Netting and conventional tagging used to study movements of ringed seals (*Phoca hispida*) in Greenland

Finn O. Kapel[1], Jens Christiansen[2] †, Mads Peter Heide-Jørgensen[3], Tero Härkönen[4], Erik W. Born[3], Lars Øivind Knutsen[5], Frank Riget[6] and Jonas Teilmann[7]

[1] *Skovvænget 10 A, DK-2970 Hørsholm, Denmark*
[2] *Marine Identification Agency*
[3] *Greenland Institute of Natural Resources, c/o National Environmental Research Institute, Department of Arctic Environment, Tagensvej 135[4], DK-2200 København N, Denmark*
[4] *Höga 160, S-442 73 Kärna, Sweden*
[5] *Ö. Löa, Pl 8229 b, S-714 94 Kopparberg, Sweden*
[6] *National Environmental Research Institute, Department of Arctic Environment, Tagensvej 135[4], DK-2200 København N, Denmark*
[7] *Danbiu ApS, Tornagervej 2, DK-2920 Charlottenlund, Denmark*

ABSTRACT

Seven studies of netting and tagging of ringed seals (*Phoca hispida*) in Greenland 1976-1997 are described. The areas of operation were: northern part of the Upernavik area (Northwest Greenland), Kong Oscars Fjord (Northeast Greenland), and Avanersuaq (Thule, North Greenland). Altogether, 135 seals were caught, of which 99 were tagged and released with Dalton Jumbo rototags. Recapture of 38 tagged seals has been reported to date. The recaptures demonstrate movements of ringed seals in Greenland of more than 100km within districts, as well as long-distance movements of more than 1000km from the site of release.

INTRODUCTION

Eight experiments have been conducted in Greenland with the purpose of live-capture and tagging of ringed seals (*Phoca hispida*) to study their movements. A description of methods and results has been published for one of the experiments (Heide-Jørgensen *et al.* 1992), while the others have so far only been available as unpublished meeting documents or preliminary field reports (primarily in Danish). In this paper information on these seven experiments are summarised and updated.

The first experiment was conducted in October-November 1976 as part of a study of the occurrence and exploitation of ringed seals in the northern part of the Upernavik area, Northwest Greenland, see Fig. 1 (Christiansen and Jessen Jensen 1977, Christiansen 1981).

Another experiment was conducted in the same area in October-November 1980 as a part of environmental studies initiated in relation to plans for year-round transportation of liquified natural gas through the Baffin Bay-Davis Strait region (the "Arctic Pilot Project", Christiansen 1981).

In Northeast Greenland tagging experiments were carried out in the Kong Oscars Fjord area (Fig. 1) as an element in studies of ringed seal populations that could be influenced by oil exploration and exploitation activities on Jameson Land (Heide-Jørgensen and Härkönen 1985).

The remaining studies were all conducted in Avanersuaq (the Thule area, North Greenland, Fig. 1). The fourth experiment was conducted in June 1988 as a study of satellite tracking; re-

sults have previously been presented (Heide-Jørgensen *et al.* 1992) and it is only mentioned here for reference. The fifth and sixth tagging experiments, in August 1988 and May-June 1989, were conducted during studies on the walrus (*Odobenus rosmarus*) population (Knutsen and Born 1989, Born and Knutsen 1990). In the two final experiments conducted in August-September 1996 and June to August 1997 conventional tagging as well as deployment of satellite transmitters was carried out (the results of the latter will be presented elsewhere).

In addition to the primary objective of collecting information on the movements of ringed seals in Greenland, a common feature of the first of these studies was the development and testing of gear and methods for live capture of ringed seals under varying environmental conditions. This paper presents the performance of the methods used for netting, the application of conventional plastic tags, and the reporting of recaptures of tagged animals. Other studies conducted in connection with these experiments (e.g. anaesthesia studies, satellite tracking), are not reported here.

MATERIAL AND METHODS

Netting

To catch seals, 0.9mm monofilous, green nylon nets with a mesh width of 14-15cm were used. In addition, a 250m long, twisted black nylon line net was used in Kong Oscars Fjord, 1985. The depth of the nets was about 2m (1.9- 2.3m) and the length of each net was 70-100m, but several nets (up to nine) were set end-to-end. At the top of the net, foam plastic rings or a nylon floatline were used, and in the bottom small stones or a lead line were used as sinkers.

The 1976 and 1980 studies in the northern part of the Upernavik area were both carried out at the time of first formation of the land fast ice (late October to early November), and the same vessel, a locally based 36' cutter, was used as operation platform. Nets were set either perpendicular to the shore with one end attached to the coast and the other to a stone anchor, or, more often, in a lead created by the vessel in the new ice with stone anchors at both ends, and sometimes attached by a line to the vessel. The nets were only loosely tightened in order to allow captured seals to surface.

In Kong Oscars Fjord, netting was conducted in the drifting fast ice floes in early August and in open water in late August-early September 1985. In the drifting ice, the net was either set across a lead anchored to a floe at both ends, or an inflatable boat was used as a buoy at one end. In open water, the nets were initially anchored to land at one end and placed perpendicular to the shore with a stone anchor at the other, but later most nets were placed as "swinging" nets with only one end anchored to stones close to the shore, while the other end was allowed to follow the changing currents freely.

In Avanersuaq, three different settings were tried: 1) perpendicular to the coast with one end of the net attached to land and the other to a stone and a buoy; 2) attached to land but either one net in an acute angle to the coastline, or two nets forming an angle to each other; 3) un-attached to land but anchored to stones and buoys at both ends, and parallel to the direction of the current. The bottom line of the net was not fastened in order to allow captured seals to surface. Areas with little ice and with muddy or silty water close to glaciers or river outlets were preferred as netting sites.

Handling and tagging the seals

In the Upernavik area, the nets were most often set or checked in the late afternoon and examined in the morning. If a live seal was found, it was handled while still in the net: the sex was determined, the age was estimated by examining claw marks (or "bands", McLaren 1958), and the length was measured or estimated. It was tagged with a yellow Dalton Jumbo rototag in one of the hind flippers. The net was then cut to free the seal. In 1976 the seals were released immediately after tagging close to the locality where they were captured, whereas most seals in 1980 were taken farther offshore before release.

In Kong Oscars Fjord, nets could be set and tended at any time due to almost continuous daylight during August-early September, and as

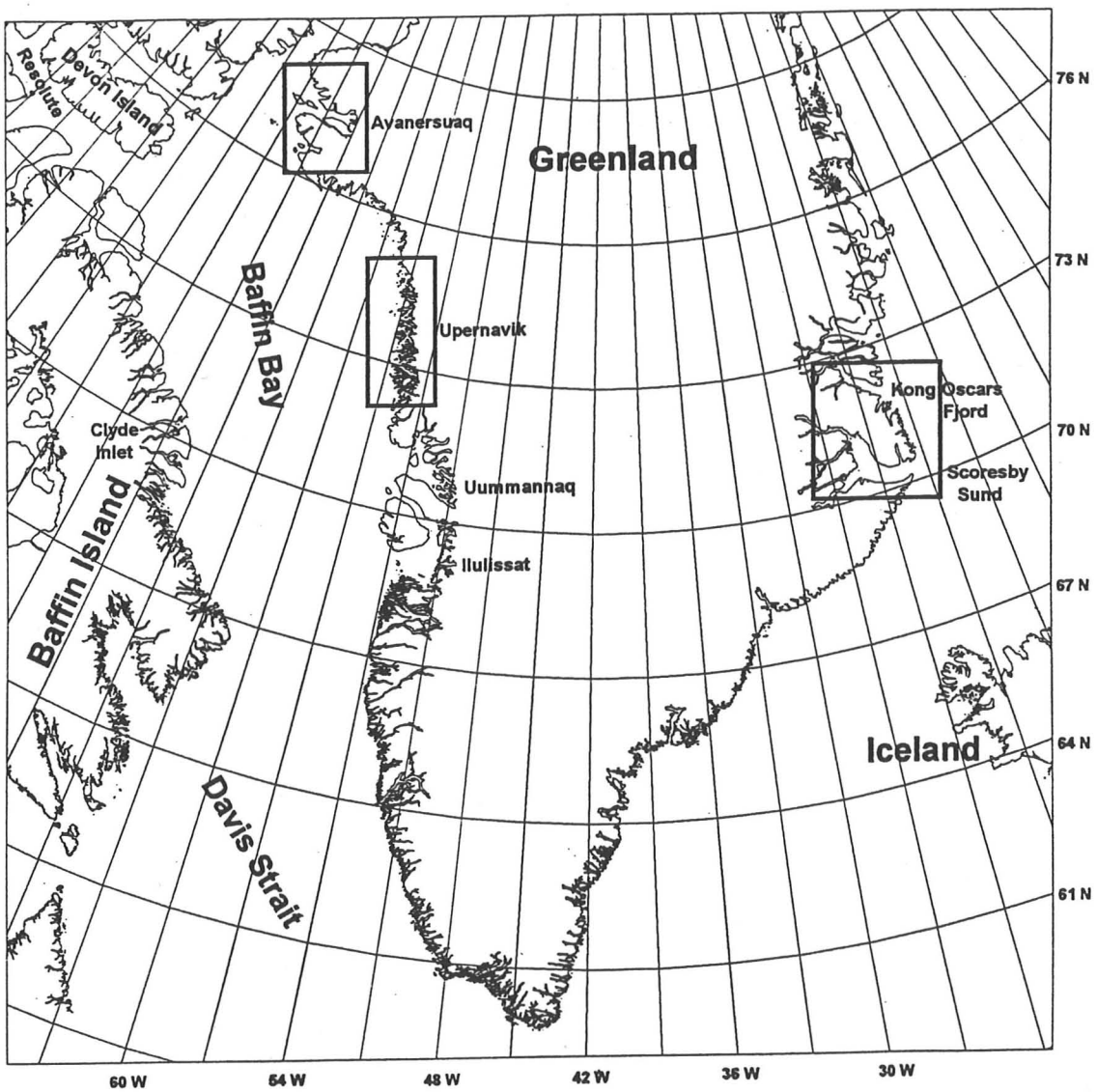


Fig. 1
Map of Greenland showing the three study areas for ringed seal netting and tagging.

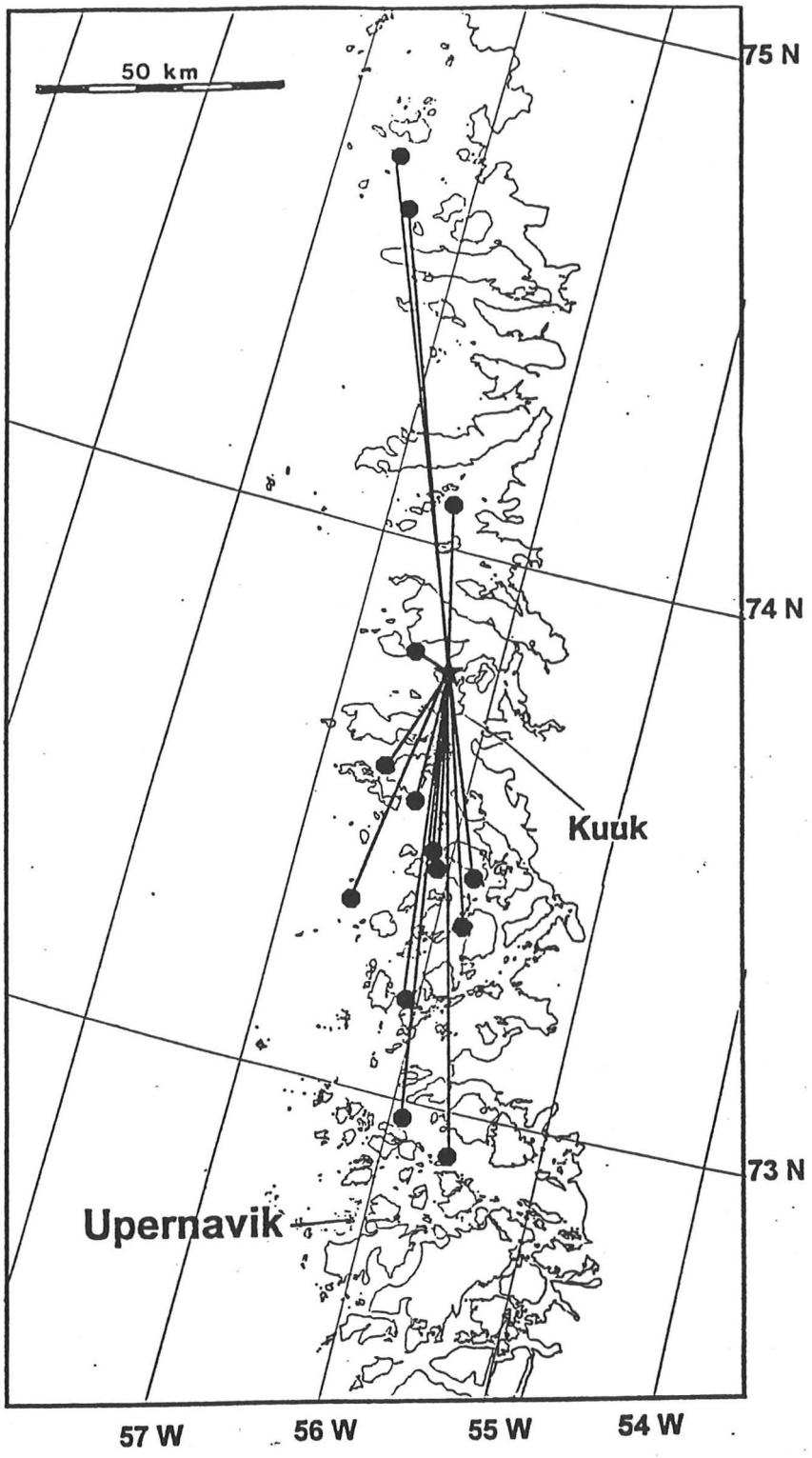
a minimum they were checked in the evening and in the morning, sometimes also during the day. Captured seals were sexed and weighed, and in some cases length and girth measurements were taken. After tagging, the seals were released a short distance from the nets.

During the studies in Avanersuaq nets were surveyed continuously through binoculars. Live-captured seals were fairly easy to grasp by the hind flippers and pull onboard. In order to calm the seal, it was placed in a dark fabric bag during transport to the shore. In 1996 and 1997, a stretcher (two wooden poles with a piece of trawl net in between) was used to grasp the seal and pull it on board.

In 1988 and 1989, the seals were first weighed (still in the bag), before they were taken out to be anaesthetised; in 1996 and 1997 seals were physically restrained in the stretcher to ease handling. The following measurements were taken: standard length, zoological length, axillary and maximum girth, and information on claw marks, possible scars and other individual characteristics were noted. Before release in 1988 and 1989, the seals were marked with yellow paint on the top of the head in order to facilitate recognition if observed again during the following days.

In 1976, 1980 and 1988, the seals were tagged in the left hind flipper, in 1985, 1989, 1996 and

Fig. 2
Locations of net capture, release and recaptures of ringed seals tagged in the Upernavik area in 1976.



1997 in both hind flippers. In 1976, tags were provided by the Norwegian Institute of Marine Research, Bergen (series HAVFORSK #D 0944-0965), but since 1980 tags from the Greenland Fisheries Research Institute (GRØNFISK) were used (Tag numbers and other tagging details are given in Appendix Tables I-III).

RESULTS

Capture and tagging

Upernavik area

In 1976 nets were set in a sound near the abandoned settlement Kuuk (Fig. 2). The net setting worked well in calm weather, and swells did not create great problems. In strong wind, however, meter-high waves caused the nets to wind up around the line. The highest catches were obtained at night, and with thin (< 2-3cm) ice cover. During 26-29 October, nine seals were caught, of which two were found dead. In the period 3-9 November 28 seals were caught, of which 13 seals were found dead. The exact date is lacking for one lost seal, so during the entire period the total catch was 38 seals, of which 16 (42 %) died and 22 were tagged (Table 1).

The 1980 experiment took place in almost the same area, but the nets were set at different locations during the study period. Originally, the intention was to catch seals offshore, which was tried during the period 12 to 27 October. The weather conditions were, however, so bad that the idea had to be dropped. Only two seals were caught and tagged during this initial period, and only one of these was caught "offshore" (about 35km offshore, Fig. 3, Loc. 5). During the following twelve days the nets were positioned at four inshore locations (Fig. 3, Locs 9-12), where a total of 46 seals were caught, of which 8 (17 %) were found dead and 38 were tagged, giving a total of 48 caught and 40 tagged that year (Table 1).

All the seals caught and tagged in Upernavik district were young animals, primarily young of the year - judging by the size and the absence of claw marks; a few individuals were estimated to be one or two years old at the time of capture (Appendix Table I). The sex ratio of tagged animals was skewed towards males: 0.68 in 1976 and 0.58 in 1980 (Table 1).

Kong Oscars Fjord

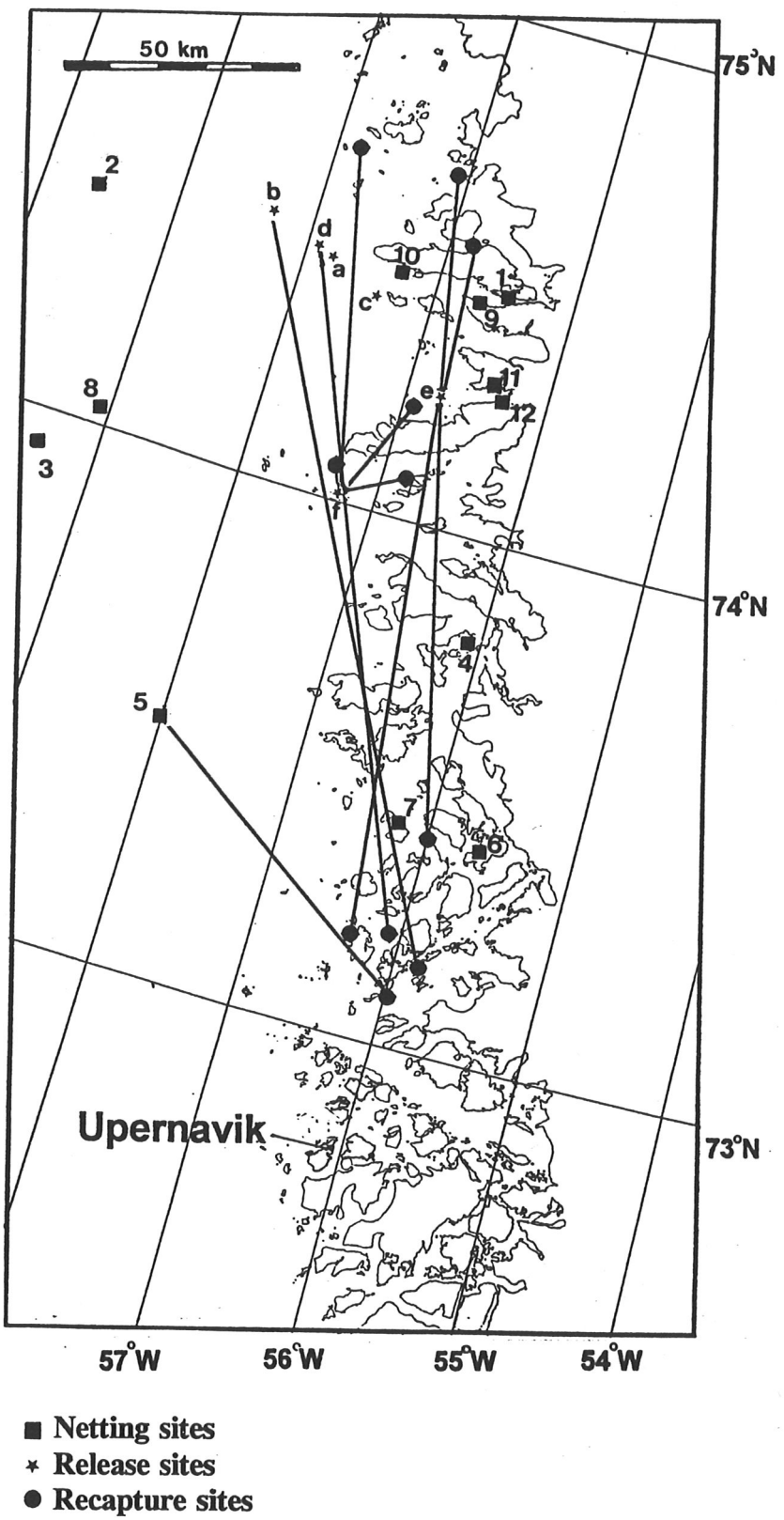
In early August 1985, Kong Oscars Fjord was still filled with floes of one-year-old ice, and ringed seals were observed both on the floes and in channels between them. Between 9 and 14 August, nets were set in the drifting ice (Fig. 4, Loc. 1, Fig. 5), and two seals were caught and tagged (Appendix Table II). In late August, the ice had disappeared at several localities in the

Table 1. Netting and tagging of ringed seals in Greenland, 1976-1997.

Area	Year	Month	Number of seals caught	lost	tagged	M	F
Upernavik	1976	October-November	38	16	22[1]	13	6
	1980	October-November	48	8	40	23	17
Kong Oscars Fjord	1985	August-September	9	4	5	1	4
Avanersuaq	1988	August	15	3	12	6	6
	1989	May-June	2	-	2	2	-
	1996	August-September	16	4	12	6	6
	1997	June & August	7	1	6	4	2
Grand total	1976-97		135	36	99[1]	55	41

[1] Sex not reported of three animals.

Fig. 3
Locations of net capture, release and short-distance recaptures of ringed seals tagged in the Upernavik area in 1980.



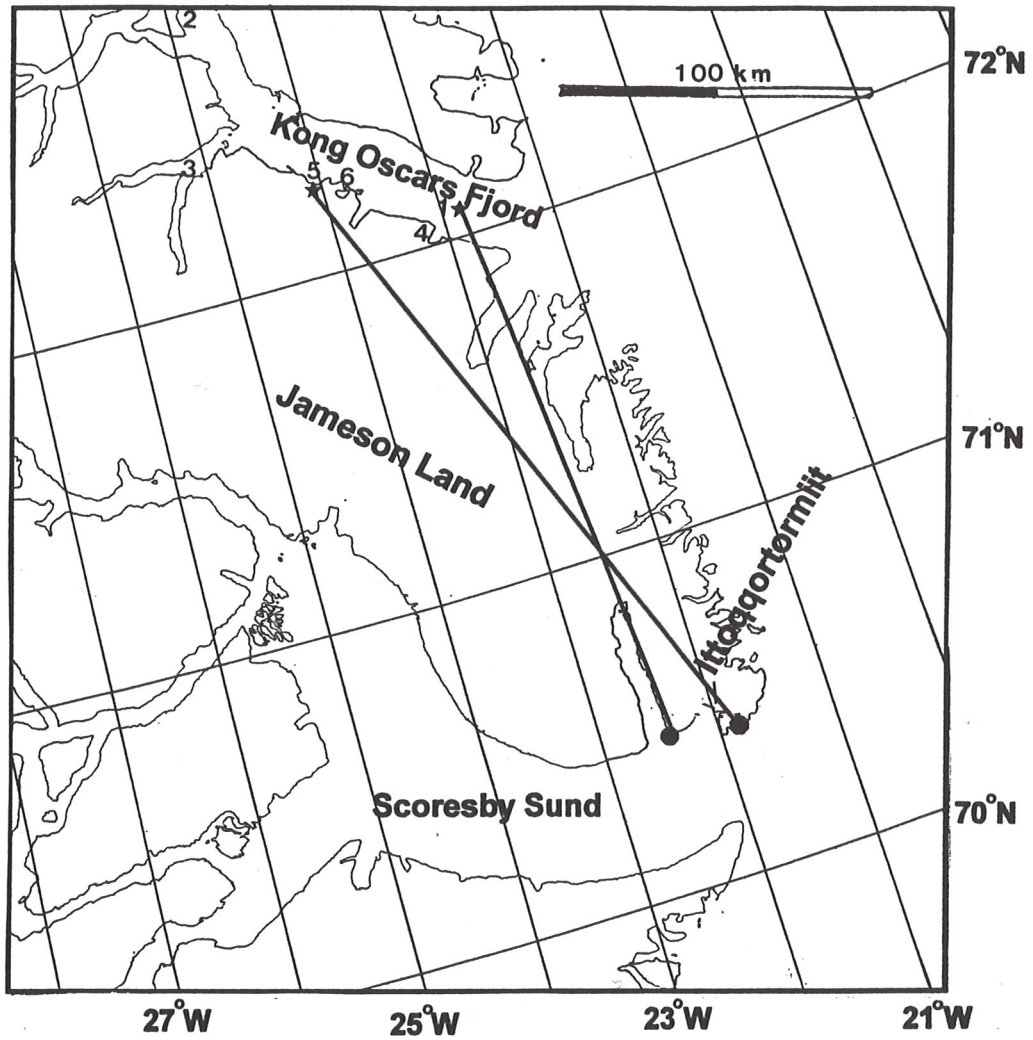


Fig. 4
Positions for net capture of ringed seals in Kong Oscars Fjord, 1985, and recaptures in Scoresby Sund.

1-6 Netting sites
★ Release sites
● Recapture sites

Fig. 5
Capturing of ringed seals in the drifting fast ice of Kong Oscars Fjord, East Greenland in 1985. (Photo: M.P. Heide-Jørgensen

inner part of the fjord system and near the entrance. Nets were set in open water at three different locations between 17 and 26 August but without catching any seals (Fig. 4, Locs 2, 3 and 4). In early September, also the central part of the fjord was almost ice free, and nets were put out at two locations between 2 and 19 September (Fig. 4, Locs 5 and 6). Seven seals were caught of which four (57 %) were found dead in the net and three tagged and released (Appendix Table II). For the entire study in Kong Oscars Fjord, the overall result was a catch of 9, with 4 lost (44 %) and 5 tagged (1 male, 4 females, Table 1).

Avanersuaq

On 6 to 7 August 1988 four net settings were tried at the northern shore of Olrik Fjord (Fig. 6, Loc. 1). No seals were caught at this location. Between 7 and 13 August five settings were made in the head of the fjord (Fig. 6, Loc. 2), where 13 seals were caught (Appendix Table III). On 17-18 August 1988 two settings were made in Foulke Fjord (Fig. 6, Loc. 3). Two seals were caught, of which one was found dead, the other tagged (Appendix Table III). For the entire 1988 study, 15 seals were caught, of which one perished in the net. Two more seals died during anaesthetization, so the total mortality was 20 %. The sex ratio of tagged animals was 1:1 (Table 1).

In 1989, an attempt to net ringed seals was first made in the Moriusaq-Appat area (Fig. 6, Loc. 4) on 10 May, but it was soon stopped due to ice cover and no seals were captured. During the period 7 to 11 June 1989, another attempt was conducted in Bowdoin Fjord (Fig. 6 Loc. 5). Two male ringed seals were caught, double-tagged and released (Table 1 and Appendix Table III).

In Avanersuaq, August-September 1996 was unusually cold and windy, resulting in much ice in Inglefield Bredning and tributary fjords during the entire field period. Exceptions were the inner parts of Mac Cormick and Olrik Fjords. Between 11 and 14 August, nets were set on the eastern coast of Mac Cormick Fjord (Fig. 6, Loc. 6) and at four sites in the head of this fjord (Loc. 7). Three seals were caught, of which one died in the net and two were tagged (Appendix Table III). During the period 20 to 26 August, nets were set at two sites in Olrik Fjord (Fig. 6, Loc. 8 and 9). At the first of these locations, nine seals were caught, of which two died in the net and seven were tagged (Appendix Table III); at the second location there was no catch. Between 29 August and 1 September, netting was tried at several sites in the sound between the Howard Islands in the head of Inglefield Bredning (Fig. 6, Loc. 10), where two seals were caught and tagged. Finally, nets were set farther out in Inglefield Bredning (Fig. 6, Loc. 11) on 12 September, resulting in the catch of two seals of which one perished in the net while the other was tagged and released (Appendix Table III). The total for 1996 was thus 16 caught, 4 lost and 12 tagged (sex ratio 1:1, Table 1)

In late June 1997, nets were set in cracks in the fast ice of Bowdoin Fjord (Fig. 6, Loc. 5), where five seals were caught and tagged between 19 and 28 June (Appendix Table III). In August, netting was tried at four locations: netting in Neqe Fjord (Fig. 6, Loc. 12), Booth Sund (Loc. 13) and Wolstenholme Fjord (Loc. 14) gave no captures, whereas two seals were caught on 10 August near Howard Islands (Loc. 10) of which one escaped before being tagged. The total catch in 1997 was 7, with one lost and 6 tagged (4 males, 2 females, Table 1 and Appendix Table III).

Recaptures

Of the 22 seals tagged in 1976, recaptures of 16 (73 %) have been reported (Fig. 2, Table 2). During the first winter (November to February) eight seals were recaptured, one of them 34km north, the other seven up to 92km south of the tagging location. From the spring hunt in April-June 1977, three recaptures were reported, one was just west of and two were 34 and 95km north of the tagging locality. During the open water hunt two recaptures were reported, one in August 100km south and one in September 106km north of the tagging area. Within a year, 13 recaptures were thus reported (Appendix Table I).

During the following year, 1978, two additional tags were received, one from late May and one from November, both approximately 60km

Table 2. Recoveries of ringed seals tagged in Greenland.

	Tagging		Recoveries				
				In tagging area		In other areas	
Area	Year	Nos	Total	1st year	later	1st year	later
Upernavik	1976	22	16	13	3	-	-
	1980	40	14[1]	7	4	1	2[1]
Kong Oscars Fjord	1985	5	2	-	-	-	2
Avanersuaq	1988	12	3[1]	1	1	1	-[1]
	1989	2	-	-	-	-	-
	1996	12	1	1	-	-	-
	1997	6	1	1	-	-	-
Grand total		99	38[1]	23	8	2	5[1]

[1] A recovery near Arctic Bay in June 1997 may derive from the 1980 or 1988 tagging.

north of the tagging locality. The last recovery from the 1976 series was not received until 1990 during field work in a settlement in the Upernavik area, but according to the hunter's recollection, it came from a seal caught in August 1982. All recoveries of tags from the 1976 experiment thus derived from the Upernavik area, although spread along the entire coastline of this area up to about 100km north and south of the tagging location.

Recaptures of 14 (35 %) of the seals tagged in 1980 have been reported (Figs 3 and 7, Table 2). Five of these were netted during the first winter, close to and up to 75km north of the release sites; one was shot on the ice in March 1981 as far south as in the Uummannaq area (70°58'N 51°10'W, appr. 450km to the south, Fig. 7). The seventh recapture within the first year was reported in October about 120km south of the tagging site (Appendix Table I). The following year, 1982, brought four reports: one netted in February close to the site of release, two caught in April about 160km south of that - and one shot in the water in late July near Clyde Inlet, eastern Baffin Island, approximately 600km southwest of the tagging area (Fig. 7). Almost two years later, in late May 1984, another long-distance traveller was reported from Inglefield Bredning, Avanersuaq area, about 430km to the northwest (Fig. 7). Two additional tags were discovered during field work in 1990 (Appendix Table I, # 02 and 29). One of the hunters indicated that the seal was caught in May 1983 near the settlement Naajat (73°06'N 55°59'W), whereas the other did not recall either date or site of recapture. Thus, also in the 1980 experiment, most recaptures were reported within Upernavik area, but three demonstrated long-distance movements of young ringed seals.

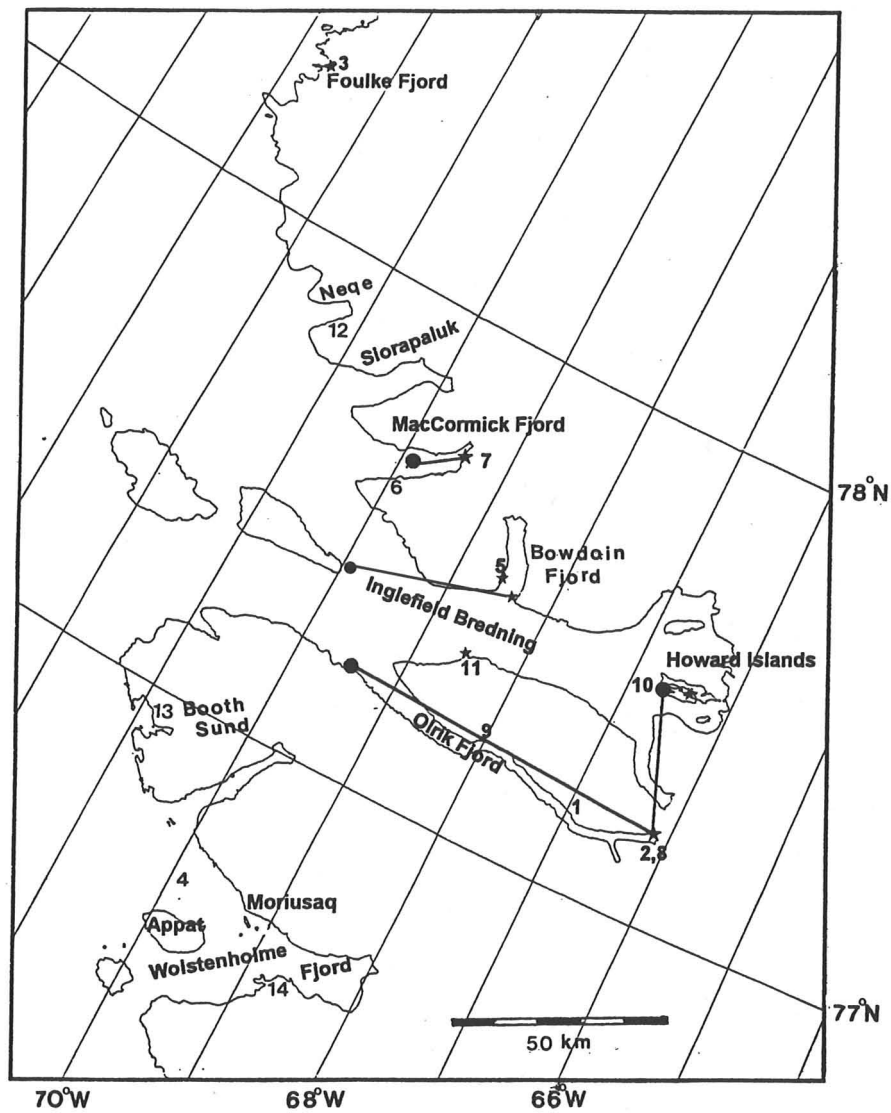
Proportions of numbers of recaptured/released differed significantly between the 1976 and 1980 experiment (0.73 vs 0.35; $p < 0.05$, $z = 2.579$, $df = 1$).

Of the five seals tagged in Kong Oscars Fjord in 1985, two recaptures have been reported, both at the entrance of Scoresby Sund (c. 180-220km south of the tagging area, Fig. 4, Table 2), in February 1988 and in March 1991 (Appendix Table II).

Of the twelve seals tagged and released in Olrik Fjord 1988, two were observed farther out in the fjord about 10 km from the site of release 1½ and 3 days later, respectively. They appeared to perform normal swimming and surfacing behaviour. Three recaptures (25%) have been reported (Table 2): one was shot 15 December 1988 approximately 75km west of

Fig. 6
Positions for net settings, tagging and short-distance recaptures of ringed seal in Avanersuaq, 1988, 1989, 1996 and 1997.

1-14 Netting sites
★ Release sites
● Recapture sites



the release site (Fig. 6), a second was caught 29 December near Ilulissat (c.1,000km south of that (Fig. 7), and the third was caught in net two years later, 9 November 1990 near Qeqertat (Howard Islands) in the head of Inglefield Bredning, north of the tagging area (Fig. 6, Annex Table III).

Neither of the two seals tagged in Bowdoin Fjord in 1989 have been reported to date.

Of the twelve seals tagged in 1996, one has been recaptured (Table 2). It was released 14 August in MacCormick Fjord and shot in the same fjord on 24 August 1996 (Fig.6). Another individual released 22 August at the head of Olrik Fjord was caught and released twice at the same site on 25 and 26 August 1996 (Appendix Table III). One of the six seals tagged in 1997 was recaptured 3 February 1998 at Qeqertarsuaq, about 40km west of the site of release (Fig. 6, Table 2).

In June 1997 a "GRØNFISK" tag was recovered near Arctic Bay in northern Baffin Island (73°11'N 85°16'W). The half of the tag with number had broken off, so it is not known with certainty which of the tagging experiments this tag belongs to. There was no trace of a tag in the other hind flipper, so the 1989 and 1996 experiments can be excluded. It was an adult seal, 135cm long and weighing 72.5kg, so the seal could have come from either the 1988 (Avanersuaq) or 1980 (Upernavik) series.

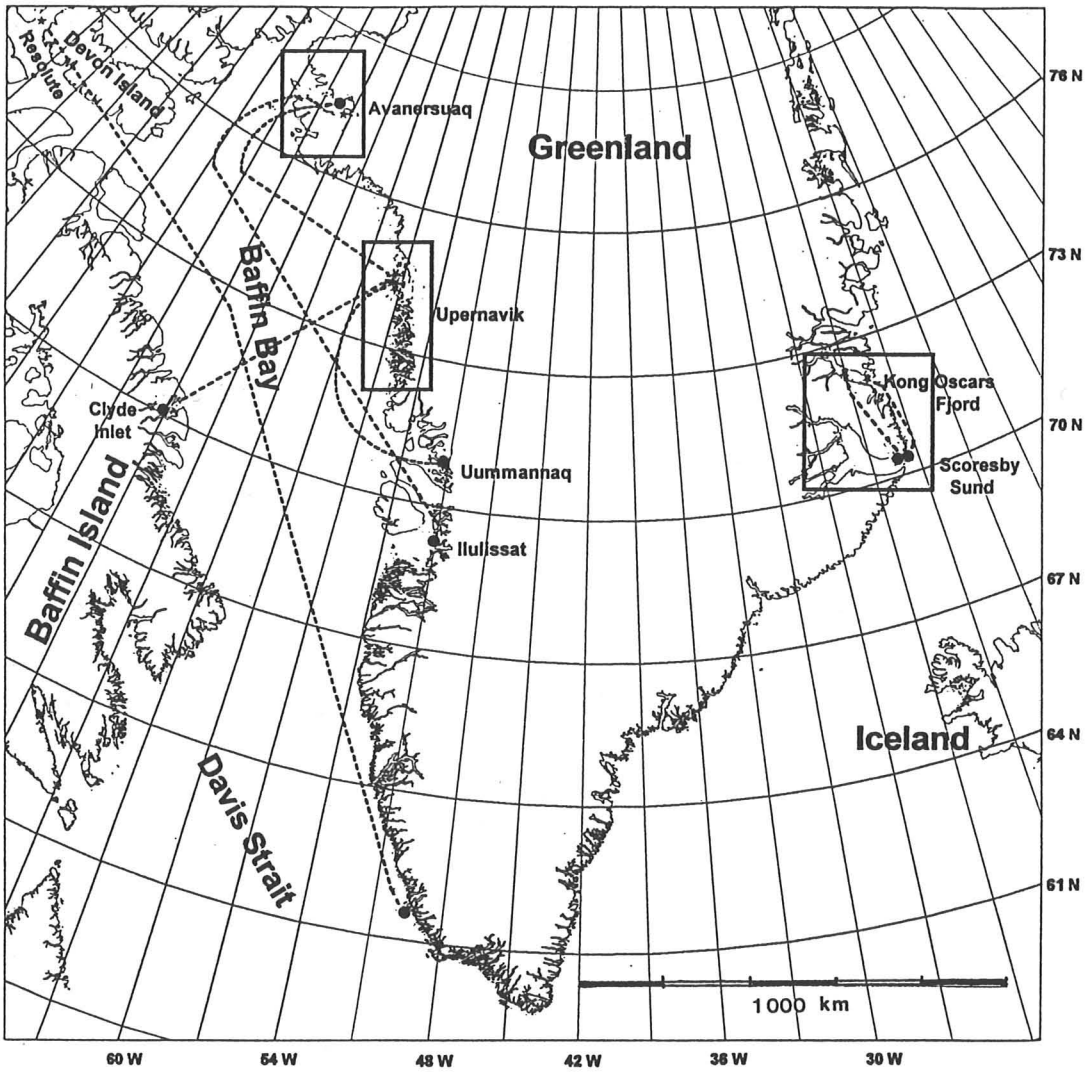


Fig. 7
Positions of long-distance recaptures of ringed seals tagged in the Upernavik area in 1980, in Kong Oscars Fjord (Northeast Greenland) in 1985, in Avanersuaq (North Greenland) in 1988, and in Resolute Passage (Arctic Canada) in 1991 (Kelly and Wartzok 1996).

★**Release sites**
● **Recapture sites**

DISCUSSION AND CONCLUSIONS

In 1976, when the first of the studies described in this paper was initiated, little tagging of ringed seals had been conducted, and few results were published. Smith *et al.* (1973) described netting and marking of 229 ringed seals in the western Canadian Arctic in August-September 1971 and 1972. Their nets were constructed for open water operation and were pulled out at freeze-up.

Netting of ringed seals under the winter fast ice is an important hunting method in Greenland and accounts for a considerable part of the total catch in Northwest Greenland (Kapel 1975, Teilmann and Kapel this volume). The nets used are small (4-6m long, 2m deep), and set in a manner that causes a captured seal to die quickly. In Greenland, netting in open water has never been a common method for catching ringed seals.

Hunters of the northern part of the Upernavik area were of the opinion that most ringed seals leave the area during the summer but return at the time of formation of the new fast ice. Hunting statistics confirmed that the catch of ringed seal in this region was at a minimum during July-September and increased in October-November (Kapel 1975, Teilmann and Kapel this volume). This information was one reason for selecting the area and time of the year for conducting the experiment; another one

was that extensive sampling of material for examining age-frequencies in catches had been carried out here since 1974, so the likelihood of getting reports of recaptures was high. The study in Upernavik 1976 therefore aimed at testing feasible methods of catching ringed seals alive at the time of freeze-up, hoping to get a sufficient number of recoveries to shed some light on their movements.

The nets constructed for the 1976 experiment worked fairly well in the sense that 38 young ringed seals were caught during a two week period. The fact that only young seals were caught agrees well with the finding that yearlings and one-year-old ringed seals dominate the catch both in the open water hunt and in the winter netting in the region (Teilmann and Kapel this volume), but this was not known in 1976. Similarly, young of the year also dominated in the net catches in the Canadian Western Arctic (Smith 1987). For this reason, this study only contributes to the knowledge of movements of young ringed seals, and gives no new information on the possible movements of adult seals.

Various ways of expressing the catch efficiency of nets in numerical terms for comparison of these and other studies could be considered. One problem is that comparable data are not available in all the reports of field work that form the basis for this review. For the first experiments, only dates and length of nets were given, not exact netting time from start to end of each setting, as was reported for later studies, for which indices such as number of seals caught/hour/net meter could be calculated.

For all of the studies, however, it is obvious that factors other than time and net length influenced the netting success. They include visibility of the net (daylight, clearness of water), sea state, ice formation or ice drift, direction of currents, positioning of nets, and, of course, presence and density of seals. In the studies presented here, environmental conditions were not expressed in numerical terms and numerical indices are therefore not presented in this article.

Two causes for mortality during the 1976 experiment (total 42%) were reported: formation of thick ice (>2-3cm) over the net, or stretching of the floating line due to ice pressure, both causes preventing the seals from surfacing to breathe. Continuous surveillance of the nets during night hours was not possible at this time of the year. In 1980, inspection of the nets reduced the mortality (17%), and revealed that heavy ice formation over the net caused the death of four seals, line stretched by ice pressure led to the death of three others, whereas one seal apparently died from direct physical damage caused by extremely hard tightening of the net.

In early August 1985, when netting was conducted among the drifting ice in Kong Oscars Fjord, light conditions allowed almost continuous surveillance of the nets, and no seals were lost. In early September increasing darkness during night made control of nets more difficult, resulting in a high mortality (57%). In one case the net was covered by new ice, and in three cases the deaths may have resulted from strong currents submerging the nets and buoys.

During the studies in Avanersuaq in 1988, 1989, 1996 and 1997, continuous surveillance of the nets through binoculars was attempted in order to reduce mortality. In 1988, only one seal died during capture (7% mortality). It was entangled about 1m below the surface, and apparently perished during the night when inclement weather with strong winds impeded surveillance of the nets. During the 1996 study, four seals died during capture (25%). In all cases inclement weather with rough sea surface prevented close inspection of the nets.

In the 1976 experiment, recapture of a very high percentage of the tagged seals was reported (73%), so also in that sense the experiment was a success. For comparison, of seals marked in Arctic Canada in 1971 and 1972, the recovery rate was 2.5 and 0.9%, respectively (Smith 1987). The recoveries during the winter in1976/77 indicated a general southward movement of the young seals. This fact apparently supported the aforementioned hunters' view that the seals, after spending the summer months in offshore or more northerly waters in the Melville Bay, re-invaded the coastal archipelago area in the fall. Later recoveries were also reported from the area of tagging or north of that, thus indicating dispersal of young seals

all along the coast of the Upernavik area during the following spring and summer.

The next tagging experiment conducted in the Upernavik area, in 1980, had initially a somewhat different scope. Data from population structure studies in Upernavik 1974-76 raised the question of whether the estimated production in that area could be large enough to sustain the existing exploitation, or whether it was supplemented by immigration of seals from the hypothesized distinct breeding population in the offshore Baffin Bay pack ice (Finley *et al.* 1983). It was therefore decided to attempt tagging of seals in offshore waters to investigate whether seals from these areas contributed to the hunting in nearshore waters. As described above, it proved impossible to carry out offshore tagging under the prevailing environmental conditions with the gear and methods used. Instead, the 1980 experiment turned out to be a repetition of the 1976 tagging, with some modifications, and improved efficiency (lower mortality, more seals tagged).

The pattern of recoveries did, however, differ from the results of the previous experiment: The recovery rate was much lower (35% vs. 73% in 1976), although still high compared to other tagging studies. Further, the initial recaptures were reported north of the sites of release instead of south as in 1976. More importantly, in addition to recoveries within the Upernavik area, three long-distance movements of tagged animals were reported from the 1980 experiment. The reasons for these differences are not clear. During the first winter, eight of 22 seals tagged in 1976 (36.4%) were reported, whereas only five of 40 released in 1980 (12.5%) were reported. Judging by the catch statistics, the hunting activity (the number of ringed seals caught, the number of hunters) in 1980-81 was similar to that in 1976-77. The fact that most of the seals in the 1980 experiment were released farther off the coast might have contributed to a lower initial recapture rate, because most hunting activity is conducted in nearshore waters, particularly at the time when the winter ice is being formed.

During the spring and summer in 1977, five additional recoveries (22.7 % of the tagging) were reported, all within the Upernavik area. In 1981 only two more reports were received (5 %), one of which revealed long-distance movement from the tagging site. This recovery demonstrates that at least some of the animals tagged in 1980 moved out of the area. If such an emigration had started immediately after tagging, a lower initial recapture rate within the Upernavik area could be expected. During the second year after tagging, recovery rates were similar in the two experiments (9.1 and 10.0%, respectively). Of recoveries reported more than two years after tagging, only one is certain (from Thule), whereas data given on the three others (discovered in 1990) should be treated with caution.

It is obvious that the distances measured between the site of release and the site of recapture are not real travel distances (as clearly demonstrated by satellite telemetry studies, e.g. Heide-Jørgensen *et al.* 1992) but could be called "dispersal distances" (minimum distances moved from the site of release). Calculated for the initial phase of the two experiments, the values of average dispersal distances are similar (42 and 39km, respectively), but when later recoveries are included the within-area dispersal appears to be slightly higher in the last experiment (53 and 74km, respectively). If the three long-distance "dispersers" in the 1980-experiment are included the average dispersal distance for that experiment is 165km.

Calculations of dispersal distances by sex give lower values for males than for females for 1976 (44 and 70km, respectively) but similar values for within-district movements in 1980 (75 and 73km). Including the three long distance movements of the 1980 experiment (one male and two females) results in a lower average dispersal distance for males (126km) than for females (202km) also for the latter experiment. It appears that calculation of averages adds little if any information on the character and extent of movements, whereas dispersal distances for individual animals are of interest as they provide minimum ranges of movement.

Additional evidence on movements of ringed seals in the Baffin Bay region came from two studies carried out in the Thule area in 1988:

satellite tracking of four animals from Wolstenholme Fjord in early June (Heide-Jørgensen *et al.* 1992), and the above-mentioned tagging with conventional rototags in August. The tracks of the instrumented seals demonstrated extensive movements within the Avanersuaq region and adjacent waters (Heide-Jørgensen *et al.* 1992), and the three recaptures from the tagging in Olrik Fjord in August 1988 give further evidence of movements within the Avanersuaq area as well as long-distance movements of young ringed seals in the Baffin Bay region.

The recovery of a Greenland tag near Arctic Bay in June 1997 is further evidence of long-distance movement of a ringed seal across the Baffin Bay, whether from Upernavik or Avanersuaq.

Additional evidence of long-distance movement comes from an un-intended tag-recovery event: In April-June 1991 studies of ringed seal diving performance and behaviour, using acoustical transmitters, were conducted in Resolute Passage, Barrow Strait (74°43'N 95°17'W, Kelly 1996, Kelly and Wartzok 1996). The seals were supposed to lose the transmitters during the moult in June, but one seal did not. This 88cm, 37kg young male was fitted with a transmitter on 1 June, recaptured and released again on 4 June, and its movements were monitored for the next two weeks (B.P. Kelly, *in litt.*). The following spring (22 March 1992) it was caught near Narsalik, Southwest Greenland (61°40'N 49°17'W), still carrying the transmitter after having travelled at least 2,272km during the intervening nine months.

The two recoveries of tagged seals at the mouth of Scoresby Sund, about 200km south of the tagging site in Kong Oscars Fjord, do suggest that ringed seals conduct extensive movements also in Northeast Greenland, but evidence of long-distance travelling of ringed seals in this region is not available, partly because of limited tagging effort and lower probability of getting recaptures in this region where hunting only takes place at the entrance of Scoresby Sund, and in the Ammassalik area about 800km farther south.

It has long been maintained that at least young ringed seals may perform fairly extensive movements (Frost and Lowry 1981, King 1983). Based on observations of relative densities of adult and young seals it was argued that whereas adult ringed seals have a tendency to become fairly sedentary in areas with stable winter fast ice, immature animals appear to conduct small-scale seasonal movements as well as dispersal from centers of high production of seals (McLaren 1958). Comparison of seasonal differencies in the age-frequency distribution of catches in two adjacent areas of southeastern Baffin Island led to the suggestion that immature seals migrated from one area to the other (Smith 1973). It has also been suggested that changing climatic conditions may lead to mass emigration of ringed seals from regions with deteriorating environmental conditions (Vibe 1967, Stirling *et al.* 1982).

Of the 229 ringed seals marked in Arctic Canada in 1971 and 1972 (Smith *et al.* 1973), four were recaptured 1½ to 3 years later by Inuit hunters in other areas, 565 to 1,330km away from the sites of release (Smith 1987).

In all the studies conducted in Greenland, the number of seals tagged was quite small, so their contribution to the knowledge of ringed seal movements in the region would be expected to be limited. The rates of recovery were, however, surprisingly high, so these tagging studies did give new information on the dispersal of young ringed seals and the possible interrelation between ringed seal populations in Greenland and adjacent waters.

ACKNOWLEDGEMENTS

The 1976 tagging experiment was part of a project conducted by the Greenland Fisheries Research Institute with a special grant from the Danish Natural Science Research Council (grant No. 521/9-3). The 1980 tagging experiment was conducted by the Marine Identification Agency ApS for Petro-Canada Exploration Inc. As in the previous study, the locally based cutter SILA was used as operation platform.

The study in Kong Oscars Fjord 1985 was conducted by Danbiu ApS on behalf of Greenland Fisheries and Environmental Research Institute

and the Agency for Management of Mineral Resources in Greenland.

The tagging in Avanersuaq 1988 and 1989 was made possible through a walrus study program initiated by the Department of Wildlife Management, Greenland Home Rule, and financed by the Aage V. Jensen's Foundation. The 1996 tagging study was financed by grants from the Danish Natural Science Research Council and the Commission for Scientific Research in Greenland. The 1997 study was financed by grants from a special fund (MIKA) of the Danish Ministry for the Environment.

All the organisations mentioned above, who in one way or another have contributed to the studies presented in this article are gratefully acknowledged.

REFERENCES

Born, E.W. and Knutsen, L.Ø. 1990. Fangst af ringsæl (*Phoca hispida*) i Bowdoin Fjord [Catch of ringed seal in Bowdoin Fjord, North Greenland]. pp. 34-36 in Hvalrosundersøgelser: Rapport over feltarbejde i 1989. Grønlands Hjemmestyre, Miljø- og Naturforvaltningen, Teknisk Rapport Nr. 13 - februar 1990. 42 pp. (In Danish with an abstract in English)

Christiansen, J. and Jessen Jensen, F. 1977. Tagging and recapture of ringed seal (*Pusa hispida*) in Northwest Greenland. ICES paper C.M. 1977/N:16. 9 pp.

Christiansen, J. 1981. Ringed seal tagging. Report from Marin ID Aps, DK-2942 Skodsborg, to Petro Canada (Arctic Pilot Project), December 1981. 40 pp.

Finley, K.J., Miller, G.W., Davis, R.A. and Koski, W.R. 1983. A distinctive large breeding population of ringed seals (*Phoca hispida*) inhabiting the Baffin Bay pack ice. *Arctic* 36:162-173.

Frost, K.J. and Lowry, L.F. 1981. Ringed, Baikal and Caspian seals *Phoca hispida* Schreber, 1775; *Phoca sibirica* Gmelin, 1788 and *Phoca caspica* Gmelin, 1788. pp. 29-53 in S.H. Ridgway and R.J. Harrison (eds.) *Handbook of marine mammals vol. 2 seals.* Academic Press, London. 359 pp.

Heide-Jørgensen, M.P. and Härkönen, T. 1985. Sælundersøgelser i Kong Oscars Fjord 1985 [Seal research in Kong Oscars Fjord, Northeast Greenland, 1985]. Rapport til Grønlands Fiskeri- og Miljøundersøgelser og Råstofforvaltningen fra Danbiu ApS (Biologiske konsulenter), DK-2900 Hellerup. 53 pp. (In Danish)

Heide-Jørgensen, M.P., Stewart, B.S. and Leatherwood, S. 1992. Satellite tracking of ringed seals *Phoca hispida* off northwest Greenland. *Ecography* 15:56-61.

Kapel, F.O. 1975. Recent research on seals and seal hunting in Greenland. *Rapp. P.-v. Réun. Cons. int. Explor. Mer* 169:462-478.

Kelly, B.P. 1996. Live capture of ringed seals in ice-covered waters. *J. Wildl. Managem.* 60:678-684.

Kelly, B.P. and Wartzok, D. 1996. Ringed seal diving behaviour in the breeding season. *Can. J. Zool.* 74:1547-1555.

King, J. 1983. *Seals of the world.* Oxford University Press. 240 pp.

Knutsen, L.Ø. and Born, E.W. 1989. Garnfangst, mærkning og bedøvelse af ringsæl (*Phoca hispida*) in Avanersuaq (Thule, Nordgrønland), august 1988 [Netting, tagging and immobilization of ringed seal in North Greenland, August 1988] Grønlands Hjemmestyre, Miljø- og Naturforvaltningen, Teknisk Rapport Nr. 5 - januar 1989. 27 pp. (In Danish with an abstract in English)

McLaren, I.A. 1958. The biology of the ringed seal (*Phoca hispida* Schreber) in the eastern Canadian Arctic. *Bull. Fish. Res. Bd Can.* 118. 97 pp.

Smith, T.G. 1973. Population dynamics of the ringed seal in the Canadian eastern Arctic. *Bull. Fish. Res. Bd Can.* 181. 55 pp.

Smith, T.G. 1987. The Ringed Seal, *Phoca hispida*, of the Canadian western Arctic. *Can. Bull. Fish. Aquat. Sci.* 216. 81 pp.

Smith, T.G., Beck, B. and Sleno, G.A. 1973. Capture, handling, and branding of ringed seals. *J. Wildl. Managem.* 37:579-583.

Stirling, I., Kingsley, M. and Calvert, W. 1982. The distribution and abundance of seals in the eastern Beaufort Sea, 1974-79. *Can. Wildl. Serv. Occ. Pap.* 47. 25 pp.

Teilmann, J. and Kapel, F.O. (This volume.) Exploitation of ringed seal (*Phoca hispida*) in Greenland.

Vibe, C. 1967. Arctic animals in relation to climatic fluctuations. *Meddr Grønland* 170. 227 pp.

APPENDIX

Table I. Ringed seals tagged in the Upernavik area, Northwest Greenland, October-November 1976 and 1980

Tag No.	Release[1] Date YeMoDa	Sex	Standard length cm	Claw marks	Recapture Date YeMoDa	Area	Length cm
D 0944[2]	761026	M	86	0			
D 0945	761026	M	80	0	770422	Upv., Apparsuit	102
D 0946	761027	F	90	0	761110	Upv., Tasiusaq	100
D 0947	761027	M	92	0			
D 0948	761028	M	80	0	7611??	Upv., Aappilattoq	.
D 0949	761028	F	90	0	770822	Upv., Aappilattoq	.
D 0950	761028	M	90	0	761108	Upv., Nutaarmiut	103
D 0951	761103	M	97	0	8208??	Upv., Tasiusaq	.
D 0952	761104	M	95	0	770112	Upv., Nutaarmiut	.
D 0953	761104	M	107	1?	770629	Upv., Kullorsuaq	90
D 0954	761105	M	90	0	770120	Upv., Nutaarmiut	.
D 0955	761105	M	85	0	770122	Upv., Tasiusaq	.
D 0956	761105	F	100	0	781126	Upv., Innaarsuit	.
D 0957	761105	F	85	0			
D 0958	761107	M	85	0	7706??	Upv., Nuussuaq	105
D 0959	761108	M	95	0	770217	Upv., Tasiusaq	.
D 0960	761108	.	90	0			
D 0961	761108	.	90	0			
D 0962	761108	.	90	0			
D 0963	761109	F	(100)	0	761210	Upv., Nuussuaq	122
D 0964	761109	F	(90)	0	770902	Upv., Kullorsuaq	145
D 0965	761109	M	(106)	0	780519	Upv., Tasiusaq	.
01[3]	801018	M	83	0			
02	801020	M	86	0	8305??	Upv., Tussaaq	.
03	801029	F	87	0	820730	Clyde Inlet	.
04	801030	M	98	1			
05	801030	F	82	0			
06	801030	F	85	0			
07	801030	M	85	0			
08	801030	M	65	0			
09	801030	M	96	1	820412	Upv., Naajat	.
10	801031	M	93	0			

11	801031	F	90	0			
12	801031	F	95	0			
13	801031	M	86	0	810303	Uummannaq	98
14	801031	M	87	0			
15	801101	M	85	0			
16	801101	M	78	0	820429	Upv., Innaarsuit	.
17	801101	F	80	0			
18	801104	F	95	0			
19	801104	F	78	0			
20	801105	M	90	0			
21	801105	M	82	0			
22	801106	F	99	0			
23	801106	M	97	0			
24	801106	F	100	0	840524	Avanersuaq	150
25	801107	F	90	0	801215	Upv., Kullorsuaq	95
26	801107	M	95	0			
27	801107	F	85	0	8110??	Upv., Tasiusaq	.
28	801107	F	87	0			
29	801107	F	(85)	0	??????	Upv., Innaarsuit	.
30	801107	M	95	2			
31	801107	M	90	0			
32	801107	F	88	0	801211	Upv., Kullorsuaq	112
33	801108	M	97	0	801219	Upv., Nuussuaq	139
34	801108	F	85	0	810127	Upv., Kullorsuaq	88
35	801108	M	95	0			
36	801108	F	87	0			
37	801108	M	85	0			
38	801108	M	104	0			
39	801108	M	98	0	810108	Upv., Nuussuaq	115
40	801108	M	102	1	820214	Upv., Nuussuaq	112

1. Locations shown on Figs 2 and 3.
2. Yellow rototags HAVFORSK
3. GRØNFISK
() measurement imprecise

Table II. Ringed seals tagged in Kong Oscars Fjord, Northeast Greenland, August–September 1985.

Tag Nos right/left flipper	Release[1] Date YeMoDa	Sex	Standard length cm	Weight est kg	Age[2]	Recapture Date YeMoDa	Area	Length cm
GRØNFISK								
500/499	850809	F	88	20	0	910308	Scoresby Sund	.
497/498	850810	M	.	30	0-1?			
496/495	850905	F	.	21	0			
493/494	850911	F	.	22	0	880217	Scoresby Sund	.
491/492	850914	F	.	20	0			

[1] Locations shown in Fig. 4.
[2] Age estimated from body weight.

Table III. Ringed seals tagged in Avanersuaq, North Greenland, August 1988, June 1989, August-September 1996, June and August 1997.

Tag	Release[1]		Standard	Weight	Age[3]	Recapture		
	Date	Sex	length		est.	Date	Area	Length
Nos	YeMoDa		cm	kg		YeMoDa		cm
GRØNFISK								
101	880808	F	78	20	0	881229	Ilulissat	130
102	880808	F	82	22	0			
103	880809	M	96	42	1	881215	Olrik Fjord	130
104	880809	M	80	23	0			
106	880809	F	85	30	0			
107	880810	F	101	40	1	901109	Howard Islands	131
108	880810	M	96	38	1			
109	880810	F	94	37½	1			
110	880811	M	75	19	0			
111	880811	M	75	19	0			
113	880811	M	84	25½	0			
114/115[2]	880818	F	68	15½	0			
116/117	890609	M	94	37	1?			
118/119	890610	M	109	50	2?			
201/202	960812	M	-	25½	0			
203/204	960814	M	-	19	0	960824	MacCormick Fjord	
205/206	960821	F	78	25	0[4]			
207/208	960822	F	70	21	0[5]	960826	Olrik Fjord	
209/210	960822	F	80	24	0			
211/212	960823	F	-	21	0			
213/214	960824	F	80	22	0			
215/216	960824	M	-	26	0			
217/218	960825	M	-	82	3?			
219/220	960831	M	87	33½	?			
221/222	960901	M	-	28½	0			
223/224	960912	F	77	25	-			
226/225	970619	M	95	38	1			
228/227	970621	M	99	39	2			
230/229	970622	F	120	83	4-5?			
292/291	970627	M	96	47	3	980203	Qeqertarsuaq	
294/293	970628	F	96	33	2			
295/296	970812	M	117	96	6			

[1] Locations shown on Fig. 6

[2] Double tagged in right and left hind flipper.

[3] Age estimated from claw marks and body dimensions.

[4] Observed at the same site 24 August 1996.

[5] Caught in the net at the same site and released again 25 and 26 August 1996.