in distribution of white whales

White whales were previously present, at least seasonally, in large numbers in Southwest and South Greenland (south of 65°N). Those that wintered along southwestern Greenland came from the north and were part of a southward movement in the autumn, similar to the present situation. The origin (*i.e.* main summer distribution) of the whales that occurred in southwestern Greenland south of Qeqertarsuatsiaat (63°N) is less certain as Degerbøl & Nielsen (1930) suggested that at least some of them came from Canada. The present situation is clearly different: white whales are rarely seen or caught south of Sisimiut (67°N). The most likely explanation for the change in distribution is the exploitation on the southern wintering grounds. Intensive hunting may have depleted the stock wintering south of 63°N, and especially the drive fishery at Nuuk and the drive-net fishery at Maniitsoq may have severely reduced the number of whales wintering in Maniitsoq and Nuuk districts after 1930. The catch statistics show a brief peak followed by an obvious decline in all three areas (Nuuk, Maniitsoq and Kangersuatsiaq) with organised drive fisheries.

The sea temperature in southwestern Greenland (63°N) gradually declined from 1876 to 1920, after which time it increased rapidly and remained high until the late 1960s. Cold conditions have developed rapidly since the 1960s (Buch 1990). It could be speculated that the higher sea temperatures in South Greenland after 1920 contributed to a change in white whale distribution, with less whales present in South Greenland. However the decline in sea temperatures after 1968, that was just as pronounced as the increase in the 1920s (Smidt 1983), did not result in an increased abundance of white whales in South Greenland.

Eastern Canadian stocks of white whales were also severely reduced during the 1920s and 1930s (Mitchell & Reeves 1981, Reeves & Mitchell 1987a, 1987b). In Cumberland Sound reported catches in the drive fishery during 1920–39 totalled 5 242 whales and by the late 1930s the population was probably depleted (Brodie 1971, Mitchell & Reeves 1981, Reeves & Mitchell 1987a).

The collapses of stocks of white whales off southwestern Greenland and in Cumberland Sound and Ungava Bay may have been mutually reinforcing if the stocks were connected by movement of animals across Davis Strait. Recently white whales have been observed in the middle of Davis Strait in March and mid-May (Mitchell & Reeves 1981), suggesting some exchange between stocks in eastern and western Baffin Bay and Davis Strait. Mixing among neighbouring stocks in southern Davis Strait and perhaps the Labrador Sea is more likely to have occurred before commercial exploitation started, especially during winter months when distance between white whale concentrations in eastern Canada and West Greenland is shortest (Richard *et al.* 1990).

Catches

The largest catches of white whales during the 1980s were made in the drive fishery in the municipality of Upernavik. The catch due to ice entrapment in Disko Bugt in 1990 exceeded the catch in Upernavik, but this was an exceptional event. Kapel (1977) reported three ice entrapments between 1954 and 1975, all in Disko Bugt, with catches of 425, 342 and 260 white whales. Some unusually large autumn catches of narwhals have also been made recently in Uummannaq. The reason for the sudden appearance of large numbers of narwhals in Uummannaq remains obscure. Favourable weather and ice conditions during November may partly explain the rise in catches, but also the sudden abundance of prey species and the disturbance from trawlers offshore have been suggested as contributing factors.

Born (1987a) estimated that 150 narwhals were taken annually in the municipality of Avanersuaq during the 1980s. This may be an underestimate as my calculations suggest that at least 150 have been taken to balance the purchases of mattak, and some additional catch would have been needed to provide for local mattak consumption. Correcting for the local consumption gives a total estimated catch of about 195 per year in Avanersuaq.

Official catch statistics for both white whales and narwhals are incomplete. As the catches show large fluctuations from year to year, catch statistics can not be corrected unless detailed data from each area are available. Annual catches during the late 1980s were probably in the magnitude of 500–1000 white whales and 500 narwhals in West Greenland. To this should be added the proportion of whales that are killed-but-lost.

Trends in population size

The calculations of population trends based on catch statistics, estimated population sizes and estimated net recruitment rates are subject to various uncertainties. The population sizes may be underestimates because the entire distributions of white whales and narwhals have not been covered in any of the surveys. Some of the unsurveyed areas may, however, be of marginal importance. Also, the estimates from aerial surveys are not adjusted to account for the whales that were submerged during the passage of the aircraft. Removals are usually under-reported as hunting loss is never included and some areas and settlements report their catches only infrequently. Among these is the municipality of Avanersuaq, where it was possible to estimate catches from sources other than

the Hunters' List of Game. In other areas, where under-reporting may be less obvious, not enough information is available to estimate actual removals.

It is not possible, at present, to apply a simple correction factor to survey estimates to account for submerged whales (*cf.* Koski & Davis 1994) and only unsubstantiated estimates of hunting loss rates in West Greenland are presently available (*e.g.* IWC 1980: 127). Born (1987a) and this study represent the first attempts to quantify under-reporting of narwhals in Avanersuaq. Under-reporting in other areas and for white whales remains to be quantified. It is nevertheless clear that the Baffin Bay white whale population would have had to be considerably larger than the 1981 population estimate to have sustained the reported catches and purchases of mattak since then. It seems unlikely that the extensive surveys conducted in the Canadian High Arctic in 1981 would have resulted in a population estimate that is only half or less of the true population size. It must be concluded that white whales are probably being harvested above the replacement yield and that a decline in the population size has taken place during the 1980s. This is also supported by systematic aerial surveys of the wintering stock of white whales off West Greenland that indicate a 30% decline in relative abundance from 1982 to 1991 (Heide-Jørgensen *et al.* 1993).

The Baffin Bay white whale population may be especially vulnerable to overexploitation because of the whales' coastal habits. During the autumn they move south along the west coast of Greenland, passing near a number of settlements with intensive white whale hunting and where especially females are taken in large numbers (Heide-Jørgensen & Teilmann 1994). These coastal areas may act as "bottlenecks" for the whale population. The recent increase in price of the much-desired mattak, combined with improved hunting equipment (fast dinghies with outboard engines), has increased the hunting pressure on the white whales.

Narwhals are taken in smaller numbers in Greenland and they are more difficult to find and pursue. The projection of the narwhal population seems to be more stable than that of white whales although some narwhal catches in some recent years may have exceeded the replacement yield. Overexploitation of narwhals in Greenland is less likely to happen because they are found farther offshore than white whales, and their range at any time of the year is much larger than that of white whales. However, this may not be true for Canada, where deep-water concentrations of narwhals are found near shore in areas and periods where considerable hunting takes place.

The uncertainties of the status of both the white whale and narwhal populations warrant more thorough study so that catches can be adjusted to sustainable levels and further declines can be prevented.

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