# Ice entrapments of narwhals (*Monodon monoceros*) and white whales (*Delphinapterus leucas*) in Greenland

HELLE SIEGSTAD and MADS P. HEIDE-JØRGENSEN

Siegstad, H. & Heide-Jørgensen, M. P. 1994. Ice entrapments of narwhals (*Monodon monoceros*) and white whales (*Delphinapterus leucas*) in Greenland. – Meddr Grønland, Biosci. 39: 151–160. Copenhagen 1994-04-22.

Information on historical and recent ice entrapments of narwhals (*Monodon monoceros*) and white whales (*Delphinapterus leucas*) in Greenland is presented. Most entrapments occur in the inner parts of Disko Bugt where both narwhals and white whales are caught. In this area entrapments happened under particular weather conditions and at certain sites at intervals of two to three years during the 1970s and 1980s. In the Uummannaq and Upernavik areas entrapments occurred less frequently and usually involved only narwhals. No entrapments were documented in East Greenland. The data suggest that whales sometimes die in entrapments that are not discovered by hunters and that ice entrapments may be regarded as contributing to the natural mortality of narwhals and white whales. These large-scale, periodic die-off events probably affect long-term population trends and represent a concern for the management of arctic whale stocks.

Key words:
Narwhal, *Monodon monoceros*, white whale, beluga, *Delphinapterus leucas*, ice entrapment, sassat, Baffin Bay, Greenland.

*Helle Siegstad, Greenland Fisheries Research Institute, Box 570, DK-3900 Nuuk, Greenland and Mads P. Heide-Jørgensen, Marine Mammal Section, Greenland Fisheries Research Institute, Tagensvej 135, DK-2200 Copenhagen N, Denmark.*

## Introduction

Arctic whales are periodically entrapped by ice, especially in periods with extremely low temperatures when fast ice forms rapidly. Among the arctic whales, narwhals (*Monodon monoceros*) and white whales (*Delphinapterus leucas*) seem to be particularly vulnerable to ice entrapment. Bowheads (*Balaena mysticetus*) were occasionally reported in ice entrapments in the past in Greenland and elsewhere (Mitchell & Reeves 1982) but a recent review concluded that relatively few bowheads die from ice entrapment (Philo *et al.* 1993). In Baffin Bay and Davis Strait the depleted status of the stock of bowheads (Reeves *et al.* 1983) may help explain the absence of recent entrapments.

Porsild (1916, 1918) provided the first detailed description of ice entrapments of whales in Greenland (Fig. 1), although the phenomenon had been recognized for more than a century (Egede 1788, Gad 1973, Glahn 1991). Porsild (1916) used the Greenlandic word "savssat" ("sassat" in modern Greenlandic) to describe an event in which "whales and birds are surprised by sudden low temperatures [and] they congregate in large herds in the remaining holes in the ice to breathe". We found that "ice entrapment of whales" requires a more restrictive definition as both white whales and narwhals often naturally occur in leads and cracks in dense ice. It is somehow arbitrarily decided when the animals are lethally (or otherwise dangerously) entrapped. For this compilation we decided that an entrapment of whales is ultimately fatal. Thus a true "ice entrapment" event occurs only when the whales are unable or unwilling at any given instant to escape from a restricted open-water reservoir that is surrounded by fast ice or pack ice. This definition is necessary because arctic whales live for the major part of the year in areas with heavy pack ice where they are often found in surroundings that 'at first glance' may look like an entrapment but in fact is their preferred habitat. For instance narwhals that winter in the Baffin Bay area show a strong preference for areas with more than 9/10 of pack ice (Koski & Davis 1994) where they may live for months in relatively small leads and cracks.

The significance to the whale populations of mortality caused by ice entrapment has been dicussed by several investigators (Mitchell & Reeves 1981, Brodie 1982,

Fig. 1. Flensing of narwhal taken in sassat in Disko Bugt during February 1915. Photo: M. Porsild. Copyright Arktisk Institut. Denmark.

Burns & Seaman 1986, Ivashin & Shevlyagin 1987). When discovered by hunters, entrapped whales are subjected to intensive hunting (*e.g.* Mitchell & Reeves 1981). In this paper we summarize data on the frequency and distribution of ice entrapments in Greenland. Some information on the survival of entrapped whales is also presented. We discuss ice entrapment of whale populations as a factor contributing to both natural and hunting mortality.

## Materials and methods

Published sources (*e.g.* scientific literature, newspapers) were consulted for information on ice entrapments. All available issues of local newspapers from Ilulissat/Jakobshavn ("Iluliarmioq": 1954–1992), Qeqertarsuaq/Godhavn ("Qaqaliaq": 1962–1992), Vaigat ("Qulleq": 1954–1972), Uummannaq ("Nasiffik": 1936–1992) and Upernavik ("Qimusseq": 1953–1992) were searched for reports on sassat's. Information on ice entrapments of whales throughout Greenland was obtained through extensive interviews with hunters and fishermen conducted under the project "Inventory of Renewable Resources in Greenland" (Siegstad 1991). During the course of that project all municipalities in Greenland were visited by one of the authors (HS) and hunters with particular insight into the past occurrence of whales were interviewed. To obtain information on numbers caught in ice entrapments the Hunters' List of Game was also consulted (Anon. 1953–1987). However, large catches in winter months were not used as indications of ice entrapments unless auxiliary information so suggested. Entrapments of narwhals in the Uummannaq area and white whales in Disko Bugt in 1984 were witnessed by one of us (HS). A large entrapment of white whales in 1990 in Disko Bugt was visited by research staff, who collected biological specimens including lower jaws. Ages of thirteen entrapped white whales were estimated by counting dentinal growth layers in teeth from the lower jaw (Heide-Jørgensen *et al.* 1994) and sex was determined by chromosomal analyses (Palsbøll *et al.* 1992). Data on purchases of whale skin ("mattak") at fish processing plants were used to estimate numbers of whales killed in some sassat's.

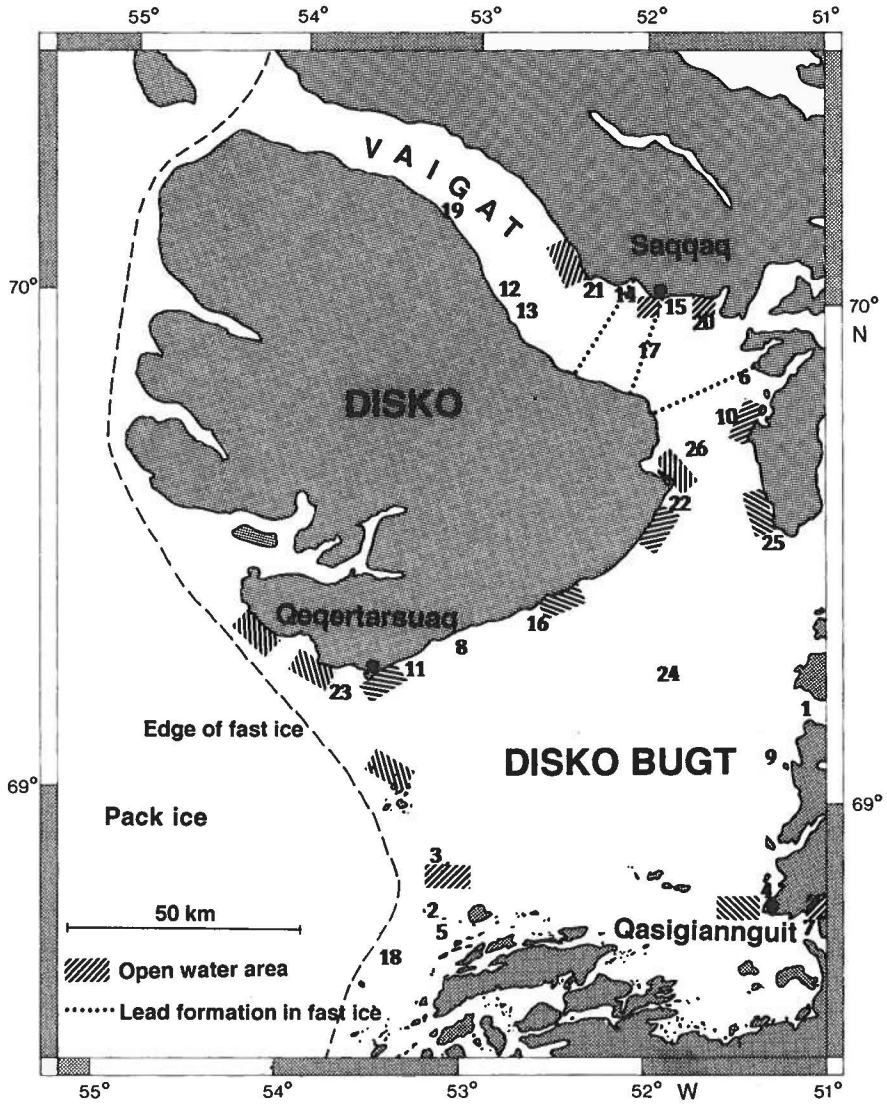


Fig. 2. Map of the Disko Bugt region showing positions of ice entrapments (keyed to nos. in Table 1), and areas where leads and open water in the fast ice are frequently found during January-March. The information on open-water areas and leads was collected during the project "Inventory of Renewable Resources in Greenland".

# Results

## Occurrence and distribution of entrapments in Greenlandic waters

Narwhals are present year-round along the coast of East Greenland and in the Greenland Sea. During the open-water season they are frequently present in the fjords of East Greenland (Dietz *et al.* 1994). White whales are only occasionally observed in East Greenland and these may be stragglers from West Greenland or from Svalbard (Dietz *et al.* 1994). No published accounts or descriptions from hunters of ice entrapments in East Greenland have come to our attention. This may be due partly to the low abundance of whales and partly to the extreme mobility of the coastal sea ice and the predictability of the formation of fast ice in the fjords of East Greenland.

In West Greenland ice entrapments have been reported from the municipalities in Disko Bugt and from Uummannaq and Upernavik municipalities (Tables 1 and 2, Figs 2 and 3). Ice entrapments occur relatively frequently in Disko Bugt but less frequently in Uummannaq and Upernavik municipalities. In Disko Bugt narwhals and white whales can be found in mixed or single-species entrapments (Table 1, Fig. 2). In the Ummannaq and Upernavik areas usually only narwhals are entrapped (Table 2, Fig. 3).

The entrapments in Disko Bugt are remarkably uniform in their geographical distribution. Particular currents and patterns of ice formation may determine the localities of the entrapments (Fig. 2). In Disko Bugt freeze-up rarely occurs until December and March is

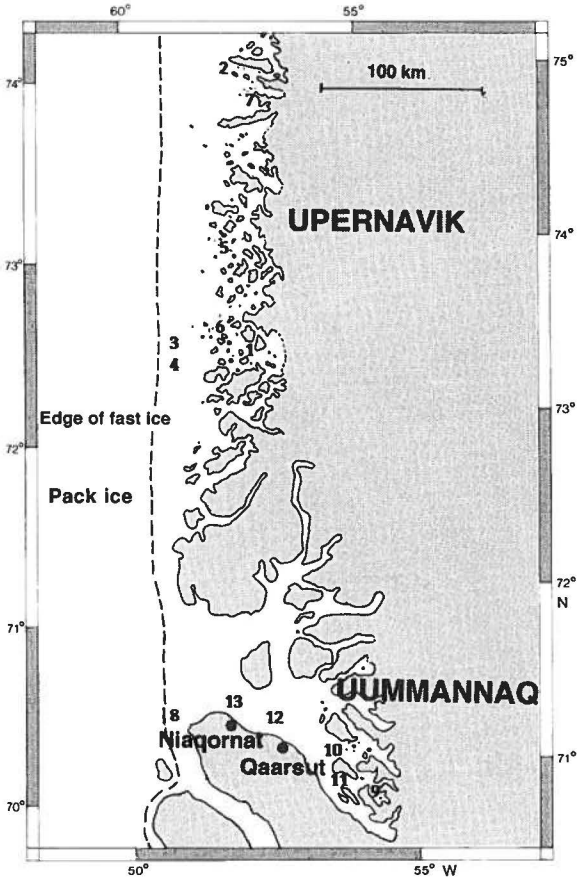


Fig. 3. Map of the municipalities of Uummannaq and Upernavik showing positions of ice entrapments (keyed to nos. in Table 2).

generally the coldest month. Whales are usually entrapped in the period January to March and occasionally in April (Tables 1 and 2). A period with stable and cold weather normally precedes an entrapment, and hunters often expect the entrapments to occur during certain ice and temperature conditions (see below).

The largest entrapment reported from Greenland took place in 1955 when an estimated 3 000 white whales were landed by the hunters (Table 1, Fig. 2; No. 17). This event was described in detail by Golodnoff (1956) and the size of the catch was estimated by a local inhabitant of Saqqaq who had witnessed several entrapments (Hannibal Fencker *in litt.*). The entrapment had been expected by the hunters because, after a period with open water early in January, the air temperature suddenly dropped and remained near −30°C. Within a week the sound of Vaigat (Sullorsuaq) was covered with fast ice except for a narrow lead 0.5–1 m wide extending across the Vaigat from Saqqaq to Disko (the island of Qeqertarsuaq). The white whales were discovered in this lead in late January (Golodnoff 1956).

## Recent entrapments of white whales and narwhals

*April 1988*: At "Per Dams skib" close to the town of Qeqertarsuaq (Godhavn, Table 1, Fig. 2; No. 8) 100–150 white whales were entrapped. It is uncertain whether the presence of outboard motor boats actually scared the whales into the ice. A large proportion of the killed whales floated and could be recovered, so hunting loss was considered minimal. It was suggested by some hunters that the entrapped whales were primarily females with calves because it was more difficult for them to leave the area than it was for the mature males (Hans Christian Petersen, Greenland Home Rule, Nuuk, pers. comm.). The amount of mattak purchased after this entrapment was 10.3 tons (Niels Bjerregaard, Royal Greenland, Qeqertarsuaq *in litt.*). The mattak yield from a sample of four white whales taken in Qeqertarsuaq in May 1992 ranged between 100 and 150 kg per whale (Heide-Jørgensen unpubl. data). This is considerably higher than the estimated yield for white whales taken in Upernavik (Heide-Jørgensen 1994). The difference is explained mainly by the larger size of the whales taken in spring at Qeqertarsuaq (Heide-Jørgensen & Teilmann 1994). Nevertheless, the purchased amount of mattak corresponds to a kill of at least 100 white whales if all mattak was sold.

*February 1990*: After a cold period with almost no wind that began in mid January and lasted till mid February (Fig. 4), ice cover in Disko Bugt was extensive and thick. In late January and early February a large herd of white whales was discovered close to the eastern part of Disko (Table 1, Fig. 2; No. 26). The whales were in a lead 5 m wide and 5–10 km long. Hunters from several settlements and towns within Disko Bugt and even some from the municipality of Uummannaq participated in the catch. Figures indicating a total catch of between 300 and 1000 were frequently mentioned, but no exact data on catches or losses are available. The purchases of mattak totalled 9.4 tons at Ilulissat and 6.4 tons at Saqqaq (Per Lyster, Greenland Statistical Office, Nuuk *in litt.*). Assuming that each whale produced an average of 75 kg of mattak (see Heide-Jørgensen 1994) then a minimum of 210 whales would have been taken to produce this amount of mattak. Additionally, some mattak was sold locally or consumed by local people. Using an equation developed by Heide-Jørgensen (1994) showing the relationship between the amount of mattak purchased and the catch of whales per settlement, we can estimate a combined catch in Ilulissat and Saqqaq of 285 white whales. Mattak was also delivered to other villages (*e.g.* Qeqertarsuaq/Godhavn and Qasigiannguit/Christianshåb), so a more likely estimate of the total catch is around 400 white whales. There are no estimates of the loss rate (*i.e.* whales killed but not retrieved) but it is likely to have been high as the air temperature was low (-30°C) and there was little daylight.

Table 1. Ice entrapments of narwhals and white whales in Disko Bugt. See Fig. 2 for localities. HLG is Hunters' List of Game (Anon 1953–1988).

| Year | Month | No. | Position | Comments | Source |
|---|---|---|---|---|---|
| 1738 | January | 1 | Ice Fjord at Ilulissat | More than 100 white whales | Egede 1788 |
| 1750 | | 2 | Near Aasiaat | More than 1000 *D.leucas* and 21 bowheads | Gad 1969 |
| 1803 | March to April | 3 | Near Kronprinsens Ejland | "A fantastic entrapment comprising both *M.monoceros* and *D.leucas*" | Gad 1976 |
| 1860 | April | 4 | Near Qasigiannguit | "Hundreds" of *D.leucas* and *M.monoceros* | Brown 1868 |
| 1898 | April | 5 | Near Aasiaat | 22 *M.monoceros* or *D.leucas* | Anon. 1944, Kapel 1979 |
| 1899 | May | 6 | Nuak in Ritenbenk district | 80 *M.monoceros* or *D. leucas* | Anon. 1944, Kapel 1979 |
| 1915 | January | 7 | Akulleq | 6 *D.leucas* | Porsild 1918 |
| 1915 | February | 8 | Between Qeqertarsuaq and Aamaruutissat | More than 1000 *M.monoceros* were caught in two sassat | Porsild 1918, Anon. 1944, Rosendahl 1957 |
| 1915 | March | 9 | Ilimanaq in Qasigiannguit | About 130 *M.monoceros* | Porsild 1918, Anon. 1944 |
| 1915 | April | 10 | Ritenbenk | 25–33 *D.leucas* | Porsild 1918, Anon. 1944 |
| 1920 | | | Sisimiut | 40 *M.monoceros* and/or *D.leucas* | Anon. 1944, Kapel 1979 |
| 1933 | | 10 | Ritenbenk | About 100 *M.monoceros* and/or *D.leucas* | Anon. 1944, Kapel 1979 |
| 1934 | March | 11 | Qeqertarsuaq | About 50 *M.monoceros* and/or *D.leucas* | Anon. 1944, Kapel 1979 |
| 1935 | | 12 | Qullissat | About 100 *M.monoceros* and/or *D.leucas* | Anon. 1944, Kapel 1979 |
| 1943 | March | 13 | Qullissat-Ujarasussuk | 340 *D.leucas* and *M.monoceros* | Fencker *in litt.*, Anon. 1943 |
| 1945 | February | 14 | At Taartuna | *M.monoceros* and *D.leucas*-no other information | Fencker *in litt.* |
| 1951 | February | 15 | Saqqaq | HLG (February): 85 *M.monoceros* and 173 *D. leucas* | Fencker *in litt.*, Golodnoff 1956 |
| 1952 | March | 16 | Aamaruutissat | About 450 *M.monoceros* | Anon. 1988a |
| 1955 | January | 17 | Saqqaq-Sioraleq in a 30 km long lead | More than 3000 *D.leucas* | Fencker *in litt.*, Anon. 1955, 1961, Golodnoff 1956 |
| 1960 | | 18 | Aasiaat | About 100 *M.monoceros* and/or *D.leucas* | Anon. 1961 |
| 1967 | March | 14 | Taartuna | Mixed *M.monoceros* and *D.leucas*, the ice broke after one week – few days later a new sassat was discovered – this time with only *D.leucas*. HLG (March): 31 *M.monoceros* and 3 *D.leucas* | Fencker *in litt.*, |
| 1968 | February | 19 | Northwest of Qullissat at Kuusinerssuaq | Both *M.monoceros* and *D.leucas* – 600 HLG (February): 161 *M.monoceros* and 234 *D.leucas* | Berliner 1968, Fencker *in litt.* Kapel 1977 |
| 1969 | January | 20 | East of Saqqaq | Only *M.monoceros* – no information on numbers | Fencker *in litt.* |
| 1970 | January | 21 | Nuunguaq NW of Saqqaq | Only *M.monoceros*. (Kapel: > 100 caught) | Fencker *in litt.*, Kapel 1977 |
| 1970 | January | 22 | Nuuk at Disko Island | 1000 *D.leucas*. (Kapel: > 340 caught) | Anon. 1970a, 1970b, Kapel 1977 |
| 1970 | April | 12 | Northwest of Qullissat | Only *D.leucas* – less than 50 | Fencker *in litt.* |
| 1976 | January | 23 | Qeqertarsuaq | HLG (for the town): 479 *D.leucas* in early January and 147 *D.leucas* in late January (and 15+12 for Kangerluk). "More than 500 caught off Brededal" | Kapel unpubl. |
| 1982 | February | 24 | Between Aamaruutissat Ilulissat | Between 50–200 *D.leucas* caught | Born *in litt.* |
| 1982 | April | 4 | At Qasigiannguit | 45 *M.monoceros* caught. The animals were found under air-filled cupolas in the ice | Born *in litt.* |
| 1984 | February | 22 | Marraat (Mudderbugten) | About 200 *D.leucas* | Anon. 1984 |
| 1984 | April | 25 | Niaqornarsuk | 20 *D.leucas* caught-the animals disappeared | Witnessed by H. Siegstad |
| 1988 | April | 8 | Between Qeqertarsuaq and Aamaruutissat | About 100–150 *D.leucas* | Anon. 1988b |
| 1990 | January | 26 | Between Marraat and Appat | About 500 *D.leucas* caught | Anon. 1990a, 1990b, 1990c |

The mean estimated age of a sample of the entrapped white whales was 13.9 years (range 5.5–24, N = 6) for females and 10.5 years (range 1.5–17, N = 7) for males, which indicates that mature whales of both sexes are present in Disko Bugt in winter and that they are susceptible to entrapments.

*January 1991*: In mid January groups of narwhals were discovered entrapped in the outer parts of the municipality of Uummannaq off Niaqornat; 26 were caught and one was lost (Table 2; J. Tobiassen pers. comm.).

## Mortality of entrapped narwhals in Uummannaq

A small entrapment of 8 narwhals was discovered on 29 April 1984 between Qaarsut and Niaqornat in Uummannaq (Table 2, No. 12; Fig. 3). The whales were found in a small open-water area (about 3 $m^2$) in the fast ice approximately 5 km from shore. During searches with mirrors under the ice a further 25–30 dead narwhals could be seen frozen into the underside of the fast ice. A few of these were grappled and hauled onto the ice (Fig. 5). They had all been dead for a considerable time and were

Table 2. Ice entrapments of narwhals and white whales in the Upernavik and Uummannaq areas. See Fig. 3 for localities. IRR = "Inventory of Renewable Resources in Greenland".

| Year | Month | No | Position | Comments | Source |
|---|---|---|---|---|---|
| *Upernavik* | | | | | |
| 1920–30 | | 1 | Aappilattoq | A sassat saved a starving settlement | Siegstad unpubl. |
| 1939 | | 2 | North of Nuussuaq<br>Amdrup Isle | 100 *M.monoceros* killed in a lead | IRR, Anon. 1940<br>Kapel 1979 |
| 1948 | | 3 | West of Upernavik | About 200 *M.monoceros* | IRR |
| 1956 | | 4 | West of Upernavik | 100–150 *M.monoceros* | Knudsen 1958, Anon. 1961<br>Kapel 1977 |
| 1958 | | 5 | North of Tasiusaq | *M.monoceros*– no information on number | IRR |
| 1960–63 | | 6 | Northwest of Upernavik<br>at Pututaasaq | 10 *M.monoceros* | IRR |
| 1968 | January | | Upernavik area | Caught about 50 *M.monoceros* | Kapel 1977 |
| 1969 | March | 7 | Illulik | 60 *M.monoceros* | IRR, Haller 1986 |
| *Uummannaq* | | | | | |
| 1781 | | | 150 km N of Uummannaq | No information on species | Gad 1973 |
| 1917 | | 8 | Nuussuaq | No information on number and species | Bertelsen *et al.* 1921 |
| 1922 | | 9 | Sermilik | About 25 *M.monoceros* or *D.leucas* | Anon. 1944<br>Kapel 1979 |
| 1956 | December | 10 | Uummannaq town | Caught 250 *M.monoceros* | Hadrup 1971, Kapel 1977,<br>Anon. 1961 |
| 1961 | April | | | 272 *M.monoceros* | Anon. 1962, Kapel 1977 |
| 1968 | January | 11 | West of Uummannaq | 84 *M.monoceros* | Kapel 1977, Anon. 1968 |
| 1984 | Late April | 12 | North of Ikorfaat | 8 *M.monoceros* caught and 25–30 *M.monoceros*<br>found dead under the ice | Witnessed by H. Siegstad |
| 1991 | January | 13 | North of Niaqornat | 26 *M.monoceros* | J. Tobiassen 1991 (pers.<br>comm.) |

partly decomposed. A large tusk-bearing narwhal was found 50–100 m from shore in the tidal zone between the fast ice and the land-fast ice foot approximately 5 km away from the breathing hole. When hauled onto the ice this whale appeared decomposed and amphipods had been feeding heavily on the mattak.

During the same period Greenland sharks (*Somniosus microcephalus*) caught at the ice edge 50 km east of the sassat had meat from marine mammals in their stomachs, indicating that they may have been feeding on dead narwhals.

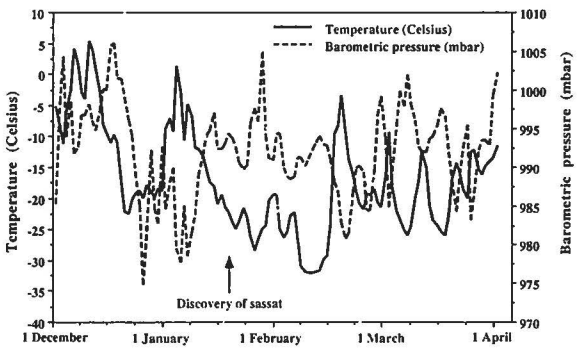


Fig. 4. Daily measurements of air temperature and barometric pressure in Ilulissat during December 1989 through March 1990. (Source: Grønlands Forundersøgelser).

# Discussion

## Limitations of the study

Our search for reports on ice entrapments primarily covered published sources. Hence some ice entrapments that were not reported, or that were reported but not published, may have escaped our notice. However, our sample of entrapment reports offers a consistent description of the geographical distribution of entrapments and for the past decade or two the frequency of discovered entrapments is probably also reliably described. Most observations of whale entrapment stem from discoveries by hunters. In winters when weather conditions favour ice entrapments hunters will search for whales in areas with open water and where whales are known to have been entrapped previously. These searches are usually effective because ice fog, visible at long distances, is emitted from the open water. After entrapped whales are found, they are invariably subjected to intensive hunting.

Thomsen (1993) recently presented a study of Inuit knowledge of narwhals and white whales. Her study reveals a similar picture of the frequency and general distribution of ice entrapments. The discrepancies between her study and ours may be attributed to different definitions of ice entrapment (see Introduction) and to the fact that her study was based on human recall rather than written sources.

Fig. 5. Narwhals frozen into the fast ice and discovered in late April 1984 (Table 2; No. 12) in Uummannaq. Photo: H. Siegstad.

## Weather conditions during an entrapment

Narwhals and white whales are in danger of becoming ice-entrapped when air temperatures are low and new ice is rapidly forming. Factors responsible for an entrapment could include a group of whales' lack of experience with dangerous ice conditions, their preoccupation with exploiting a concentration of prey, or simply a failure to respond quickly enough to a rapid change of environmental conditions. In West Greenland the entrapments occur most frequently in the northern part of the area influenced by the influx of Atlantic water. South of Disko Bugt open water can usually be found along the coast during the winter. The weather situation for an entrapment in 1990 is in accordance with descriptions from previous incidents of entrapment in Disko Bugt: a period with open water early in January is suddenly reversed when a period with extremely low temperatures and no wind results in rapid freezing of the sea surface (Porsild 1918, Golodnoff 1956).

## Destiny of entrapped whales

The discovery of dead narwhals frozen into the fast ice in the Uummannaq area suggests that when whales are trapped well inside the persistent fjord ice they are at risk of dying when the last open water freezes. However, the definition of an ice entrapment is important when considering the whales' ability to survive. The entrapment at Qeqertarsuaq in April 1988 was probably a short-term entrapment in deteriorating ice conditions as the spring break-up of land-fast ice was progressing. No new ice was forming during daytime because of the elevation of the sun in mid April and this entrapment must therefore be considered temporary, with limited or no mortality of whales expected due to the entrapment itself. However, as the whales were discovered by hunters, they experienced high mortality from the hunt.

The pertinent question is whether the whales that are killed by hunters would have died anyway because of their lack of access to open water. If the whales usually survive an entrapment, then the mortality caused by hunting should be considered additive to the natural mortality. It seems likely that there is no simple solution to this problem. The survival of entrapped whales depends en-

tirely on the persistence of the ice conditions and the time of the year. Generally, we feel confident that whales that are entrapped early in winter with the prospect of continued low temperatures and increasing ice coverage have a high probability of dying regardless of whether they are hunted or not. This may often be the case for entrapments in the eastern parts of the Uummannaq area and perhaps also in the eastern parts of Disko Bugt. Entrapments later in the season in areas where ice conditions are likely to change within a few weeks will probably always be survived by the whales. This may be the case for entrapments in the western parts of Disko Bugt and Uummannaq, and in the Upernavik area.

The observation of dead narwhals frozen into the fast ice in the vicinity of a small open-water area suggests that entrapment can be fatal even when the whales are not hunted. Degerbøl & Freuchen (1935) and Mitchell & Reeves (1981) mentioned similar incidents in which narwhals were found late in the season in the fast ice in northern Canada. Freeman (1968) described ice entrapments of white whales near Grise Fiord where the whales were discovered in the autumn and were hunted throughout the winter. The animals became progressively thinner and in poorer condition during the winter, suggesting that they would have eventually succumbed to starvation if they had not been killed by the hunters. Lowry *et al.* (1987) listed the relatively few entrapments of white whales in Alaska and described two incidents, both in April, when entrapped white whales died from natural causes. In both incidents polar bears were observed to prey upon or scavenge from the entrapped whales.

## Population effects

If entrapment mortality is usually a part of natural mortality then it must constitute a major proportion of this mortality. The numbers of dead whales at some entrapments are high relative to the estimates of population size. The white whale population centered in Baffin Bay is in the magnitude of 10 000 to 20 000 and less likely to be 30 000 (Smith *et al.* 1985). When 500 whales die in an entrapment it constitutes a mortality of 2–5%, which is a high instantaneous mortality rate for an odontocete. Independent estimates of annual mortality rates for white whales are in the range of 2–4% (Beland *et al.* 1988, Doidge 1990). To balance this periodic pulse in mortality the remaining population would need to have a reduced natural mortality during the rest of the year and in the preceding and succeeding years.

Other marine mammals do experience pulses of mass mortality that greatly exceed the natural mortality for normal years. The most dramatic example is the mass die-off of harbour seals, *Phoca vitulina*, in the North Sea area during 1988 when more than 18 000 seals died during six months, corresponding to an instantaneous mortality rate of 60% in some areas (Heide-Jørgensen *et al.* 1992). Various odontocetes mass strand, particularly *Globicephala spp.*, *Pseudorca crassidens*, and *Physeter catodon* (Sergeant 1982). Also, walruses (*Odobenus rosmarus*) sometimes die in unusually large numbers because of overcrowding at haul-out sites (Fay & Kelly 1980). These mass die-offs certainly exceed the natural mortalities and have pronounced effects on long-term population trends (Harwood & Hall 1990). The population-regulating effects of density-dependent changes in reproduction and mortality rates are masked by the mass die-offs caused by epizootics or stranding events, and this may also be true for the mass die-offs of narwhals and white whales caused by ice entrapment.

From a management point of view, the mass die-offs are particularly intriguing as most predictions about stock responses to exploitation assume relatively constant population parameters. If unpredictable catastrophic mortalities, independent of the population size, were to be incorporated into a management scheme, the result could be that the margins or surpluses available for exploitation are surprisingly small. This could be true regardless of whether the entrapped and hunted whales would have succumbed from natural causes alone. Entrapments provide unpredictable opportunities for windfall catches of unusually large numbers of whales. The population effects of such events should be carefully monitored to allow rapid adjustments in the hunt-management scheme.

## Acknowledgements

We wish to thank the hunters and fishermen in Greenland for sharing with us their hard-won knowledge about ice entrapments of whales during the project "Inventory of Renewable Resources in Greenland". This study was jointly financed by Aage V. Jensen's Charity Foundation and by the Greenland Home Rule. A. E. Kristensen collected the samples from the ice entrapment in Disko Bugt in 1990 and F. O. Kapel provided additional information on entrapments.

## References

Anon. 1940. Beretninger vedrørende Grønlands styrelse. – Nr.1. p. 374. København. (Annual reports and announcements).

Anon. 1943. – "Grønlandsposten". 1943. Nr.16. p. 145. (Newspaper in Danish).

Anon. 1944. Beretninger vedrørende Grønlands Styrelse. – Nr.1. Sammendrag af Statistiske Oplysninger. p. 624–625. Ministeriet for Grønland, København. (Statistical information on hunting and trade).

Anon. 1953–1988. Sammendrag af Grønlands Fangstlister. – Until 1984 Ministeriet for Grønland, Copenhagen. After 1985 Erhvervsdirektoratet, Nuuk.

Anon. 1955. – "Iluliarmioq". 1955. Nr.3. 12. Februar. (Local newspaper in Greenlandic and Danish from Ilulissat).

Anon. 1961. Beretninger vedrørende Grønland. – Nr. 1. 1961. p. 101. Ministeriet for Grønland, København. (Annual reports and announcements).

Anon. 1962. Beretninger vedrørende Grønland. – Nr. 1. 1962. p. 79. Ministeriet for Grønland, København. (Annual reports and announcements).
Anon. 1968. – "Nasiffik". 1968. Nr. 1. Februar 33. årg. (Local newspaper from Uummannaq).
Anon. 1970a. – "Iluliarmioq". 1970. Nr. 2. 30. januar. (Local newspaper in Greenlandic and Danish from Ilulissat).
Anon. 1970b. – "Atuagagdliutit/Grønlandsposten". 1970. Nr. 2. 29. januar. p. 1. (Newspaper in Greenlandic and Danish).
Anon. 1984. – "Iluliarmioq". 1984. Nr. 2. 2. februar. p. 14. (Local newspaper in Greenlandic and Danish from Ilulissat).
Anon. 1988a. – "Nuuk Ugeavis". 1988. August. (Local newspaper in Greenlandic and Danish from Nuuk).
Anon. 1988b. – "Atuagagdliutit/Grønlandsposten". 1988. 15. april. (Newspaper in Greenlandic and Danish).
Anon. 1990a. – "Atuagagdliutit/Grønlandsposten". 1990. 2. februar. Nr. 14 (Newspaper in Greenlandic and Danish).
Anon. 1990b. – "Atuagagdliutit/Grønlandsposten". 1990. 5. februar. Nr. 15 (Newspaper in Greenlandic and Danish).
Anon. 1990c. – "Sermitsiaq". 1990. Nr. 7. (Newspaper in Greenlandic and Danish).
Béland, P, Vézina, A. & Martineau, D. 1988. Potential for growth of the St. Lawrence (Québec, Canada) beluga whale (*Dephinapterus leucas*) population based on modelling. – J. Cons. int. Explor. Mer 45: 22–32.
Berliner, F. 1968. Grønland – Fra Kap Farvel til Ammassalik. "Savssat" . – Carit Andersens Forlag: 144–149.
Bertelsen, A. 1921. Umanaq Distrikt. – In: A. Bertelsen, M. P. Porsild & H. Ostermann. Grønland i tohundredeaaret for Hans Egedes Landing. Meddr Grønland 60: 342–429.
Brodie, P. F. 1982. The beluga (*Delphinapterus leucas*); growth at age based on a captive specimen and a discussion of factors affecting natural mortality estimates. – Rep. int. Whal. Commn 32: 445–447.
Brown, R. 1868. Notes on the history and geographical relations of the Cetacea frequenting Davis Strait and Baffin's Bay. – Proceedings Zoological Society of London 1868: 533–556.
Burns, J. J. & Seaman, G. A. 1986. Investigations of belukha whales in coastal waters of western and northern Alaska. II Biology and ecology. – Alaska Department of Fish and Game, 1300 College Road, Fairbanks Alaska 99701, USA.
Degerbøl, M. & Freuchen, P. 1935. Mammals. – Vol. 2, nos 4–5: 278 pp. In: Report of the fifth Thule expedition 1921–24. Copenhagen, Nordisk Forlag. Part I. Systematic notes by Degerbøl. Part II. Field notes and biological observations, by Freuchen.
Dietz, R., Heide-Jørgensen, M. P., Born, E. W. & Glahder, C. M. 1994. Narwhals (*Monodon monoceros*) and white whales (*Delphinapterus leucas*) in East Greenland. – Meddr Grønland, Biosci. 39: 69–86.
Doidge, D. W. 1990. Age and stage based analysis of the population dynamics of belugas whales, *Delphinapterus leucas*, with particular reference to the Northern Quebec population. – Ph.D. Thesis McGill University, Montreal, Quebec.
Egede, P. 1788. Efterretninger om Grønland uddragne af en Journal holden fra 1721 til 1788. – Original from 1788 but issued by Mads Lidegaard 1988. – Det grønlandske Selskabs Skrifter XXIX: 1–204.
Fay, F. H. & Kelly, B. P. 1980. Mass natural mortality of walruses (*Odobenus rosmarus*) at St. Lawrence Island, Bering Sea, Autumn 1978. – Arctic 33: 226–245.
Freeman, M. M. R. 1968. Winter observations on beluga (*Delphinapterus leucas*) in Jones Sound, N.W.T. – Can. Field Natur. 82: 276–286.
Gad, F. 1969. The history of Greenland II. 1700–1782. – McGill-Queen's University Press, Montreal, i-xvii + 446 pp. + 32 pls.
Gad, F. 1976. Grønlands Historie III. 1782–1808. – Nyt Nordisk Forlag Arnold Busck, København, 615 pp.
Glahn, H. C. 1991. Anmærkninger over de tre første bøger af Hr. David Crantzes Historie om Grønland – Original from 1771 but issued by Mads Lidegaard 1991. – Det grønlandske Selskabs Skrifter XXIX: 1–205.
Golodnoff, M. 1956. Den store savssat. – Tidsskriftet "Grønland", no. 7: 269–280.
Hadrup, G. 1971. Erindringer fra Umanaq. – Bygd 2. year no. 1: 9–13.
Haller, A. A. 1986. The spatial organisation of the marine hunting culture in the Upernavik District, Greenland. – Bamberg. 1–175.
Harwood, J. & Hall, A. 1990. Mass mortality in marine mammals: its implications for population dynamics and genetics. – TREE 5, August: 254–257.
Heide-Jørgensen, M. P. 1994. Distribution, exploitation and population status of white whales (*Delphinapterus leucas*) and narwhals (*Monodon monoceros*) in West Greenland. – Meddr Grønland, Biosci. 39: 135–150.
Heide-Jørgensen, M. P., Härkönen, T., Dietz, R. & Thompson, P. M. 1992. Retrospective of the 1988 European seal epizootic. – Dis. of Aquat. Org. 13: 37–62.
Heide-Jørgensen, M. P. & Teilmann, J. 1994. Growth, reproduction, age structure and feeding habits of white whales (*Delphinapterus leucas*) in West Greenland waters. – Meddr Grønland, Biosci. 39: 195–212.
Heide-Jørgensen, M. P., Larsen, A., Teilmann, J. & Jensen, J. 1994. Age estimation of white whales (*Delphinapterus leucas*) from West Greenland. – Meddr Grønland, Biosci. 39: 187–193.
Ivashin, M. V. & Shevlyagin, K. V. 1987. The white whale (*Delphinapterus leucas* Pallas, 1776): Entrapment and escape in the ice of Senjavin Strait, USSR. – Rep. int. Whal. Commn 37: 357–359.
Kapel, F. O. 1977. Catch of belugas, narwhals and harbour porpoises in Greenland, 1954–1975, by year, month and region. – Rep. int. Whal. Commn 27: 507–520.
Kapel, F. O. 1979. Supplementary list of litterature on the occurrence and exploitation of white whale and narwhal in Greenland. – Paper SC/31/SM22 presented to the IWC Scientific Committee, Cambridge, June 1980: 3 pp. + Figs 1–2.
Knudsen, H. 1958. Et træk fra narhvalernes liv. Virkelighed eller ammestuehistorie. – Tidsskriftet Grønland: 353–356.
Koski, W. R. & Davis, R. A. 1994. Distribution and numbers of narwhals (*Monodon monoceros*) in Baffin Bay and Davis Strait. – Meddr Grønland, Biosci. 39: 15–40.
Lowry, L. F., Burns, J. J. & Nelson, R. R. 1987. Polar bear, *Ursus maritimus*, predation on belugas, *Delphinapterus leucas*, in the Bering and Chukchi seas. – Can. Field-Natur. 101: 141–146.
Mitchell, E. & Reeves, R. R. 1981. Catch history and cumulative catch estimates of initial population size of cetaceans in the Eastern Canadian Arctic. – Rep. int. Whal. Commn 31: 645–682.
Mitchell, E. & Reeves, R. R. 1982. Factors affecting abundance of bowhead whales *Balaena mysticetus* in the eastern Arctic of North America, 1915–1980. – Biol. Conserv. 22: 59–78.
Palsbøll, P. J., Vader, A., Bakke, I. & El-Gewely, M. R. 1992. Determination of gender in cetaceans by polymerase chain reaction. – Can. J. Zool. 70: 2166–2170.
Philo, L. M., Shotts, E. B. Jr. & George, J. C. 1993. Morbidity and mortality. – In: J. Burns, J. J. Montague & C. J. Cowles (eds.). The bowhead whale. – The Society for Marine Mammalogy. Special Publication Number 2: 275–312. P.O. Box 368, Lawrence, KS 66044.
Porsild, M. 1916. II. Den store narhvale-"Søvs" i Disko Bugt vinteren 1914–15. Om nogle vestgrønlandske pattedyr og fugle I-II. – Meddr Grønland 55: 41–54.
Porsild, M. 1918. On 'Savssat': a crowding of arctic animals at holes in the sea ice. – Geogr. Rev. 6: 215–228.
Reeves, R., Mitchell, E., Mansfield, A. & McLaughlin, M. 1983. Distribution and migration of the bowhead whale, Balaena mysticetus, in the eastern North American Arctic. – Arctic 36: 5–64.
Rosendahl, P. 1957. Jakob Danielsen, en grønlandsk maler.

Narhval-savssat, Diskos sydkyst, Februar 1915. – Det grønlandske Forlag: 71–73.
Sergeant, D. E. 1982. Mass strandings of toothed whales (Odontoceti) as a population phenomenon. – Sci. Rep. Whales Res. Inst. 34: 1–47.
Siegstad, H. 1991. Inventory of Renewable Resources in Greenland. In: I. Egede (ed.), Nature Conservation in Greenland. – Atuakkiorfik 1991: 20–30.
Smith, T. G., Hammill, M. O., Burrage, D. J. & Sleno, G. A. 1985. Distribution and abundance of belugas, *Delphinapterus leucas*, and narwhals, *Monodon monoceros*, in the Canadian high Arctic. – Fish. Aquat. Sci. 42: 676–684.
Thomsen, M. L. 1993. Local knowledge of the distribution, biology, and hunting of beluga and narwhal. A survey among Inuit hunters in West and North Greenland. – Report to Inuit Circumpolar Conference, Nuuk, Greenland: 98 pp + 6 appendices.