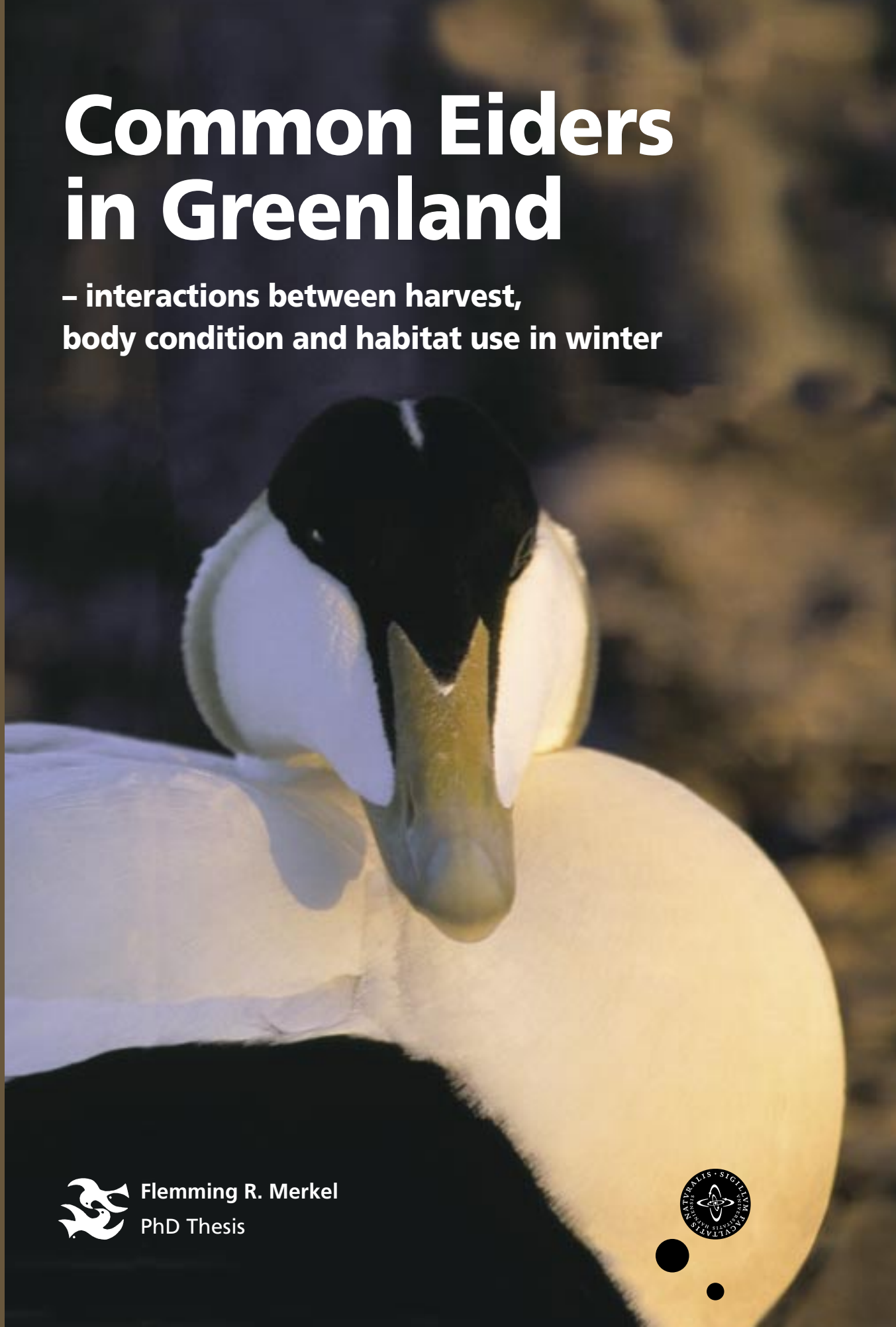
Common Eiders in Greenland

– interactions between harvest, body condition and habitat use in winter



Flemming R. Merkel

PhD Thesis

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PhD thesis

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Greenland Institute of Natural Resources
and
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1 Merkel, F. R., Mosbech, A., Boertmann, D., Grøndahl, L., 2002. Winter seabird distribution and abundance off south-western Greenland, 1999. Polar Research 21(1), 17-36.

2 Merkel, F. R., 2004. Evidence of population decline in Common Eiders breeding in Western Greenland. Arctic 57(1), 27-36.

3 Merkel, F. R., 2004. Impact of hunting and gillnet fishery on wintering eiders in Nuuk, Southwest Greenland. Waterbirds 27(4), 469-479.

4 Falk, K., Merkel, F. R., Kampp, K., Jamieson, S. E., in press. Embedded lead shot and infliction rates of common and King Eiders wintering in Southwest Greenland. Wildlife Biology.

5 Merkel, F. R., Falk, K., Jamieson, S. E., in press. Effect of embedded lead shot on body condition of Common Eiders. Journal of Wildlife Management.

6 Jamieson, S. E., Gilchrist, H. G., Merkel, F. R., Falk, K., Diamond, A. W., in press. An evaluation of methods used to estimate carcass composition of Common Eiders. Wildlife Biology.

7 Merkel, F. R., Mosbech, A., Sonne, C., Flagstad, A., Falk, K., Jamieson, S. E., submitted. Local movements, home ranges and body condition of Common Eiders wintering in Greenland.

8 Merkel, F. R., Jamieson, S. E., Falk, K., Mosbech, A., submitted. The diet of Common Eiders wintering in Nuuk, Southwest Greenland.

9 Merkel, F. R., Mosbech, A., submitted. Diurnal and nocturnal feeding strategies in Common Eiders.

10 Merkel, F. R., Mosbech, A., Riget, F. Feeding time allocation in Common Eiders and the influence of human disturbances.

1. Preface

This thesis is the result of my PhD at the University of Copenhagen, Department of Population Biology and the Greenland Institute of Natural Resources. It was funded partly by the Danish Research Academy, the Danish Ministry of Science and the Greenland Home Rule Government. Most studies were part of a research programme of wintering eiders in Southwest Greenland, funded by the Greenland Institute of Natural Resources, the National Environmental Research Institute of Denmark, and the Danish Environmental Protection Agency as part of the environmental support programme Dancea (Danish Cooperation for Environment in the Arctic).

The Greenland Institute of Natural Resources is the Greenland Home Rule Centre of Natural Science and provides data to ensure a sustainable use of the living resources in Greenland. The Common Eider (*Somateria mollissima*) is one of the key species of concern in Greenland and next of the Thick-billed Murre (*Uria lomvia*) it is the most important living resource among the bird species. Prior to the mid 1990s mainly the murres had been studied in Greenland, but with the establishment of the Greenland Institute of Natural Resources a more dedicated effort to update current knowledge about Common Eiders in Greenland was initiated.

The fact that relatively little was know beforehand about Common Eiders in Greenland was both encouraging and frustrating at the same time. Some of the results were badly needed and used right away for management purposes, which was a highly inspiring process, however, the lack of basic information also made it more difficult to approach things from a theoretical point of view.

While doing my PhD for Greenland Institute of Natural Resources I have been lucky to work with a number of stimulating and friendly people on issues besides my PhD. Together we produced several papers, that are related to eiders, but are not included in my thesis. They are listed here:

Boertmann, D., Lyngs, P., Merkel, F. R., Mosbech, A., 2004. The significance of SW Greenland as winter quarters for seabirds. Bird Conservation International 14, 87-112.

Gilliland, S., Gilchrist, H. G., Rockwell, R., Robertson, G. J., Savard, J.-P., Merkel, F. R., Mosbech, A., submitted. Evaluating the sustainability of harvest among Northern Common Eiders in Greenland and Canada.

Mehl, K. R., Alisauskas, R. T., Hobson, K. A., Merkel, F. R., in press. Linking breeding and wintering grounds of King Eiders: Making use of polar isotopic gradients. Journal of Wildlife Management.

Mosbech, A., Danø, R. S., Merkel, F. R., Sonne, C., Gilchrist, H. G., in press. Use of satellite telemetry to locate key habitats for King Eiders (*Somateria spectabilis*) in western Greenland. Proceedings of the Waterbirds around the World Conference.

Mosbech, A., Gilchrist, H. G., Merkel, F. R., Sonne, C., Flagstad, A., submitted. Comparing spring and autumn migration of Arctic Common Eider based on satellite telemetry.

Nyegaard, H., Mosbech, A., Merkel, F. R., submitted. Reproductive success of the Common Eider *Somateria mollissima* in a colony in West Greenland.

Jamieson, S. E., Gilchrist, H. G., Merkel, F. R., Diamond, A. W., Falk, K., 2005. Endogenous reserve dynamics of northern Common Eiders wintering in the Greenland. Polar Biology, DOI 10.1007/s00300-005-0093-2.

2. Acknowledgments

The Greenland Institute of Natural Resources gave me the opportunity to begin a PhD while working with marine birds in Greenland. For that I am very grateful. The institute gave me latitude to conduct the necessary studies and lots of opportunities to travel for extended periods. Especially, I am grateful to my director, Klaus Nygaard, for making this possible and supporting me throughout the process. Many thanks go to my colleagues at the Institute and my superior, head of department Arild Landa and Michael Kingsley, for great support, fruitful discussions, and for standing in for me while I was away from the Institute. Lotte Rasmussen, Kristian Wæver and Thomas Peitersen are acknowledged for the hard work in the lab as wells as in the field.

I am most grateful to Gösta Nachmann for his support as a supervisor. Although I was present at the university only for short periods during the four years, he was always there when I asked for his support, both in technical matters and for practical things. I owe tremendous thanks to my external supervisor, Anders Mosbech, who has supported and inspired me throughout the PhD. We have worked together on most of the studies in Greenland and during my two years stay in the Arctic department of the Danish National Environmental Research Institute I greatly benefited from Anders' long experience and insight in the Arctic environment. My sincere gratitude to Jesper Madsen, head of the Arctic department, for making room for me in a crowded department, for his genuine interest in my work and for inspiring leadership. Much appreciation to Frank Riget for always being available in statistical matters. Many thanks to Christian Sonne for his huge effort in surgical matters and for many cheerful times in the field and at the office. I am also grateful to Annette Flagstad for supervising us in surgical matters and for making all the needed equipment available.

I have had the privilege to work with Grant Gilchrist on a number of marine bird issues in Canada and Greenland and I am extremely grateful to him for sharing so many great ideas during the planning phase of my PhD and for providing extensive and invaluable comments on the proposal. Many thanks to Tony Diamond for hosting me during my stay the University of New Brunswick. I am grateful to Tony, his coworkers, and students for being very open minded and for sharing their experience. Especially, my thoughts go to Sarah Jamieson and Joel Bêty for their unconditional support, enthusiasm, and numerous fruitful discussions. I was extremely fortunate that Sarah took the time, busy as it was, to go to Greenland and Denmark on several occasions to help process the carcasses and diet samples and to share her excellent skills in these matters.

The local hunters, Kristian Heilman and Karl Tobiasen, are greatly acknowledged for collecting samples of eiders in the field. Also the whole troop of hunters, who gave me invaluable information about the harvest that they brought to the local market, is deeply appreciated. Without these people the present study could not have been conducted. I also thank the crew of the Adolf Jensen research vessel for invaluable support and great skills in handling nets and catching birds, and I thank the captain, Flemming Heinrich, for safe navigation in challenging conditions.

Finally, this PhD would not have been possible had it not been for the understanding and patience of my wife, Janne Merkel, and my children Max, Maria and Luna, at times when I was not there for them – THANKS.

3. Summary

Winter ecology is a key issue in research and conservation of marine birds. Winter may be the period of greatest mortality of both young and adult marine birds, and their physical condition by the end of winter may also be related to performances in the breeding season. Consequently, fitness during winter may greatly influence the general status of a population. Winter body condition is influenced by the availability of suitable feeding habitats, in which birds can balance their energy budgets on a daily basis, and in addition, built up energy storages to buffer times with limited food intake during harsh weather conditions, migration, etc. However, habitat selection is influenced by the mortality risks associated with inhabiting it, and birds may be dislodged from otherwise highly profitable habitats to avoid risks like predation and hunting, or side-effects of human activities, such as disturbances and unintentional bycatch or wounding of birds during hunting.

These issues are of special relevance for the Northern Common Eider (*Somateria mollissima borealis*) since the vast majority of this population depends on a large open water area in Southwest Greenland throughout most of the annual cycle. Here, the eiders have traditionally been harvested in large numbers, but the sustainability of this harvest has been questioned due to various indications of population declines.

Focus and aims

The work for this thesis was conducted in two steps. The initial step aimed at, 1) quantifying the distribution and abundance of Common Eiders wintering in Greenland, and 2) collecting information about numbers and population trends in breeding areas of West Greenland. The second step focused on a smaller case study area in Southwest Greenland (Nuuk) and the interactions between harvest, body condition and habitat use of Common Eiders during winter. This work included data collection on several winter ecology aspects for which no previous knowledge existed, with the purpose of 3) pinpointing factors that are important for the local distribution and behaviour of birds in winter, and 4) assessing the vulnerability of the local eider population to human harvest activity and if possible quantify the impacts of these activities. The overall objective was to obtain a more solid foundation for future management of the Common Eider.

Nuuk was appropriate as a case study area due to high densities of eiders and hunters and due to the existence of contrasting winter habitats (fjord versus outer coast). These differ considerably in terms of human exposure and habitat characteristics and allow the use of a comparative study approach when studying the impact of human activity. Methods used included aerial surveys, satellite telemetry, harvest surveys, harvest statistics analysis, X-ray lead shot examinations, body condition analysis, diet sampling, and behavioural observations.

Winter distribution and abundance (ms 1)

During aerial surveys conducted in Southwest Greenland in February / March 1999 the Common Eider was identified as the most abundant seabird species in the coastal zone with ca. 360,000 birds present. Additionally, ca. 104,000 birds were located in the fjords. In general, a large number of small flocks were distributed in the coastal zone and a small number of very large flocks occupied the fjords, with flock sizes up to 6,500 birds. The Nuuk area and the Julianehåb Bay area, South Greenland, were identified as key wintering areas for Common Eiders with ca. 57,000 and 96,000 birds present, respectively. The survey results lead to the conclusion that there is a massive influx to the Southwest Greenland wintering area

from Canadian breeding grounds – more than 400,000 birds.

Population development (ms 2)
Breeding ground surveys carried out in West Greenland in 1998-2001, covering the districts of Ilulissat, Uummannaq and Upernavik (69°15' N to 74°05' N), confirmed previous suggestions of a large population decline. A total of 937 potential nesting islands were surveyed and 106 eider colonies were identified with a total of 4,097 ± 468 active nests. In 15 colonies, where comparable and well-documented surveys were conducted approximately 40 years ago, a population decline of 81% (from 3,361 to 624 nests) was detected. A more rough comparison showed that among 51 eider colonies surveyed in 1920, 1960, or 1965, 71% were either gone or had declined in breeding numbers when resurveyed in 1998–2001. The total breeding population in West Greenland was estimated at 12,000–15,000 pairs.

Hunting and bycatch of eiders (ms 3)
Surveys at the local market in Nuuk (2000-2001) showed that human activities varied considerably between the coastal area and the fjord system. Hunting within 30 km of the city was the source of 98% of all eiders sent to the local market from October until March. In contrast, bycatch in gillnets accounted for 52% of the eiders brought to the market in March and April. Especially bycatch in the fjords appeared to be a critical factor due to an over representation of adult birds in this area. Simplified modelling showed that rescheduling the harvest exclusively to the fall and early winter would lower the take of adult birds by 31%, even if the total number of harvested birds remained at the same level.

Embedded lead shot and body condition (ms 4 – 6)
X-raying for embedded lead shot indicated a segregation of birds between the outer coastal area and the inner fjord system. Adult birds collected in the fjord were significantly less burdened with embedded lead shot from previous shooting incidences (24.5%) compared to birds collected in the more heavily hunted coastal area (35.0%). Age was also a significant factor influencing the risk of being wounded. Immature and adults had a yearly infliction rate of estimated 1.8-3.0%, while 13.2% of the less experienced juvenile birds became inflicted during their first winter. Juveniles contained more embedded pellets (mean 2.2) than adults (mean 1.7), suggesting that the most burdened juveniles die before entering the older age classes. In addition, juvenile birds carrying embedded shot had significantly poorer body condition compared to non-inflicted juveniles - on average 19% less fat. No impact on the body condition was detected for immature and adult birds and suggests that there is no long-term effect on body condition once birds have survived the initial effect of wounding.

Habitat use and body condition (ms 7)
Despite high levels of disturbances most coastal eiders exhibited strong site fidelity during winter, with a mean core area (50% home range) of 5.7 km^2, and the exchange of birds between the outer coast and the fjord was small and only one-way; between 8-29% moved to the fjord and stayed until spring migration. Only short distances were travelled between roosting sites and daytime feeding areas, on average 1.7 km. Among 32 eiders, 72% used only one wintering area, whereas the remaining 28% used on average 2.1 sites. The body condition of adult fjord birds was either equal or superior to that of coastal birds, but in general, adult body condition declined from late winter to early spring, suggesting that eiders mainly build up body reserves for the breeding season elsewhere.

Habitat and diet (ms 8)
Diet sampling showed that diet diversity was highest at the coast, while fjord birds

relied more heavily on bivalve species. Juvenile birds in the coastal area contained relatively high proportions of high-energy crustacean prey species compared to other age groups. In contrast, no crustaceans were found in the fjord diet and may explain why relative few juvenile birds were present there. Overall, the dominant prey was the soft bottom species *Mya eideri* (36.0% ww) and not *Mytilus edulis*, which is usually reported as the most important food item for Common Eiders.

Foraging and the impact of disturbances (ms 9-10)

Behavioural observations showed that feeding in the coastal area took place during daylight and twilight, while birds in the fjords fed only during night and twilight periods. At night, the fjord birds often fed directly on vertical cliff surfaces, which were densely covered with mussels, and probably visual cues are not very important at such feeding sites. Only juvenile birds attempted to feed during daylight in the fjord, but this feeding activity was discontinued due to interactions with White-tailed Sea Eagles (*Haliaeetus albicilla groenlandicus*). Nocturnal feeding in the fjord is probably an anti-predator mechanism, and juvenile birds appeared unsuccessful in meeting their energy requirements using this strategy. This may also explain the small numbers of juveniles in the fjord.

A detailed analysis of the diurnal feeding pattern in the coastal area showed that disturbances from human activities (hunting and fishery) played a significant role in determining when eiders fed. Human disturbances affected the habitat use on a daily basis by reducing the feeding activity in the study area up to 60% when most heavily disturbed. At the same time locomotion activity tripled and induced increased energy expenditure due to the additional movements. Eiders attempted to compensate for lost feeding opportunities by rescheduling some of the feeding activity; when undisturbed, they avoided feeding during high tide and intensified feeding at the start and at the end of the day, but these tendencies were levelled out if the eiders were disturbed. When disturbed, the time since the last disturbance and the distance to the last disturbance were both significant factors for the feeding activity. In addition, there was a cumulative effect of repeated disturbances when these were close in time (<1h). The day with the highest number of recorded disturbances coincided with observations of nocturnal feeding the following night and may suggest that a critical threshold of disturbances was reached where eiders no longer could rely on a diurnal feeding strategy.

Conclusion

The present thesis emphasize the importance of Southwest Greenland as wintering grounds for the Northern Common Eider population and confirms previous suggestions, that the breeding population in western Greenland has suffered a large decline. With Nuuk as a case study area, several critical direct or indirect sources of eider mortality were identified, and the local winter population was assessed as potentially highly vulnerable to local environmental conditions due to a high degree of site fidelity in winter. Although net-consequences of human disturbances were not quantified, they clearly had an effect on eider feeding behaviour. Disturbances induced extra energy expenditures due to risk-avoidance behaviour and lost feeding opportunities. Despite low hunting pressure in nearby fjord locations the emigration to these areas was limited, probably due to a substantial predation-risk factor caused by while-tailed sea eagles. The findings accentuate the need for managing wintering Common Eiders in Southwest Greenland at a local scale, taking site fidelity and local environmental conditions into account.

4. Dansk resumé

Vinterøkologi er et vigtigt element i forskning og forvaltning af havfugle. Vinteren er ofte den periode på året, hvor både unge og voksne havfugle har den højeste dødelighed og deres kropskondition i slutningen af vinteren kan desuden påvirke deres ynglesucces. En konsekvens af dette er, at forholdene i vinterkvarteret kan have stor betydning for den generelle status for populationen. Fuglenes vinterkondition bliver påvirket af tilgængeligheden af egnede fødesøgningsområder, hvor fuglene dagligt kan afbalancere deres energibudget samt opbygge energireserver, så de er i stand til at klare perioder med begrænset fødeoptag fx i perioder med dårlige vejrforhold og under træk. Fuglenes valg af habitat er imidlertid påvirket af den lokale dødelighedsrisiko, og fugle kan blive afskåret fra at udnytte ellers velegnede habitater som konsekvens af predation og jagt, eller sideeffekter af menneskelige aktiviteter, så som forstyrrelser, bifangst og anskydning.

Disse forhold har stor betydning for den almindelig ederfugl (*Somateria mollissima borealis*), idet størstedelen af denne population er afhængig af et stort åbentvandsområde i Sydvestgrønland gennem det meste af dens årscyklus. Her er ederfugle traditionelt blevet nedlagt i stort antal, men der er sat spørgsmålstegn ved bæredygtigheden af denne fangst på baggrund af forskellige indikationer om tilbagegang i bestanden.

Fokus og mål

Materialet til denne afhandling blev indsamlet i to faser: Den første fase sigtede mod 1) at kvantificere antallet og fordelingen af almindelige ederfugle der overvintrede i Grønland og, 2) indsamle viden om antal og bestandsudvikling blandt ynglefuglene i Vestgrønland. Anden fase var koncentreret omkring et mindre vinterområde i Sydvestgrønland, Nuuk, og omhandler interaktioner mellem jagt på almindelige ederfugle, deres kropskondition og deres habitatudnyttelse. Arbejdet omfattede dataindsamling om en række hidtil ubeskrevne aspekter af fuglenes vinterøkologi med det formål, at 3) indkredse faktorer, som er vigtige for fuglenes lokale fordeling og adfærd gennem vinteren, og 4) vurdere den lokale populations sårbarhed overfor jagt og, om muligt, at vurdere konsekvenserne af denne jagt. Det overordnede mål var at opnå et mere solidt grundlag for fremtidig forvaltning af den almindelig ederfugl.

Nuuk blev valgt som case-study område idet de indledende optællinger fra fly identificerede Nuuk som et vigtigt område for overvintrende ederfugle. Dertil kommer at det største antal erhvervs- og fritidsfangere er samlet i Nuuk, hvilket gør området ideelt til studier af menneskelig påvirkning på ederfuglebestanden. Endeligt eksisterer der to generelle habitattyper for ederfugle i området omkring Nuuk – kystområdet og det indre fjordsystem. Områderne er markant forskellige både hvad angår habitat karakteristika og menneskelig aktivitet, hvilket gør det muligt at foretage sammenlignende studier af påvirkning og respons. Metoderne omfattede flytælling, satellitsporing, overvågning af jagt og jagtudbytte, røntgenundersøgelser af anskydningsgrad, undersøgelser af kondition og fødevalg samt adfærdsstudier.

Vinterudbredelse og antal (artikel 1)

Flytællinger i februar/marts 1999 i Sydvestgrønland viste, at almindelig ederfugl var den hyppigst forekommende havfugl i kystområdet - ca. 360.000 fugle. Derudover blev der observeret ca. 104.000 ederfugle i fjordene. Generelt blev der set mange, men små flokke langs kysten, mens det var omvendt i fjordene med flokstørrelser på op mod 6.500 fugle. Området omkring Nuuk samt Julianehåb Bugt i Sydgrønland blev identificeret som særlig vigtige overvintringsområder med hhv. ca. 57.000 og 96.000 fugle. På baggrund af resultaterne fra flytællingerne kunne det konkluderes, at der foregår en

massiv indvandring af ederfugle til overvintringsområdet i Sydvestgrønland fra canadiske yngleområder – over 400.000 fugle.

Bestandsudvikling (artikel 2)
I 1998-2001 gennemførtes undersøgelser i ederfuglens yngleområder i Ilulissat, Uummannaq og Upernavik kommuner (69°15' N - 74°05' N) i Vestgrønland. Resultaterne bekræftede antagelser om en stor tilbagegang i bestanden. I alt blev 937 potentielle ynglelokaliteter undersøgt og der blev registreret 106 ynglekolonier med i alt 4.097 ± 468 aktive reder. I 15 kolonier, hvor der var udført sammenlignelige undersøgelser ca. 40 år tidligere, var bestanden reduceret med 81 % (fra 3.361 til 624 reder). En mere forenklet sammenligning viste, at ud af i alt 51 ederfuglekolonier, som var undersøgt i 1920, 1960 eller 1965, var 71 % af dem enten helt forsvundet eller reduceret i antal, da de blev undersøgt igen i 1998-2001. Den totale bestand af ynglepar i Vestgrønland blev vurderet til 12.000-15.000 par.

Jagt og bifangst af ederfugle (artikel 3)
Undersøgelser på brættet i Nuuk (2000-2001) viste, at jagten varierede betydeligt mellem kystområdet og fjorden. I perioden fra oktober til marts blev 98 % af alle ederfugle, der blev solgt på brættet, skudt inden for en radius af 30 km fra byen. I marts og april blev 52 % af alle ederfugle på brættet imidlertid fanget som bifangst i net. Specielt bifangsten fra net i fjorden viste sig at være problematisk på grund af en stor overvægt af voksne fugle i dette område. Modellering viste, at det ville mindske fangsten af voksne fugle med 31 %, hvis fangsten udelukkende foregik om efteråret og tidligt på vinteren. Dette selvom det totale antal nedlagte fugle var uændret.

Anskydning og kropskondition (artikel 4-6)
Røntgenundersøgelser efter blyhagl antydede at fuglene fra kystområdet og fjorden var adskilte. I fjorden havde markant færre voksne fugle blyhagl i kroppen fra anskydninger (24,5%) end fugle fanget i kystområdet (35,0%), hvor jagttrykket er langt større. Fuglens alder var en anden afgørende faktor, som influerede på risikoen for anskydning. 1,8-3,0% af de halvvoksne og voksne fugle blev årligt anskudt, mens 13,2% af de unge og mindre erfarne ederfugle blev anskudt i løbet af deres første vinter. Unge fugle havde gennemsnitlig flere hagl i kroppen (2,2 hagl) end voksne (1,7 hagl), hvilket antyder, at en del af de kraftigt anskudte unge fugle dør inden de når voksenalderen. Dertil kommer at anskudte unge fugle havde markant dårligere kropskondition end ikke anskudte – i gennemsnit 19 % mindre fedt. Blandt halvvoksne og voksne ederfugle blev der ikke registreret nogen effekt på konditionen som følge af anskydninger, hvilket antyder at der ikke er nogen langtidseffekt af anskydninger på fuglenes kondition, når først de har overlevet den første kritiske periode.

Kropskondition og habitatudnyttelse (artikel 7)
Satellitsporing viste, at de fleste ederfugle i kystområdet var ret stedfaste gennem vinteren på trods af mange forstyrrelser. De opholdt sig i gennemsnit inden for et kerneområde på 5,7 km². Der var en lille udveksling af ederfugle fra kystområdet til fjorden, mens ingen bevægede sig den anden vej. 8-29 % af ederfuglene flyttede fra kystområdet til fjorden og blev der indtil forårstrækket. Fuglene bevægede sig kun over korte afstande mellem overnatningsområderne og fødesøgningsområderne, i gennemsnit 1,7 km. Ud af 32 ederfugle brugte 72 % kun ét overvintringsområde, mens 28 % i gennemsnit udnyttede 2,1 område. Kropskonditionen hos voksne fjordfugle var enten den samme som eller bedre end konditionen hos kystfuglene, men konditionen faldt generelt fra senvinteren til det tidlige forår, hvilket indikerer at ederfuglene primært opbyggede energireserver til ynglesæsonen andre steder.

Habitat og føde (artikel 8)
Ederfuglenes fødeemner varierede mere i kystområdet end i fjorden. Unge fugle i kystområdet fouragerede relativt meget på energirige arter af krebsdyr sammenlignet med ederfugle fra andre aldersgrupper. Som kontrast til dette blev der ikke fundet krebsdyr blandt fødeemnerne hos fugle fra fjorden, hvilket kan være en af årsagerne til at der var relativt få unge fugle i fjorden. Generelt var det dominerende fødeemne blødbundsarten *Mya eideri* (36,0 % vv) og ikke *Mytilus edulis*, som normalt rapporteres som det vigtigste fødeemne for almindelige ederfugle.

Fødesøgning og påvirkning af forstyrrelser (artikel 9-10)
Observationer af fuglenes adfærd viste, at fødesøgningen i kystområdet fandt sted om dagen og i skumringen, mens de voksne fjordfugle udelukkende fouragerede om natten og i skumringen. Om natten fouragerede fjordfuglene ofte på lodrette klippefalder, som var tæt dækket af muslinger. På sådanne fødesøgningssteder er de visuelle stimuli sandsynligvis mindre afgørende for fødesøgningen. Kun de unge fjordfugle forsøgte at finde føde om dagen, men blev altid afbrudt på grund af interaktioner med havørne (*Haliaeetus albicilla groenlandicus*). Natlig fouragering i fjorden er sandsynligvis en anti-predatorer strategi, og de unge fugle havde det tilsyneladende svært med denne strategi. Det kan også forklare det relativt lille antal unge fugle i fjorden.

En detaljeret analyse af fødesøgningsmønstret i kystområdet viste, at forstyrrelser fra menneskelige aktiviteter (jagt og fiskeri) spillede en afgørende rolle for hvornår ederfuglene søgte føde. Menneskelige forstyrrelser påvirkede dagligt den effektive habitat-kvalitet ved at reducere fødesøgningen i området med op til 60 %, når området var mest forstyrret. Samtidig genererede forstyrrelserne et øget energiforbrug hos fuglene, som et resultat af hyppige flugtreaktioner. Ederfuglene forsøgte at kompensere for afbrydelserne ved at fouragere på andre tidspunkter. Når de ikke blev forstyrret, undlod fuglene at fouragere ved højvande, og de intensiverede fødesøgningen i starten og slutningen af dagen, men denne tendens var væsentlig mindre udtalt, når ederfuglene blev forstyrret. Ved forstyrrelser, var der en klar sammenhæng mellem tiden og afstanden til den seneste forstyrrelse og fødesøgningsaktiviteten. Dertil kom at der var en kumulativ effekt ved gentagende forstyrrelser, når disse forekom med korte mellemrum. Den dag, hvor der var flest forstyrrelser, blev der efterfølgende observeret nat-fouragering. Det indikerer, at en kritisk grænse for mængden af forstyrrelser var nået, hvor ederfuglene ikke længere kunne opretholde energibalancen ved at fouragere i dag- og skumringstimerne.

Konklusion
Denne afhandling understreger vigtigheden af Sydvestgrønland som overvintringsområde for den nordlige bestand af almindelig ederfugl og bekræfter tidligere antagelser om, at ynglebestanden i Vestgrønland er gået kraftigt tilbage. Med Nuuk som undersøgelsesområde er der påvist flere direkte og indirekte faktorer som har, eller kan have, betydning for fuglenes overlevelse eller reproduktion. Den lokale vinterbestand blev vurderet som potentielt meget sårbar overfor lokale miljømæssige forhold grundet stor stedfasthed i vinterperioden. Selvom de ultimative konsekvenserne af menneskelige forstyrrelser ikke er kvantificeret, er der påvist en tydelig effekt på ederfuglenes fødesøgningsaktivitet. Forstyrrelser resulterer i øget energiforbrug i forbindelse med fuglenes flugtreaktioner, og samtidig mister fuglene mulighed for at søge føde. På trods af et mindre jagttryk i de nærliggende fjorde var det kun et begrænset antal fugle, som emigrerede til fjordområderne. Årsagen er sandsynligvis risikoen for predation fra havørne. Resultaterne aktualiserer behovet for at forvalte overvintrende almindelige ederfugle i Sydvestgrønland lokalt, med hensyntagen

til fuglenes udbredelse og bevægelsesmønstre samt forholdene i det omgivne miljø.

5. Kalaallisut eqikkaaneq

Timmissat imarmiut ilisimatuutut misissuiffigineranni ingerlatsivigineqarnerannilu ukiuunerani pissusiusartut pingaaruteqartuupput. Ukiuunera tassaagajuppoq timmissat imarmiut, piaraagunik inersimasuugunilluunniit, toqorarnerpaasarfiat, ukiullu qaangiukkiartulernerani qanoq pualatiginerat piaqqiornerminni qanoq iluatitsititiginissaannut sunniuteqarsinnaasarpoq. Tamatumami ukiuunerata ingerlanerani timmissat pualassutsikkut qanoq innerat timmiaqatigiit nalinginnaasumik qanoq atugaqarnerannut pingaarutilerujussuusinnaasarnera kingunerisarpaa. Timmissat ukiuunerani qanoq innerat naleqquttunik neriniarfissaqarnernit, timmissat ullut tamaasa nukissaminnik katersuisinaanerannut sillimmatissaminillu puallarsersinnaanerannut sunnerneqartarpoq, tamatumuunami nerisassakilliornarnerani, soorlu silarlunnerani imalunniit ingerlaanerminni, sillimmatissarsisarmata. Timmissalli uninngaarfissaminnik toqqaasarnerat najukkami toqorartoqarsinnaneranut navianartorsiornarsinnaaneranit sunnerneqartarpoq, timmissammi uninngaarfinnik naleqqutuugaluartunik atuinissaat ajornarsitinneqartarmat ulorianartunit, soorlu aallaaniartoqarneranit, akornusersuutinilluunnit allanit, piniutinit allanut sammisitanit pisarisuuisarnernit aallaammillu pissataasarnernit, tassa inuit ingerlatsaasa siunertaanngikkaluartumik sunniutaannit.

Pissutsit tamakkua timmiaqatigiinnut miternut (*Somateria mollissima borealis*) avannarlernut sunniutilerujussuupput, timmiaqatigiimmi taakkua amerlanersaat ukiup kaajallakkiartornerani pissuserisartakkamik annersaani Kalaallit Nunaata kujataata kitaani immamik ammasumik annertoorsuarmik pisariaqartitsisarmata. Tamaani miternik amerlasoorujussuarnik pisaqartarneq ileqquuvoq, kisiannili timmiaqatigiit ikiliartorunarnerannik takussutissat assigiinngitsut tunngavigalugit tamatuma imminut nammassinnaasuunera apersuuserneqarpoq.

Pingaarnerutitat anguniakkallu

Ilisimatuutut allaaserisami uani suliaq marluinut immikkoortinneqarpoq: Siulleq sammitinneqarpoq 1) mitit siorartuut Kalaallit Nunaanni ukiisartut amerlassusiisa agguataarsinaeratalu aalajangerniarnerannut, aamma 2) Kalaallit Nunaata kitaani timmissat erniortut amerlassusiannut timmiaqatigiillu ingerlaasiannut tunngatillugu ilisimasassat katersornerat. Aappaanni Kalaallit Nunaata kujataani kitaani, Nuummi, ukiisarfiannut aalajangersumut tunngatinneqarpoq, taannalu mitit siorartuut pualassusiannut najukkaminnillu atuinerannut aallaaniarnerup sunniutaanut sammitinneqarpoq. Suliamiipput timmissat ukiisarnerannut tunngatillugu pissutinut arlalinnut suli allaaserineqarsimanngitsunut paasissutissanik katersuineq. Tamatumani siunertarineqarpoq 3) ukiuunerani timmissat agguataarsimanerannut iliuusaannullu pissutsit pingaarutillit paasiniarnissat, aamma 4) timmiaqatigiit tamaaniittut aallaaniarnermit qanoq sunneruminartigissusiat, aammalu ajornanngippat aallaaniarnerup taassuma sunniutaasa nalilersorniarnissaat. Anguniagaq pingaarneq tassaavoq siunissami mitip siorartuup ingerlatsivigineqarnerani tunngaviusussamik isumannaannerusumik pilersitsinissaq.

Nuup misissuiffissatut toqqarneqarneranut pissutaavoq aallarnersaataasumik timmisartumiit kisitsisarnertigut Nuuk miternut ukiivittut pingaaruteqartutut paasineqarsimammat. Aamma tassunga ilaavoq inuussutissarsiutigalugu piniartut sunngiffimmilu aallaaniartartut amerlanerpaartaasa Nuummiinerat, taamaalilluni tamaani inuit miteqatigiinnut sunniutaannik misissuinissamut tulluartunngortillugu. Aaammalumi Nuup eqqaaniipput mitit najugannaaqarfii nalinginnaasut marluummata - sineriaani kangerluillu qinngorpasissuini. Taakkua najugannaatut pissutsimikkut inunnillu angallavittut assigiinngitsorujussuupput, taamaammallu sunniutinik kingunerinillu sanilliussuussivigalugit misissuiffissatut

piukkunnartunngorlutik. Periaatsit atorneqartut tassaapput timmisartumiit kisitsineq, satellitit atorlugit malittarinninneq, aallaaniarnermik pisanillu nakkutilliineq, qinnguartaalluni issutanik pissaasarnerup annertussusianik misissuineq, timmissat pualassusiannik sunillu nerisaqarnerannik aammalu pissusilersornerannik misissuinerit.

Ukiisartut – amerlassusiat agguataarsimanerallu (artikel 1)

Kalaallit Nunaata kujataani kitaani 1999-imi timmisartumiit februar/martsimi kisitsinerit takutippaat sinerissami tamaani miteq siorartooq timmissanit imarmiunit tamaanit nalinginnaanerpaasoq – mitit 360.000 missaanniillutik. Taakkua saniatigut kangerlunni mitit 104.000-it missingi takuneqarput. Nalinginnaavoq sinerissami timmissat eqimattaararpassusarnerat, akerlianilli kangerlunni eqimattat timmissat 6.500 tikillugit amerlassuseqarsinnaasarlutik. Nuup eqqaa Kujataanilu Qaqortup kangerliumarna ukiisarfittut pingaarnerusutut paasineqarput, tassa 57.000 aamma 96.000 miss. miteqarlutik. Tamassa pissutigalugu timmisartumiit kisitsinikkut inerniliunneqarsinnaalerpoq Canadami mitit erniorfiiniit Kalaallit Nunaata kujataata kitaani ukiisarfinnut annertoorujussuarmik pularartoqartartoq – timmissat 400.000 sinnillit tamaannartarlutik.

Miteqassutsip ingerlaasia (artikel 2)

Kitaani 1998-2001-imut mitit erniorfiinik Ilulissat, Uummannap Upernaviullu kommuniini (69°15’ N – 74°05’ N) misissuineqarpoq. Misissuinerit inernerisa miteqatigiit annertoorujussuarmik ikileriarsimanerannik pasitsaasimasat ilumoornerat uppernarsarpaat. Katillugit erniorfiusinnaasut 937-t misissorneqarput. Katillugit ullut najorneqartut 106-it 4.097 ± 468 nalunaarsorneqarput. Miteqarfinnut 15-inut ukiut 40-t miss. matuma siornagut misissuiffiusimasunut naleqqiussuussiviusinnaasuni mitit 81 %-imik ikileriarsimapput (tassa ullut 3.361-iniit 624-inngorsimapput). Paasiuminarnerusumik sanilliussuussinikkut takuneqarsinnaavoq mitit erniorfiini katillugit 51-iusuni, 1920, 1960 imaluunniit 1965-imi misissorneqarsimasunit 71 %-it 1998-2001-imut misissueqqinnermi mitterutivissimallutilluunniit ikileriarfiusimapput. Kitaani tamaani mitit aappariit erniortut amerlassusiat 12.000-15.000-inut nalilerneqarpoq.

Mitit piniarneqarnerat pisarisorne qartartullu (artikel 3)

Nuummi kalaalimineerniarfimmi (2000-2001-imut) misissuinerit takutippaat sinerissami kangerlummilu aallaaniarneq malunnartumik allanngorartuusoq. Oktoberimiit martsimut mitit pisarineqartut kalaalimineerniarfimmi tunineqartut tamarmiusut 98 %-ii illoqarfimmiit 30 km ungasissusillip iluani pisarineqartarput. Martsimi aprilimilu mitit kalaalimineerniarfimmiittut tamarmik 52 %-ii qassutinik pisarisuugaasarput. Pingaartumik kangerlummi pisarisuuisarneq ajornartorsiutitaqartoq paasinarpoq, tassami tamaaniittut amerlanerpaartaat inersimasusarmata. Missingersuusiornikkut paasinarsivoq piniagaanerat ukiakkuinnaq ukiullu aallarteqqaanerinaani pisartuuppat miternik inersimasunik pisaqartarneq 31 %-imik appartinneqarsinnaagaluartoq. Imaappoq mitit pisaasartut tamarmiusut amerlassusiat allanngunngikkaluarpalluunniit.

Timmigaluartitsisarneq pualassusiallu (artikel 4-6)

Amerlasuunik aqerluusunik qinnguartaanikkut timmissat sinerissamiittut kangerlummiittullu immikkoortuusut malunnarpoq. Kangerlummi timmissat inersimasut pissatat amerlasoortallit malunnartumik (24,5 %) sinerissami, aallaaniarfiuneroqisumi, pisanit ikinnerupput (35,0 %). Aamma timmigaluartitaanissamut timmissap qanoq utoqqaatiginera apeqqutaalluinnarpoq. Timmissat kuukujuit utoqqaallu 1,8-3,0 %-ii ukiumut pissanneqartarput, massali mitit piaqqat, taamalu misilittagaqannginnerusut, ukeeqqaarnerminni ukiumut 13,2 %-ii timmigaluartinneqartarlutik. Piaqqat agguaqatigiissillugu timiminni amerlasoortaqarnerupput (amerlasuut 2,2) inersimasuninngarnit (amerlasuut 1,7),

imaapoq piaqqat annertunerusumik pissanneqartartut inersimasunngortinnatillu toqussusarlutik. Aammalu piaqqat pissatat malunnartumik pissataanngitsunit salunnerusarput - agguaqatigiissillugu 19 % orsukinnerusarlutik. Kuukujuit inersimasullu akornanni pissanneqarnerup kinguninngua qaangerneqareeraangat amerlasoortaqarnerup pualassusiannut sunniuteqartarneranik malugisassaqanngilaq.

Pualassusiat najukkamillu atuinerat (artikel 7)

Satellitit atorlugit malinnaanikkut paasineqarpoq mitit sinerissamiittut amerlanersaat ukiuunera tamaat akornusersuutepassuaqaraluartoq tamaaniiginnartartut. Agguaqatigiissillugu najugannaaminniittarput 5,7 km² annertussusillip iluani. Annikitsunnguamik mitit sinerissamiittut kangerlummut illuartarput kangerlummiilli sinerissamut illuartoqassanani. Mitit 8-29 %-it sinerissamiit kangerlummut nuuttarput upernaakkullu ingerlaarlernissap tungaanut taqqamaaniittarlutik. Annikitsuinnarmik unngaartarfimminniit neriniartarfimminnut nikerartarput, agguaqatigiissillugu 1,7 km isorartussusilimmik. Miternit 32-init 72 %-it ukiivik ataasiinnaq atorneqarpoq, agguaqatigiissilluguli 28 %-it najugaq 2,1 km isorartussusilik atortarlugu. Timmissat inersimasut kangerlummiittut pualassusiat sinerissamiittutulli ippoq pitsaanerulluniluunniit, kisiannili nalinginnaasumik ukiup naggaataatungaanit upernaleqqaarneranut sanigortarput, tamannalu mitit allami piaqqiulernissaminnut puallarsertarnerannut takussutissaasinnaavoq.

Najukkat nerisallu (artikel 8)

Mitit sinerissami nerisaat kangerlumminngarnit allanngorarnerupput. Piaqqat sinerissamiittut annertungaatsiartumik peqqukkunnik puallarnartunik, miternut allatut utoqqaassusilinnut naleqqiullugit, neriniarnerupput. Tamatuma akerlianik mitit kangerlummiittut nerisaanni peqqukkunnik nassaartoqanngilaq, tamannalu kangerlummiittut piarartaqarpallaannginnerannut pissutaalluarsinnaavoq. Nalinginnaasumik nerisani saqqumilaarneruvoq immap naqqani aqitsormioq Mya eideri (36,0 % vv), tassa *Mytilus edulis*-iunngitsoq, naak nalinginnaasumik taanna mitit siorartuut nerisaanni pingaarnerpaanerarneqartaraluartoq.

Nerisassarsiorneq akornusersuutillu sunniuteqarnerat (artikel 9-10)

Timmissat pissusiisa alaatsinaaneqarnerisigut paasinarpoq sinerissami neriniartarnerat ulluunerani, qaammalernerani tarrajussineranilu pisartoq, mitilli kangerlummiittut unnuaanerani qaammalernerani taarrajussineranilu taamaallaat neriniartarlutik. Unnuaanerani mitit kangerlummiittut qaarsuni qutaarluusuni uillunik qalligaasuni neriniarajunnerupput. Neriniarfinni taamaattuni nerisassarsiornermi isigalugit neriniarnissaq apeqqutaavallaarsimagunanngilaq. Mitit kangerlummiittut inuusukaat kisimik ullunerani neriniartaraluarput kisiannili nattorallit (*Haliaeetus albicilla groenlandicus*) akuliunnerannit unitsinneqartarlutik. Kangerlummi unnuaanerani neriniartarneq timmissanit tigutsisilinnit pisarineqannginnissamik siunertaqarluni aallartissimagunarpoq, periaaserli taanna timmissat inuusukaat sungiusimasimagunanngilaat. Tamanna kangerlummi timmissat piaqqat ikittunnguunerannut aamma nassuiaatissaagunarpoq.

Sinerissami nerisassarsiortarnerup peqqissaartumik misissuiffigineqarnerata inuit ingerlataasa (piniarnerup aalisarnerullu) akornusersuisarnerata qaqugukkut mitit neriniartarnerannut apeqqutaalluinnarnerat takutippaa. Inuit ullormut akornusersuisarnerata najukkamik atuilluarluni nerisassarsiornissaq, tamanna akornusersugaavallaarsimagaangat, 60 % angullugu annikillisittarpaa. Tamatumunnga peqatigitillugu akornusersuinerup, qimaasaqattaarnerat pissutaalluni, timmissat nukissamik atuinerat annertusisittarpaa. Mitit neriniarnerminni akornusersugaanermik taartissaanik piffissani allani neriniartarlersarput. Akornusersorneqanngikkaangamik ulinngatillugu mitit neriniarneq ajor-

put ullullu qaammalernerani taarsilerneranilu neriniarnerulersarlutik, akornusersorneqartillutilli taamaattarnerat annikinnerulluartarpoq. Akornusersorneqartillutik akornuserneqarnermit kingullermiit neriniarnissamut piffissap sivisussusia erseqqissumik ataqatigiippoq. Uteqqiattumik akulikitsumik akornusersuisoqartillugu taakkua sunniutaat annertusiartortarpoq. Ulluunerani akornusersuutit amerlavallaarsimagaangata unnuami neriniartarnerat takuneqartarpoq. Tamatumuuna malunnarpoq akornusersuutit killissartik tikissimagaat, allaat mitit ullukkut aammalu qaammalernerani taarsilerneranilu neriniartarnermikkut naammattumik nukissarsisinnaasarnertik attassinnaajunnaartarlugu.

Inerniliineq

Ilisimatuutut allaatigisap uuma Kalaallit Nunaata kujataata kitaata mitit siorartuut avannarpasissumiittut ukiisarfiattut pingaaruteqarnera erseqqissarpaa, aammalu siusinnerusukkut Kalaallit Nunaata Kitaani mitit siorartuut piaqqiortut annertuumik ikileriarsimanerannik isumaqartarnerit uppernarsarlugit. Nuup misis suiffigineratigut toqqaannartumik toqqaannanngitsumillu mitit siorartuut toqussutigisartagaat arlallit paasineqarput. Nunap nammineq mittii ukiisartut ukiuunerani najukkaminni allamut nikijuitsuunertik pissutigalugu assorujussuaq avatangiisiminnit sunnernerlukkuminartutut nalilerneqarput. Naak inunnit akornusersugaanerata kingunerlorujussuarsinnaanera erseqqissumik nalilersorneqanngikkaluartoq mitit neriniartarnerat erseqqissumik eqqorneqartartoq ersersinneqarpoq. Akornusersuutit mitit qimaasaqattaarnerat pissutaalluni nukissamik atuinerulernerannik kinguneqartarpoq taammaammallu timmissat aamma neriniarsinnaajunnaartarlutik. Naak kangerlunni qanittuniittuni piniagaanerat annikitsunnguugaluartoq timmissat ikittuinnaat kangerlummut nuuttarput. Tamanna nattoralinnut aarlerinermik pissuteqarunarpoq. Mitit siorartuut, timmissat taakkua siaruarsimanerat, ingerlaartarnermikut aammalu avatangiisitigut pissutsit atugaat pissutigalugit Kujataani najukkani ataasiakkaani ingerlatsivigineqarnissaanik pisariaqartitsineq misissuinermi paasisat erseqqissitippat.

6. Synopsis

6.1 Introduction

There are several good reasons to study the winter ecology of Common Eiders (*Somateria mollissima*) in Greenland. The more general ones include the fact that for Common Eiders and most other migratory arctic bird species the non-breeding season makes up a very extensive period of the annual cycle. Therefore, the non-breeding season may potentially be of the utmost importance for the dynamic of migratory bird populations (Newton 1998; Scott 1998). During this period birds must restore body reserves lost during the breeding season and they must maintain sufficient reserves throughout the winter to buffer against energy shortfalls (King and Murphy 1985; Blem 1990). Additionally, among large migratory Arctic birds, body condition at the end of the non-breeding season may influence their breeding performance (Ankney and MacInnes 1978; Coulson 1984; Ebbinge and Spaans 1995; Bêty et al. 2003). At the same time, mortality risks caused by natural factors may be severe at high latitudes; periodically inflicted by extreme weather conditions (Harris and Wanless 1984; Lovvorn 1994; Robertson and Gilchrist 1998) or generally challenged by low temperatures and reduced day length (Jenssen et al. 1988; Systad et al. 2000; Systad and Bustnes 2001). Mortality threats often also include natural predation and hunting by man (e.g., Quinlan and Lehnhausen 1982; Denlinger and Wohl 2001), as well as side-effects of human activities, such as disturbances, unintentional bycatch and wounding of birds during hunting (Fig. 1) (Madsen and Fox 1995; Barrow and Hicklin 2004).

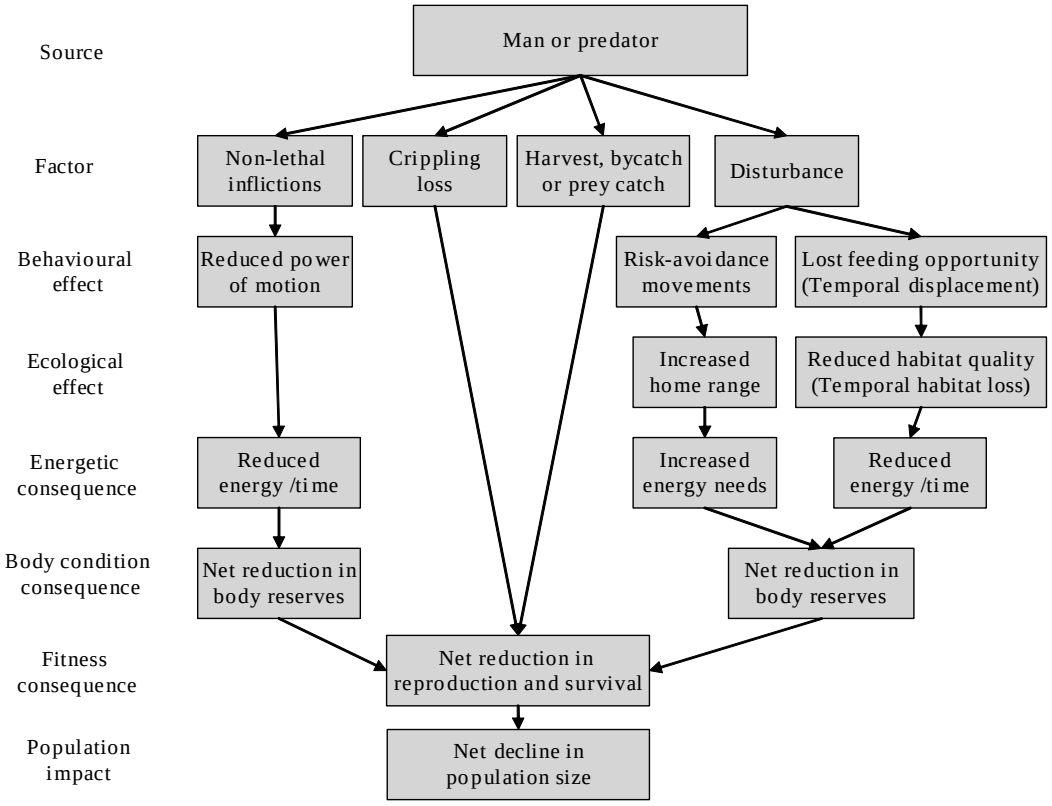

Fig. 1. Human- or predator-induced effects on waterbird populations during winter. The term "net reduction" or "net decline" indicate that compensatory mechanisms may minimize some effects.

Among the more site-specific regulating factors harvest by man and derived side-effects are especially relevant in the case of Greenlandic wintering Common Eiders and this is the main focus of this thesis. Greenland has a long history of seabird harvests, including eider harvest. Historically, eiders were taken for down, skins, eggs, and meat (Müller 1906; Krabbe 1907), and today eider hunting is still culturally and economically important in Greenland, although the down and skins are no longer used to any significant extent and the egging is forbidden (Christensen 2001; Merkel 2002). From 1993, when the current bag-report system started, and until 2002 (see 6.10), the annual total of bagged eiders ranged between 60,000 and 90,000 eiders, of which approximately 90% were shot during fall, winter and spring in Southwest Greenland (Fig. 2) (The Greenland Home Rule Department of Hunting and Fishing). In this period, the eider hunting season in Southwest Greenland was open from October 1 to May 31. The above mentioned harvest includes also King Eiders (*Somateria spectabilis*) because hunters often do not reliable discriminate between the two species. In the Nuuk area 20 - 30% are King Eiders (ms 3).

There was a growing concern for the sustainability of this harvest, partly because a major population decline of the Thick-billed Murre (*Uria lomvia*) was ascribed to human exploitation (Kampp et al. 1994), and partly because historical records on eider down collection in West Greenland indicated a large population decline for the Common Eider (Müller 1906; Salomonsen 1967). Among two recent surveys, one confirmed such a large decline (Frich et al. 1998), while the other did not (Christensen and Falk 2001). More information on distribution and total abundance were needed to reliably assess the sustainability of the harvest in Greenland. Southwest Greenland was known as the main wintering area for northern Common Eiders breeding in eastern Canadian Arctic and West Greenland (Salomonsen 1967; Reed and Erskine 1986); however, no information on the total number of birds was available. Therefore, a series of studies was initiated in Southwest Greenland in the winter 1999. Southwest Greenland was the obvious place to start since this wintering area represents the place and the time when eiders are less widely distributed (compared to breeding areas) and because the majority of eiders are bagged in this area.

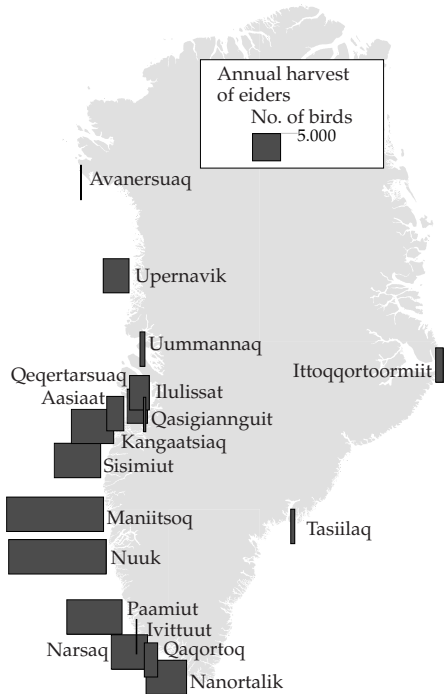

Fig. 2. The annual mean no. of eiders (King- and Common Eiders combined) reported shot for each municipality of Greenland for the period 1993-1999 (The Greenland Home Rule Department of Hunting and Fishing).

6.2 Focus and aims

This introductory chapter is meant to give a brief overview of the circumstances and ecological context that gave rise to the study components and outlines the most important findings, conclusions and significance of the work. As far as possible, I have aimed at presenting things in a step-by-step manner, letting one section serve as the background and introduction to the

next one and so on. This disposition also represents the approximate order by which the manuscripts were written. In the manuscripts my coauthors and I have focused both on the results that can contribute to what is known about northern eider biology in general or winter ecology in general and on the results that relate more specifically to Greenland and the study area in question. In this introduction I have focused most on the last issue, partly as an attempt to learn as much as possible about this particular wintering area - acknowledging that habitat characteristics and human exploitation are indeed highly site-specific variables, and partly because the studies in this thesis primarily had a management scope.

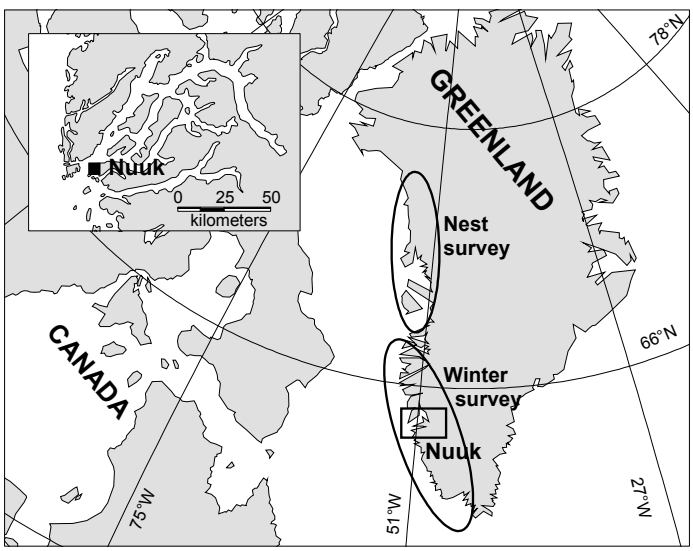

Fig. 3. Study areas, 1998 - 2003.

With respect to focus and aims the thesis can be divided in two parts. The first part aimed at, 1) quantifying the distribution and abundance of Common Eiders wintering in Greenland, and 2) collecting information about numbers and population trends in breeding areas of West Greenland (Fig. 3). These surveys (ms 1+2) were initiated prior to my PhD proposal, but included because they compose important settings for the main thesis and because some of this work was carried out within the four-year time frame of my PhD. The second part focused on a smaller case study area in Southwest Greenland (Nuuk, Fig. 3) and the interactions between harvest, body condition and habitat use of Common Eiders during winter. This work included data collection on winter ecology aspects for which no previous knowledge existed, including information about abundance in key marine habitats, daily movements and home ranges in mid and late winter, body condition in relation to habitat use and hunting issues, assessment of the impact of hunting and bycatch levels, and information on foraging behaviour and diet habits in relation to habitat characteristics and disturbances. By focusing primarily on a single study area and by using a range of methods, I aimed at 3) pinpointing factors that are important for the local distribution and behaviour of birds in winter, and 4) assessing the vulnerability of the local eider population to human harvest activity and if possible quantify the impacts of these activities. The overall objective was to obtain a more solid foundation for future management of the Common Eider.

Nuuk was an appropriate choice for the second part of the work since the initial winter survey (ms 1) identified this area as a key wintering area within the open water area of Southwest Greenland. In addition, Nuuk support the largest concentration of commercial- and recreational hunters in Greenland and therefore makes it ideal for studies on human impacts. At the same time, Nuuk supports two general types of eider habitats – outer coastal habitats and fjord habitats, which differ markedly in terms of habitat characteristics and human exposure and which allows the use of a comparative approach. The outer coastal area is an extensive ar-

chipelago that includes relatively large areas of shallow waters, whereas the fjords to the east are lined with steep cliffs and only few shallow water areas.

The methods used during the course of this PhD include aerial surveys, breeding ground surveys, local market surveys, harvest statistics analysis, satellite telemetry, body condition analysis, X-ray examinations, diet analysis, behavioural observations and a variety of statistical methods. With these I will not go into details, but only refer to the manuscripts. Fieldwork and satellite transmitting periods spanned over the period 1998 - 2002, including the aerial winter survey and breeding ground survey.

6.3 Winter distribution and abundance

The Baffin Bay and the western part of the Davis Strait are dominated by the cold, southward flowing Labrador Current. During winter, dense pack ice is formed in this area (Fig. 4). On the Greenland side, the north flowing West Greenland Current dominates the eastern part of the Davis Strait. The upper layer (0 - 150 m) of this current consists of cold water of polar origin from the East Greenland Current, where the bottom layer (150 - 800 m) of warmer water originates from the Irminger Current—a branch of the North Atlantic Current (Valeur et al. 1997). Both layers are transported round the southern tip of Greenland, Kap Farvel (Cape Farewell). As they mix and move north, they create a year-round open water area along Southwest Greenland—referred to as the Southwest Greenland open water area. It usually extends from Sisimiut (67° N) in the north to Paamiut (62° N) in the south (Fig. 4) (Valeur et al. 1996; Valeur et al. 1997; Mosbech et al. 2000).

Previous efforts to quantify seabird abundance in the open water area of Southwest Greenland primarily focused on important offshore wintering areas with respect to oil pollution concerns, such as Store Hellefiskebanke and Fyllas Banke (Durinck and Falk 1996; Mosbech and Johnson 1999), while only a small proportion of the coastal waters and the fjords in Southwest Greenland had been surveyed. The offshore areas are of little importance to the Common Eider (Ibid, Heide-Jørgensen et al. 1999).

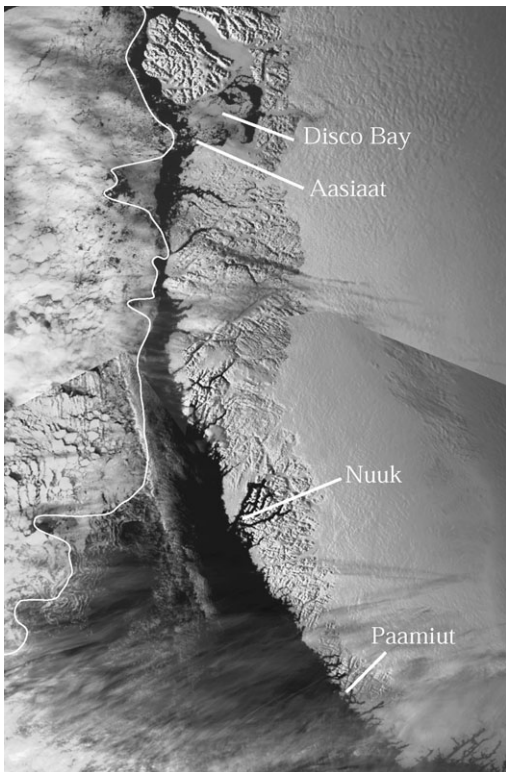

Fig. 4. The Southwest Greenland open water area, showing the western edge of the pack ice in March 1998 (modified from Boertmann et al. 2004).

The aerial survey that we conducted in 1999 covered for the first time ever the entire coastal zone of the open water area and at least half of the fjords (ms 1). The Common Eider was identified as the species with the most wide-ranging distribution in the coastal zone of Southwest Greenland and also the most abundant species. The number of birds in the coastal zone was estimated at 358,960 birds (95 % CL: 243,025 – 530,202). Combined with a count of 103,834 birds in the fjords, the total number of Common Ei-

ders was estimated at 462,794 birds (95 % CL: 341,573 – 627,036). In general, the sighting rate was high and flock size low at the coastal zone, whereas relatively few, but large flocks were seen in the fjords, with up to 6,500 birds per flock. Waters around Nuuk and within the Julianehåb Bay area, South Greenland, were identified as key wintering areas for Common Eiders due to high densities both at the coastal zone and in the adjoining fjord system. An estimated number of 56,735 (95 % CL: 44,962 – 71,589) birds occupied the Nuuk area and 95,754 (95 % CL: 78,256 – 117,165) the Julianehåb Bay area. In both cases, approximately half the birds were located in the fjords.

For the Common Eider the results emphasized the importance of Southwest Greenland as a wintering area for the eastern Canadian breeding population. From band recoveries it was known that only birds from western Greenland and eastern Canadian Arctic wintered in Southwest Greenland, however, the magnitude of contribution from Canada was uncertain (Salomonsen 1967; Abraham and Finney 1986; Lyngs 2003). Combining information from the winter survey with a concurrently updated estimate on the breeding population in West Greenland (Merkel 2002), which indicated that no more than 15,000 pairs was breeding there, it was now clear that there was a massive influx from Canadian breeding grounds – more than 400,000 birds.

The results from the Greenland winter survey were combined with available numbers on the smaller segment of Common Eiders that winter in Maritime Canada to estimate the total size of the northern Common Eider population (Fig. 5). Based on this, a Northern Common Eider population model was developed (Gilchrist et al. 2001). This model indicated that reported harvest levels in Southwest Greenland were not sustainable. Estimated, the harvest should be reduced by approximately 40% to stop projected population declines.

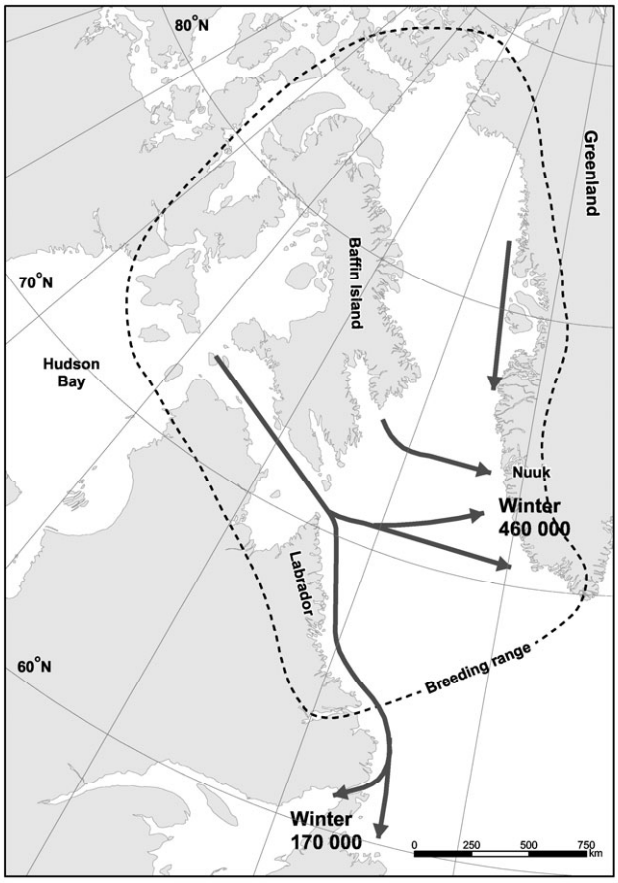

Fig. 5. Approximate breeding range for the Northern Common Eider, autumn migration flyways as determined by satellite telemetry (Mosbech et al. submitted) and winter population estimates in Greenland (ms 1) and Canada (S. Gilliland, pers. com.).

6.4 Population development

Although the northern eider model indicated unsustainable harvest levels in Greenland and it was commonly accepted that the Greenland breeding population had suffered a major decline, the evidence for this was fragmentary and not conclusive. Most quantitative information about

breeding numbers dated back to the 1960s and only a few recent efforts had been made to evaluate population status. In 1997, a minor survey in mid-west Greenland (Kangaatsiaq) showed a dramatic decline of approximately 80% since the 1960s (Frich et al. 1998), while a survey in Northwest Greenland (Avanersuaq) indicated a stable breeding population (Christensen and Falk, 2001).

To fill in the incomplete picture of the population status in West Greenland, I initiated surveys in three other districts of West Greenland: Upernavik, Uummannaq, and Ilulissat (69°15' N to 74°05' N, ms 2). From old surveys these areas were known as important breeding grounds in West Greenland (Joensen and Preuss 1972). In the period 1998–2001, we conducted ground surveys on 937 potential nesting islands in West Greenland, covering most of the three districts. On 216 islands, corresponding to 106 eider colonies, 4,097 ± 468 active nests were identified. When comparing 15 colonies that were surveyed with similar methods in 1960, the results indicate a population decline of 81% (from 3361 to 624 nests). A larger, but more rough comparison (including extra colonies with less detailed historical information), showed that of 51 eider colonies surveyed in 1920, 1960, or 1965, 71% were either abandoned or had a smaller number of active nests when resurveyed in 1998–2001. At the colony level, the 1998–2001 surveys revealed large year-to-year variations in nesting numbers, but not nearly enough to explain the observed decline.

The results confirmed previous concerns that the West Greenland breeding population had suffered a large decline. The recent surveys in West Greenland suggest that the decline has occurred in all major breeding areas, except for the most northern area (Christensen and Falk 2001). What remains unanswered is exactly when the decline occurred, given that most previous surveys were conducted approximately 40 years ago. The 1998-2001 survey did not pinpoint any obvious reasons for the observed decline. Colony specific clutch size data from the Upernavik district showed that clutch size was slightly higher during the 1998-2001 survey compared to a 1965 survey (3.40 versus 3.20 eggs/nest, respectively), and does not indicate more favourable historical breeding conditions. The study did reveal, however, that egging is still practiced to some extent in these areas. Egging has not been legal since 1977.

Fig. 6. The local market in Nuuk.

6.5 Hunting and bycatch of eiders

As previously mentioned, the wintering area of Nuuk was appropriate as a case study area due to high densities of both eiders and hunters, and due to the existence of both coastal habitats and the more remote fjord habitats, which I knew beforehand differed in terms of human activity and habitat characteristics.

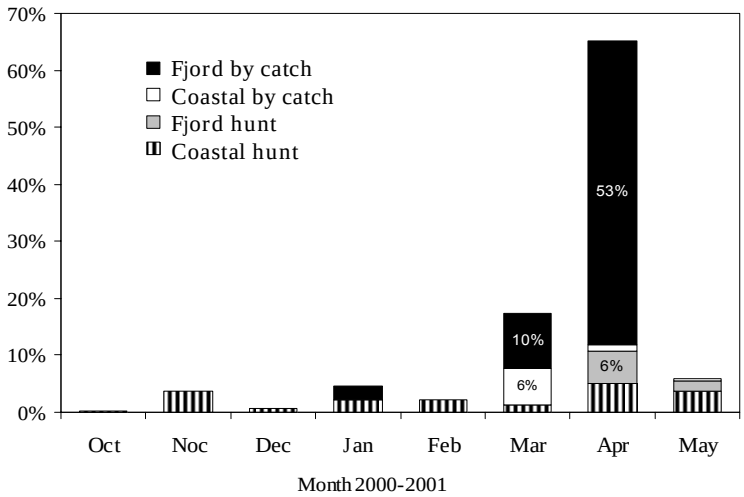

Fig. 7. Distribution and origin of adult Common Eiders supplied by commercial hunters to the local market in Nuuk during the eider hunting season from Oct. 2000 until May 2001.

The Greenland winter survey gave the first indication that also the habitat use of the eiders differed between these two areas. The fjord birds congregated to form huge and very densely packed flocks. In contrast, eiders at the coastal zone were distributed rather evenly as individuals or in small groups. Why this difference in behaviour?

As a descriptive baseline for the work carried out in Nuuk, I studied the composition and the spatial and temporal distribution of the eider harvest in Nuuk. The official bag-report system collects harvest information on a monthly basis for each hunter and does not include records on the specific origin of the harvest. This can, however, be obtained at the local market, which is the place where commercial hunters and fishermen take their captures for sale. Most communities in West Greenland have their own local market and usually they are open all year around. Game bagged by recreational hunters cannot be sold at the local market and therefore is not represented by local market surveys. However, at least in Nuuk, commercial hunters account for the majority of the eider harvest, approximately two thirds.

I surveyed the local market in Nuuk during the hunting season (Oct.-May) in 2000 and 2001. I found that no hunting took place in the inner part of the fjord system, but hunting within 20 km of the city was the source of 91% of all eiders sent to market from October until March. In contrast, bycatch in Lumpsucker (*Cyclopterus lumpus*) gillnets accounted for 52% of the eiders recorded at the market in March and April. The April bycatch were mainly from remote fjord locations and compared to bycatch incidences within the coastal area the proportion of adult birds was very high (Fig. 7). A minimum estimate for the total bycatch of eider was 1,486 birds in 2000 and 1,828 in 2001. The large quantity of bycatch was a bit surprising because previous studies at the local market in Nuuk did report such bycatch (Frich and Falk 1997). This is probably related to an increasing Lumpsucker industry; processing companies in Nuuk report on a tenfold increase in Lumpsucker landings during recent years, from approximately 100 tons/year prior to 1996 and 989 tons in 2001. These findings may indicate a huge conservation problem if bycatch occurs at similar rates elsewhere in Southwest Greenland. Nuuk accounts for one third of the Lumpsucker landings in Southwest Greenland.

Since the Common Eider is a species with high adult survival rate, small clutch size and delayed maturity its population dy-

namic is far more sensitive to reductions in adult survival than breeding failure or survival of immature birds (Furness and Monaghan 1987; Goudie et al. 2000). Thus, with respect to harvest, the relative impact and the potential additive effect to other mortality factors are much higher when killing adult birds compared to juvenile birds. To assess the relative impact of harvest (hunting and bycatch) in Nuuk I employed a simplified model, which accounted for some of these factors. As measured by the removal of potential reproductive eiders, this model showed that April and May constituted the more critical harvest period for the Common Eider; partly because the share of adult birds in the harvest increased over the season and partly because the survival of juvenile birds markedly increased as winter progressed. By simulating that all Common Eiders harvested in April and May instead were shot early in the hunting season (equally distributed over the period Oct.-Dec.), the model predicted that the take of adult birds would be reduced by 31%, even though the total number of eiders harvested would remain unchanged. Thus, from a conservation perspective, it appears that a lot could be gained by rescheduling the harvesting effort. However, the management is complicated by the fact that there is a sympatric distribution of King Eiders within the most common hunting grounds and this species will not benefit from such changes (see 6.10).

6.6 Embedded lead shot and body condition

In addition to the direct hunting mortality, an unknown number of birds are wounded and not retrieved. A proportion of the wounded individuals later die as a direct consequence of the shot, but some survive and carry the non-lethal lead pellets as embedded shot (Fig. 1). This embedded shot factor is a widely reported side-effects of hunting (Scheuhammer and Norris 1995; Newton 1998). Depending on the type of injury, lead pellet carriers may be expected to experience a reduced ability to move around and forage for a period of time after being injured, and hence body condition might be reduced as a direct consequence of infliction (Van Dyke 1981). In Pink-footed Geese (*Anser brachyrhynchus*) it has been shown that birds carrying embedded shot had a lower annual survival rate than non-carriers (Madsen & Noer 1996).

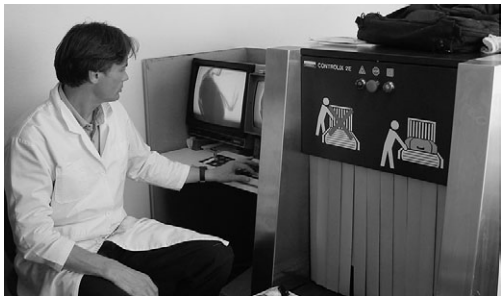

Fig. 8. Eiders X-rayed for embedded shot at the local airport in Nuuk.

Although traditional lead shot has been replaced by steel shot in many countries this is not the case in Greenland. Therefore, the embedded shot may have consequences not only for the eiders, but also for humans and wildlife that may consume contaminated eider meat.

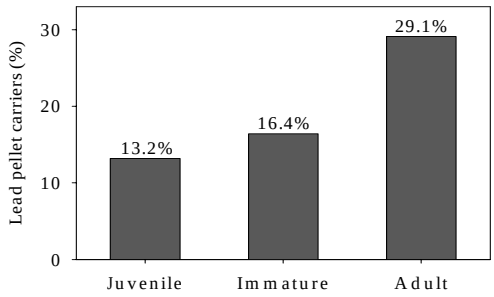

Fig. 9. The proportion of lead pellet carriers among 625 Common Eiders from Nuuk (ms 4).

In Nuuk, we studied the frequency of embedded shot and the effect on Common Eider body condition (ms 4 + 5). The X-ray examinations showed that the proportion of Common Eiders carrying em-

bedded shot increased gradually by age (Fig. 9). Overall, 22 % carried embedded shot when pooled over age. According to logistic regression analyses, only age and sampling habitat (coast or fjord) were significant factors contributing to the risk of an eider being wounded. A significantly smaller proportion of the adult birds collected in fjord were embedded with lead shot (24.5 %) compared to birds collected in the more heavily hunted coastal areas (35.0 %) and suggests some extent of segregation between these areas. Among inflicted birds, juveniles contained more pellets (mean 2.2) than adults (mean 1.7), despite the adults' longer time to accumulate pellets from multiple inflictions, suggesting that the most burdened juveniles die before entering the older age classes. To what extent this mortality is additive to natural sources of mortality is not known. Based on certain assumptions and estimated infliction rates of 13.2% for juvenile birds and 1.8 – 3.0% for older birds (immature and adult), each year 21,000 juveniles, 1,200-1,800 immatures and 4,800-7,300 adults become new carriers of embedded shot in Southwest Greenland.

Prior to the analysis of body condition, we conducted total carcass analyses on 92 birds to extract the total amount of lipids and protein (ms 6). By doing this we were able to test previously published models and derive new models for accurately estimating the lipid content. We found that previously published models did not provide an accurate estimation for northern Common Eider ducks. However, new models that were derived using body mass, weights of individual fat depots and muscle groups, measured during dissection, were able to accurately estimate the lipid content (R_{adj}^2 = 0.93, Root Mean Squared Error = 14.60). The analyses also showed that models derived using only external measurements resulted in inaccurate models, and emphasize that dissections are important if lipid mass data are required.

Using the best model for body condition, derived from the total carcass analysis (ms 6), we found that embedded lead shot had a significant effect on juvenile body condition (ms 5). Unwounded juvenile birds carried on average 19% more fat compared to wounded juveniles (Fig. 10). No impact of wounding was detected on immature and adult body condition. For most of these older birds, the shooting incidence took place one or several years ago, and the non-significant test results indicate the absence of a long-term effect on body condition once birds have survived and healed from the initial effect of wounding.

Related studies indicate that the management of Common Eiders also should account for the possibility of biochemical (toxic) effects on man and wildlife, caused by the ingestion of eiders killed or wounded by lead shot. Johansen et al. (2004) calculated that just one meal of ei-

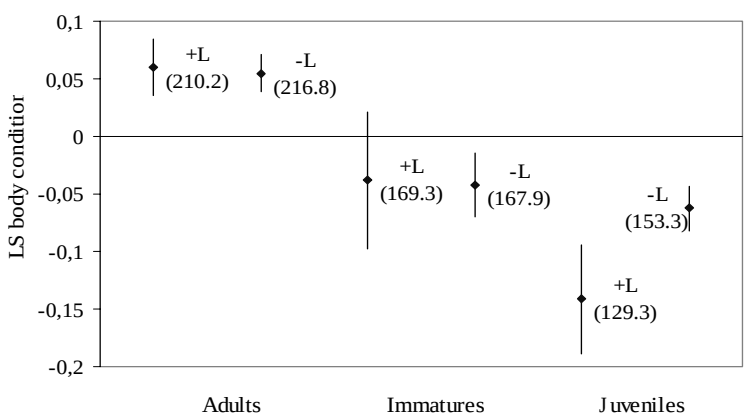

Fig. 10. Body condition (least square means) in relation to age and embedded lead shot for Common Eiders collected in Nuuk 2000-2002. Numbers in brackets show the estimated total body fat (grams). +L = embedded with lead shot, and –L = no lead.

der (killed by lead shot) per week, on average resulted in a lead intake close to unsafe limits. For the White-tailed Sea Eagle (*Haliaeetus albicilla groenlandicus*), a common predator of eiders in Greenland, Krone et al. (2004) concluded that secondary lead poisoning sometimes are lethal to the eagles.

Fig. 11. Common Eider drake with satellite transmitter.

6.7 Habitat use and body condition

The findings outlined so far indicate that there is reason to distinguish between eiders in the inner fjord habitats east of Nuuk and in the coastal habitats of Nuuk. They differ markedly with respect to: distribution patterns (flock sizes, ms 1); demography (a large proportion of young birds in coastal areas and a large proportion of adults in the fjord, ms 3); the frequency of birds embedded with lead shot (25% in the fjord and 35% in coastal areas); and finally, their exposure to hunting differed distinctively. Based on the estimated infliction rate for older birds (1.8 – 3.0%), it is clear that a 10% differences in embedded shot frequency could not exist if birds selected randomly between coast and fjord on a yearly basis. On the other hand, it is clear that fjord birds will be exposed to hunting in autumn and spring when they pass the coastal area, but hardly enough to arrive at 25%. Since the vast majority of the eiders in Southwest Greenland are from Canadian breeding grounds wounding incidences at Greenlandic breeding grounds would add only little to this. Additional wounding incidences on the Canadian side may occur in the main "source area" of the eiders, Baffin Island and Hudson Strait in Nunavut; however, eider hunt in Nunavut is moderate compared to the Greenland hunt; Gilchrist et al. (2001) cite the Nunavut Wildlife Management Board for about 2,400 adult eiders killed mainly in an early spring hunt. Further, steel shot has been gradually introduced in Canada over the period 1997 - 1999 and we did not detect one single steel pellet during dissections. Therefore, to explain the embedded shot frequency of 25% in the fjord some movements from the coastal area must occur, however, limited to such an extent that a significant difference in embedded shot frequency can be maintained.

In the winter 2000 and 2001 we implanted 33 Common Eiders with satellite transmitters in the Nuuk area (Fig. 11). Besides the intention to explore the nature of the exchange of eiders between fjord areas and coastal areas, we wanted get information about winter home ranges, range utilization, as well as daily movement patterns. Site fidelity during winter, within or between seasons, has received little attention (Robertson and Cooke 1999), although this is important to understand how local environmental conditions (e.g. food availability, oil spill incidents, fishing- and hunting activities) may affect fitness of wintering birds. Satellite telemetry was also employed with the purpose of linking wintering areas and breeding grounds (Mosbech et al. submitted); however, the migration issue is not dealt with in this thesis.

The satellite telemetry indicated strong site fidelity among eiders in the study period from mid-winter until spring migration with a mean core area (50%) of 5.7 km^2 and distances travelled between roosting sites and daytime feeding areas were short - on average 1.7 km. Of 32 eiders, 28% used on average 2.1 wintering

sites, but the remaining 72% used only one site. The study supports the prediction of a limited exchange of birds between coastal areas and the inner fjord system. Among birds marked at coastal habitats, between 8 – 29% of the birds also used the inner fjord habitats. The 8% represent the observed number, while 29% take into account that some birds may have moved to fjord habitats after the transmission period. Birds that did move to the inner fjord system did not return to the coastal area and none of the birds marked within the fjord went to the coastal area before the onset of spring migration. Thus, the results indicate a small one-way exchange from the coast to the fjord, which may explain why there is only a 10% difference in the embedded shot frequency.

The body condition of adult fjord birds was either superior or equal to that of coastal birds. However, variation both within-years and between-years in body condition were largest for fjord birds, suggesting that they were challenged by a higher unpredictability in habitat quality. Our findings accentuate the need for managing wintering Common Eiders in Southwest Greenland at a local scale, taking site fidelity into account. In both years (2000 and 2001) at the coastal area and in one year in the fjord (2000) adult body condition declined from late winter to early spring and suggests that eiders often build up body reserves for the breeding season elsewhere.

6.8 Habitat and diet

According to optimal foraging theories birds should select the habitat that provides the highest gain of energy per time unit in order to maximize individual fitness (Werner et al. 1981; Stephens and Krebs 1986; Abrahams and Dill 1989). However, habitat selection may be influenced by factors beside food availability and quality. Birds may be exposed to high predation or human disturbances (Madsen and Fox 1995) and may be able to improve overall fitness by moving to poorer quality habitats, i.e., food-wise (Abrahams and Dill 1989). In the Nuuk wintering area there are obvious reasons why eiders should avoid coastal habitats – the risk of getting shot and the risk of loosing valuable feeding time when disturbed. Despite of this, approximately half the local winter population occupy the coastal area (ms 1) and it appears that most of these remain faithful to this area throughout extended periods of the winter, assuming that we have tracked representative individuals (ms 7). Therefore, we expected the fjord habitats to be associated with one or more compromising factors of habitat quality, which could explain why eiders did not abandon the coastal area to any large extent. The diet quality could be such a factor.

Fig. 12. *Mya eideri*, the dominant prey species

We analysed 241 gullet samples (esophageal-proventricular content) collected over three winters in Nuuk. To avoid potential bias due to differences in retention time for different prey types we did not include gizzard samples (Swanson and Bartonek 1970; Bustnes and Systad 2001). The diet habits of Common Eiders had not previously been studied in Greenland.

The results showed that there was a considerable difference in the diet between

coastal habitats and fjord habitats. Although there was a relatively high diet overlap (59%), diet diversity was significantly higher in coastal habitats. The fjord diet was dominated more by bivalves; two species of echinoderms were absent and no crustaceans were present in the fjord diet. Crustacean diet items represent high-energy food, but often they are less predicable in time and space compared to sessile bivalves. Juvenile birds contained relatively high proportions of this diet and only for this age group did crustaceans make up more than 10% of the diet. This may be a consequence of juveniles having higher nutritional demands (smaller and not fully grown) or less developed gizzards. At the same time juveniles are often in poor body condition (Fig. 10 and ms 5), compared to older more experienced foragers and may therefore behave as "risk-prone foragers" more often, seeking the high-energy, but less predicable crustacean diet to enhance their survival (Guillemette et al. 1992; Bustnes et al. 2000). This theory is in accordance with a study of Goudie and Ankney (1986), who found an inverse relationship between diet quality and body size in four sea duck species. They concluded that the higher energy requirements per gram live mass for the small species could not be met by low-energy benthic prey species. In the Nuuk case, the higher preference for high-energy crustacean diet among juvenile birds may be partly responsible for the disproportional small numbers of juveniles in the fjord.

6.9 Foraging and the impact of disturbances

As with several other aspects of the Common Eider winter ecology studied in Nuuk, no previous information was available on the feeding habits in the Southwest Greenland wintering area. We conducted behavioural observations within a coastal study area and at a remote fjord location to describe their overall feeding patterns and to explore if differences in habitat characteristics and hunting pressure were reflected in the daily behaviour of the eiders (ms 9). Especially, we were interested in whether birds from the more disturbed coastal area expanded their feeding beyond the diurnal period to fulfill their daily energy needs in mid-winter when day length was markedly reduced. Studies from other eider locations at northern latitudes show that birds can cope with reduced foraging time (day length) by extending their feeding into periods with lower light intensities (Systad et al. 2000; Systad and Bustnes 2001). Among other waterfowl species, nocturnal feeding has been reported as a common strategy to compensate for human or predator disturbances during daylight hours (reviewed by McNeil et al. 1992).

In the more disturbed coastal area of Nuuk we did find evidence of nocturnal feeding, however, only as an exception to the general feeding pattern. Primarily, eiders were identified as diurnal feeders, although feeding normally was extended to include the twilight periods (Fig. 13). Nocturnal feeding was recorded in two of 24 night observation periods and in one case this coincided with the highest number of human disturbances recorded during daytime. In the other case no information on daytime events was available.

In contrast to our expectations, eiders in the less disturbed fjord habitat were identified as nocturnal feeders (Fig. 13). During daytime birds were consistently gathered in large communal roosts away from feeding areas. As an exception to this pattern, feeding was occasionally initiated by juveniles during daytime; however, the feeding was discontinued due to interactions with White-tailed Sea Eagles. These observations indicate that nocturnal feeding in the fjord is an anti-predator mechanism. The more experienced adult birds did not attempt feeding during daylight hours. Large communal roosts located at deep waters were observed at numerous

fjord locations during the aerial winter survey (ms 1) and suggest that nocturnal feeding is common throughout the fjords in Southwest Greenland.

The results indicate that the predation-risk factor caused by White-tailed Sea Eagles in the fjord constitute a compromising factor that can explain why the fjord habitats are not obvious refuge sites for coastal birds experiencing a high level of human activity. The observations that juvenile birds attempted to depart the nocturnal feeding strategy in the fjord adds further to the discussion about nutritional demands of smaller and younger birds and compose an additional or alternative explanation for the disproportional small numbers of juveniles in the fjord.

We performed a more thorough analysis of the feeding activity in the coastal study area to assess whether the human-induced disturbances in fact had a measurable impact on the feeding behaviour of the eiders. If not, there was perhaps no reason to expect eiders to avoid these areas. We studied the feeding time allocation of the eiders and the impact of human disturbances relative to natural variables, such as tide levels and light conditions. We found that human disturbances reduced the effective habitat quality (probability of diving and inter-dive surface time versus other activities at a given site) in the study area up to 60% on a daily basis when most heavily disturbed. Instead, more time was allocated to locomotion (up to three times as much) and induced increased energy expenditure due to the risk-avoidance movements. Logistic regression analyses showed that eiders attempted to compensate for lost feeding opportunities by rescheduling some of the feeding to periods where feeding conditions were relatively less

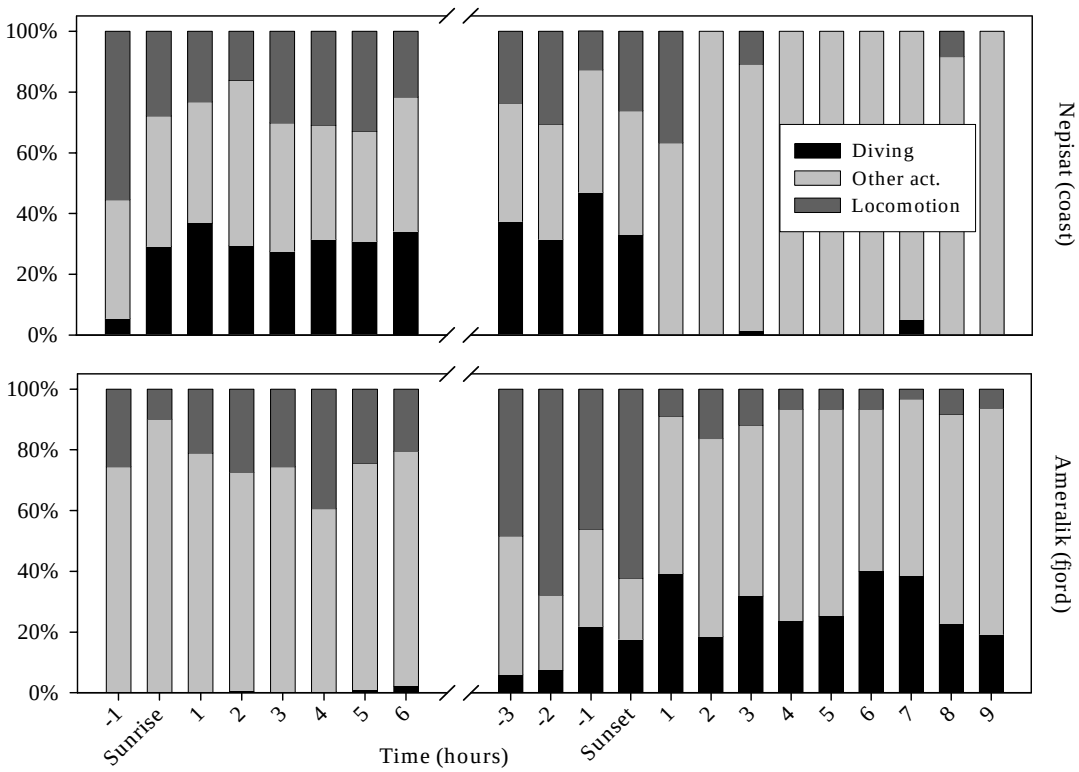

Fig. 13. The proportion of common eiders engaged in diving, locomotion and other activities in relation to time since sunrise and sunset and study site (coast or fjord), January - April, 2002.

profitable with respect to other variables. Eiders avoided feeding during high tide and they intensified feeding in the morning and again in late afternoon when undisturbed, but when disturbed, time of day and tide did not constitute important factors for feeding. When disturbed, the time since the last disturbance and the distance to the last disturbance were both significant explanatory variables for the feeding activity. Further, there was a cumulative effect of disturbances if these were repeated with short time intervals (3 boats / hour).

As previously mentioned the day with the highest number of recorded disturbances (17 boats) coincided with observations of nocturnal feeding the following night. This may indicate that a critical threshold of disturbances was reached where eiders no longer could obtain sufficient amounts of energy by diurnal feeding. On the other hand, if nocturnal feeding as a supplement to diurnal feeding is a competitive foraging strategy to balance the energy budget, then the eiders would posses a large potential for compensating even more if needed. However, seen in the light that adult eiders not far away appear to rely exclusively on nocturnal feeding, it is perhaps more plausible that diurnal feeding in combination with nocturnal feeding are durable only as a short-term solution.

6.10 Management concerns, recommendations and status

Some of the information generated from the current studies is highly relevant for the management of the northern Common Eider. For some management concern there are clear recommendations as how to improve the situation; however, for others the management may be more complicated. In the following I have listed the most important issues.

Harvest

- Southwest Greenland serves as wintering area for ca. 75% of the northern Common Eider population. At the same time more than 90% of the eiders breed outside Greenland (in Canada). A wise management of the staging and wintering areas in Greenland is therefore internationally important.
- It is possible that hunting mortality of Common Eiders becomes increasingly additive to natural mortality during the course of the hunting season due to increasing proportions of adults being killed. Avoidance of late winter and spring harvest would benefit both the adult survival and the reproduction.
- Based on the 1999 aerial winter survey the Nuuk area and the Julianehåb Bay area support one third of the total winter population of Common Eiders in Greenland. Cities and settlements within these two areas also support a large proportion (ca. 40%) of the Greenlandic human population and in consequence, both areas are heavily hunted. Therefore, high management priorities should be given to these two areas.
- The management of wintering eiders in Southwest Greenland is complicated by the fact that there is a sympatric distribution of King and Common Eiders in coastal waters, which also represent popular hunting grounds. Since the ratio between King and Common Eider changes during the hunting season in Nuuk, any joint conservation schedule would not benefit both species equally. The spring period (April and May) appears to be the more critical harvest period for the Common Eider, while the impact of harvest is probably highest during midwinter (January and February) for the King Eider. This is mainly due to a higher proportion of King Eiders in the coastal area during midwinter.

- This study, as well as previous ones, shows that hunters only rarely discriminate between King and Common Eiders. Usually around 5% are reported as King Eiders, while the true proportion is around 20-30% according to local market surveys in Nuuk. However, they are easy to tell apart if knowing what to look for. Knowledge about these characteristics should be more widely distributed.

Embedded shot

- Embedded lead shot significantly affects the body condition of juvenile Common Eiders. This may have consequences for their survival because juveniles, in general, carry limited body reserves compared to older birds.
- Up to 30,000 eiders will become new carriers of embedded shot each year in Southwest Greenland (all age groups). Measures should be taken to reduce the infliction rate. In Denmark a campaign about recommended shooting distances has successfully reduced the infliction rate for several species of waterbirds (Noer et al. 2001).
- In the case of Common Eider the importance of reducing the infliction rates is especially relevant for Greenland since the results clearly indicate that hunting in Greenland, rather than Canada, is responsible for the vast majority of embedded lead shot incidences. This is best illustrated by the juvenile birds, which arrive clean in Greenland, but by the end of their first hunting season 13% carries embedded shot.
- An unknown proportion of eiders will be severe wounded and later die (within hours or few days) as a direct consequence of the shot. To improve the knowledge about this crippling loss official harvest statistics should include the ratio between eiders "going down" and "eiders retrieved".
- As a worst case scenario up to 3,600 adult females might be unable to breed annually as a consequence of freshly embedded lead shot. This is approximately equal to a temporal loss (one year) of the breeding population in all 106 colonies (~ 4100 breeding pairs) in the central part of West Greenland (ms 2).
- The management of Common Eiders should account for the possibility of biochemical (toxic) effects on man and wildlife, caused by the ingestion of eiders killed or wounded by lead shot (Johansen et al. 2004; Krone et al. 2004) and thus should consider implementing steel shot regulations.

Bycatch

- The April bycatch of Common Eiders in Lumpsucker gillnets should be of high management concern (Fig. 7). Especially the bycatch from inside the Nuuk fjord system is highly damaging for the population due to the presence of a disproportional large number of adult birds. Initiatives should be taken to quantify the bycatch levels elsewhere in Southwest Greenland.
- It appears that the distribution of Common Eiders in the Nuuk fjord system coincide with important Lumpsucker fishing grounds. Among 23 incidents of Common Eider bycatch in the most remote fjord areas recorded during spring in 2000 and 2001, 17 occurred within areas previously defined as "important Lumpsucker fishing areas" by local fishermen (Nielsen et al. 2000). This clearly complicates the process of reducing the bycatch of eiders.
- There is evidence that only a fraction of the bycatch of eiders is reported as harvest. Initiatives should be taken to validate the harvest statistics.

Habitat

- The high density of eiders throughout the coastal zone of Southwest Greenland make them highly vulnerable to oil pollution (Mosbech et al. 1996). Exploratory drilling took place in the Fylla area (west of Nuuk) in 2000 and more is expected to come. Birds

occupying the innermost fjord sections may avoid exposure to oil. Spatial modelling that aims at forecasting eider distribution and abundance during winter is recommended.

- Common Eiders show a high degree of site fidelity during winter, which makes them more dependent/vulnerable to local environmental conditions, such as human activity and depletion of food resources.
- A possible demand for high-energy crustacean diet among juvenile Common Eiders may cause these birds to be more dependent on the coastal wintering area. As a consequence they are highly exposed to hunting and human-induced disturbances. However, from a conservation point of view this is advantageous since juvenile mortality has less influence as a factor for population regulation (more compensatory than adult mortality).
- Predator-prey interactions between eagles and eiders make the fjord habitats less qualified as natural refuge sites for coastal eiders when these experience high levels of hunting and disturbance. The present work indicate that this may also be the case elsewhere in Southwest Greenland. Behavioural studies are recommended at other fjord locations to confirm whether this is in fact the case.
- Human disturbances can seriously affect effective habitat quality on a daily basis as measured by the proportion of eiders devoted to feeding at a given site. In the coastal area of Nuuk a 60% reduction in feeding activity was detected. In ecological terms this is equal to a temporal habitat loss, which may become a permanent habitat loss if disturbances reach higher levels.
- Human disturbances caused by boating in the coastal area induce higher energy expenditure for the eiders due to risk-avoidance movements and lost feeding opportunities. When eiders attempt to compensate for this by intensifying feeding in undisturbed periods they often need to feed under unfavourable conditions, such as high tide levels. Spatial or temporal regulation in the form of permanent disturbance-free reserves or time-of-day limitations in access would ensure more favourable feeding conditions for the eiders.

The recommendation to avoid exploitation of Common Eiders in late winter and spring when mortality is expected to be most additive and harmful to the population has already been implemented – at least for the hunting part (not for the bycatch part). From 2004 the hunting season was shortened by three month - March, April and May. A first attempt to shorten the hunting season in 2002 failed and in 2003 the old hunting regulations were resumed. According to the official harvest statistics the harvest level has been reduced significantly subsequent to the new regulations, to about 30,000 birds (King and Common Eiders combined). Assuming that this number represents the actual take, this is less that half of what previously was reported and according to the 40% reduction recommended by Gilchrist et al. (2001) within sustainable levels.

Along with the regulations it became illegal to sell the bycatch of eiders at the local market and it became mandatory to report the bycatch of eiders as bycatch and not as hunted eiders. Currently, it is uncertain what this means for the bycatch level and whether the “harvesters” are willing to report bycatch. Until now up to ca. 1,250 Common Eiders have been reported as bycatch per year for all Greenland.

Habitat protection is not part of the new regulations.

6.11 Conclusions and future research

In conclusion, the present work accentuates the need for a flexible conservation protocol, which will enable adaptive management of subunit winter populations according to local environmental

conditions. Presently, wintering Common Eiders are managed the same throughout the open water area in Southwest Greenland, by open and closed seasons. This may, however, put excessive and unsustainable pressure on local fragments of the population. Unsustainable use, as a result of high site fidelity among waterbirds and poor management of wintering grounds has been reported for goose species. In Ireland and Britain such factors lead to local extinctions of Greenland White-fronted Geese (*Anser albifrons flavirostris*) (Ruttledge and Ogilvie 1979; Norriss and Wilson 1988). For Common Eiders wintering in Southwest Greenland, we recommend to use non-hunting disturbance-free reserves as a supplemental conservation tool. Experiments with a reserve network for migratory and wintering waterfowls in Denmark showed that both the number of birds and biodiversity increased when reserves were established (Madsen et al. 1998; Madsen 1998). In addition, the experiment showed that a reserve not only attracts more birds to the core area, but also the adjacent areas. Hunters thereby gain a form of compensation for lost hunting areas through improved hunting opportunities in surrounding areas (Madsen et al. 1998). Alternatively, temporal regulation is an option. Prohibiting access to certain areas every second day or every morning would allow eiders to rebalance their energy budget on a more regular basis. Based on experiments in Denmark temporal regulation is not as effective as spatial regulation (Madsen 2001; Bregnballe et al. 2004).

To what extend the recent shortening of the hunting season will make spatial or temporal habitat protection unnecessary is unknown. It is important to monitor population trends within breeding areas now and in the near future to see if breeding populations stabilize or start to increase. There is however, no question that the highest sustainable harvest yield can be obtained by managing eiders at the local scale using a combination on conservation tools; e.g., in Nuuk, the new regulations do not deal with the issue of bycatch, which in the current study period had a larger impact on the population than the bag removed by hunting.

The eiders tracked by satellite telemetry in Nuuk indicate high site fidelity within the season. However, management at the local scale is even more important if birds are also site faithful on a year-to-year basis. According to Spurr and Milne (1976) and Goudie et al. (2000) this is probably the case with Common Eiders. The satellite telemetry in Nuuk supports this assumption, although based on a small sample size: two of three transmitters, which were still active the next fall, were carried back (from Canada) to the original sampling site in Nuuk. The third bird arrived in Greenland in mid October ca. 150 km south of Nuuk and had not returned to Nuuk when transmissions stopped in early November. A forth eider was recovered (bycatch) at the original sampling site four years after implantation (Mosbech et al. submitted). In time, when satellite transmitters have improved to such an extent that they can transmit for several years, we will know much more about this.

In the Nuuk coastal area it appears that hunting and human disturbances impose challenging winter conditions for the eiders; however, one may argue that these are the trade offs for avoiding White-tailed Sea Eagle predation and a presumable less efficient nocturnal feeding strategy. The one-way exchange of birds from the outer coast to the inner fjord may indicate that some birds can benefit from switching to the fjord habitats under the current study conditions. However, the distribution and behaviour of juvenile birds suggest that this was not case for this age group. For the juveniles, a high energy demand perhaps combined with limitations in the capacity to process the shell content of bivalves may play a sig-

nificant role for habitat selection. For these inexperienced birds there may also be a learning process involved in practicing a nocturnal feeding strategy.

This study showed that eiders exposed to human-induced disturbances compensated for lost feeding opportunities by changing the allocation of feeding time to alternative periods; however, potentially they could compensate in a number of ways, e.g., by switching to more high-energy prey items or increase the ratio between diving time and surface time. Such factors were not considered in this thesis. Also the relationship between prey selection and prey availability was not studied. This is required to fully understand the role of food for habitat selection. Ultimately, habitat selection is decision-making based on a variety of trade offs and the present work may have identified only some of the trade offs that exist in the Nuuk wintering area.

Factors such as gained experience and social connections may prove to be important for habitat selection. If birds remain faithful to a certain area for such reasons they may not necessarily be expected to move to, or search for, superior alternative habitats. In the Nuuk area foraging is limited within fjord habitats to areas very close to land due to the lack of shallow waters elsewhere; here eiders are heavily exposed to predation from the White-tailed Sea Eagle during daylight hours. In contrast, coastal habitats support larger areas of shallow waters, at which eiders can feed in safe distance from land. This clearly illustrates the potential significance of being faithful to a specific area, for which birds have obtained familiarity. Familiarity to specific areas (for breeding, staging or wintering) is believed to be one of the most important factors responsible for establishing site fidelity (Robertson and Cooke 1999). Social connections between individuals may play a similar role for site fidelity, but little is known about this. In some cases eiders are known to pair on the wintering grounds (Goudie et al. 2000), but there may be other factors that tie individuals together. From breeding areas it is known that eiders occur in family groups (crèches) (Bustnes and Erikstad 1991), but it is unknown for how long these bonds are maintained. If they are maintained also during winter they could easily play a role in habitat selection and for site fidelity. To my knowledge, this has not been studied.

Finally, nocturnal feeding in eiders deserves more attention. In the case of Southwest Greenland it would be important to know whether nocturnal feeding is practiced throughout the fjords in Southwest Greenland as suggested by the distribution pattern of birds during daytime. Further, the use of nocturnal feeding during winter-time is interesting with respect to body condition dynamics. In the Arctic, mid-winter is often considered as a critical and limiting period in terms of survival due to harsh weather and short days (Lima 1986; Furness and Monaghan 1987; Blem 1990). This may be a simplified prediction for nocturnal feeders since mid-winter will represent the period with the maximum amount of time available for nocturnal feeding. A more thorough quantification of nocturnal feeding could be obtained by using new prototypes of satellite transmitters, which include pressure sensors (Mosbech et al. in press). The general assumption is that sea ducks are visual feeders; however, clearly this is not always the case. More knowledge is needed about foraging techniques to fully understand the capacity of diving birds to balance their energy budget. A recent and striking example is the findings by Grémillet et al. (2005), who demonstrated that the Great Cormorant (*Phalacrocorax carbo*) perform up to 50% of its dive bouts in complete darkness during the Arctic mid-winter period. The Great Cormorant is a visual hunter preying on fish and expectedly highly dependent on visual cues.

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PhD thesis

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