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An input to oil spill sensitivity mapping

*NERI Technical Report, no. 345*

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*January 2001*

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# Data sheet


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Abstract: Aerial surveys for seaducks were conducted in West Greenland in July 1998 and 1999. Important concentrations of harlequin ducks, common eiders and red-breasted mergansers were located in central and southern West Greenland, while only few king eiders had yet arrived to the moulting grounds in central and northern West Greenland.



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|---|---|
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# Contents

# 1 Introduction

In recent years oil exploration has increased in offshore areas of West Greenland. Extensive regional seismic surveys have been carried out, and in the summer of 2000, the first exploration well since 1977 was drilled. This took place in the Fylla-licence area west of Nuuk (Fig. 1). The well was dry and it is still not decided whether further drillings will be carried out in the area. In another licence area further north "Sisimiut-West" (Fig. 1) the licensee has no drilling obligation, and whether or not drilling will take place there is unknown.

Exploration drilling has increase the risk of marine oil spills. NERI-AE has since 1992 surveyed seabird populations in Greenland as a part of oil spill sensitivity mapping. These studies have included breeding birds (Boertmann et al. 1996, Boertmann & Mosbech 1997, 1998) and non-breeding birds both during winter and summer (Mosbech & Boertmann 1999).

The general impression is that during summer, the offshore areas hold relatively few seabirds compared to the winter. However, along the coasts, concentrations of breeding birds and moulting non-breeding birds occur, and the present study was mainly aimed at moulting non-breeding seabirds, and was carried out in July 1998 and July 1999. As we happened to visit the Avanersuaq area in 1998, a photographic mapping of the huge breeding colonies of little auks also was performed. These colonies hold many million pairs (Boertmann & Mosbech 1998) which may constitute as much as 80 % of the global population of this species (Nettleship & Evans 1985).


The field work in 1998 was financially supported by the Danish Environmental Protection Agency (EPA), as a part of the environmental support program Dancea - Danish cooperation for Environment in the Arctic (grant 123/001-0060). The field work in 1999 was funded by the Statoil-group, license 3/97 (contract no. VMS72024). The authors are solely responsible for all results and conclusions presented in this report, and this do not necessarily reflect the position of the Danish EPA or the Statoil-group.

The main purposes of the fieldwork was:

1/ A survey of moulting king eiders mainly in Upernavik and Qeqertarsuaq municipalities to test the hypothesis that early moulters may congregate there and subsequently, when the birds have regained their flying ability, move out. If this holds true, these birds were not recorded when we surveyed there in

1993-1995 (Mosbech & Boertmann 1999), as these surveys were carried out mainly in August.

2/ A survey of moulting and breeding common eiders and moulting harlequin ducks along the coast mainly from Disko Bugt and southwards, and

3/ A photographic survey of all the breeding colonies of little auks in Avanersuaq in 1998.

# 2 Methods

The field work in 1998 was carried out in the period 9 – 31 July (Table 1), and the field work in 1999 was carried out in the period 20 – 31 July (Table 2).

All surveys were aircraft based. We used a Partenavia P-68 Observer, equipped with GPS navigation system. Besides the pilot, two observers participated, observing from the rear seats trough bubble windows allowing a view also below the aircraft. All observations including marine mammals were recorded on tape recorders via the aircrafts intercom. A time signal was simultaneously recorded on the tape, making it possible subsequently to link all observations to a geographic positions recorded by the GPS linked to a portable PC. Four kinds of surveys were performed:

1) **Total counts** along coastlines, where we, while flying close to the coastlines, recorded all birds observed. The width of the track (both sides included) in which seaducks were recorded was in general 1500 – 3000 m depending on seastate and bird species. Where reefs and large shallows extended further from the coast some additional flight lines were flown. Total counts, in general, identify coastal areas with high densities of birds. However, south of Disko Bugt where the outer coast is dominated by large archipelagos and long fjords only samples of the coastline could be covered. A fixed distance off the coastline could not be systematically maintained, because of the irregularity of the coastline.

The surveys for king eiders in Upernavik and Qeqertarsuaq municipalities were focused on areas where we in 1993-1995 (August) had located many moulting eiders (Mosbech & Boertmann 1999).

Important sites and areas in Greenland are shown in Fig. 1.

The total counts were in 1998 flown between Avanersuaq in the north and Nuuk municipality in the south (Fig. 2). Except for flights in the fjords Nassuttooq and Afersiorfik , these surveys were performed along the outer coasts. In 1999 only few total counts were carried out, and all south of Disko Bugt (Fig. 3).

| Date in July | Activity |
|---|---|
| 9 | Survey for seaducks along coast between Kangerlussuaq and Disko Bugt |
| 10 | No flying due to bad weather in survey areas |
| 11 | No flying due to bad weather in survey areas |
| 12 | No flying as airport Sunday closed |
| 13 | Survey for seaducks in southern part of Upernavik municipality |
| 14 | Survey for seaducks in southern part of Upernavik municipality |
| 15 | Survey for seaducks in inner parts of the fjords Afersiorfik and Nassuttooq |
| 16 | Survey for seaducks in northern part of Upernavik municipality |
| 17 | Survey for seaducks in Avanersuaq |
| 18 | No flying as Thule Airbase is weekend closed |
| 19 | No flying as Thule Airbase is weekend closed |
| 20 | Photo survey for little auk colonies and survey for seaducks in Avanersuaq |
| 21 | Photo survey in Avanersuaq and in northern part of Melville Bugt |
| 22 | Survey for seaducks in Disko Bugt |
| 23 | No survey as aircraft grounded for 50 hours check |
| 24 | No survey as aircraft grounded for 50 hours check |
| 25 | Survey for seaducks along coast between Kangerlussuaq and Maniitsoq |
| 26 | No flying as airport Sunday closed |
| 27 | No flying due to bad weather in survey area |
| 28 | Survey for seaducks from central Maniitsoq to southern Nuuk municipalities |
| 29 | Survey for seaducks in Disko Bugt, however much reduced due to fog |
| 30 | Survey for seaducks in Nordfjord, northern Qeqertarsuaq |

Table 1. Itinary for the survey in 1998.

| Date in July | Activity |
|---|---|
| 20 | Survey for seaducks from southern Sisimiut to Kangaatsiaq municipalities |
| 21 | Survey for harlequin ducks in Northern Paamiut and in Nuuk municipalities |
| 22 | Survey for Greenland Institute of Natural Resources |
| 23 | No survey due to bad weather |
| 24 | Survey for harlequin ducks in Nuuk and Maniitsoq municipalities |
| 25 | No survey, airport Sunday closed |
| 26 | No survey due to fog in survey areas |
| 27 | No survey due to fog in survey areas |
| 28 | Survey for seaducks in southern Sisimiut municipality |
| 29 | Survey for seaducks in Nuuk municipality |
| 30 | Survey for mergansers and harlequin ducks in southern Nuuk and in Paamiut and Qaqortoq municipalities |
| 31 | Survey for harlequin ducks in Nuuk municipality |

Table 2. Itinary for the survey in 1999.

2) **Designated harlequin duck surveys**. Harlequin ducks stay in the contact zone between sea and land at the most exposed coast where the wave action often is strong. The harlequin ducks are very difficult to observe, and require a 100 % attention to their habitats excluding observation of most other birds. The surveyed area during harlequin duck surveys is therefore limited to the 200 m on both sides of the aircrafts trackline.

The flights 21, 24, 29, 30 and 31 July 1999 (Fig. 3) were especially designed for counting harlequin ducks. When calculating the density of harlequin ducks, the coastline was divided in 40 segment 25 km long (in straight line) (Fig. 12), and in each of these the length of the surveyed coast line was measured on a digitised map in scale 1:250.000.

3) **Line transect surveys** were performed in order to get an estimate of the total population of eiders in selected archipelagos supposed to hold rather dense populations of breeders. Total counts along coastlines are labour-intensive and in archipelagos inaccurate because of the extension of the archipelago and because of the responsive (to the approaching aircraft) movements by the birds. Line transect surveys were conducted with distance sampling sensu Buckland et al. (1993). See details in Appendix 1. Distances were measured with inclinometer when birds were perpendicular to the aircrafts flying track (fixed flying altitude). For flushing birds perpendicular distances were measured to the point of flush. Most birds were flying at altitudes few meters above sea level and the perpendicular distance could be measured to a point on the sea below them. Both during total counts and transect surveys, flight level was 250 feet and flight speed was 85 knots. In 1998, east-west transects were placed with a distance of two nautical miles (3.6 km) in the three archipelagos Sassat, Akia and Qimmit (Fig. 2), the latter subdivided in two: Qimmit N and Qimmit S. In 1999, flights in the three common eider areas were repeated, but with transect lines closer to each other (one nautical mile, 1.8 km), and covering larger areas in Sassat and Akia and omitting the Qimmit N subarea (Fig. 3).

4) **The little auk breeding colonies** in Avanersuaq were recorded on video from the aircraft, when flying along the coastline in heights of mainly 8000 feet. The extent of the breeding colonies can later be seen on the video, due to colour differences, and subsequently transcribed to maps.

# 3 Results

## 3.1 Total count surveys

In addition to the seaducks, a few more species are included in this account, as they stay in similar habitats and may be exposed to oil spills in the same way. These species are great cormorant and mallard.

### 3.1.1 Great cormorant *Phalacrocorax carbo*

Figs. 4 and 5 show the distribution of the great cormorants observed during the surveys. From Nassuttooq and northwards the observations coincide with the distribution of the breeding colonies (Boertmann & Mosbech 1997), why the majority of the birds there mainly represent adult breeders. However, to the south of Nassuttooq very few breeding colonies are known and these are situated inside the fjords (Boertmann et al. 1996). The birds observed along the outer coast there, may therefore represent non-breeding and immature birds. These occur generally as small flocks dispersed along the coast, but at least in the archipelago to the south of Nuuk a larger assemblage have been recorded during both surveys. In 1998, 180 birds and in 1999 165 were observed there. Two birds seen on the island Qioqe in western Qaqortoq municipality behaved like breeding birds, although no proof of breeding was seen.

### 3.1.2 Mallard *Anas plathyrhynchos*

Mallards are breeding in West Greenland as far north as Upernavik municipality. The breeding habitats are lakes, ponds, and sheltered coasts with shallow water. Fig. 6 shows the distribution of the mallards observed in 1998. In 1999 only nine mallards were seen, and no map is presented. The majority of the mallards were seen inside the fjordlands, particularly in the Nassuttooq and Afersiorfik. Large concentrations are not known, but during moult in summer and during winter, minor concentrations may occur along sheltered coast. Some of the flocks seen may represent moulting males.

### 3.1.3 Common eider *Somateria mollissima*

Common eiders nest in small colonies and dispersed along the coast of West Greenland (Boertmann et al. 1996). Inside the fjords Nassuttooq and Afersiorfik some colonies are known

(Frich et al. 1997), and really large colonies are today only known from the Avanersuaq area (Frich et al. 1997, Christensen

& Falk 1999). During summer many non-breeding adults, moulting adult males and immature birds occur along the West Greenland coast, although specific moulting areas with large concentrations are not known. The 1998 and 1999 surveys confirms this (Figs. 7 and 8) and only in one site, Qasigissat on western Disko, a large concentration (c. 7500 birds, all flying) was seen.

The common eiders seen in Avanersuaq represents both breeding birds (females with ducklings, pairs) and congregations of males (pre-moulting). Particularly in Booth Sund, a large flock of males (flying) (1050) was observed.

### 3.1.4 King eider *Somateria spectabilis*

The king eiders which occur during July in West Greenland are moulting birds mainly from breeding grounds in Arctic Canada (Salomonsen 1968, Frimer 1993, 1994, Mosbech & Boertmann 1999). They occur from Disko Bugt and northwards, with the most important moulting habitats in Nordfjord on Disko, in Umiiarfik southern Upernavik and the interior fjords in central Upernavik (Mosbech & Boertmann 1999). The formerly very important moulting site in Mudderbugten eastern Disko seems now to be abandoned (Mosbech & Boertmann 1999).

The observations in July 1998 are shown in Fig. 9. None were seen during the 1999 survey, which also was situated to south of the moulting areas. No birds were yet flightless due to the moult. Only rather small numbers were seen on Disko (2800), where the largest numbers surprisingly was observed in Mudderbugten (1074). Another remarkable observation was 510 bird (all flying) at Grønne Ejland in Disko Bugt. In Umiiarfik small numbers were seen (423). Further north in Upernavik large flocks were seen in the fjords east and northeast of the settlement Naajat (in total 3250 birds). Elsewhere in Upernavik and Avanersuaq only small numbers were seen.

### 3.1.5 Long-tailed duck *Clangula hyemalis*

Long-tailed ducks are dispersed breeders along sheltered coast and at lakes in West Greenland. During summer flocks (up to a few hundred) of moulting birds are found at shallow coasts both in the fjordlands and at the outer coast. Figs. 10 and 11 show the observations in July 1998 and July 1999 respectively. The birds seen are probably moulting birds except those seen on a lake in Inglefield Land in Avanersuaq. It is worth

mentioning that the concentration in southern Upernavik at Tukingassoq have been recorded every time we have passed this area in July or August (1993, 1994, 1995), and that the birds always are found in some particular bays.

### 3.1.6 Harlequin duck *Histrionicus histrionicus*

Harlequin ducks breed in low numbers dispersed in the inland of West Greenland, where the habitat is turbulent rivers. During summer moulting birds assemble along the outer exposed coast, first the males later females and juveniles. After the moult the birds stay in the same area throughout the winter. The large number of moulting birds compared to the low number of breeding birds, made Salomonsen (1974, 1981) to assume that birds form outside Greenland may perform a moult migration the West Greenland waters. This was confirmed in 1997 and 1998 when males equipped with satellite transmitters were tracked from Labrador peninsula to West Greenland (Brodeur et al. 1999), and again in 1999 when a male ringed in Canada was caught in near Nuuk (G. Robertson pers. comm.).

In July 1998, 153 harlequin ducks in 11 flocks were observed along the outer coast of central Nuuk municipality. They were seen only when we searched specifically for this species. The result in 1998 was encouraging as it showed it was possible to locate the moulting flocks from the air, and in 1999 we carried out a special harlequin duck survey covering the outer coast of southern and central West Greenland, where the majority of the moulting population is supposed to stay.

The majority of the moulting harlequin ducks were found from segment 20 (off Nuuk) and southwards (Fig. 12). The highest density was recorded in segments 34 and 35 in Paamiut municipality, but high densities were also found in Nuuk and western Qaqortoq municipalities (Fig. 13). In total, 3549 harlequin ducks were recorded when adjusting for double registrations in areas surveyed more than once (Table 3), and flocks ranged from 2 to 100 with an average of 12 (Table 3.)

The surveys of 21 July and 31 July overlapped in segment 21, (Table 4). Moreover was a part of this segment surveyed by Greg Robertson et al. (pers. comm.) in 23-24 August the same year (Table 4).

| Segment | No. of flocks | No. of birds | Survey date | Flock average | Flock range km | Surveyed coast | Density |
|---|---|---|---|---|---|---|---|
| 1 | 0 | 0 | 20 | - | - | 15.9 | 0 |
| 2 | 0 | 0 | 20 | - | - | 31.1 | 0 |
| 3 | 2 | 15 | 20 | 7.5 | 7-8 | 35.6 | 0.42 |
| 4 | 0 | 0 | 20 | - | - | 33.7 | 0 |
| 5 | 0 | 0 | 20 | - | - | 27.9 | 0 |
| 6 | 0 | 0 | 20 | - | - | 43.7 | 0 |
| 7 | 0 | 0 | 20 | - | - | 23.9 | 0 |
| 8 | 0 | 0 | 20 | - | - | 51.2 | 0 |
| 9 | 0 | 0 | 20, 28 [2] | - | - | 41.7 | 0 |
| 10 | 0 | 0 | 28 | - | - | 15.4 | 0 |
| 11 | 0 | 0 | 24 | - | - | 21.9 | 0 |
| 12 | 0 | 0 | 24 | - | - | 20.9 | 0 |
| 13 | 0 | 0 | 24 | - | - | 27.6 | 0 |
| 14 | 0 | 0 | 24 | - | - | 16.7 | 0 |
| 15 | 2 | 19 | 24 | 9.5 | 4-15 | 27.1 | 0.70 |
| 16 | 1 | 12 | 24 | 12.0 | - | 21.2 | 0.57 |
| 17 | 0 | 0 | 24 | - | - | - | 0 |
| 18 | 1 | 7 | 24 | 7.0 | 7 | - | - |
| 19 | 1 | 6 | 31 | 6.0 | 6 | 27.0 | 0.22 |
| 20 | 7 | 81 | 31 | 11.6 | 4-50 | 24.6 | 3.29 |
| 21 | 24 | 495 [1] | 21, 31 | 20.6 | 2-100 | 73.0 [1] | 6.78 |
| 22 | 24 | 515 [1] | 21, 31 | 21.5 | 1-80 | 59.0 [1] | 8.72 |
| 23 | 21 | 144 [2] | 21, 29, 31 | 6.9 | 1-16 | 34.7 | 4.15 |
| 24 | 16 | 200 | 21 | 12.5 | 3-25 | 33.0 | 6.06 |
| 25 | 21 | 293 | 21 | 14.0 | 1-35 | 33.7 | 8.69 |
| 26 | 28 | 336 | 21 | 12.0 | 2-30 | 36.2 | 9.28 |
| 27 | 19 | 138 | 21 | 7.3 | 1-25 | 25.5 | 5.41 |
| 28 | 7 | 54 | 21, 30 | 7.7 | 1-16 | 27.3 | 1.98 |
| 29 | 13 | 94 [2] | 30 | 7.2 | 2-18 | 24.3 | 3.87 |
| 30 | 15 | 105 | 30 | 7.0 | 1-15 | 29.0 | 3.62 |
| 31 | 5 | 33 | 30 | 6.6 | 3-10 | 25.6 | 1.29 |
| 32 | 1 | 2 | 30 | 2.0 | 2 | 5.7 | 0.35 |
| 33 | 0 | 0 | 30 | - | - | 11.8 | 0 |
| 34 | 14 | 180 | 30 | 12.9 | 1-30 | 9.8 | 18.37 |
| 35 | 16 | 213 | 30 | 13.3 | 2-48 | 20.7 [1] | 10.29 |
| 36 | 4 | 54 | 30 | 13.5 | 4-35 | 20.6 | 2.62 |
| 37 | 14 | 123 | 30 | 8.8 | 2-24 | 69.5 | 1.77 |
| 38 | 9 | 112 | 30 | 12.4 | 3-35 | 21.8 | 5.14 |
| 39 | 14 | 158 | 30 | 11.3 | 2-30 | 18.4 | 8.59 |
| 40 | 18 | 160 | 30 | 8.9 | 1-18 | 35.4 | 4.52 |
| Total | 297 | 3549 | | 11.9 ± 12.2 [3] | 1-100 | 1059.7 | 5.41 [4] |

[1] only survey result for 31 July, [2] survey results for all dates added as tracks did not overlap, [3] standard deviation, [4] only segment 19-40.

Table 3. Distribution of flocks and individuals between the 25 km segments. In segments surveyed more than once highest result shown. Observations from a transect flight in area 23 included.

| Date | Effort surveyed coast km | No. of flocks | No. of birds | Flocks/km | Birds/km | Flock mean | Range | St. dev. |
|---|---|---|---|---|---|---|---|---|
| 21 July | 69.8 | 31 | 280 | 0.4 | 4.0 | 9.0 | 2-55 | 9.8 |
| 31 July | 73.0 | 24 | 495 | 0.3 | 6.8 | 20.6 | 2-100 | 22.6 |
| 23-25 August | 50.9 | 76 | 867 | 1.5 | 11.4 | 11.4 | 1-45 | 11.1 |

Table 4. Results of repeated surveys in segment 21, with a 10 day interval. (flight routes almost identical). The difference in flock size between 21 and 31 July is statistical significant at a 5 % level (p = 0,034, Mann-Whitney U test). The 23-25 August data were provided by Greg Robertson, Canadian Wildlife Service (pers. comm.), who by boat surveyed the majority of segment 21 during a harlequin duck blood sampling programme.

### 3.1.7 Red-breasted merganser *Mergus serratus*

The red-breasted merganser is a dispersed breeder at sheltered coast and lakes in West Greenland, and is generally not numerous at any site. During summer flocks of moulting birds are found scattered here and there along the coast both in the fjords and in extensive archipelagos with shallow waters.

Remarkably many mergansers (in total 861) were seen in the interior part of the fjords Nassuttooq and Afersiorfik in 1998 (Fig. 14). The concentration area in the Ikkattoq fjords in southern Nuuk was confirmed in July 1999, when in total 474 moulting mergansers were observed (Fig. 15).

## 3.2 Line transect surveys

The transects within the areas are shown on each map with the bird distributions (Figs. 16-21). The distribution of family flocks (flocks of females and ducklings) for each area is shown in Figs. 15-17. The corresponding distribution of non- or post-breeding common eiders are shown in Figs. 18-20.

When using distance sampling a detection function is fitted to the observations and the effective strip width (the distance where the number of flocks you overlook closer to the distance equal the number of flocks you record further away) is

calculated based on the assumption that all the birds on the flight line are recorded and an increasing number of birds are missed further away. The effective strip width (ESW), the encounter rate (n/L, flocks pr. km), and flock (cluster) size is estimated separately and combined in a total estimate.

In this study a common ESW has been estimated for the three areas, but stratified for flying birds, family flocks and birds on the water with no ducklings (pulli) detected. As these three kinds of flocks has different detectability, the encounter rate and flocks sizes have been estimated for each area and flock type separately.

Note that in the following estimates total adults on the water include both the females with ducklings and non- and post-breeding birds. Flying birds are calculated separately. On the distribution maps females with ducklings are depicted together with the ducklings, and all the non- and post-breeding birds - flying and resting - are pooled.

Table 5 gives number of flocks observed and a summary of the line transect estimates for the areas surveyed in 1998 and 1999, while Table 6 gives details. Note that the surveyed area at each locality differed between years (see maps Figs. 16-21), and that Qimmit N was only surveyed in 1998. See the fitted detection functions in Appendix 1

All three areas have significant numbers of eiders. Differences between areas are apparent, although most of the estimates have a considerable coefficient of variance. A large part of the variance for the flying birds is due to a few very large flocks, which contributed a large part of the total number of observed birds.

Total density of adult birds in each of the areas were very similar in the two years, but varied between areas with a maximum in Akia with about 15 birds/km$^2$ and a minimum in immit S with about 8 birds/km$^2$. In Sassat and Qimmit N about half of the adult birds were estimated from flying birds while less than a third were flying in Akia and Qimmit S.

In both years there were few ducklings in Sassat (about 1/km$^2$), and in Qimmit N (only surveyed in 1998). Ducklings were more abundant in Akia and Qimmit S, and in both these areas duckling density were higher in 1998 (7.1 and 6.1/km$^2$ respectively) than in 1999 (3.6 and 2.7/km$^2$ respectively), caused mainly by higher abundance of family flocks, but also by more ducklings in each family flock.

.

| | | Sassat | | Akia | | Qimmit N | Qimmit S | |
|---|---|---|---|---|---|---|---|---|
| | | 1998 | 1999 | 1998 | 1999 | 1998 | 1998 | 1999 |
| | Area km$^2$ | 414 | 256 | 284 | 595 | 319 | 189 | 165 |
| Flying | No. of flocks | 33 | 49 | 43 | 86 | 9 | 7 | 15 |
| | Flock size (S) | 10.5 | 10.20 | 10.1 | 6.30 | 50.1 | 5.6 | 7.80 |
| | Density (D) | 3.4 | 6.3 | 5.8 | 3.0 | 5.6 | 0.7 | 2.1 |
| | Abundance (N) | 1407 | 1615 | 1646 | 1808 | 1772 | 130 | 341 |
| Not flying | No. of flocks | 22 | 31 | 84 | 233 | 17 | 26 | 37 |
| (on the water) | Flock size (S) | 8.2 | 3.32 | 3.4 | 4.96 | 9.3 | 5.6 | 5.19 |
| | Density (D) | 5.0 | 2.2 | 10.8 | 11.1 | 5.5 | 7.6 | 5.8 |
| | Abundance (N) | 2074 | 567 | 3064 | 6575 | 1760 | 1435 | 954 |
| Total adult | No. of flocks | 55 | 80 | 127 | 319 | 26 | 33 | 52 |
| | Density (D) | 8.4 | 8.5 | 16.6 | 14.1 | 11.1 | 8.3 | 7.9 |
| | **Abundance (N)** | **3481** | **2182** | **3710** | **8383** | **3532** | **1565** | **1295** |
| Total ducklings | No. of flocks | 7 | 10 | 38 | 123 | 4 | 15 | 19 |
| | Flock size (S) | 3.4 | 4.70 | 4.3 | 2.90 | 5.3 | 7.1 | 4.50 |
| | Density (D) | 0.8 | 1.1 | 7.1 | 3.6 | 0.8 | 6.1 | 2.7 |
| | **Abundance (N)** | **319** | **274** | **2008** | **2146** | **270** | **1152** | **449** |

Table 5. A summary of the results of line transect surveys for eiders in Sassat, Akia and Qimmit. The abundance of flying birds, adults on the water and ducklings (pulli) are estimated separately due to different detection efficiency. Note that the number of flocks (clusters) not necessarily correspond to the number of flocks indicated on the maps (Figs. 16-21), as some flocks have been omitted (truncated) from the calculations, and a few flocks outside the transects have been included in the maps.

Table 6. Details of abundance estimates of eiders based on line transect surveys in Sassat, Akia and Qimmit. The abundance of flying birds, adults on the water and ducklings (pulli) are estimated separately due to different detection efficiency. Note that the number of flocks (clusters) not necessarily correspond to the number of flocks indicated on the maps (Figs. 16-21), as some flocks have been omitted (truncated) from the calculations, and a few flocks outside the transects have been included in the maps.

| 1998 | | | | | No. of | Encounter | | Cluster | | | | | 95% Conf. limits for | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Area ($km^2$) | ESW (km) | CV(esw) | Effort (L, km) | clusters (n) | rate (n/L) | CV(n/L) | size (s) | CV(s) | Density D | CV(D) | Estimate (N) | estimate(N) Lower | Upper |
| | | ***flying*** | | | | | | | | | | | | |
| Sassat | 414 | 0.451 | 0.16 | 113 | 33 | 0.290 | 0.28 | 10.50 (14.20) | 0.36 | 3.4 | 0.483 | **1,407** | 573 | 3,455 |
| Akia | 284 | 0.451 | 0.16 | 83 | 43 | 0.520 | 0.23 | 10.09 | 0.36 | 5.8 | 0.456 | **1,646** | 702 | 3,859 |
| Qimmit N | 319 | 0.451 | 0.16 | 90 | 9 | 0.010 | 0.41 | 50.11 | 0.87 | 5.6 | 0.975 | **1,772** | 357 | 8,796 |
| Qimmit S | 189 | 0.451 | 0.16 | 63 | 7 | 0.11 | 0.54 | 5.57 | 0.24 | 0.7 | 0.612 | **130** | 43 | 392 |
| | | ***not flying*** | | | | | | | | | | | | |
| Sassat | 414 | 0.159 | 0.09 | 113 | 22 | 0.195 | 0.23 | 8.18 | 0.37 | 5.0 | 0.445 | **2,074** | 902 | 4,770 |
| Akia | 284 | 0.159 | 0.09 | 83 | 84 | 1.023 | 0.15 | 3.39 | 0.12 | 10.8 | 0.210 | **3,064** | 2,040 | 4,603 |
| Qimmit N | 319 | 0.159 | 0.09 | 90 | 170 | 0.188 | 0.21 | 9.29 | 0.25 | 5.5 | 0.339 | **1,760** | 923 | 3,358 |
| Qimmit S | 189 | 0.159 | 0.09 | 63 | 26 | 0.41016 | 0.25 | 5.85 | 0.27 | 7.6 | 0.379 | **1,435** | 700 | 2,941 |
| | | ***pulli*** | | | | | | | | | | **0** | | |
| Sassat | 414 | 0.138 | 0.0724 | 113 | 7 | 0.062 | 0.29 | 3.429 | 0.25 | 0.8 | 0.390 | **319** | 152 | 666 |
| Akia | 284 | 0.138 | 0.0724 | 83 | 38 | 0.457 | 0.26 | 4.263 | 0.14 | 7.1 | 0.304 | **2,008** | 1,121 | 3,597 |
| Qimmit N | 319 | 0.138 | 0.0724 | 90 | 4 | 0.044 | 0.36 | 5.25 | 0.33 | 0.8 | 0.494 | **270** | 108 | 674 |
| Qimmit S | 189 | 0.138 | 0.0724 | 63 | 15 | 0.2366 | 0.41 | 7.067 | 0.17 | 6.1 | 0.450 | **1,152** | 497 | 2,672 |

Table 6. Continued.

1999

| | Area ($km^2$) | ESW (km) | CV(esw) | Effort (L, km) | No. of clusters (n) | Encounter rate (n/L) | CV(n/L) | Cluster size (s) | CV(s) | Density D | CV (D and N) | Estimate (N) | 95% conf. limits for estimate (N) Lower | Upper |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | ***flying*** | | | | | | | | | | | | |
| Sassat | 256 | 0.283 | 0.17 | 140 | 49 | 0.35 | 0.38 | 10.20 (22.9) | 0.34 | 6.3 | 0.54 | **1615** | 602 | 4.334 |
| Akia | 595 | 0.283 | 0.17 | 315 | 86 | 0.27 | 0.15 | 6.30 (8.5) | 0.23 | 3.0 | 0.32 | **1808** | 975 | 3352 |
| Qimmit S | 165 | 0.283 | 0.17 | 100 | 15 | 0.15 | 0.23 | 7.80 | 0.43 | 2.1 | 0.52 | **341** | 132 | 885 |
| | | ***not flying*** | | | | | | | | | | | | |
| Sassat | 256 | 0.166 | 0.05 | 140 | 31 | 0.22 | 0.15 | 3.32 | 0.17 | 2.2 | 0.23 | **567** | 362 | 888 |
| Akia | 595 | 0.166 | 0.05 | 315 | 233 | 0.74 | 0.09 | 4.96 (6.2) | 0.10 | 11.1 | 0.14 | **6575** | 4970 | 8699 |
| Qimmit S | 165 | 0.166 | 0.05 | 100 | 37 | 0.37 | 0.22 | 5.19 | 0.38 | 5.8 | 0.44 | **954** | 417 | 2.184 |
| | | ***pulli*** | | | | | | | | | | | | |
| Sassat | 256 | 0.157 | 0.07 | 140 | 10 | 0.07 | 0.40 | 4.70 | 0.22 | 1.1 | 0.46 | **274** | 116 | 648 |
| Akia | 595 | 0.157 | 0.07 | 315 | 123 | 0.39 | 0.14 | 2.90 | 0.16 | 3.6 | 0.22 | **2146** | 1391 | 3310 |
| Qimmit S | 165 | 0.157 | 0.07 | 100 | 19 | 0.19 | 0.27 | 4.50 | 0.64 | 2.7 | 0.70 | **449** | 131 | 1545 |

*Clusters = flocks;*
*ESW = effective half-strip width;*
*CV = coefficient of variation calculated as standard error in proportion to the mean.*
*Estimated cluster size (s) is computed by simple average of observations unless there is a significant correlation between flock size and observation distance (significance level = 0.1). Such a bias occur if small flocks at long distance are overlooked more than large flocks. This size bias is compensated by estimating cluster size from regression of log(observed flock size) on probability of detection at the observation distance. Where size bias compensation have been used the simple mean is given in brackets.*

## 3.3 The little auk survey

The entire coastline with little auk colonies (app. 400 km) was recorded on video. The video tapes remain to be analysed. If this work can be funded, we expect to measure the total area covered by the colonies, and from density estimates obtained from ground based counts of breeding birds (Kampp et al. 2000), a more accurate estimate than hitherto presented (Boertmann & Mosbech 1998) of the breeding population can be calculated.

# 4 Discussion

The surveys has, with rather limited effort relative to the extensive coastline, identified concentration areas for seaducks in the coastal zone during late July. The total count surveys pinpoint the concentration areas and give minimum numbers for the ducks present. It is not possible to give total estimates for West Greenland as the surveys only cover selected areas and not the entire coastline. However dedicated surveys for Harlequin ducks and eiders in selected areas have made preliminary estimates possible.

*Great cormorant*

The observations of great cormorant show that the major part of the population stay within the breeding area north of Nassuttooq Fjord, and that local and rather small concentrations of non-breeding birds may occur in more southern areas during summer. This is in agreement with earlier observations. The cormorant population in Greenland is increasing the breeding range for the time being (Boertmann & Mosbech 1996), and the observation of a possible breeding pair in western Qaqortoq is in this regard very interesting, because the island where they stayed is about 350 km to the south of the nearest confirmed breeding sites in Nuuk municipality. It should be mentioned that breeding may have occurred on Ydre Kitsissut also in Western Qaqortoq in 1992 (Kampp & Falk 1994).

*Mallard*

Only few mallards were observed during the two surveys. This is not surprising as the species is not very numerous and usually does not occur in large concentrations. The major part was seen in the interior parts of the fjords Nassuttooq and Afersiorfik, and the birds seen there may have been pre-moulting birds. A few birds and small flocks were seen at the outer coast mainly in sheltered bays and in archipelagos with shallow water.

*Common eider*

Common eiders were seen along all of the outer coasts lines, both breeding birds (females with ducklings), non-breeding birds and post-breeding males. The post-breeding males assemble in flocks to moult rather dispersed along the coast, and the larger flocks seen represent in general such males. Some of the post-breeding males were still able to fly and may not yet be located at their moulting site. The largest concentration of post-breeding males was seen at western Disko, where we during previous years have seen many flightless males later in the season (August).

The common eider areas where we conducted line transect surveys were selected based on previous observations of relatively many breeding birds. The observations show that especially in Akia and Qimmit S quite high numbers of females with ducklings are present.

Eiders are known to swim-migrate considerable distances with their newly hatched ducklings from breeding areas (offering

nest-sites with protection from predators) to rearing areas with good feeding conditions. Thus a high density of family flocks in an area does not necessarily mean a large breeding population there, as the nesting area can be 25 km or even 100 km away. However, from an oil spill sensitivity mapping perspective the identification of duckling rearing areas is equal important

We presume that these areas are both nesting and rearing areas. However, some relocation from nesting sites may take place. In 1998, the breeding season was somewhat delayed, and an unknown number of females was still incubation eggs. We saw a few flushing from small islands when flying directly above them, although brooding females usually are not seen from the air. Another reason for still brooding females could be egg-collecting, and still incubating females could then be re-lays.

Particularly Akia is an important breeding area for common eider. This is an extensive archipelago, where the eiders nest rather dispersed and not in dense colonies. The total number of breeding females with chicks in the area may reach 700 in 1999 assuming an average clutch size of three. The two other strata held 90 and 150 breeding females respectively in 1999 (with the same assumption). However, to these figure should be added the number of predated and given-up nest to reach the number of females which actually initiated breeding in the areas. Moreover, had all nests had not yet hatched during our surveys.

All three areas have important numbers of post- and non-breeding birds and especially Sassat and Qimmit N had high densities of post- and non-breeding birds relative to the number of family flocks present.

*King eider*

The purpose of the king eider survey in Disko Bugt and Upernavik was to see if concentrations of early moulting males occurred. We have previously surveyed these areas in August (Mosbech & Boertmann 1999) and in total estimated that about 30.000-40.000 king eiders reside in West Greenland in late August. However, we had a suspicion that some males could have terminated the moult and left the areas before the surveys in late august. During the July surveys, we saw many king eiders particularly in the area just north of Upernavik Isfjord east of Naajat. These birds were, however, flying and had not yet initiated the moult, and were more likely newly arrived males, which later will move to the moulting grounds. In the well known moulting areas as Nordfjord and Umiiarfik only few birds were seen (about 800 and 400 respectively) and all able to fly. In these two areas several thousands birds moult in August. It was remarkable that about 1000 (flying) birds were observed in Mudderbugten, and area previously known to hold the largest number of moulting males, but now abandoned probably due to disturbance (Mosbech & Boertmann 1999). The observation indicate that the king eiders still move to this site, but leave it again before the moult, and that it could be restored as a

moulting habitat if the disturbance was reduced. The conclusion of this survey is that there is no significant numbers of early (in July) moulting male king eiders.

*Long-tailed duck*

Long-tailed ducks assemble in small flocks both at the outer coast and in the fjords to moult. During our surveys rather few were observed, and only at three sites concentrations were recorded. Two of these in southern Upernavik municipality, in areas well known as habitats for this species from our previous surveys in August 1993-1995.

*Harlequin duck*

The results of the harlequin duck survey in 1999 was much better than expected. However as the harlequin ducks are very difficult to detect from the air, our result (Table 3) must be considered as a minimum estimate of the real numbers present in July. The repeated surveys in segment 21 (Table 4) indicate that the males still move somewhat around (the majority of the birds are still able to fly) and assemble in larger flocks through July. A month later considerable more birds were seen from boat in the same area (Table 4), but the counts cannot be compared directly as the survey platforms were too different. However, the results indicate that either a boat survey may reveal much more moulting birds than a survey from an aircraft or more birds had arrived at segment 21 following our survey. We consider the last possibility the most likely to explain the major part of the difference.

It is remarkable that the majority of the harlequin ducks were seen to the south of Nuuk (segment 20). This could be explained by the presence of the Canadian birds. All except for one of the locations received from the birds equipped with satellite transmitters were from the coast to the south of Nuuk (Brodeur et al. 1998). Perhaps the major part of the moulting males there derive from the Canadian population. The high density area in southern Paamiut municipality (Fig. 13) is well known in the literature as a coast where many harlequin duck occur (Helm 1895). The area to the south of Nuuk held the largest number observed, where about 1000 birds (28 % of the total number observed) were seen in the segments 21 and 22. Such a coastline is indeed very vulnerable to an oil spill.

*Red-breasted merganser*

In July 1985, a large concentration (about 1000 birds) of moulting red-breasted mergansers was found in the fjord Ikkattoq in southern Paamiut municipality (F. Wille pers. comm.). Since then, the site has not been visited, and in 1999 we decided to survey the fjord again. That survey confirmed the fjord as a very important moulting ground as we located about 500 moulting males. During the survey in 1998, another concentration area was located in the interior parts of the fjords Nassuttooq and Afersiorfik, where about 850 red-breasted mergansers were observed. These numbers are high in a Greenland context, where the total population of red-breasted merganser is low and perhaps not exceeding 5000 pairs.

# 5 Oil spill sensitivity mapping

The coastlines most sensitive to an oil slick are, from a marine bird perspective, those where relatively large proportions of populations occur concentrated in limited areas. Or in other words where an oil slick can cause declines in whole populations. The areas where the moulting red-breasted mergansers are concentrated are good examples. Particularly Ikkattoq Fjord, because this is close to the outer coast where an off-shore oil spill potentially can reach the birds. How large a proportion of the population assemble in Ikkattoq is unknown, but if the population, as earlier mentioned, may number 5000 pairs, about 1000 moulting males (as recorded in 1985) may represent a very significant part (10 % of the adult birds).

Also the moulting harlequin ducks occur in large concentrations in some areas. Particularly in the archipelago south of Nuuk about 1000 birds were seen, constituting about 28 % of the birds observed during the survey. The density in this area was, however not in the top category (Fig. 13), and another area in southern Paamiut had a higher density and may hold even more birds if investigated better. As the population breeding in eastern Canada was listed as endangered in 1991 (Robertson & Goudie 1999), Greenland certainly has an international obligation in protecting this population of seaducks.

Common eiders both breed and moult along the outer coasts. The aggregation of large numbers of moulting eiders are, however, not as pronounced as the moulting aggregations of harlequin ducks and red-breasted mergansers. The breeding common eiders and foraging family flocks on the other hand are more concentrated in some particular archipelagos, especially Akia and Qimmit S. The breeding population today is very low compared to what it was a hundred years ago, and this decline is caused by hunting and egg-collecting. An oil spill affecting a large part of the breeding population in July therefore have the potential to reduce it further, and the recovery potential of the population will be very low due to the hunting pressure.

Both mallards and great cormorants occur so dispersed and in so low numbers in the southern west Greenland region in July, that an oil spill probably only will affect insignificant parts of the population.

# 6 Figures

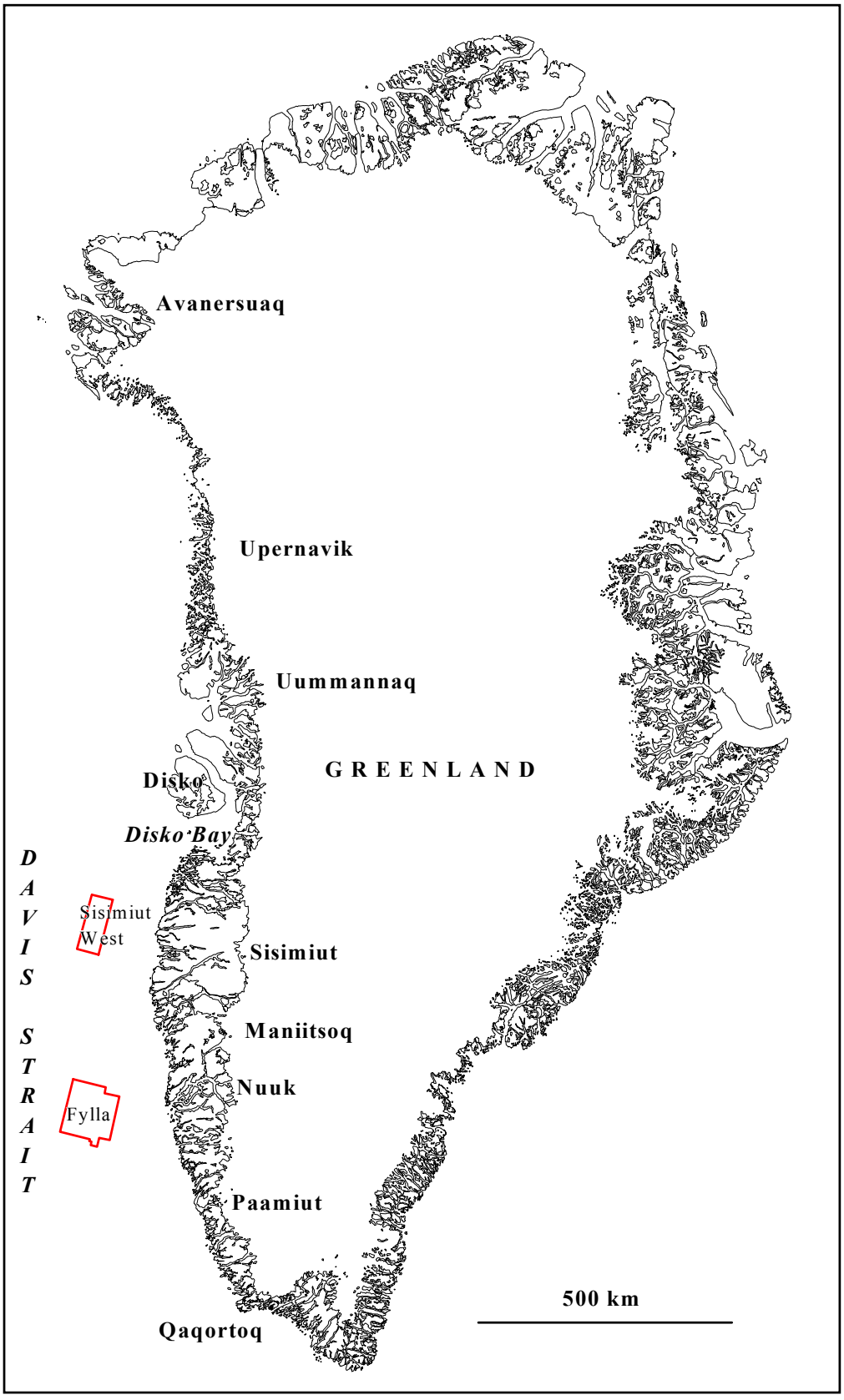


Fig. 1. Greenland with major areas and municipalities mentioned in the text and the two oil exploration licence areas indicated.

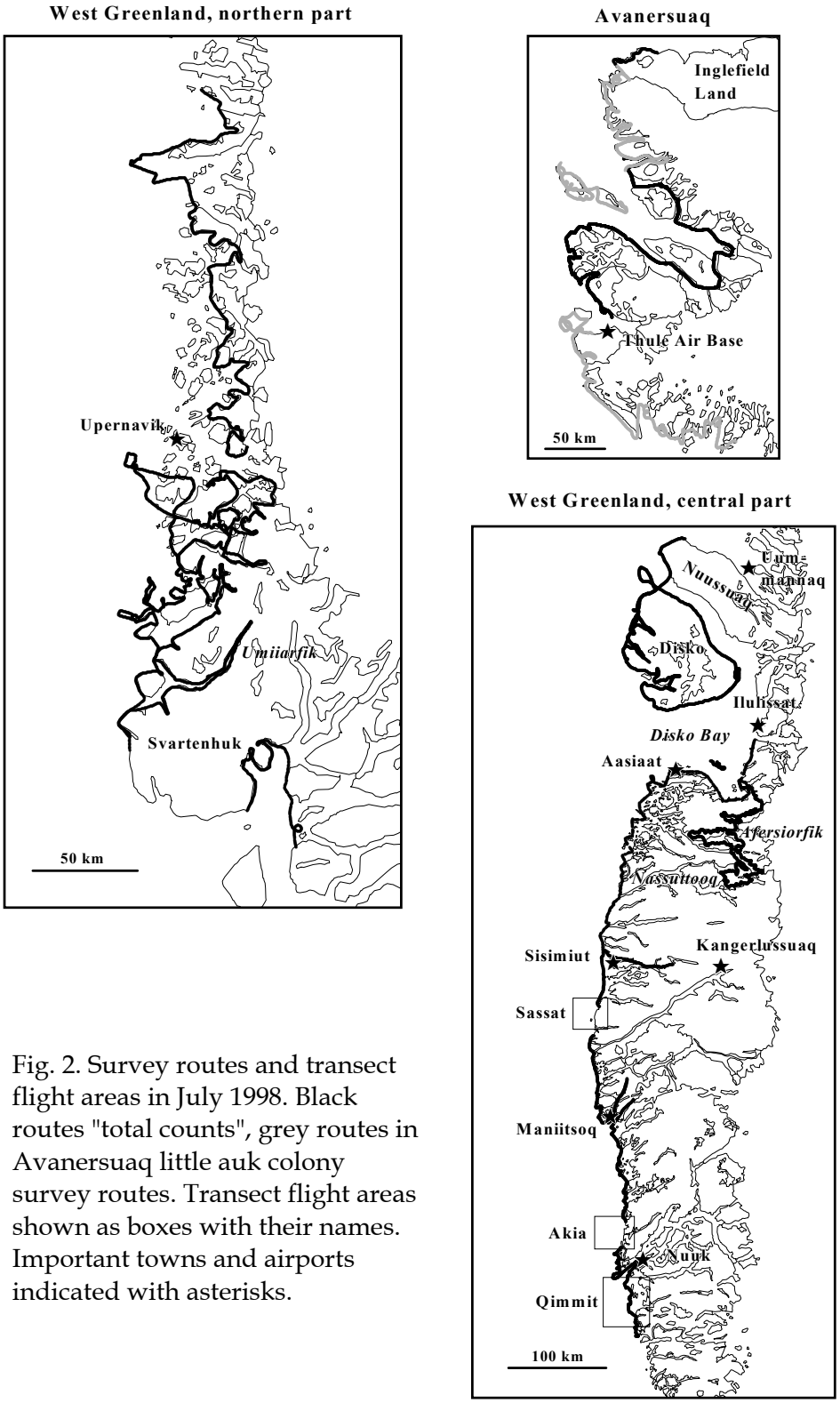


Fig. 2. Survey routes and transect flight areas in July 1998. Black routes "total counts", grey routes in Avanersuaq little auk colony survey routes. Transect flight areas shown as boxes with their names. Important towns and airports indicated with asterisks.

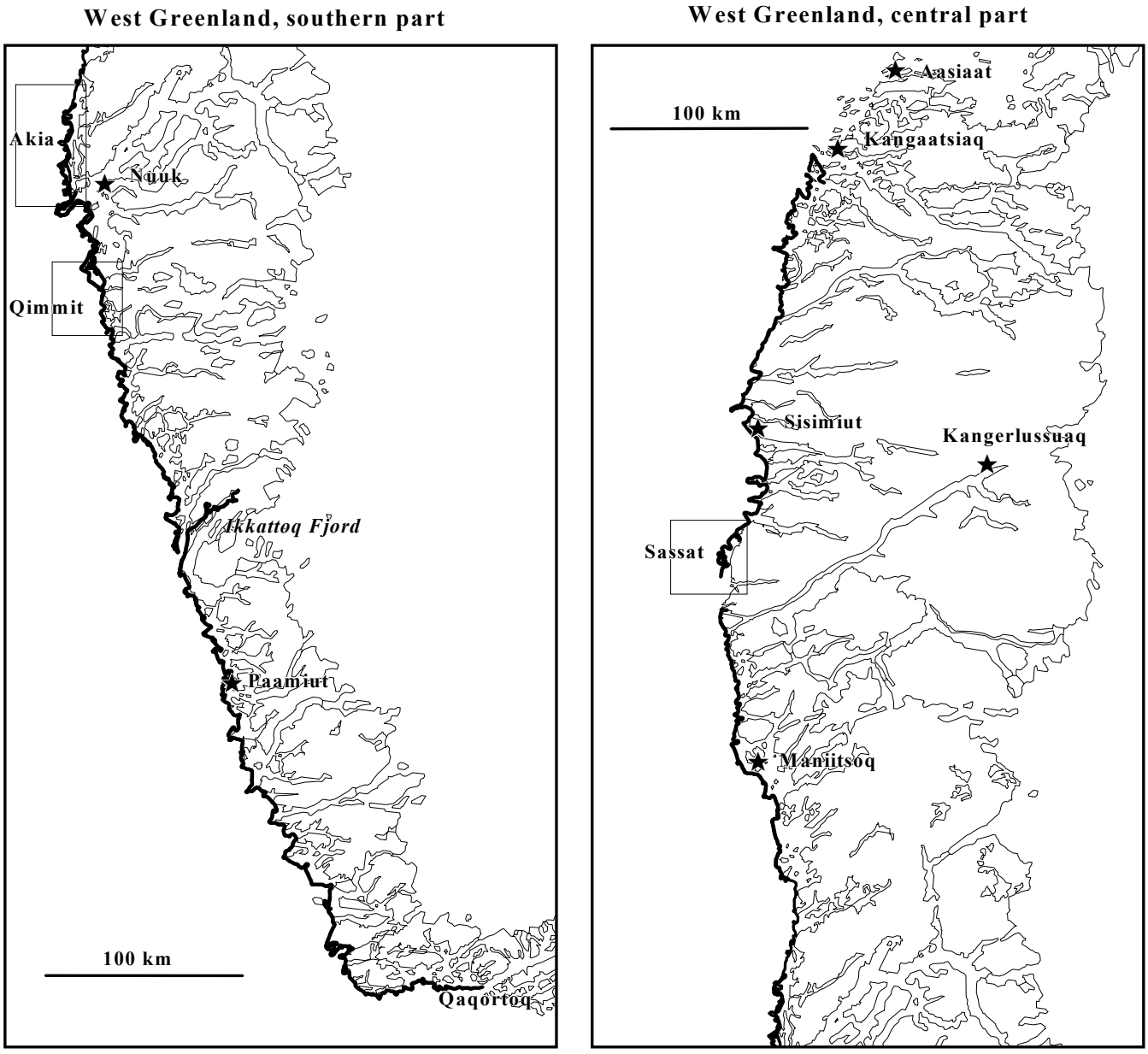


Fig. 3. Survey routes and transect flight areas in July 1999. Black routes "total counts" and transect flight areas shown as boxes with their names. Important towns and airports indicated with asterisks.

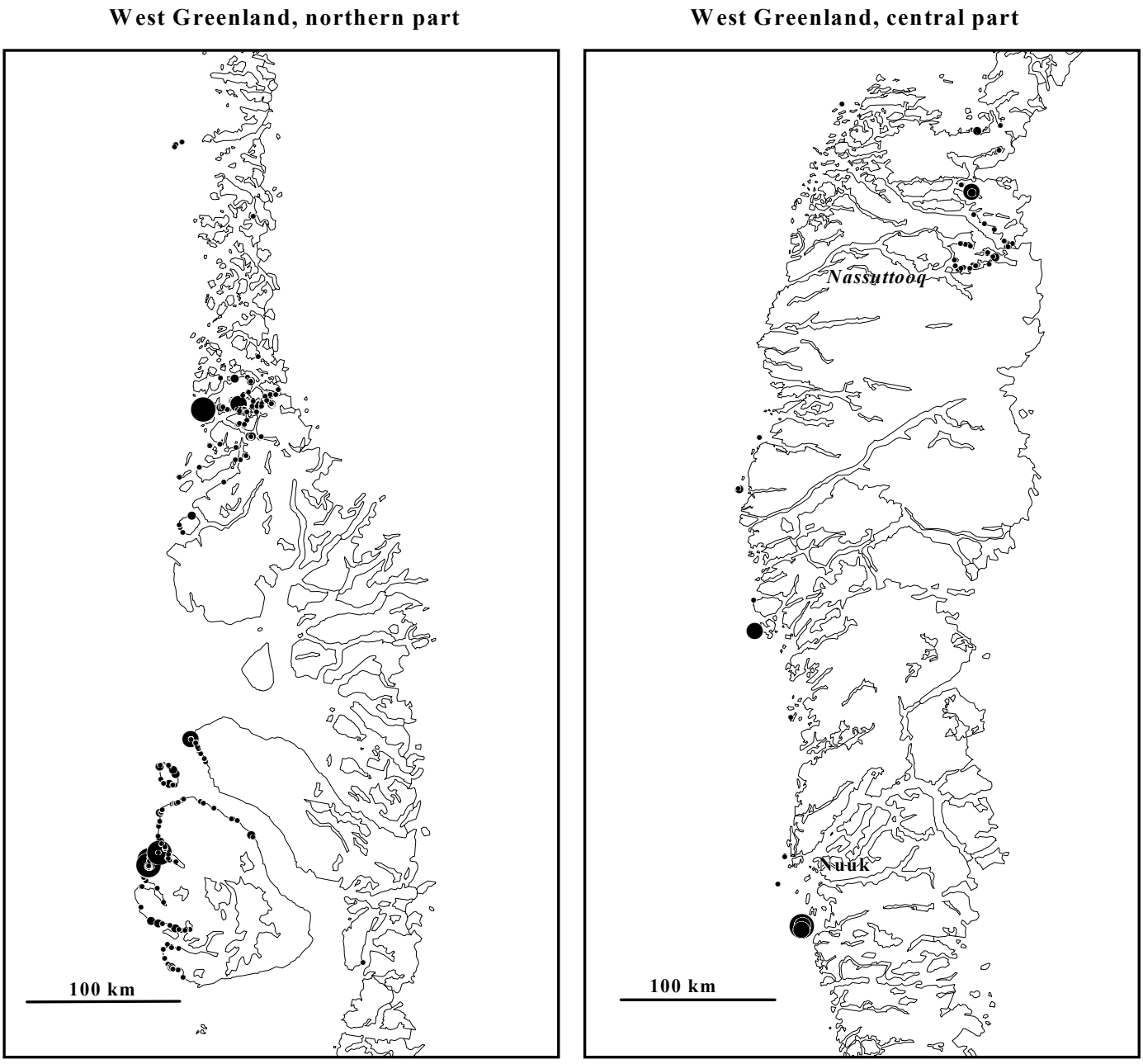


Fig. 4. Distribution of great cormorants seen during the July 1998 survey. N = 1791 birds in 273 flocks. Flock size range 1-90.

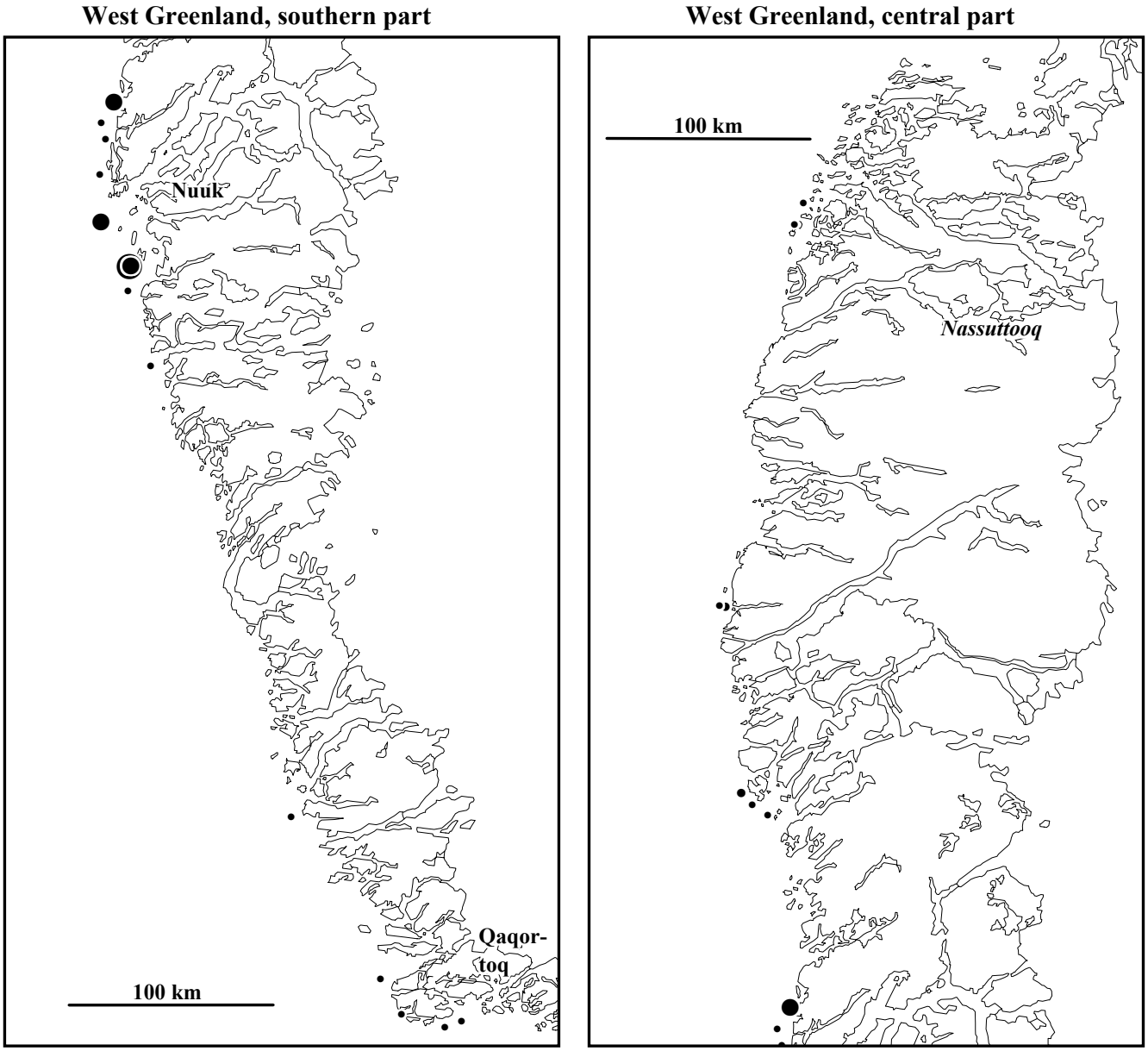


Fig. 5. Distribution of great cormorants observed during the July 1999 survey. N = 533 in 40 flocks. Flock size range 1-100.

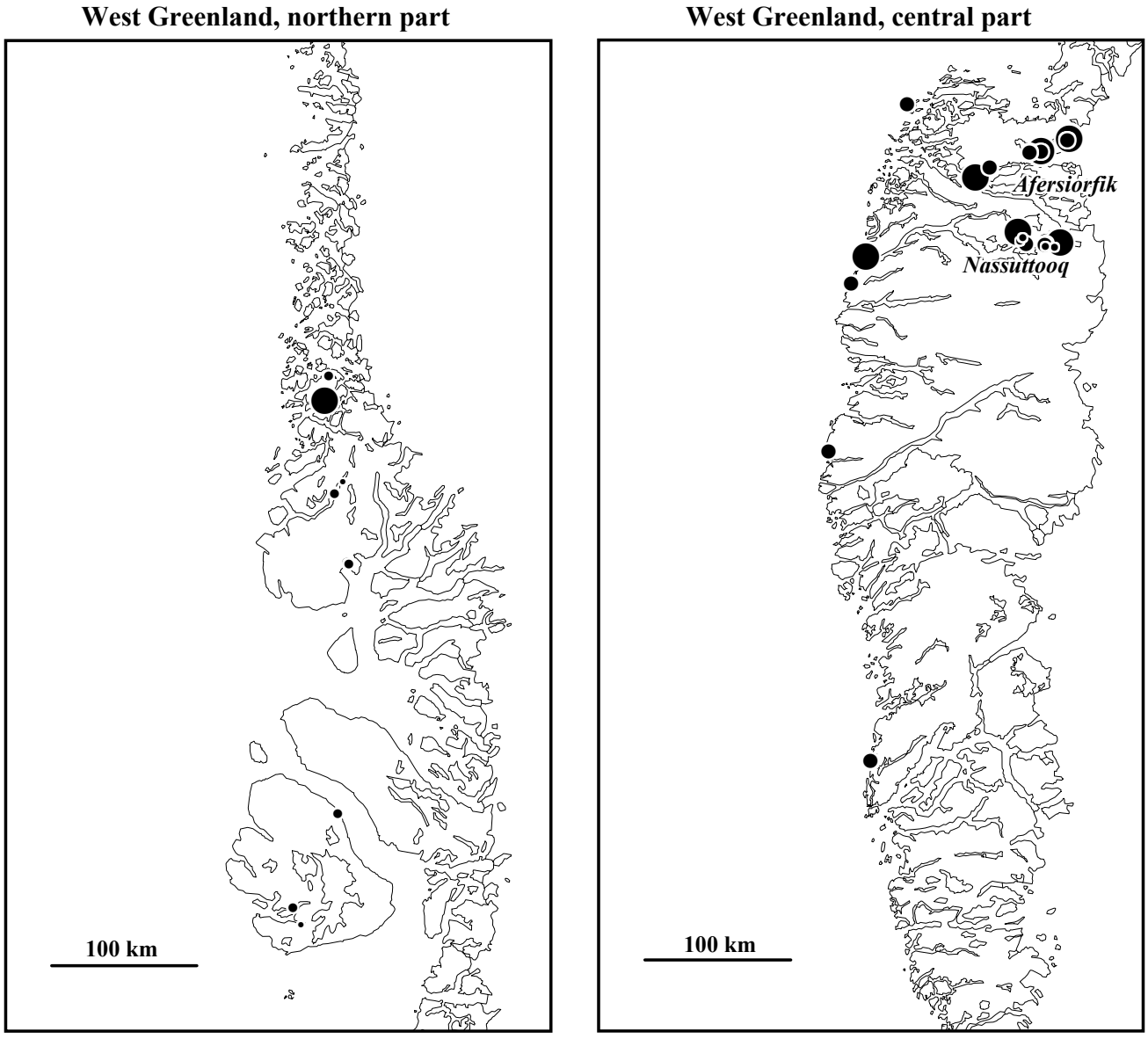


Fig. 6. Distribution of mallards observed during the 1998 survey. No observations in Avanersuaq. N = 131 birds in 33 flocks. Flock size range 1-13.

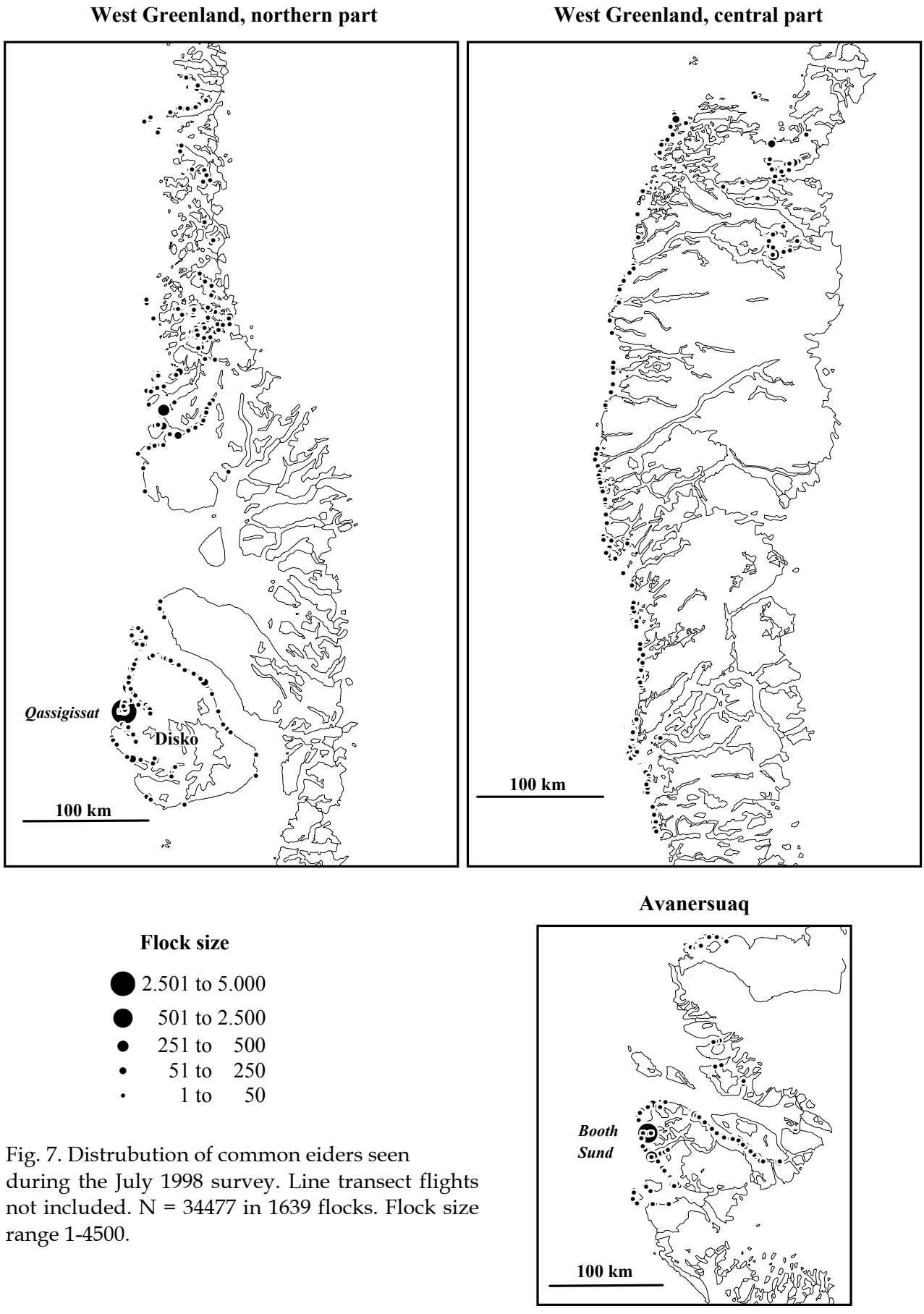


Fig. 7. Distrubution of common eiders seen during the July 1998 survey. Line transect flights not included. N = 34477 in 1639 flocks. Flock size range 1-4500.

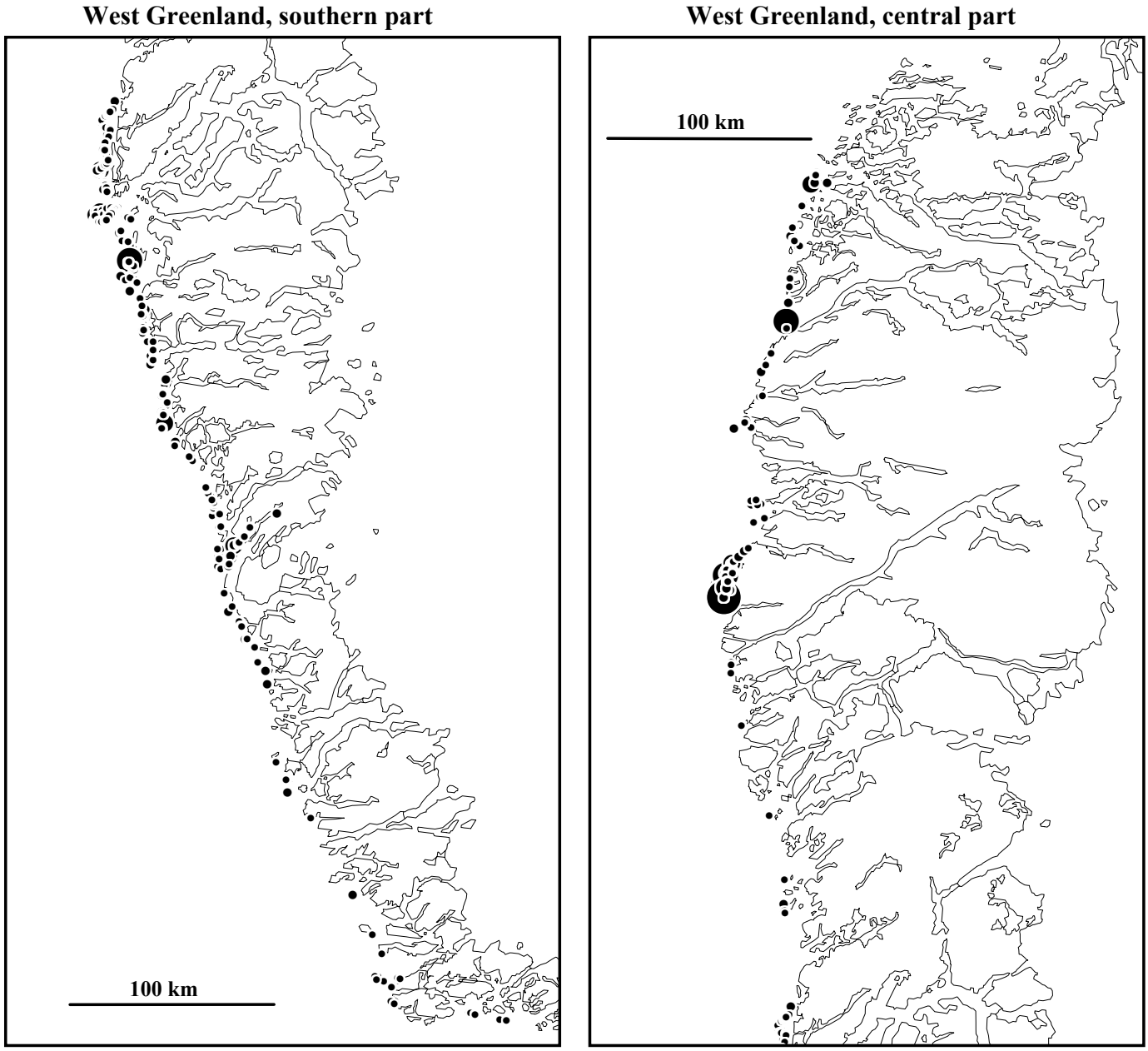


Fig. 8. Distribution of common eiders observed during the July 1999 survey. Transect flights not included. N = 6352 in 525 flocks. Flock size range 1-500.

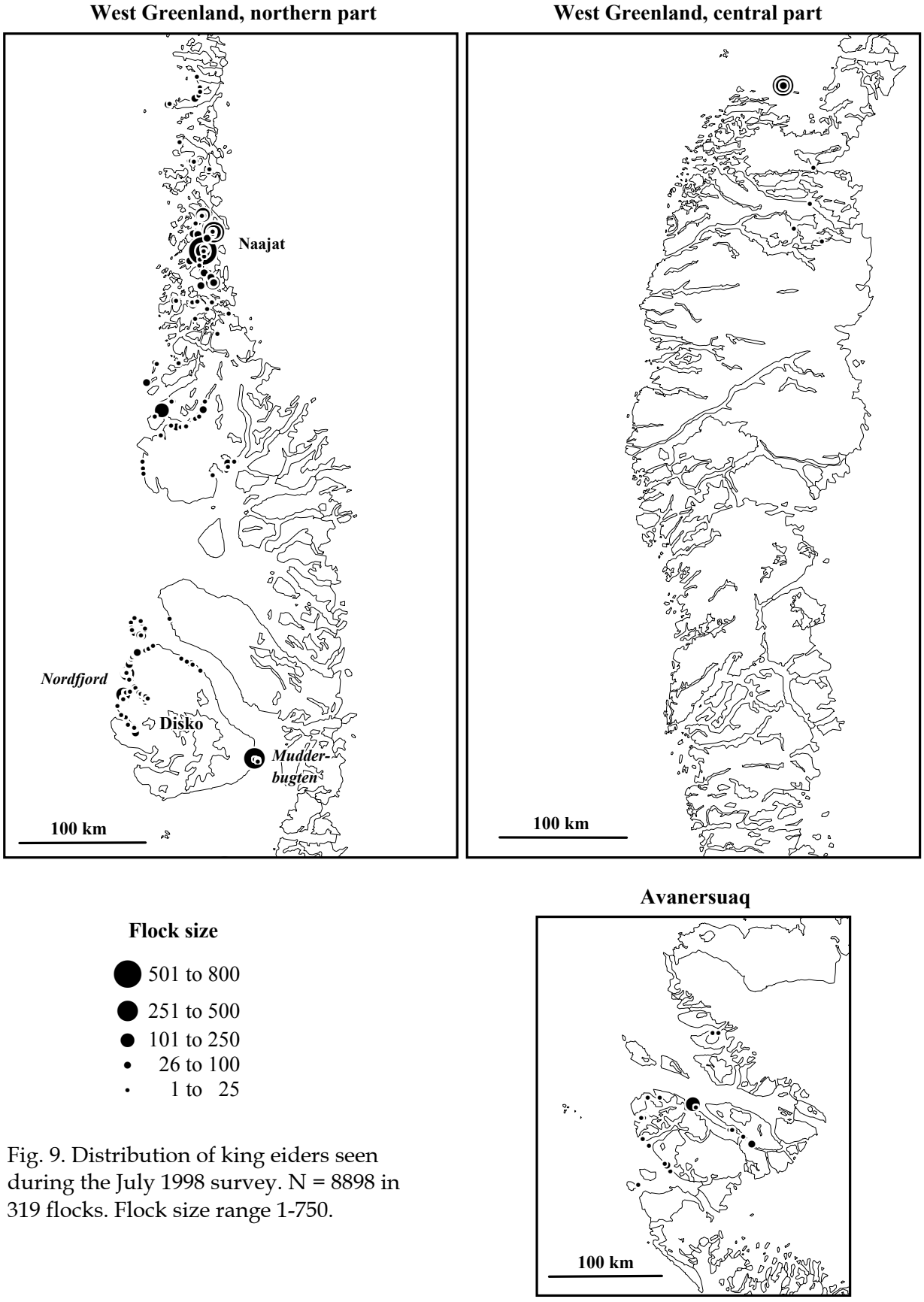


Fig. 9. Distribution of king eiders seen during the July 1998 survey. N = 8898 in 319 flocks. Flock size range 1-750.

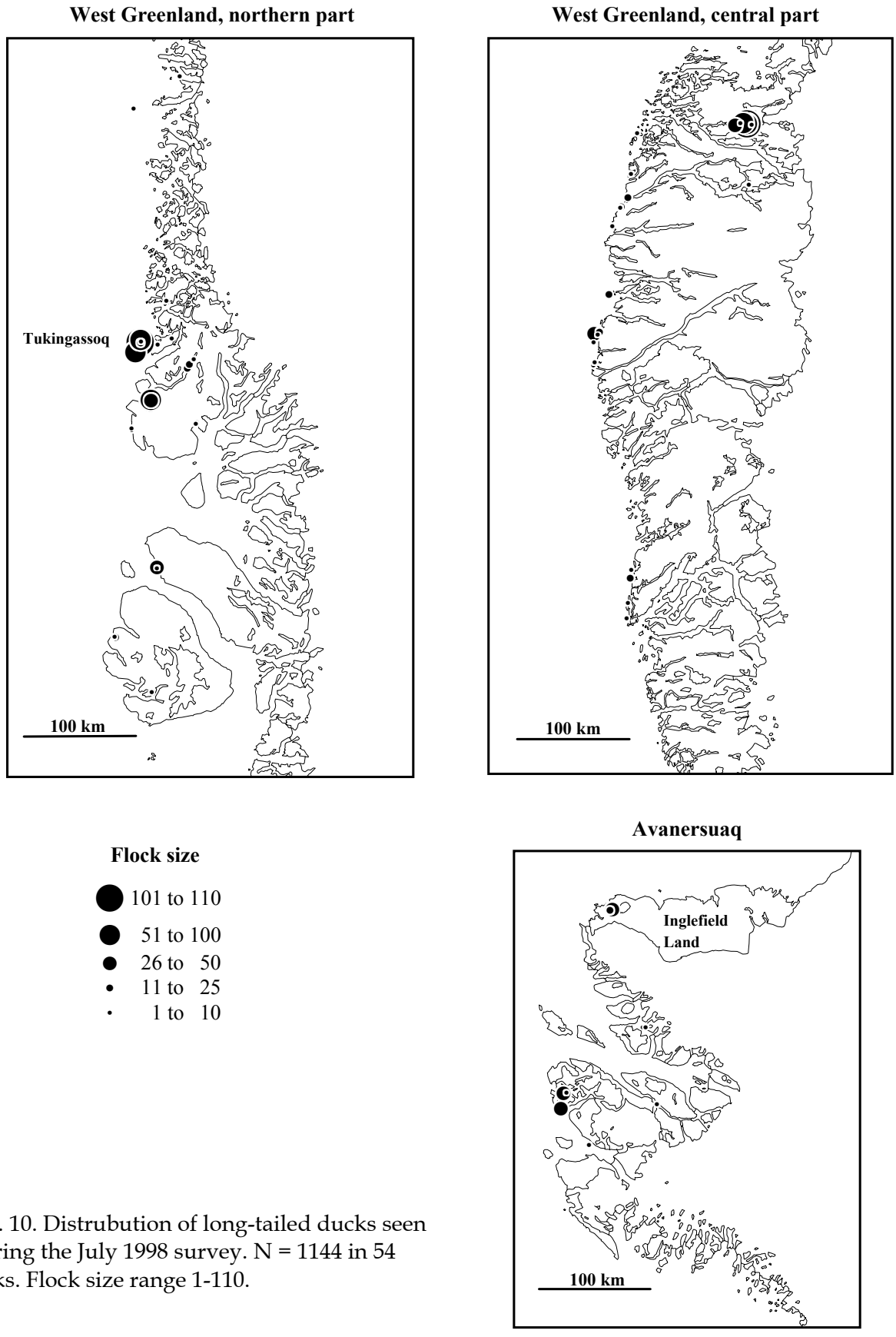


Fig. 10. Distrubution of long-tailed ducks seen during the July 1998 survey. N = 1144 in 54 floks. Flock size range 1-110.

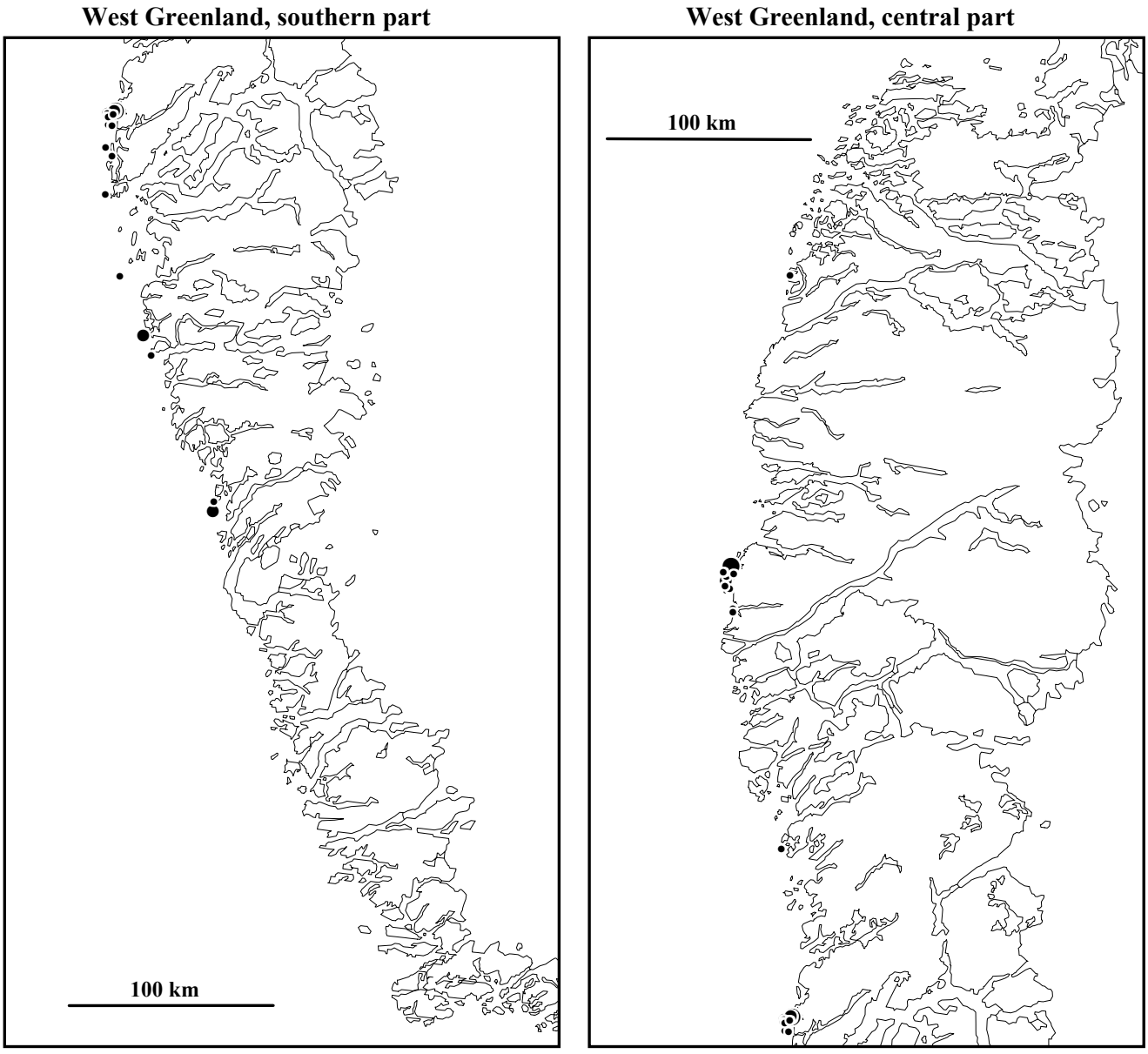


Fig. 11. Distribution of long-tailed ducks observed during the July 1999 survey. Transect flights included. N = 239 in 33 flocks. Flock size range 1-30.

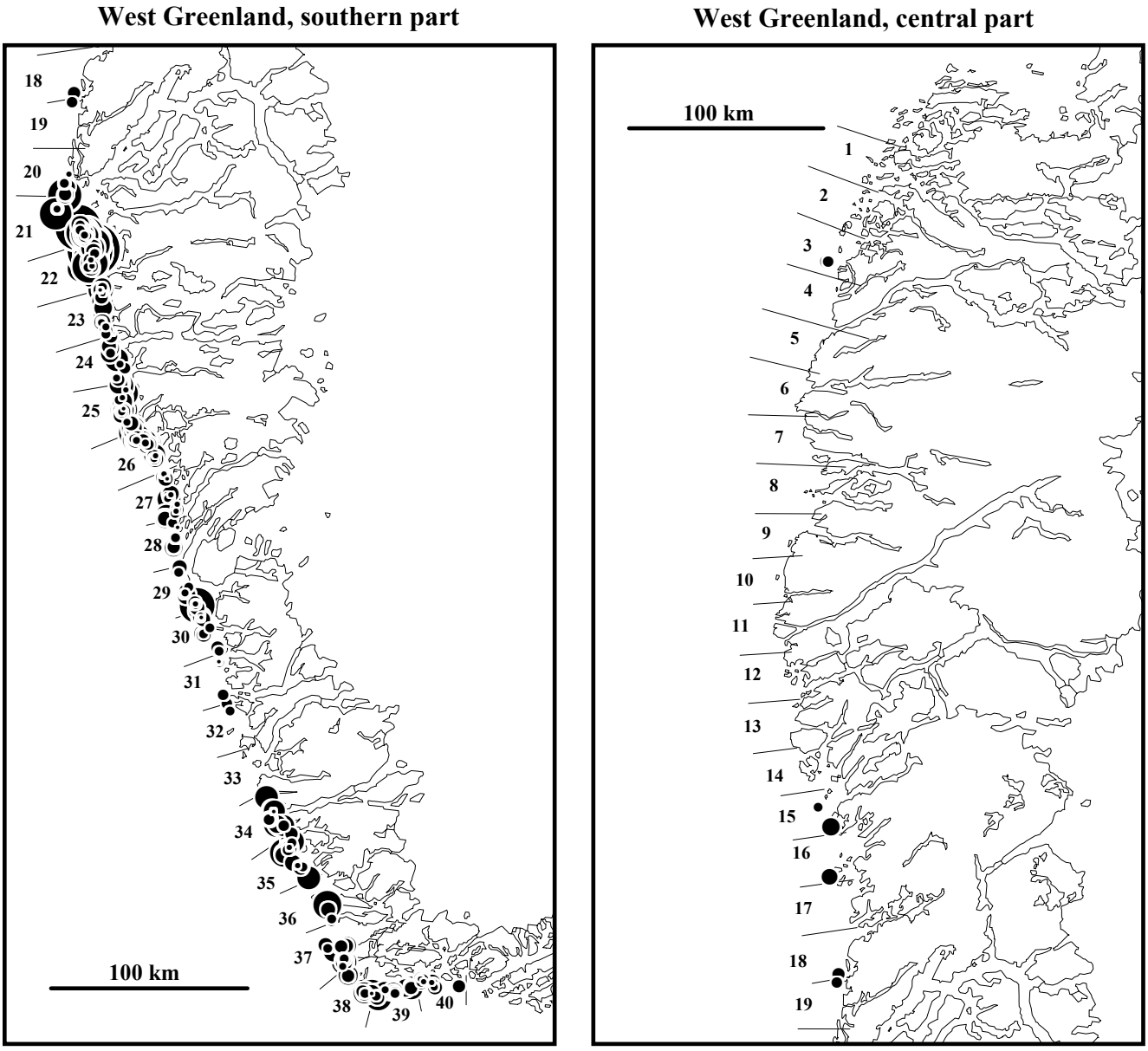


Fig. 12. Distribution of harlequin ducks observed in July 1999. N = 3549 in 297 flocks. Flock size range 1-100. The 25 km zones referred to in Table 3 are indicated.

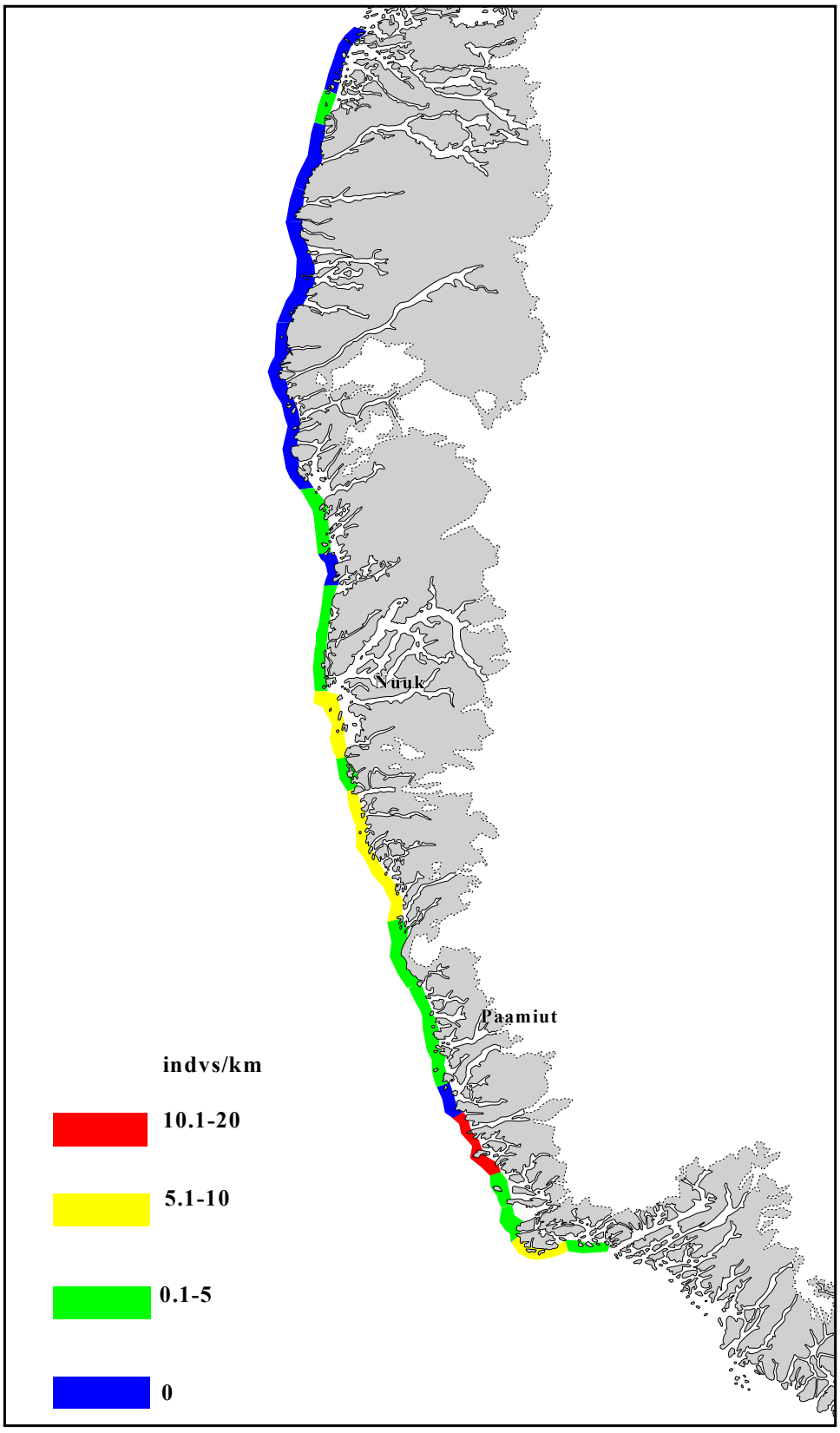


Fig. 13. The density of moulting harlequin ducks recorded in July 1999. The density is expressed as the number of birds recorded per km surveyed coastline.

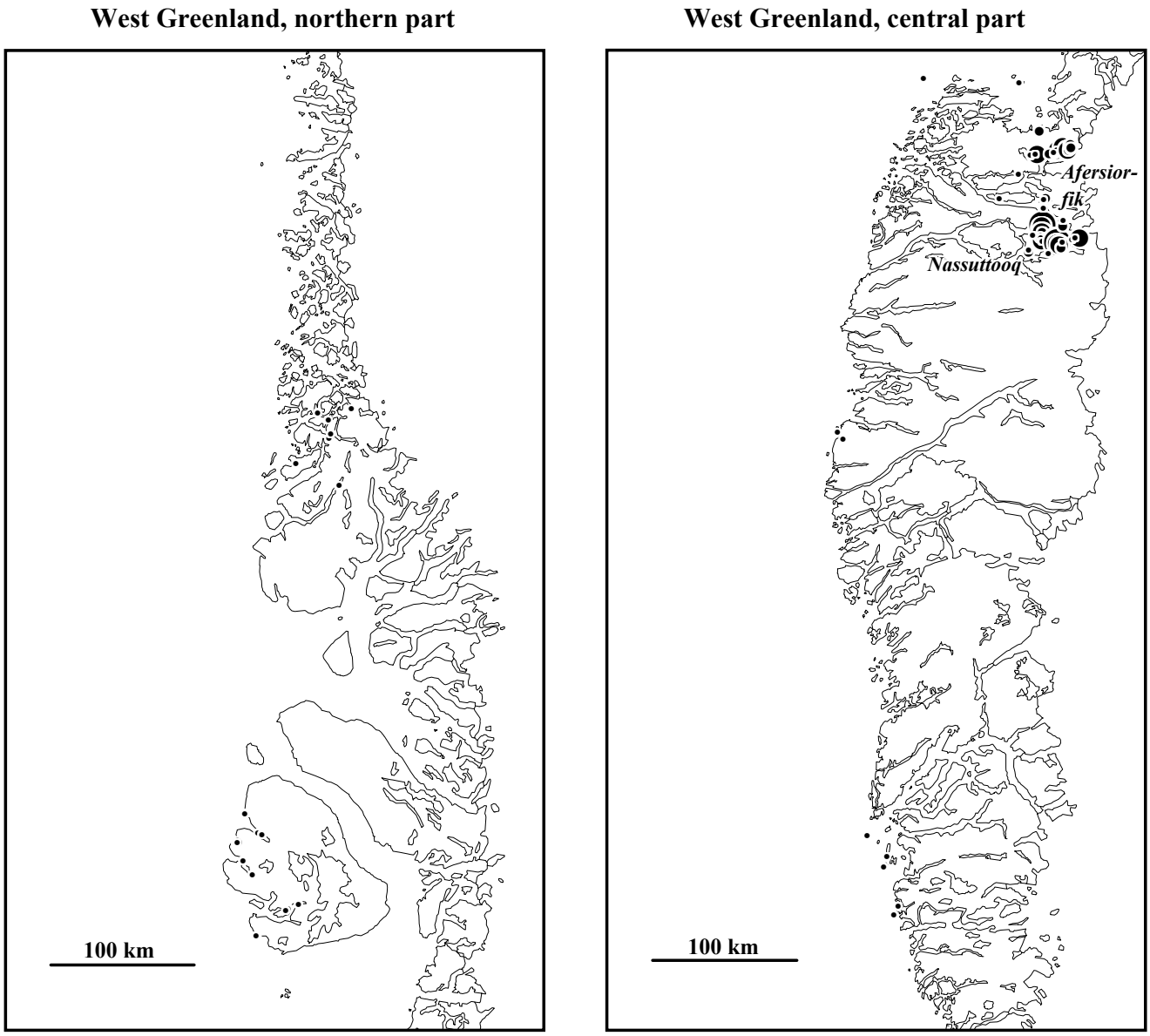


Fig. 14. Distribution of red-breasted mergansers observed during the 1998 survey. N = 1017 in 86 flocks. None seen in Avanersuaq. Flock size range 1-57.

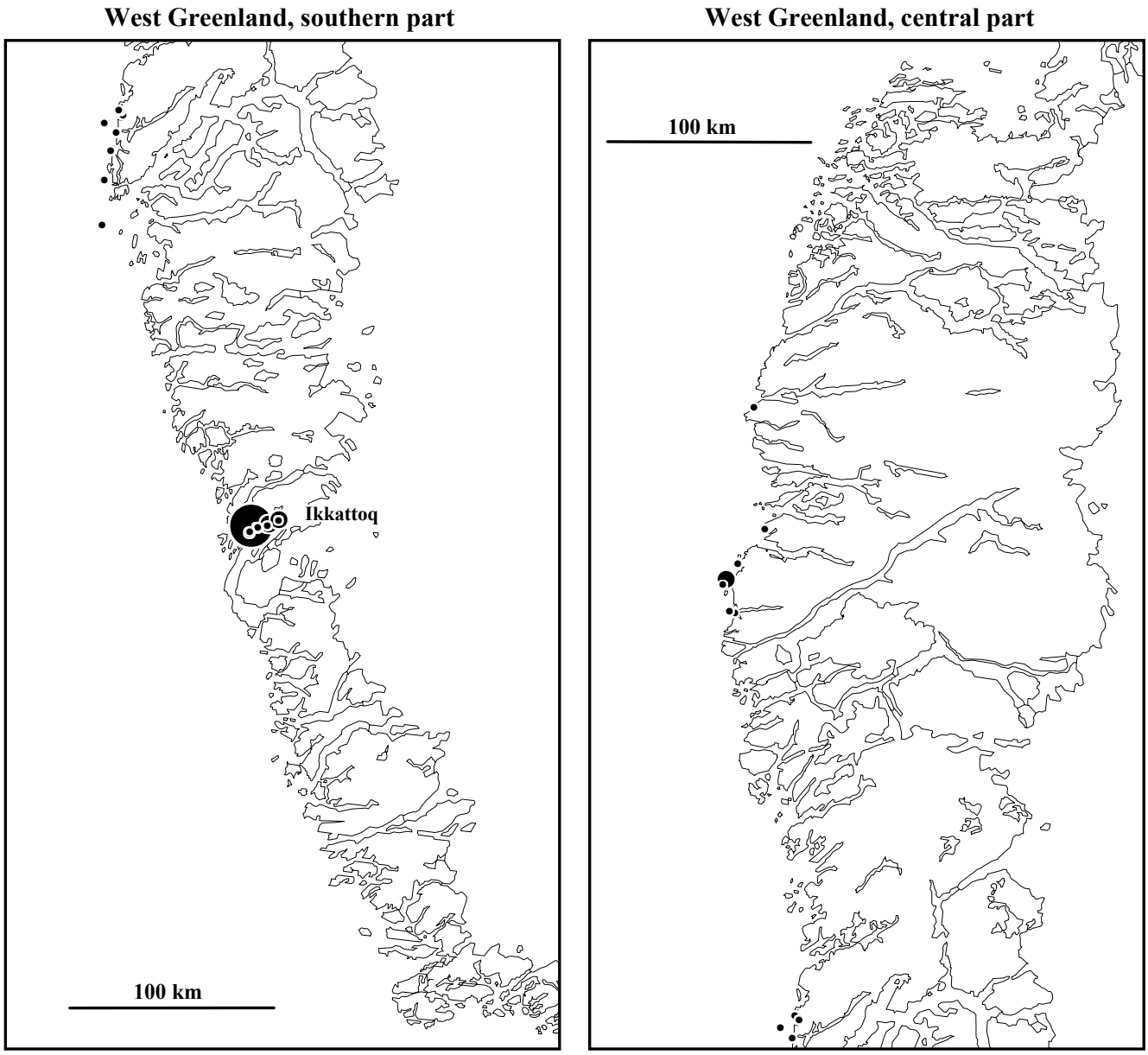


Fig. 15. Distribution of red-breasted mergansers observed during the July 1999 survey. N = 543 in 26 flocks. Flock size range 2-300.

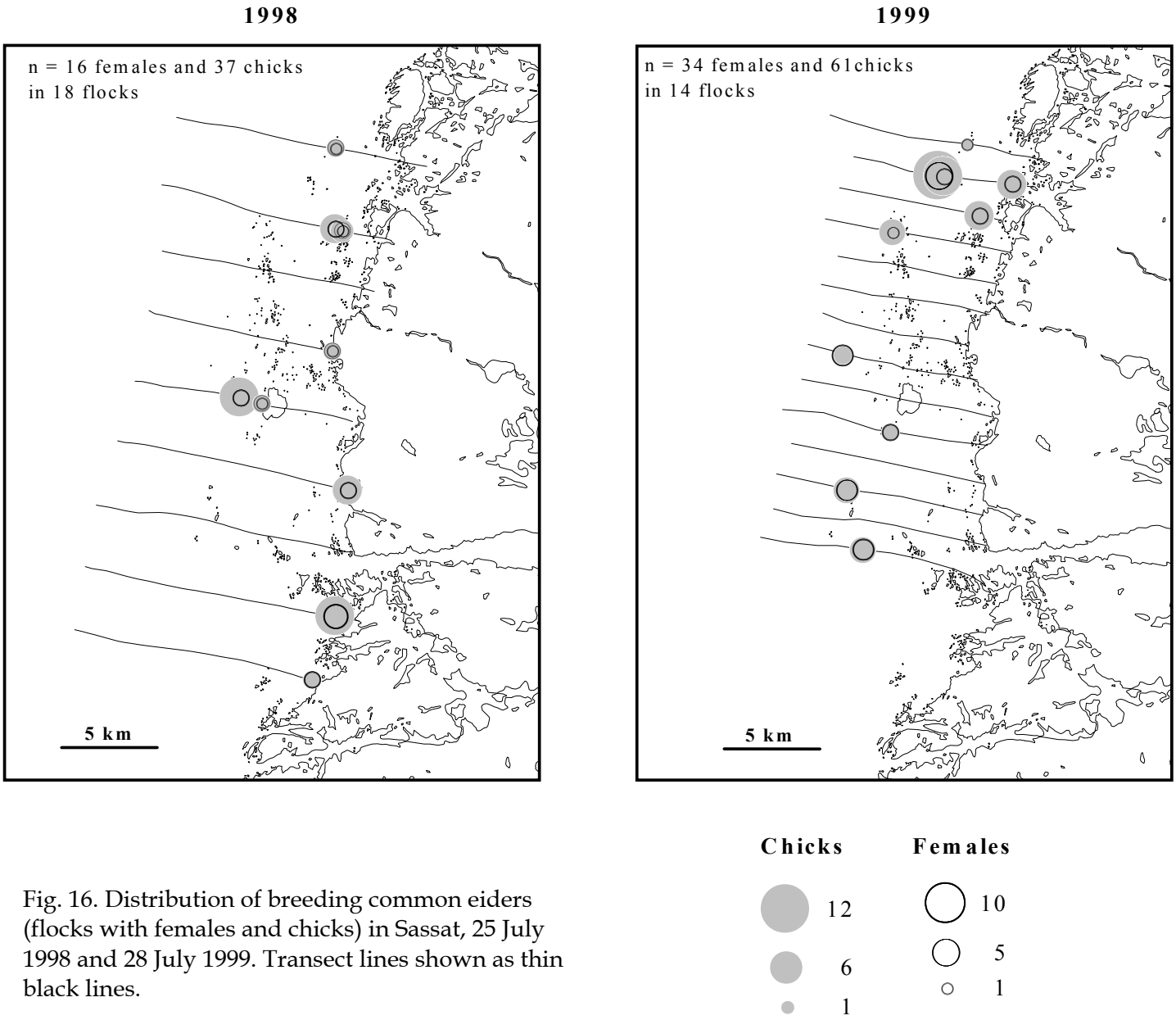


Fig. 16. Distribution of breeding common eiders (flocks with females and chicks) in Sassat, 25 July 1998 and 28 July 1999. Transect lines shown as thin black lines.

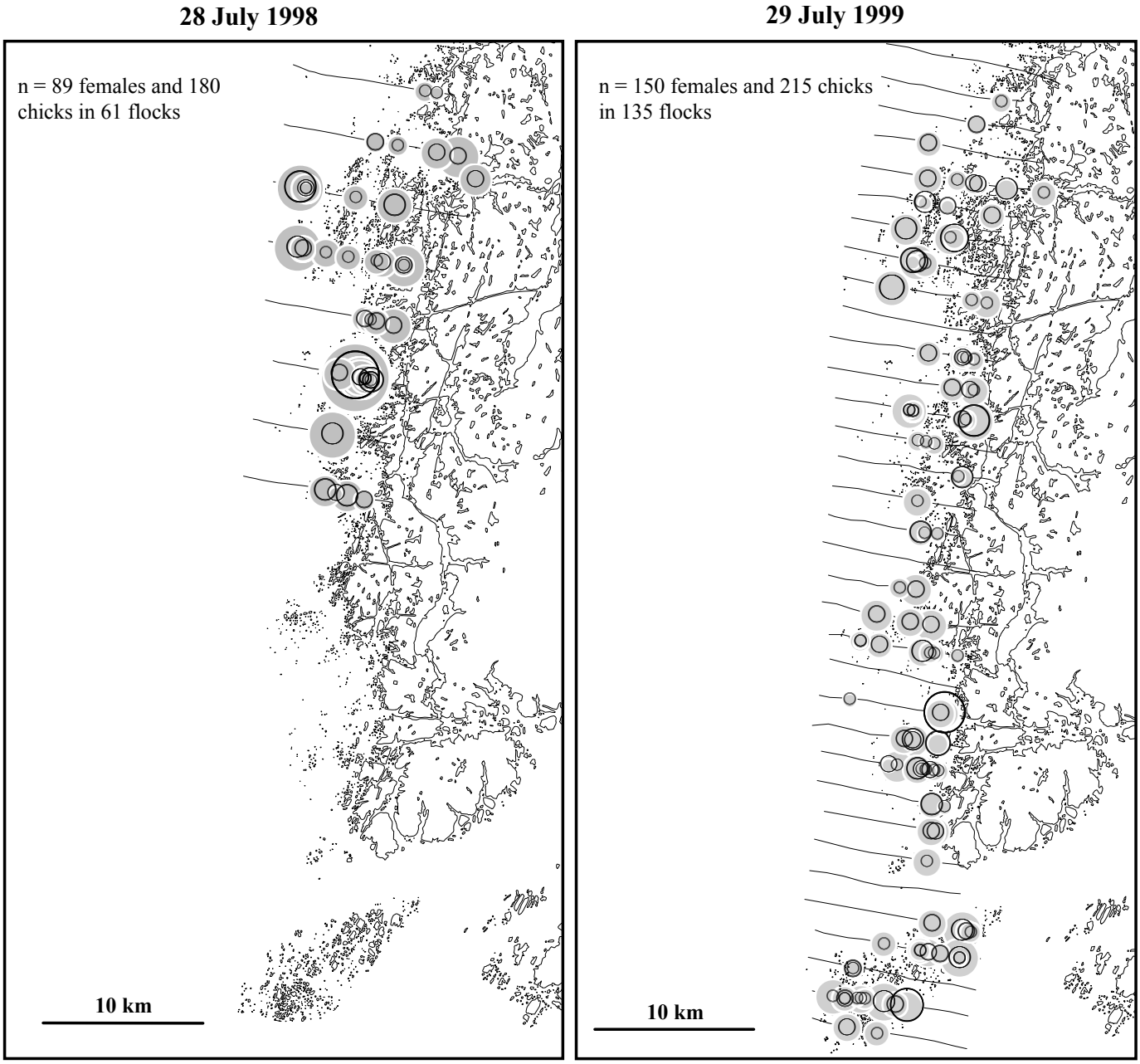


Fig. 17. Distribution of breeding common eiders (females with chicks) in Akia, 28 July 1998 and 29 July 1999. Transect lines shown as thin black lines.

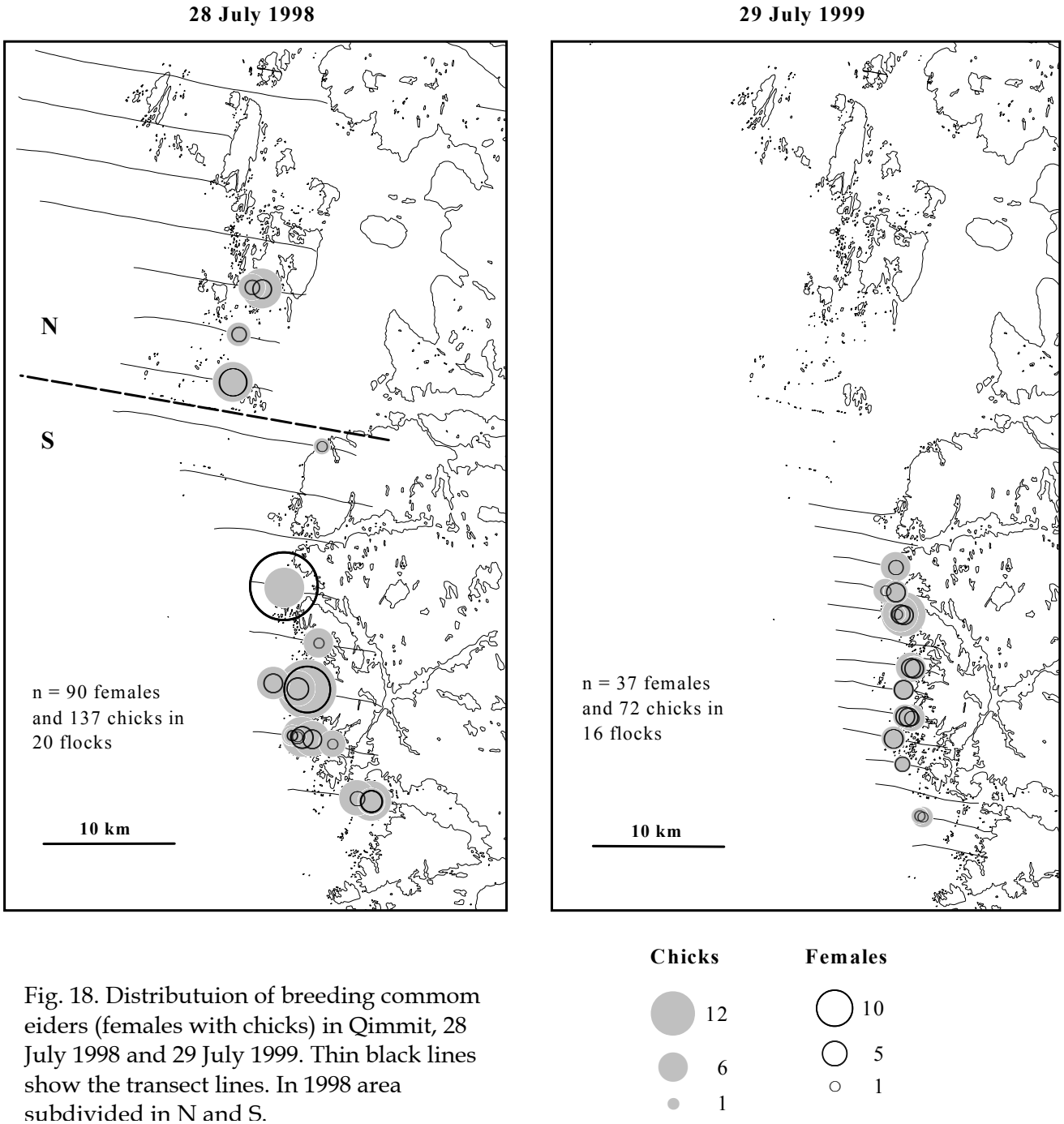


Fig. 18. Distributuion of breeding commom eiders (females with chicks) in Qimmit, 28 July 1998 and 29 July 1999. Thin black lines show the transect lines. In 1998 area subdivided in N and S.

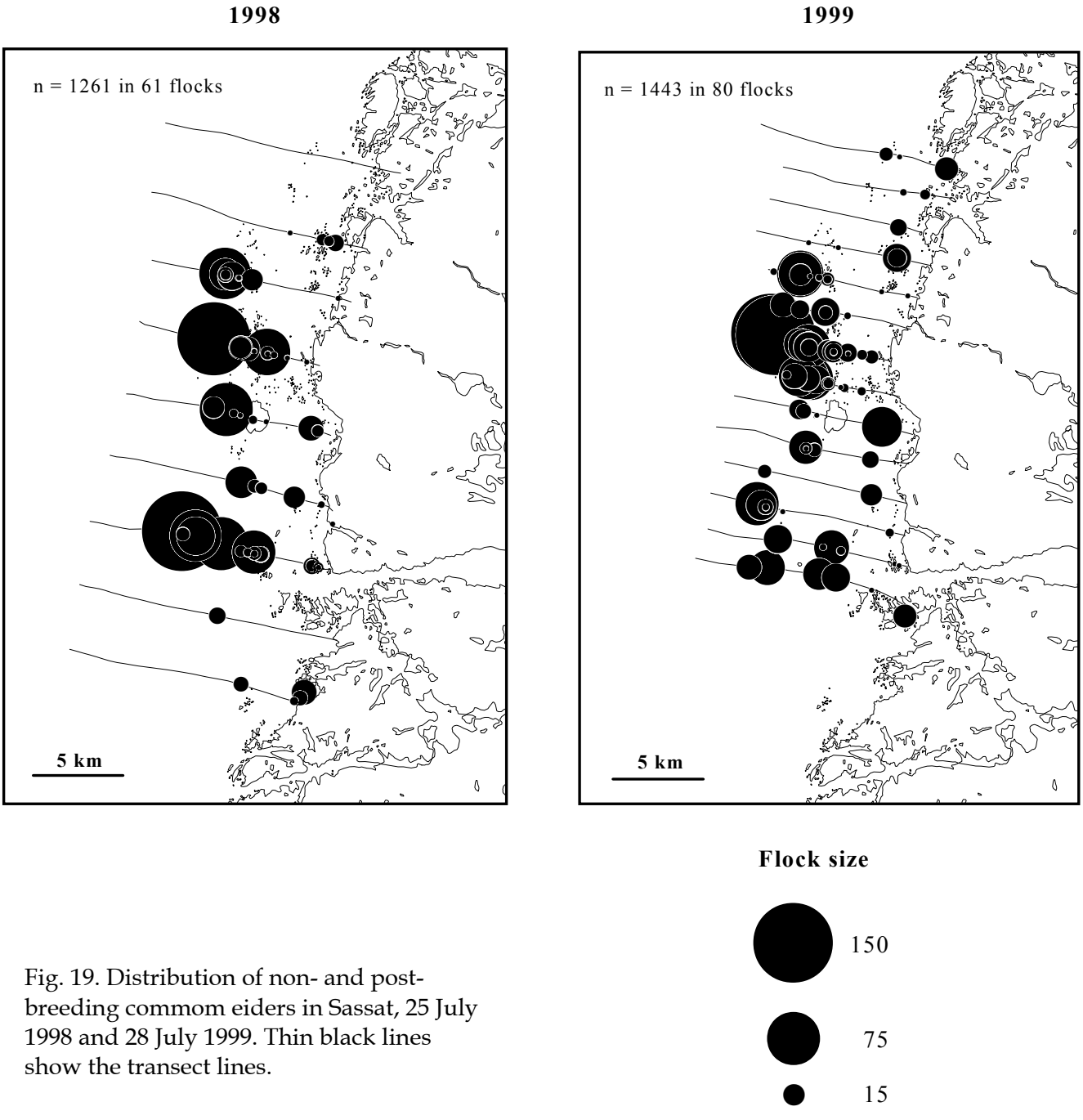


Fig. 19. Distribution of non- and post-breeding commom eiders in Sassat, 25 July 1998 and 28 July 1999. Thin black lines show the transect lines.

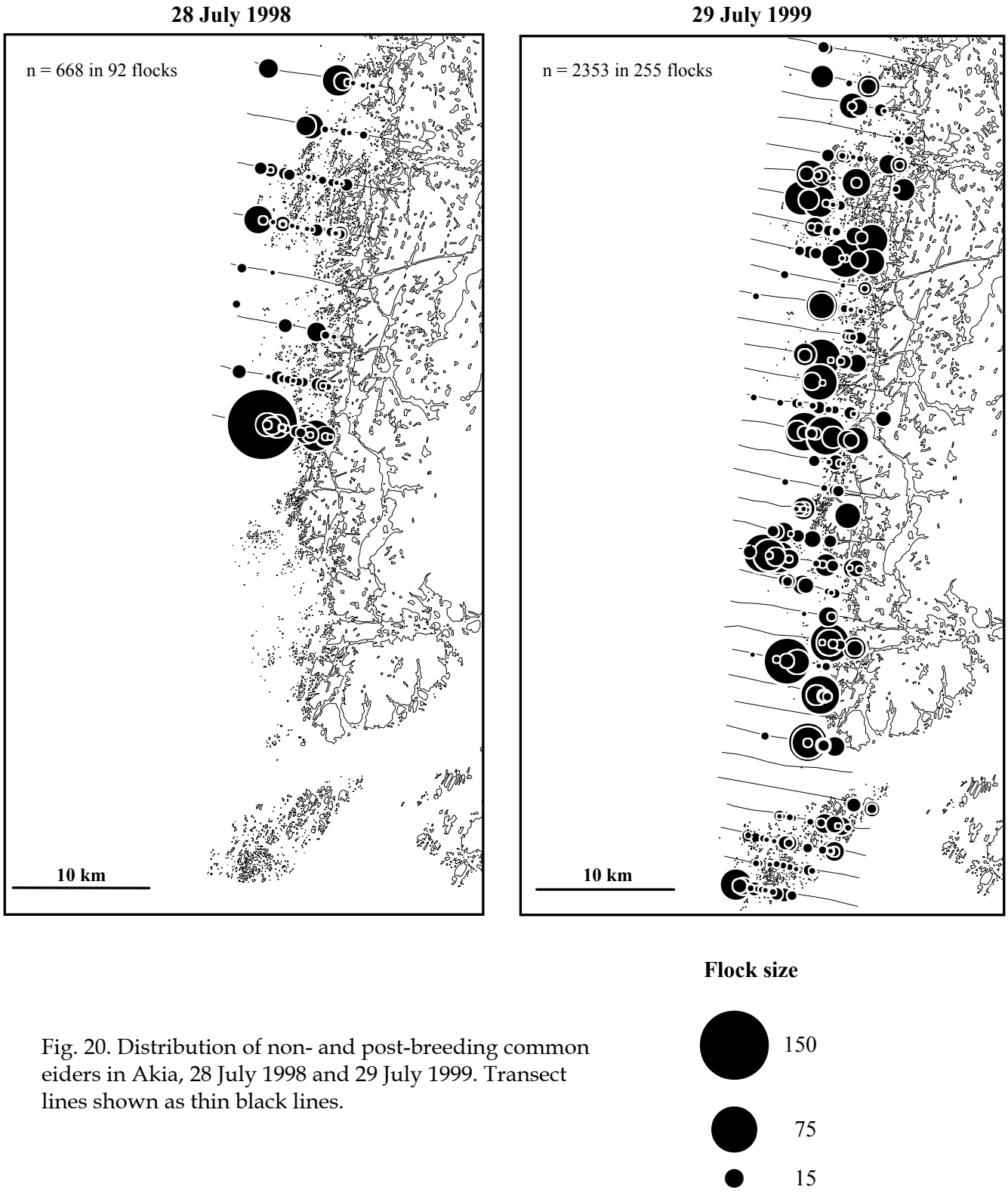


Fig. 20. Distribution of non- and post-breeding common eiders in Akia, 28 July 1998 and 29 July 1999. Transect lines shown as thin black lines.

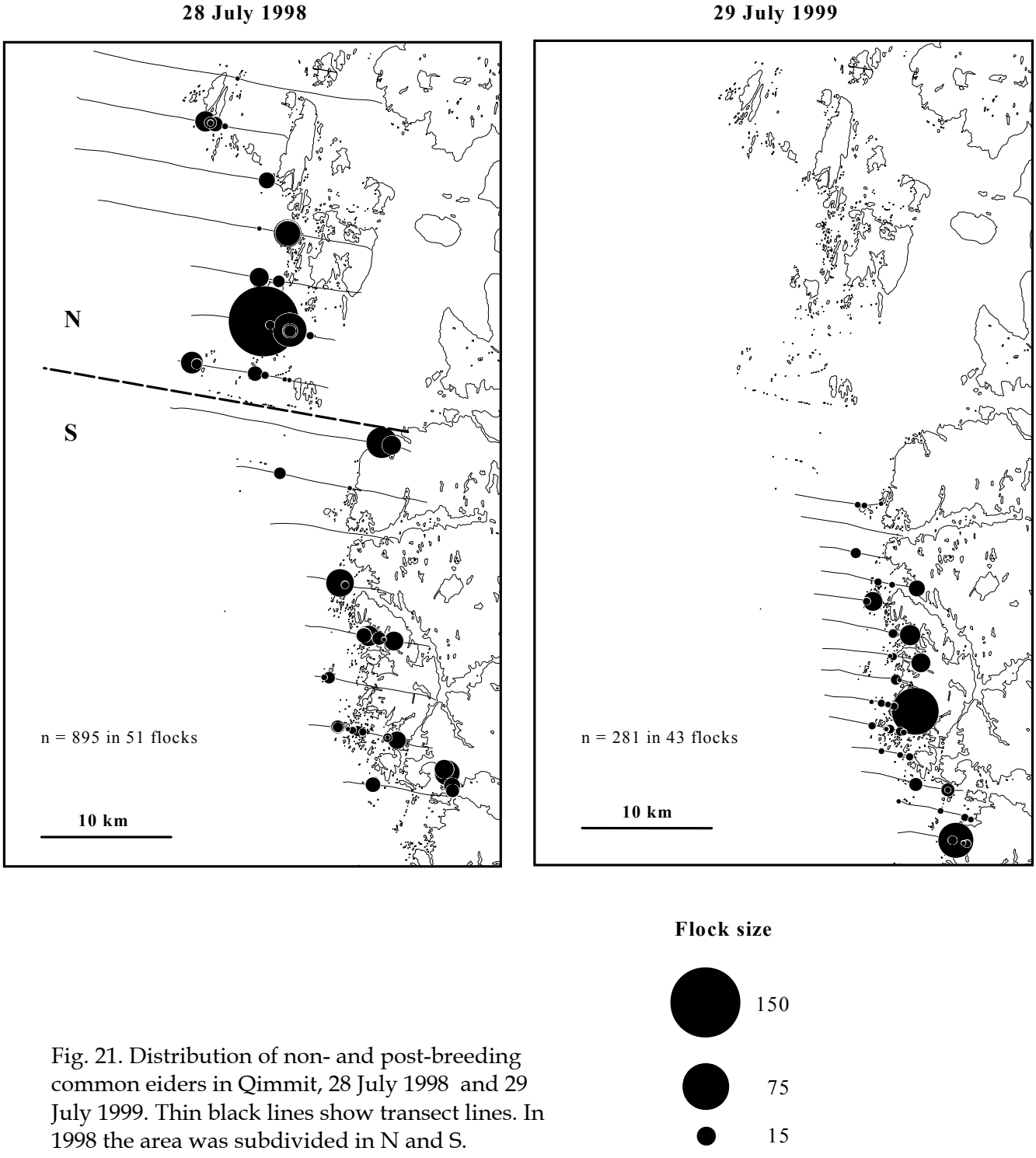


Fig. 21. Distribution of non- and post-breeding common eiders in Qimmit, 28 July 1998 and 29 July 1999. Thin black lines show transect lines. In 1998 the area was subdivided in N and S.

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# Appendix 1

**Details of the line transect analysis**

In distance sampling a detection function is fitted to the observations and the effective strip width (the distance where the number of flocks you overlook closer to the distance equal the number of flocks you record further away) is calculated based on the assumption that all the birds on the flight line are recorded and an increasing number of birds are missed further away. The effective strip width (ESW), the encounter rate (n/L, flocks pr. km), and flock (cluster) size is estimated separately and combined in a total estimate (see Buckland et al. 1993 for details).

$D = (n/ESW)2L$ and $N = D * s * A$

Where D is the density of flocks (clusters), n is the total number of sightings (of clusters), ESW is the effective strip width, L is the total length of the transects, N is the total number of birds, s is the flock size estimate and A is the area of the study area.

The confidence interval (95%) of the estimate of N was calculated from the coefficient of variation, cv, calculated as the ratio of the standard error to the mean of ESW, encounter rate (n/L) , and flock size (s)

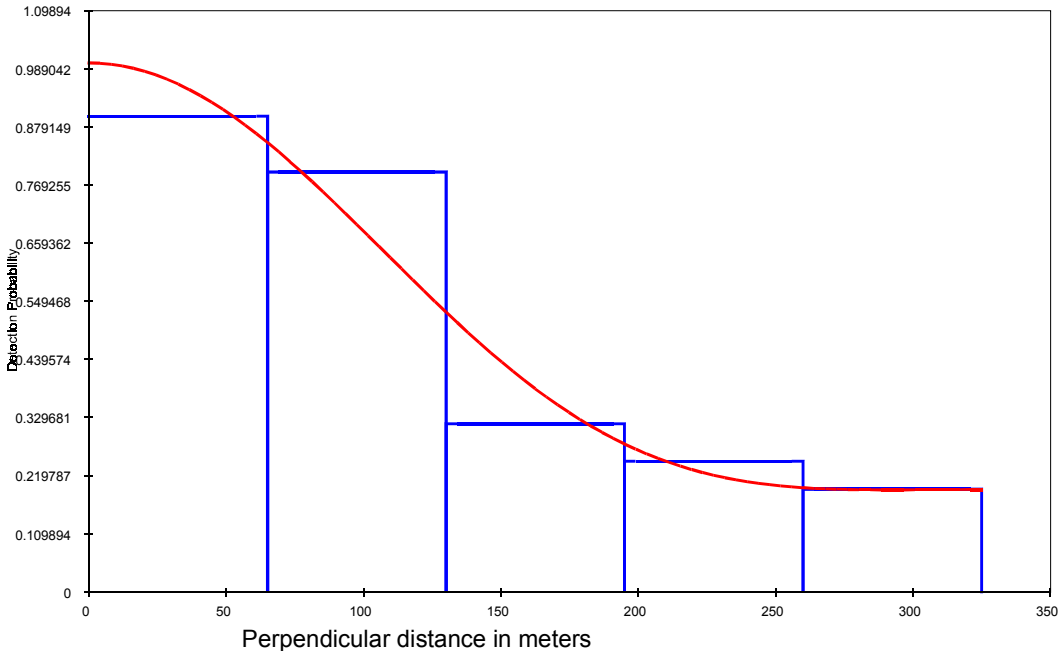
$var(N)=N^2 (cv(ESW)^2+cv(n/L)^2 +cv(s)^2)$

Assuming a lognormal distribution of N the 95% confidence interval can be calculated as N/V (lower limit) and N*V (upper limit) where

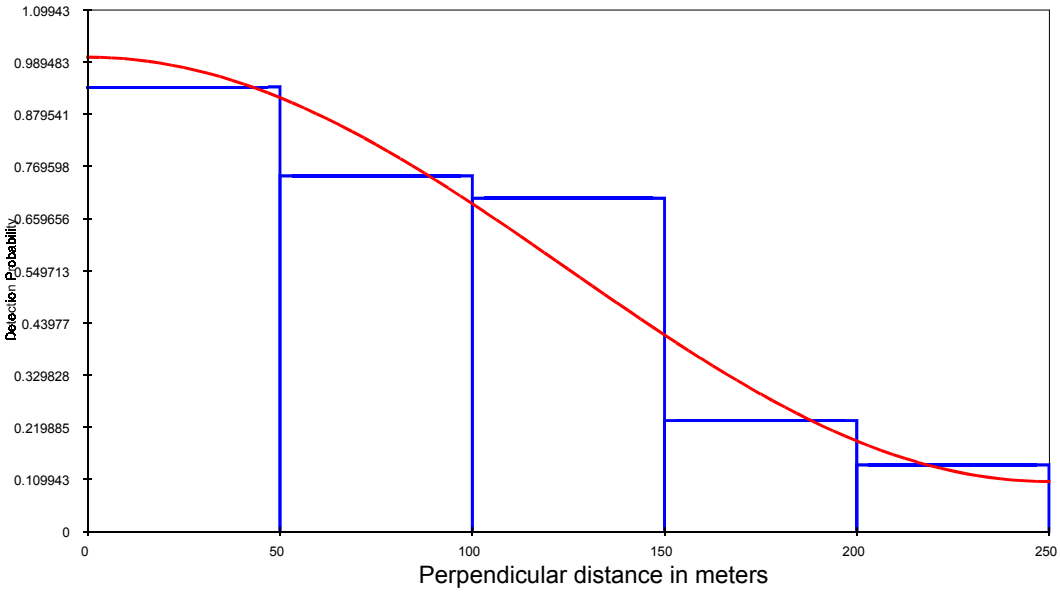
$V=exp(1.96*sqrt(var(ln(N)))$ and $var(ln(N))=ln(1+var(N)/N^2)$.

**The detection functions**

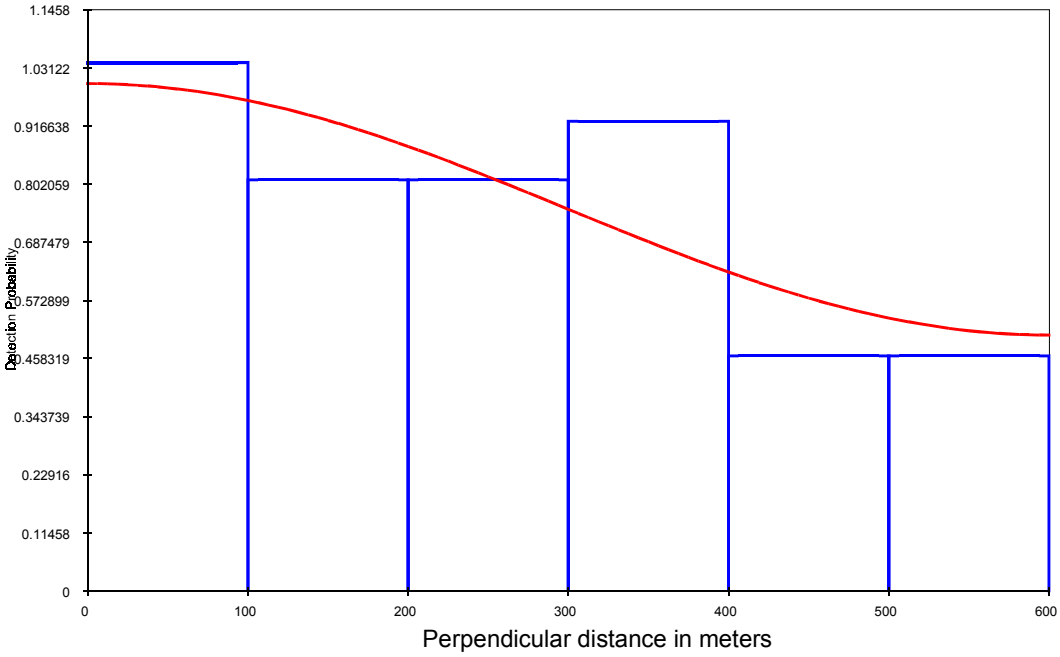
Histograms and fitted detection functions for the line transect analysis are given below as a supplement to the result section.



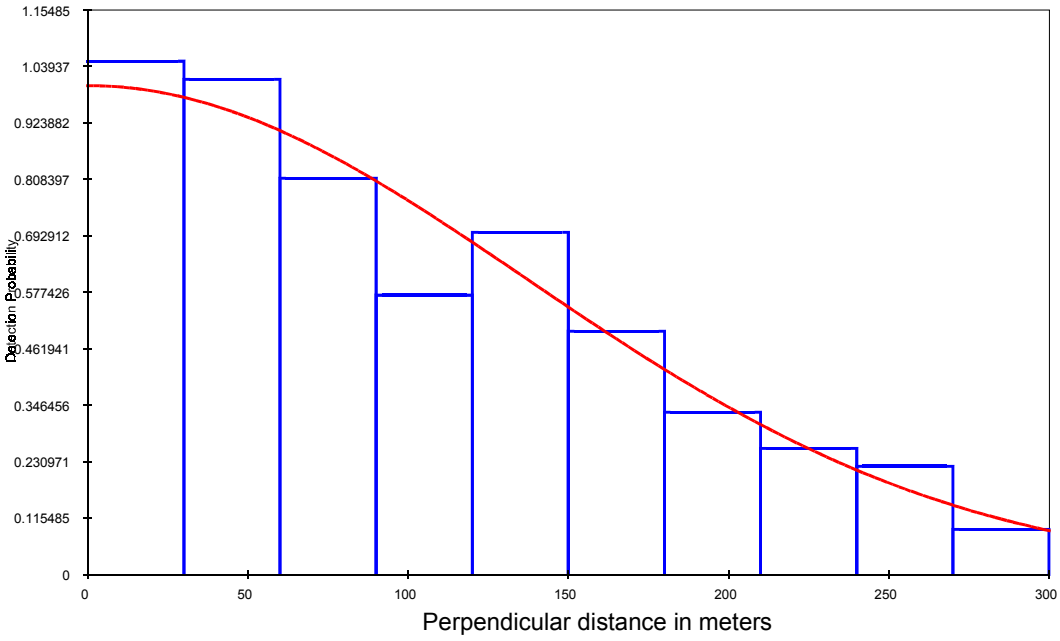

Histogram and fitted detecting function for birds on the water in 1998. The analysis is based on 5 distance intervals and data have been truncated at 325 m equivalent to 10% of the records. The selected detection model is a uniform key function with a cosine adjustment term. ESW is estimated to 159 m.



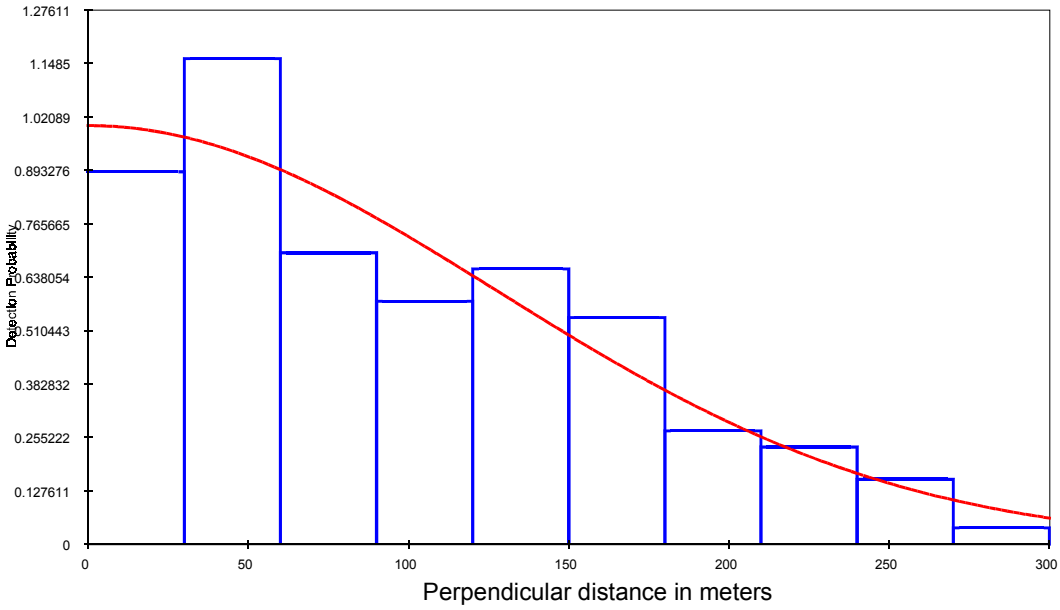

Histogram and fitted detecting function for family flocks in 1998. The analysis is based on 5 distance intervals and data have been truncated at 250 m equivalent to 10% of the records. The selected detection model is a uniform key function with a cosine adjustment term. ESW is estimated to 138 m.



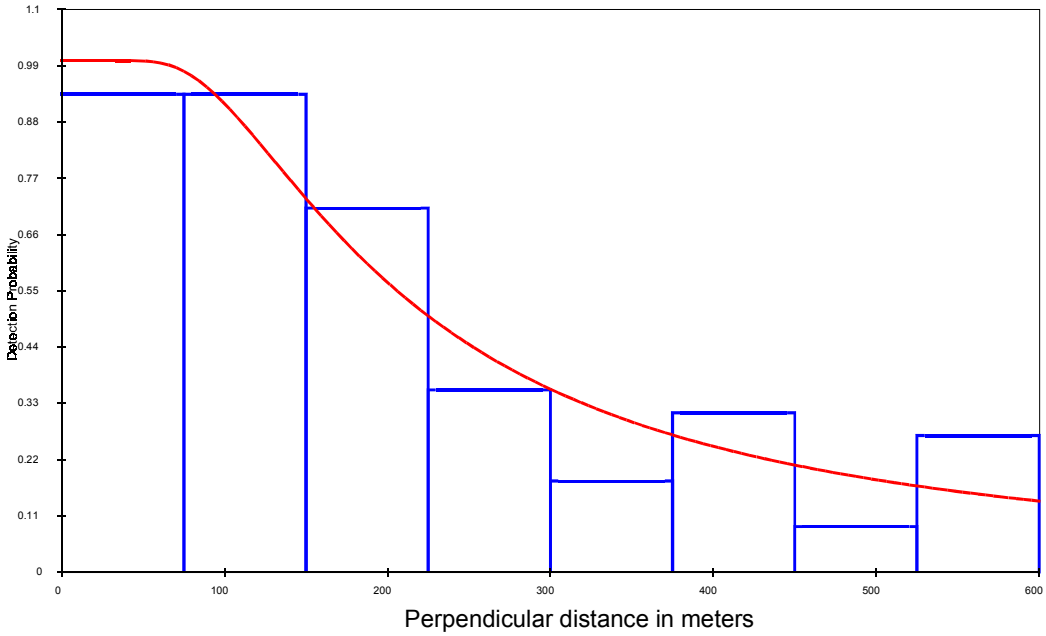

Histogram and fitted detection function for flying birds in 1998. The analysis is based on 6 distance intervals and the distance data have been truncated at 600 m. The selected detection model use a uniform key function and a cosine adjustment term. ESW is estimated to 451 m.




Histogram and fitted detection function for eiders on the water in 1999. The analysis is based on 10 distance intervals and the distance data have been truncated at 300 m. The selected detection model use a halfnormal key function and a cosine adjustment term. ESW is estimated to 166 m.




Histogram and fitted detection function for family flocks in 1999. The analysis is based on 10 distance intervals and the distance data have been truncated at 300 m. The selected detection model use a halfnormal key function and a cosine adjustment term. ESW is estimated to 157 m.




Histogram and estimated detection function for flying birds in 1999. The analysis is based on 8 distance intervals and the distance data have been truncated at 600 m. The selected detection model use a hazard rate key function. ESW is estimated to 283 m.

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