THICK-BILLED MURRE STUDIES IN DISKO BAY (RITENBENK), WEST GREENLAND

NERI Technical Report no. 749 2009

NATIONAL ENVIRONMENTAL RESEARCH INSTITUTE
AARHUS UNIVERSITY

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Abstract: Studies of Thick-billed Murre were carried out in the colony at Ritenbenk/Innaq which has declined severely and is estimated to 2447 birds in 2006. This report includes studies of colony attendance, population estimate, population modelling and sustainable harvest modelling, chick feeding and foraging activities and migration based on ringing recoveries and satellite telemetry.

Keywords: Thick-billed Murre, migration, satellite tracking, Ritenbenk, population modelling, foraging behavior, chick feeding.

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Summary and recommendations

This report describes studies carried out in 2005-07 in the thick-billed murre colony at Ritenbenk/Innaq in NE Disko Bay. This is the only remaining murre colony in Disko Bay, and breeding numbers have probably declined more than tenfold in the last 50 years. The purpose of the study programme was to improve understanding of the population decline and its causes, as well as to map the swimming migration and identify areas critical to the well-being of the colony. The aim has been to create an improved background knowledge which can be used to limit the negative effects on colony growth from oil exploration, hunting and human disturbance.

The studies have been carried out as part of a background survey programme for the Strategic Environmental Impact Assessment of oil activities in the Disko West area, the preliminary results of which are published in Mosbech *et al*. (2007). An updated version of the SEIA, including results of further biological surveys of the Disko West area, is planned for publication in 2010.

The entire colony was counted both directly and from digital photos (chapter 2). In order to correct the total counts for diel as well as day-to-day variation in murre numbers, repeated counts of study plots were carried out. The most reliable count was 2,447 individuals, based on a total direct count 19 July 2006 and corrected for diel and day-to-day variation. Taking colony attendance into account, this is estimated to correspond to 1,835 breeding pairs.

The most recent previous count of the Ritenbenk colony was in 1998, when a comparable survey method provided an estimate of 3,415 individuals. This corresponds to a decline of 28%, or 4% per year.

Both the total counts and the repeat counts of study plots indicate an increase in the number of birds present from 2005 to 2006. However, this positive result should not be overemphasized, since considerable year-to-year variation in attendance may mean that the negative trend in colony size has not been reversed.

In order to investigate the mechanisms behind the population decline a simple matrix model of the thick-billed murre population at Ritenbenk was constructed. The model estimates the maximum sustainable harvest based on a number of assumptions (chapter 4). Model results were compared to the reported numbers shot in the official harvest statistics (Piniarneq). Harvest statistics show that the annual hunting bag in Ilulissat municipality in 1993-2001 was between 100 and 206 birds (except 40 in 1998). These birds were presumably mainly adult breeders, since few immatures occur near the colonies at this time of year. A comparison with results of the harvest model indicates that shooting of adult breeders is the most likely cause for the decline in colony size up to 2001, when summer hunting was banned. The model indicates that if this ban is respected and winter hunting pressure remains constant, there is a chance that the population will stabilise.

Migration routes and geographical distribution outside the breeding season of murres from Ritenbenk were studied using both ring recoveries and satellite tracking (chapter 5). During the last 60 years, approx. 2,800 murres have been ringed and 372 ringed birds have been recovered, 89% of these as shot in Disko Bay. The recoveries also show that Ritenbenk murres winter both in western Greenland and off Newfoundland.

Twenty-seven murres were equipped with satellite transmitters and tracked for up to 112 days. After leaving the colony in late July, the murres perform a swimming migration, during which the adults moult their flight feathers and the male parent accompanies the chick. The obtained tracks showed that 15 out of 16 males left Disko Bay through Vaigat, whereas females used routes N and S of Disko Island equally. Later in August and September most tracked murres occurred dispersed in SE Baffin Bay. While most birds thus moult their flight feathers in Baffin Bay, two of the birds migrated SW towards Labrador and Newfoundland. It is concluded that a large part of the population migrates through Vaigat and past Hareøen around 1 August, and that they will be very sensitive to an oil spill in this area. Similarly, the population will be very sensitive to oil spills in Disko Bay when they arrive in May.

Foraging behaviour (dive activity and chick feeding) was studied in 2006 to investigate whether food limitation during the breeding season might affect chick survival and thus population growth. Dive activity was recorded using miniature leg-mounted data loggers, whereas chick feeding frequencies were observed directly. Capelin was an important food item in 2006, feeding trips were relatively brief, and the proportion of time birds spent diving was relatively low (< 10%). The overall impression was thus that food availability was sufficient in 2006.

The kittiwake population was counted both in 2005 and 2006 and had 2783 and 1811 'apparently occupied nests' respectively. In 1984 the population was counted to c. 22000 nests, and in 1994-98 to c. 6000 nests, indicating a severely population decline of 14% per year. Breeding success was rather high in both 2005 and 2006 with 1.8-1.7 chicks per successful nest and about 10% of the nests had three chicks, indicating that foraging conditions during breeding were favourable in both years despite the decline in population size.

The study programme also included a survey of tourist activities around the colony. Tour operators in Ilulissat were interviewed, and during fieldwork two tourist boats were observed near the colony. None of the Ilulissat tour operators made regular trips to the bird cliff at Ritenbenk, and the main reasons cited for this were distance (too far for a day trip) and lack of specific interest among tourists mainly focussed on icebergs. However, the declining population at the colony and the risk of encountering illegal hunting activities were also mentioned as contributing causes for the limited use of the colony in tourism contexts.

Recommendations

Overall, the evaluation is that the thick-billed murre colony at Ritenbenk has a chance of recovering if spring/summer hunting in Disko Bay has ceased, and if the high food availability inferred in 2006 is representative.

The decrease in the kittiwake population is of concern and needs further studies.

We recommend at the local scale:

- Frequent counts in order to monitor population growth of thick-billed murre and kittiwake
- Communicating knowledge locally in relation to changes in colony size and the importance of the ban on spring/summer hunting
- Repeated surveys of foraging behaviour using data loggers, in order to improve the knowledge base and aid generalisation
- That the important areas for the thick-billed murres are included in the Oil Spill Sensistivity Map for the region.

The study has supported the national Greenland implementation of Arctic Council's CAFF International Murre Strategy and Action Plan. The joint analysis of studies like this from murre colonies in the CAFF area increases the understanding of the dynamics of the populations and greatly improves the knowledge available for sustainable management of the populations. We know from ringing recoveries that murres from colonies all of over the north Atlantic mix during migration and wintering especially in Canada and West Greenland. In CAFF CBird we are trying to model what hunting in the different areas and the chronic oil spill induced mortality off the coast of eastern Canada means for the different murre populations (colonies). However, the data available has too many gaps to link winter mortility back to the colonies. The use of satellite tracking has contributed with new detailed knowledge about some of the migration routes. However, a cheaper new tool for tracking, the geodatalogger, based on recapture on the breeding ledge after one year offers new possibilities. The geodatalogger weighs only few grams and can be attached with a conventional leg band. It will give sufficient data to identify wintering areas and main migration routes. Some models can also collect diving information reflecting how hard the murres work to feed themselves during the year in different areas, which is important information for assessing impacts of climate change.

We recommend at the international scale that:

Greenland takes the initiative in CAFF CBird to start a CAFF coordinated North Atlantic thick-billed murre geolocator banding program. The results from such a program would provide information to bring management of murre populations to a higher level where effects of climate change, chronic oil pollution and hunting could be linked to the population development in colonies in different areas.

Sammenfatning og anbefalinger

Denne rapport beskriver undersøgelser gennemført i havfuglekolonien ved Ritenbenk (Innaq) i den nordøstlige del af Diskobugten 2005-7. Polarlomviekolonien ved Ritenbenk er den eneste tilbageværende lomviekoloni i Disko Bugt regionen, og den vurderes at være reduceret til mindre end en tiendedel på 50 år. Undersøgelsernes formål har været at få en øget forståelse for polarlomviens bestandsudvikling og årsagerne til tilbagegangen samt kortlægge svømmetrækket og andre særligt vigtige områder for koloniens trivsel. Det har været målet at skabe et bedre videngrundlag, der kan bruges til at begrænse de negative faktorer for koloniens udvikling i forbindelse med olieefterforskning, jagt og mulige forstyrrelser. Rapportens hovedvægt er på polarlomvien, men undersøgelser af ride er taget med sidst i rapporten.

Undersøgelserne er gennemført som en del af et baggrundsundersøgelsesprogram for den strategiske miljøvurdering af olieaktiviteterne i Disko Vest området, hvor de foreløbige resultater er rapporteret (Mosbech *et al*. 2007). En opdateret udgave af den strategiske miljøvurdering med resultater af en række yderligere biologiske undersøgelser fra Disko Vest området er planlagt til udgivelse i 2010. Optællingerne indgår desuden i Grønlands Naturinstituts overvågningsprogram for havfuglekolonier og undersøgelsen medvirker til Grønlands nationale implementering af Arctic Councils CAFF International Murre Conservation Strategy and Action Plan. Når resultater fra kolonier i hele det arktiske område sammenlignes fås en større forståelse for lomviebestandenes trivsel og dynamik. En viden der benyttes til rådgivning om forvaltning af bestandene.

Hele lomviekolonien er blevet optalt både ved direkte tællinger og ved optælling på fotografier (Kapitel 2). I udvalgte områder af kolonien er der gennemført undersøgelser af døgnvariation og dag-til-dag variation i antallet af lomvier for at kunne korrigere totaloptællingerne. Det mest sikre optællingsresultat vurderes at være 2.447 individer talt ved en direkte totaloptælling den 19. juli 2006 og korrigeret for døgnvariation og dag-til-dag variationer. Dette antal individer på ynglehylderne estimeres at svare til 1.835 ynglepar, når der tages hensyn til hvor lang tid fuglene tilbringer på ynglehylderne.

Den forrige optælling af Ritenbenkkolonien blev foretaget i 1998, hvor bestanden på hylderne blev estimeret til 3.415 individer ved en sammenlignelig metode. Det svarer til en tilbagegang på 28%, eller 4% per år i perioden 1998-2006.

Både totaltællingerne og de intensive tællinger i et delområde tyder på, at der skete en vækst i antallet af lomvieynglepar fra 2005 til 2006. Dette positive resultat skal dog ikke overfortolkes. Da der kan være betydelig år-til-år variation betyder det ikke nødvendigvis, at koloniens negative udvikling er vendt.

For at undersøge mekanismerne i bestandsudviklingen er der opstillet en simpel matrix model for polarlomviebestanden i Ritenbenk kolonien.

Modellen estimerer den maximale bæredygtige fangst på baggrund af en række forudsætninger (Kapitel 3). Modelresultaterne er sammenlignet med de indrapporterede jagtudbytter i fangststatistikken (Piniarneq). Det fremgår af fangststatistikken, at det årlige jagtudbytte for juni og juli måned i Ilulissat kommune i perioden 1993-2001 var fra 100 til 206 fugle (dog 40 fugle i 1998). Disse fugle har formentlig især været voksne ynglefugle, da de fleste ungfugle ikke opholder sig nær kolonierne. Det konkluderes ved sammenligning med modellen for bæredygtig fangst, at det er højst sandsynligt, at jagten på de voksne ynglefugle i sommerperioden er hovedforklaringen på nedgangen i kolonien frem til 2001. Herefter er forårs- og sommer-jagten blevet forbudt. Hvis dette forbud overholdes og vinterjagttrykket ikke forøges viser modellen, at der er en chance for at nedgangen i kolonien vil stoppe.

Trækmønstre og fordeling af lomvier fra Ritenbenk uden for yngletiden er undersøgt dels ved en analyse af genmeldinger af ringmærkede fugle, dels ved sporing af fugle mærket med satellitsendere (Kapitel 4). Der er over en periode på 60 år mærket ca. 2800 lomvier, og der er kommet 372 genmeldinger. Af disse er 89% af de voksne lomvier genmeldt som skudte fra Diskobugten. Genmeldingerne viser bl.a., at lomvier fra Ritenbenk har vinterområder både i det nordlige Vestgrønland og ved Newfoundland.

27 lomvier er blevet udstyret med satellitsendere og sporet i op til 112 dage. Lomvierne gennemfører et svømmetræk, når de sidst i juli forlader kolonien. Under svømmetrækket fælder de voksne fugle svingfjerene, og hannen svømmer sammen med ungen. Ruterne for de sporede lomvier viser, at hovedparten (15 af 16) af hannerne svømmer ud gennem Vaigat, mens hunnernes ruter er ligeligt fordelt nord og syd om Diskoøen. Senere i august og september forekommer de fleste mærkede lomvier relativt spredt i den sydøstlige Baffin Bugt. Mens hovedparten af lomvierne således gennemfører fældning af svingfjerene i den sydøstlige Baffin Bugt trak to af lomvierne mod sydvest mod Labrador og Newfoundland. Det konkluderes, at omkring 1. august trækker en stor del af bestanden gennem Vaigat - Hareø området, og bestanden vil derfor være meget sårbar overfor et oliespild her, ligesom bestanden vil være meget sårbar overfor oliespild i Diskobugten fra fuglene ankommer i maj måned.

Lomviernes dykkeaktivitet og deres fodring af ungerne på redehylderne blev i 2006 undersøgt for at få et indtryk af, om der er en væsentlig fødebegrænsning på dette tidspunkt, som kan påvirke ungernes overlevelse og dermed bestandsudviklingen (Kapitel 5). Dykkeaktiviteten blev undersøgt med små dataloggere monteret i en ring om benet, mens fodringsfrekvenser blev observeret direkte. Fisken lodde/ammassat (*Mallotus villosus*) var et meget vigtigt fødeemne i 2006, fødesøgningsturene var relativt korte og den tid fuglene anvendte på dykning var begrænset (< 10%). Det samlede indtryk var således, at fødetilgængeligheden ikke var et problem i 2006.

Bestanden af rider på Ritenbenk-fuglefjeldet var også gået tilbage (Kapitel 6). Fuglefjeldet husede 2783 og 1811 'tilsyneladende besatte reder' af rider i henholdsvis 2005 og 2006. I 1984 var bestanden ca. 22000 reder, og i 1994-98 ca. 6000 reder, dvs. en årlig tilbagegang på ca. 14%. Ynglesucces var til gengæld ret høj i begge de undersøgte år, med 1.8-1.7 unger per succesfuld rede, og med mindst 10% af rederne med 3-unge-kuld, hvilket vidner om favorable fourageringsforhold.

Det er i forbindelse med projektet blevet undersøgt i hvilket omfang kolonien er mål for turistekskursioner. Ingen af turistoperatørerne i Ilulissat havde fuglekolonien som regelmæssigt mål og som begrundelse blev der primært anført dels afstanden (for langt til at gennemføre som en dagtur), dels manglende specifik interesse blandt turister, der hellere vil se flotte isbjerge. Men koloniens negative bestandsudvikling og risikoen for at opleve ulovlig jagt blev også nævnt som årsag til, at kolonien kun udnyttes turistmæssigt i meget begrænset omfang.

Anbefalinger

Samlet vurderes det, at der skulle være mulighed for at kolonien af polarlomvier igen kan vokse, hvis forårsjagten i Diskobugten er ophørt, og hvis de positive indikatorer på fødetilgængelighed, vi fandt i 2006, er repræsentative for de fleste år. Udviklingen for riderne er bekymrende, men den høje ynglesucces peger på at problemerne primært er uden for yngletiden.

Vi anbefaler på lokalt niveau:

- At følge bestandsudviklingen i kolonien med hyppige optællinger af både polarlomvie og ride
- At formidle viden i lokalområdet om bestandsudviklingen i kolonien og betydningen for koloniens udvikling af, at forårsjagten er ophørt.
- At gentage undersøgelser af fødesøgningsaktiviteten med dataloggere så undersøgelserne styrkes med data fra flere år
- At de vigtige områder for lomvierne indgår i planlægningen af de særligt oliespildsfølsomme områder i regionen
- At jagtbetjentene fortsat har fokus på fuglekolonien.

Vi anbefaler på nationalt og internationalt niveau:

- At dødeligheden p.g.a. jagt i vinterkvarterene i Grønland og Canada samt den kroniske olieforurening i Canada ikke stiger men begrænses så vidt muligt.
- At der i CAFF regi gennemføres en koordineret mærkning med geodataloggere ("CAFFs coordinated North Atlantic thick-billed murre geolocator banding program"). Resultaterne fra et sådant program vil kunne bringe forvaltningen af polarlomvier op på et væsentlig højere niveau hvor effekter af klimaændringer, kroniske olieforurening og jagt kan ses i sammenhæng og kobles til bestandsudvikling i ynglekolonier.

Vi ved fra fangst af ringmærkede fugle at lomviebestande fra hele det nordatlantiske område blander sig under træk og overvintring i Canada og Vestgrønland. Det har på den baggrund i CAFF været forsøgt at modellere hvad jagt i de forskellige områder og den kroniske olieforurening ved Canada (der er estimeret til at koste 200.000 fugle per år livet) betyder for de forskellige kolonier, men datagrundlaget har været for mangelfuldt til at koble tilbage til kolonierne. Brug af satellitsporing har givet ny detaljeret viden om dele af trækket, men til brug for modelleringen af hvordan bestandene fra forskellige kolonier blander sig uden for yngletiden er der kommet et helt nyt værktøj, geodataloggere (lysloggere) der vejer få gram og kan sættes på fuglenes ben. Geodataloggere er ikke nær så præcise som satellitsendere, men de er fuldt tilstrækkelige til at identificere vinterområder og hovedtrækruter og de er nemmere, billigere og giver positioner i længere tid end satellitsendere. Nogle af disse dataloggere kan også indsamle dykkedata og dermed fortælle hvor hårdt lomvierne må arbejde for føden i de forskellige områder, en viden der bl.a. er meget væsentlig for vurdering af effekter af klimaændringer.

Eqikkaaneq kaammattuutillu

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Amerlassusiisa allanngorat qanoq pissuseqarnersoq paasiniarlugu Appani appaqarfimmi appat pisariitsumik uuttuusiorneqarsimapput. Tunngaviit arlallit aallaavigalugit ikiliartoratik amerlanerpaamik pisarineqarsinnaaffii uuttuummi missingerneqarput (Kapitali 3). Uuttuusiami naatsorsukkat Piniarneq atorlugu pisanik nalunaarutinut sanilliunneqartarput. Pisanik nalunaarutini takuneqarsinnaavoq 1993-2001-imi qaammatini juni aamma julimi ukiumut pisat Ilulissat Kommunianni 100-iniit 206-imut amerlassuseqartarsimasut (1998-imi 40-ilusimallutik). Appat taakku inersimasuussagunavipput erniortuusut tassami piaraanerusut amerlanerit erniorfiit eqqaaniinneq ajormata. Ikiliartuutaanngitsumik pisarineqarsinnaasunut uuttuummut sanilliukkaanni ilimanarluinnarpoq aasaanerani inersimasunik erniortunik piniartarneq 2001-ip tungaanut appat ikiliartornerannut pissutaanerpaasimassasoq. Tamatuma kingorna upernaakkut aasakkullu piniartarneq inerteqqutaalerpoq. Inerteqqut taanna malinneqarpat ukiukkullu piniarneqartarnerat annerulinngippat uuttuut atorlugu takuneqarsinnaavoq appat ikiliartornerat unitsinneqarsinnaassasoq.

Erniorfiup avataani Appani appat nuuttarneri agguataarnerilu ilaatigut nalunaaqqutsikkat tigoqqinneqartarnerat aammalu qaammataasamut nassitsissusiineq atorlugu misissorneqarsimapput (Kapitali 4). Ukiut 60-it ingerlaneranni appat 2800 missaat nalunaaqqutserneqarsimapput, nalunaaqquttallu 372-it tiguneqartutut nalunaarutigineqarsimallutik. Taakku 89%-ii inersimasuullutik Qeqertarsuup Tunuani pisaasutut nalunaarutigineqarsimapput. Nalunaarutigineqartartutigut takuneqarsinnaavoq appat Appaneersut Kitaata avannaani Newfoundlandillu eqqaani ukiisarsimassasut.

Appat 27-it qaammataasamut nassitsissuseqarsimapput ullullu 112 tikillugit malittarineqarsimallutik. Appat julip naajartornerani ineqarfitsik qimakkaangamikku naluumallutik ingerlaartarput. Naluumallutik ingerlaarnerminni appat inersimasut isasarput, angutivissallu piaqqani naluumaqatigisarpai. Appat malinnaaffigineqartut angallaviisigut takuneqarsinnaavoq angutivissat amerlanersaat (15-16-it) Sullorsuakkoortartut arnavissalli avillutik Qeqertarsuaq avannaqqullugu kujaqqullugulu ingerlasartut. Kingusinnerusukkut augustimi septemberimilu appat nalunaaqqutsikkat amerlanersat Baffinip Kangerliumarngata kangimut kujasinnerusortaanut siammarsimasarput. Appat amerlanersaat Baffinip Kangerliumarngata kangimut kujasinnerusortaani isasaraluartut taamaattoq appat marluk kujammut kimmut Labradorimut Newfoundlandimullu ingerlaarsimapput. Paasisatigut inernerititaasoq tassaavoq augustip aallaqqaataata missaani appat amerlanersaat Sullorsuarmi Qeqertarsuatsiatsip eqqaatigut ingerlaartartut taamaammallu tamaani uuliamik maqisoortoqarnissaanit assorsuaq navianartorsiortitaasinnaallutik, aammalu Qeqertarsuup tunuani uuliamik maqisoortoqarnissaanut navianartorsiorsinnaaqaat maajimit tamaanga takkuttaramik.

Piaqqat uumasinnaassusiannut taamalu amerlassusiisa allanngoriartornerannut nerisaasa annertuumik killeqalernerat qanoq sunniuteqassanersoq paasiniarlugu appat aqqaamasarnerat ineqarfimminnilu piaqqaminnik nerlersuisarnerat 2006-imi misissuiffigineqarput (Kapitali 5). Nalunaarsuuteeqqat isigaanut ikkussat atorlugit aqqaamasarnerat misissuiffigineqarpoq, nerlersuisarnerallu isiginnaarlugit misissorneqarluni. Ammassaat (Mallotus villosus) 2006-imi nerisaani pingaaruteqaqaat, nerisassarsiortarnerat sivikitsunnguusarpoq aammalu piffissaq aqqaamanermut atortagaat killeqarluni (< 10%). Taamaammat 2006-imi nerisassaaleqisarsimarpasinngillat.

Appani timmissat ineqarfianni taateraat aamma ikilisimapput (Kapitali 6). 2005 aamma 2006-imi 2783-inik aamma 1811-inik inuttaqarpasissunik ulloqarpoq. 1984-imi taateraat 22000 missaanniipput, 1994-98-milu ullut 6000-iullutik, tassa ukiumut 14%-inik ikileriartarsimallutik. Ukiuni misissuiffiusuni tamani piaqqiorluarsimapput, tassa piaqqat ajoratik allisut 1.8-1.7-iusarlutik, ullullu ikinnerpaamik 10%-ii pingasuliffiusimallutik, taamaalilluni neriarfiginnerat tamatumuuna uppernarsarneqarpoq.

Misissuinermut ilanngullugu timmissat ineqarfiata qanoq takornariarfigineqartigisarnera misissorneqarpoq. Ilulissani takornariartitsisartut timmissat ineqarfiannut aalajangersimasumik takornariartitsineq ajorput, ilaatigut ungasippallaarnerat (ulluinnarlugu angalaffiginissanut) pissutaatinneqarpoq, ilaatigullu takornarianit ilulissanik kusanaqisunik takunnikkusunnerusartunit aalajangersimasumik soqutiginnittoqannginnera patsisaatinneqarluni. Aammali timmisat ineqarfiani timmissat ikiliartornerat aammalu inerteqqutaasumik piniartunik naammattuuisoorsinnaaneq ineqarfiup takornariarfiuallaannginneranut patsisaasutut oqaatigineqarput.

Kaammattuutit

Upernaakkut Qeqertarsuup tunuani piniartarneq unippat aammalu 2006-imi nerisassarissaarneq takusarput ukiuni amerlanerni atuuttarsimappat appat amerliartoqqilernissaminnut periarfissaqartutut isumaqarfigaavut.

Sumiiffik tamanna pillugu kaammattuutigaarput:
- Akuttunngitsunik kisitsisarnikkut ineqarfimmi tassani appat amerliartornerat malinnaavigineqassasoq
- Tamaani appat amerlassusiisa allanngoriartornerat pillugu tamaani najugaqartunut qaammarsaasoqassasoq aammalu upernaakkut piniartarnerup unitsinneqarnerata appaqassutsip allanngoriartorneranut pingaarutaa qaammarsaatigineqassasoq.
- Misissuinerit ukiuni amerlanerusuni paasisanik pitsanngorsarneqartussanngorlugit nalunaarsuuteeqqat atorlugit neriniartarnerinik misissuinerit ingerlateqqinneqassasut
- Sumiiffiit appanut pingaaruteqartut sumiiffiit uuliamik maqisoornikkut navianartorsiortinneqarataanaasut pilersaarusiorfigineqarneranut ilaatinneqassasut
- Piniarnermik nakkutilliisunit timmissat ineqarfiat nakkutigilluarneqassasoq.

Nuna tamaat nunallu tamalaat eqqarsaatigalugit kaammatuutigaarput:
- Kalaallit Nunaanni ukiisarfiini piniarnikkut toqorarneqartartut kiisalu Canadami uuliamik mingutsitsiuarneq killilersimaarneqassasut.

- CAFF-ip susassaqarfiani ataqatigiissaakkamik sumiissusiorsiutitalersuisoqassasoq (”CAFFs coordinated North Atlantic thick-billed murre geolocator banding program”). Suliniummit taama ittumit paasisat atorlugit appat aqunneqarnerat pitsaanerulersinneqarsinnaavoq, silap allanngornerata, uuliamik mingutsitsiuarnerup aammalu piniarnerup sunniutai ataatsimoortillugit takuneqarsinnaanngussallutik kiisalu piaqqiorfiini timmissat amerlassusiisa allanngoriartorneranut attuumatinneqarsinnaalissallutik.

Nalunaaqutsikkat pisarineqartarnerannit nalunngilarput atlantikup avannaata appai tamarmik Canadami Kitaanilu ingerlaartarnerminni ukiisarnerminnilu akuleruttartut. Tamanna aallaavigalugu CAFF-imi uuttuusiorniarneqarsimavoq sumiiffinni assigiinngitsuni piniartarneq aammalu Canadami uuliamik mingutsitsineq (ukiumut appanik 200.000.-inik naleqartartutut missingerneqartoq) qanoq sunniuteqartarnersoq, paasissutissalli tamakku timmissat ineqarfiinut attuumassusern-eqarnissaminnut amigarpallaarput. Qaammataasamut nassitsissusiinik-kut ingerlaartarfiisa ilaat nutaanik paasisaqarfigineqarput, kisiannili piaqqiorfinnit assigiinngitsuneersut piaqqiornerup naliginngisaatigut qanoq akulerussuuttarneri pillugit paasiniaassutissaqalersimavoq nutaarluinnarmik, tassa sumiissusersiut (qaammanermik uuttortaat) grammialuinnarnik oqimaassusilik timmissallu isigaanut ikkuneqarsinnaasoq. Sumiissusersiutit qaammataasamut nassitsissutitut sumiiffimmik uniujaatsiginngillat, kisiannili ukiisarfiisa sumiinnerinik aqqutigisartagaannillu pingaarnerusunik paasiniutigissallugit naammalluinnarput, kiisalu pisariinneruppput, akikinnerullutik aammalu qaammataasamut nassitsissutiniit sivisunerusumik sumiiffinnik nalunaarsuisarlutik. Aamma nalunaarsuuteeqqat tamakku ilaat aqqaamasarnerinik uuttortaasinnaapput taamalu sumiiffinni assigiinngitsuni appat neriniarlutik qanoq ilungersortigisariaqartarnerat nalunaarsinnaavaat, paasisassallu tamakku silap allanngornerata sunniutaanik naliliinermut pingaarutilerujussuupput.

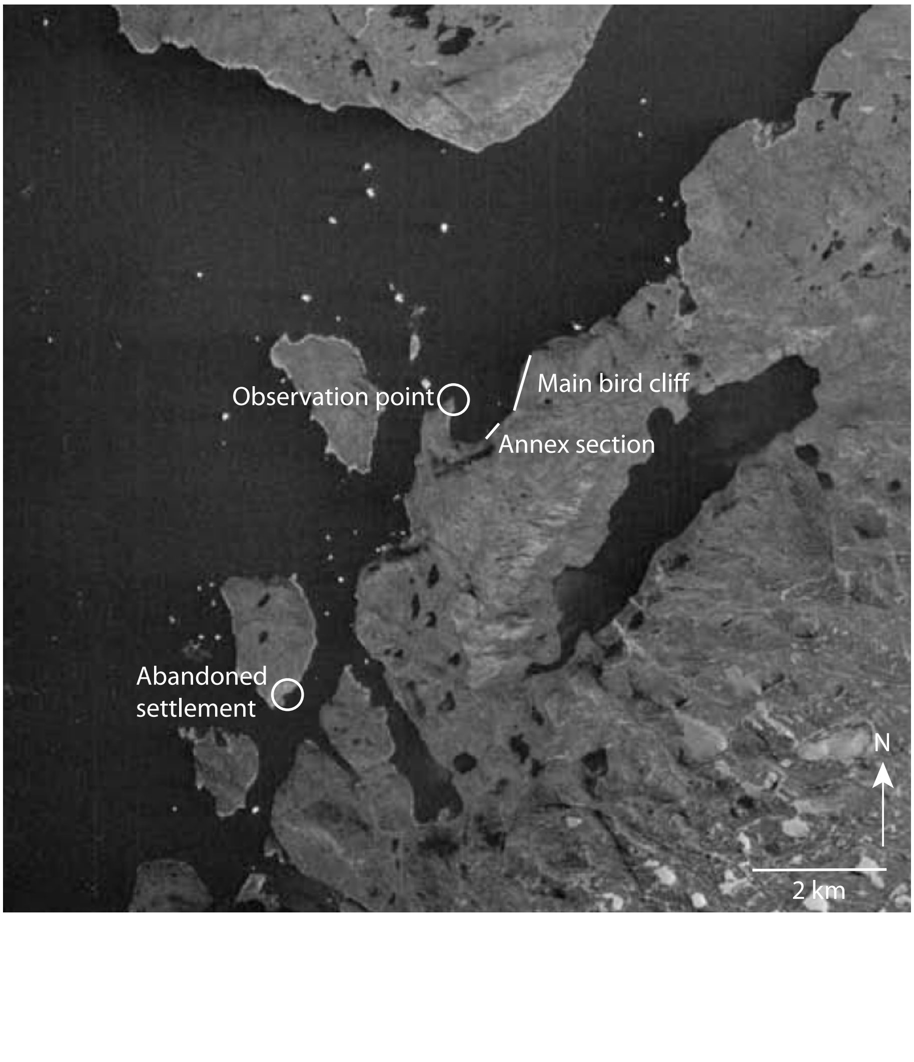
1 Introduction

1.1 Background

The thick-billed murre colony at Ritenbenk (Innaq) is the last remaining thick-billed murre colony in Disko Bay (Fig. 1.1). It has been declining for more than 50 years from about 46,000 to only a few thousands. The aim of this study has been to get a better understanding of the population development, the causes for the decline as well as the potential for increase and to identify important areas for the birds especially during the swimming migration. Hopefully the results of this study can be used for sustainable management of the colony.

The thick-billed murre is the most important hunted bird species in Greenland and it is also very vulnerable to marine oil spills. The hunting season and the hunting bag have been effectively reduced with new legislation in 2001 (Merkel & Christensen 2008). However, increasing oil activities in the Disko West Area (Mosbech *et al*. 2007) is a new challenge to the thick-billed murre population and makes it important to identify migration routes and important habitats.

Figur 1.1. The Ritenbenk seabird colony.



The study has supported the national Greenland implementation of Arctic Councils CAFF International Murre Strategy and Action Plan. The joint analysis of studies like this from murre colonies in the CAFF area increases the understanding of the dynamics of the populations and greatly improves the knowledge available for sustainable management of the populations.

1.2 The studies

Field research and monitoring activities in the Ritenbenk colony were carried out as a joint cooperation between GINR and NERI in 2005 and 2006. The activities have included studies of colony attendance, population size, chick feeding and parental foraging activities, migration based on ringing recoveries and satellite telemetry as well as population modelling and sustainable harvest modelling. Studies include the basic GINR monitoring of the colony.

The thick-billed murre population at Ritenbenk has been the main study object. However, some basic studies were also conducted on the breeding population of black-legged kittiwakes. Since the murres and the kittiwakes have very different feeding and breeding ecology, they supplement each other as indicators of the marine environment:

The thick-billed murres forage by diving to great depths (up to 200 m) to feed on zooplankton, squid and fish – the latter is the key type of food brought to its single chick, one fish at a time.

The kittiwakes are surface-feeders, relying on zooplankton and smaller fish available at the upper 1 m of the water column, and feeding up to three chicks by regurgitating the stomach contents.

All the results from studies of the kittiwake population are presented in a last section of this report (chapter 6).

As a part of the project we also studied to which extent the Ritenbenk colony was used for tourist excursions. We conducted interviews with the tourist operators in Ilulissat. The tourist operators did not have regular tours to the colony and during the field work we only observed two tourist boats near the colony. We were told by the tourist operators that the distance is too long for a day-tour and tourist were generally more interested in the scenery than specific bird species. However, the risk of encountering illegal hunting at the colony was also mentioned by a tour operator as a reason not to use the colony for tourist excursions.

1.3 Acknowledgements

We thank field assistants Allan Juhl Kristensen and Rune Rietz for hard work and good company, Jannie Fries Linnebjerg for help with preparation of dive data, and Mary Wisz for testing innovative modelling with the satellite location data.

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The Copenhagen Bird Ringing Centre, Zoological Museum, National History Museum of Denmark, kindly provided data on ringing and recoveries of murres from the Innaq/Ritenbenk colony for a reanalysis of ring recoveries.

Bureau of Minerals and Petroleum, Nuuk, is acknowledged for financial support as part of the Disko West Strategic Environmental Impact Assessment background study program. The study was co-funded by the Danish Environmental Agency as part of the environmental support programme DANCEA – Danish Cooperation for Environment in the Arctic. The authors are solely responsible for all results and conclusions presented in this report, which do not necessarily reflect the position of the funding agencies.

2 Phenology, colony attendance and population estimate

2.1 Introduction

Monitoring status and trends of murre colonies in Greenland follows a long-term monitoring plan outlined in 1998 (Falk & Kampp 1998). Depending on population trends, the report recommends a high, medium or low monitoring effort for each colony or a representative colony within a group of colonies. The Ritenbenk colony is among the declining murre colonies in West Greenland, for which the recommended survey interval is three to five years (Falk & Kampp 1998). In the Ritenbenk case this schedule has not quite been accomplished. The colony was last surveyed in 1998 by GINR (Merkel *et al*. 1999).

The Ritenbenk colony also holds a breeding population of black-legged kittiwakes, for which we also present a population size estimate (see results in chapter 6).

The number of breeding great cormorants (*Phalacrocorax carbo*), razorbills (*Alca torda*), black guillemots (*Cepphus grylle*), glaucous gulls (*Larus hyperboreus*) and Iceland gulls (*Larus glaucoides*) in the Ritenbenk colony were reported to the database of Greenlandic seabird colonies (NERI 2007), and are not included in this report.

2.2 Methods

The methods usually applied when assessing population status and trends of murre colonies in Greenland are summarised in Falk & Kampp (1997), along with relevant literature. The basic protocol includes an estimate of the total population size of the colony, along with repeated murre counts over a number of days within a few well-defined study plots. The latter is conducted to assess diurnal and day-to-day variation in murre attendance. Diurnal variation in attendance can be substantial in Greenlandic colonies and may thus hugely affect total population size estimates if not compensated for (Merkel *et al*. 1999). Day-to-day variation in attendance is usually lowest from late incubation to early fledging ("jumping" from ledge), and this is thus considered the best period for monitoring (Lloyd 1975, Gaston & Nettleship 1981, Hatch & Hatch 1989). If information is collected in the same study plots during subsequent visits, the repeated counts furthermore permits statistical comparison of numbers between years.

Total population size can be estimated by direct counts of the number of birds present on the cliffs or by counts from photographs. Previously, the photo counts were mainly used to cover the larger colonies, which require many hours of decent weather to complete by direct counts.

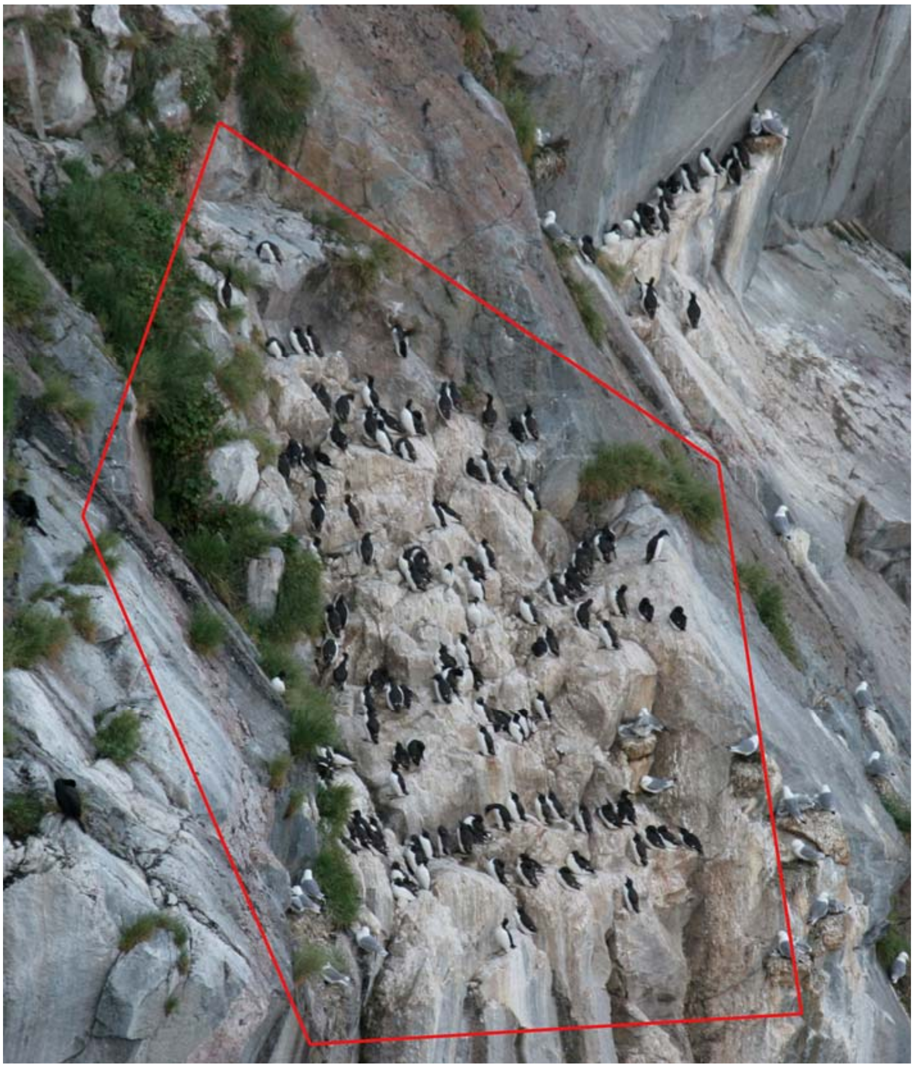
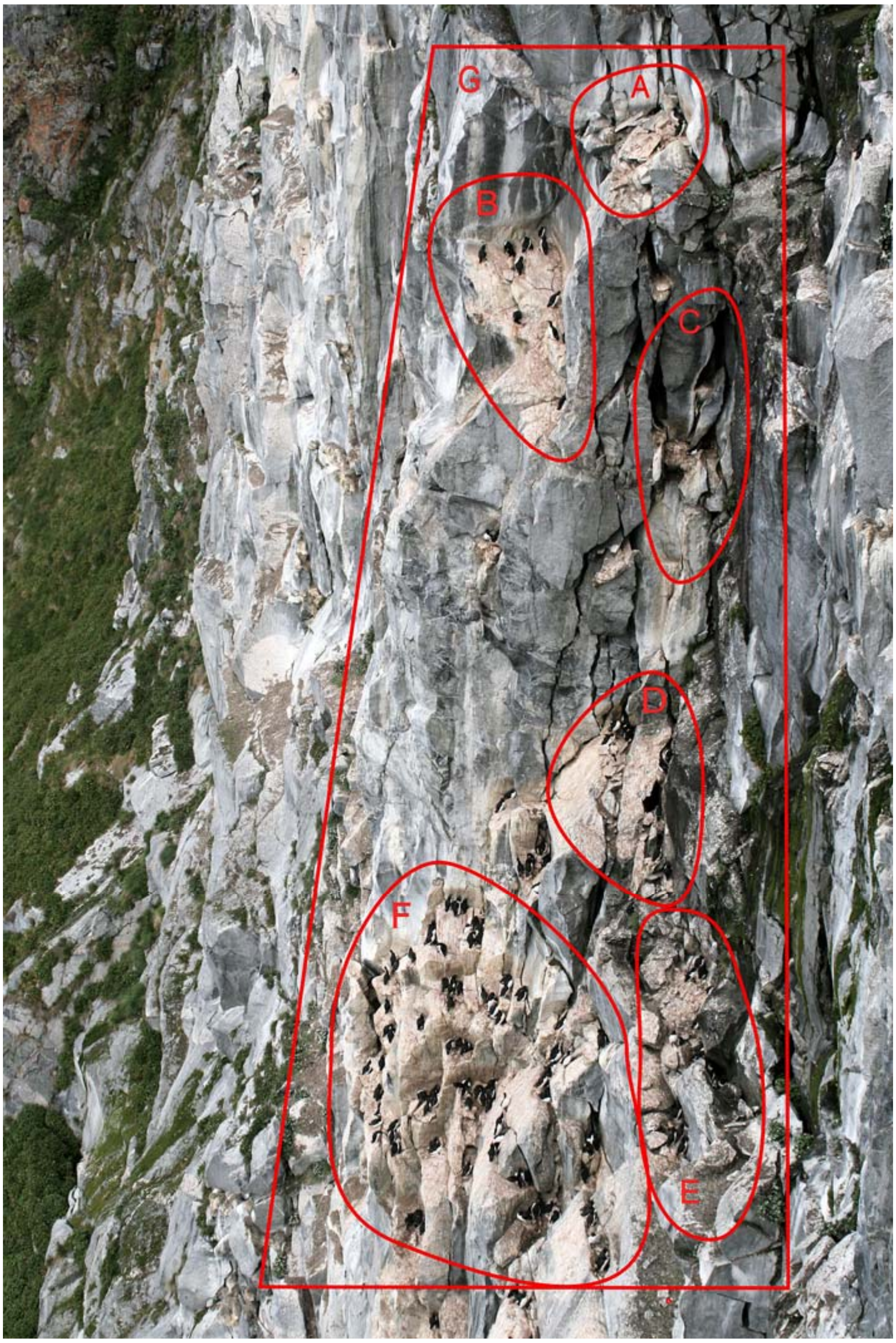


Figure 2.1. Study plot 1 in the northern section of Ritenbenk murre colony, in which murre attendance was followed from 19-27 July 2005 and from 8-23 July 2006 by means of photo-counts. GPS position of camera fix point: ca. 69°48'00.5"N; 51°12'47.3" W.

However, in recent years, the photo technique is becoming the preferred census method due to the rapid advancement of digital cameras and applicable software.

In the Ritenbenk case we used both methods for the murre counts. In 2005 we made two direct counts and one complete photo survey of murres (and kittiwakes) on 5-6 July and in 2006 two direct counts and two photo surveys were carried out on 9 July and 19 July (Tab. 2.1). Unfavourable weather conditions on 9 July made this survey less reliable and the material was never used. In all cases the work was carried out from the small peninsula on the opposite side of the bay at a distance of 1000 – 1,100 m from the colony (Fig. 1.1). We used a Zeiss Diascope 85 TFL (20x-60x) spotting scope for direct counts and for photo survey a Canon EOS 30D camera, equipped with a Canon EF 24-85 mm USM lens (overview photos) or a Canon EF 100-400 mm IS USM lens (count photos). The 100-400 mm zoom lens was used at the maximum focal length throughout the survey. To reduce the workload from counting the murres from the photos, individual photos were stitched in Adobe Photoshop CS3 to cover larger unbroken sections of the colony. For a more detailed description of this procedure see Merkel et al. (2007).

Figure 2.2. Study plot 2 in the Annex section of the Ritenbenk murre colony. Direct observations of phenology and chick feeding rates were made in subunits A-E from 11-23 July 2006, while murre attendance was followed in the entire plot (A-G) from 8-23 July by means of photo-counts. GPS position of camera fix/observation point: a few meters below 69°47'39.5"N; 51°13'31.5" W.



We defined a study plot (1) in the northern part of the colony in 2005 and one more (2) in the Annex section of the colony in 2006 (Fig. 2.1 and 2.2). Murre attendance was followed at both plots by means of photo monitoring, in study plot 1 from 19-27 July in 2005 and from 8-23 July in 2006, with an interval of 60 minutes between photos. Study plot 2 was monitored in the same period in 2006, but photos were taken every 15 minutes. We used Canon EOS 30D cameras equipped with Canon TC-80N3 timers and zoom lenses. The zoom level was fixed at 320 mm in plot 1 and at 50 mm in plot 2. Starting on 9 July, 2006, a third study plot was photographed from the small peninsula opposite to the colony using a 500 mm telephoto lens. However, the fixation of the camera failed and ruined the photos.

All photos are stored at shared drives at NERI (Q:\PROJEKT\Fotreg havfuglekolonier\Ritenbenk) and GINR (F:\40-59 PaFu\43 Fug-le\000 Data\00\01 Havfugle optællinger).

Direct observations of murre breeding status and chick feeding rates were made in study plot 2 in the period 11-23 July, 2006 (Fig. 2.2). Chick feeding rates are reported in chapter 5.

2.3 Results and discussion

2.3.1 Phenology

In study plot 2 chick fledging started on 15 July in 2006 and peaked ca. 21 July (Fig. 2.3). Some chicks probably fledged slightly earlier than recorded by us since there were periods with no observations in study plot 2. Among the 26 breeding pairs four pairs were late breeders and at least one pair was still incubating on 23 July when observations were discontinued. A peak fledging date around 21 July corresponds well with the daily mean number of murres observed in the colony, which showed a large drop in the period 20-22 July (Fig 2.4). No systematic observations of breeding phenology were conducted in 2005, but massive fledging activity was observed on 25-26 July, which corresponded well with a marked decline in murre attendance (see below).

Figure 2.3. The breeding status of 26 pairs of thick-billed murres in the Ritenbenk colony, 11-23 July, 2006. In some cases chicks may have fledged earlier that indicated (?).

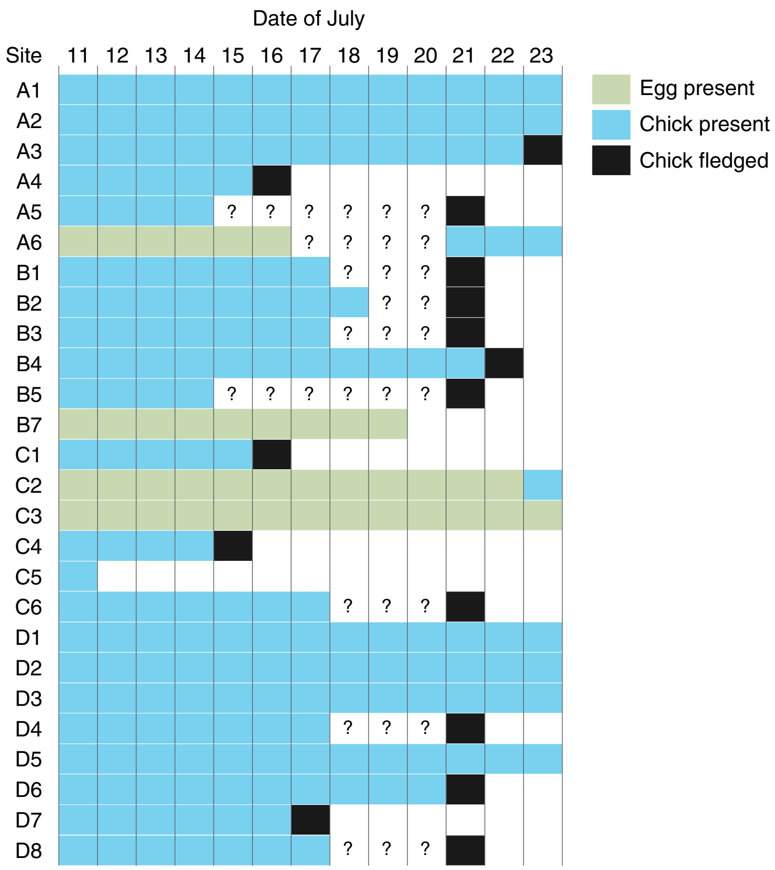
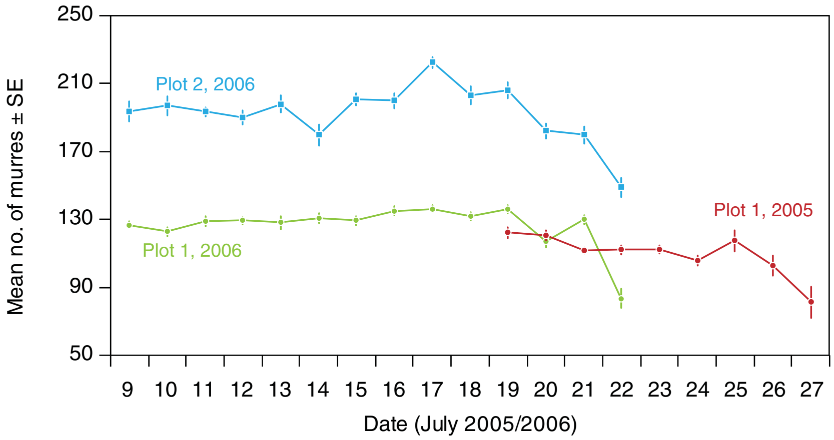


Figure 2.4. Day-to-day variation in the number of murres attending two study plots in the Ritenbenk colony in 2005 (19-27 July) and 2006 (9-22 July). Mean number of birds/day based on photo counts every hour throughout the period.



Fledging initiation on 15 July is the earliest date yet reported for the Ritenbenk colony. Merkel *et al.* (1999) estimated a fledging period from 24 July – 7 August in 1998, and earlier there is information about chick ringing in the colony from 18 July – 14 August (1946-63) and fledged birds on the waterfront from early to mid August (Falk & Kampp 1997).

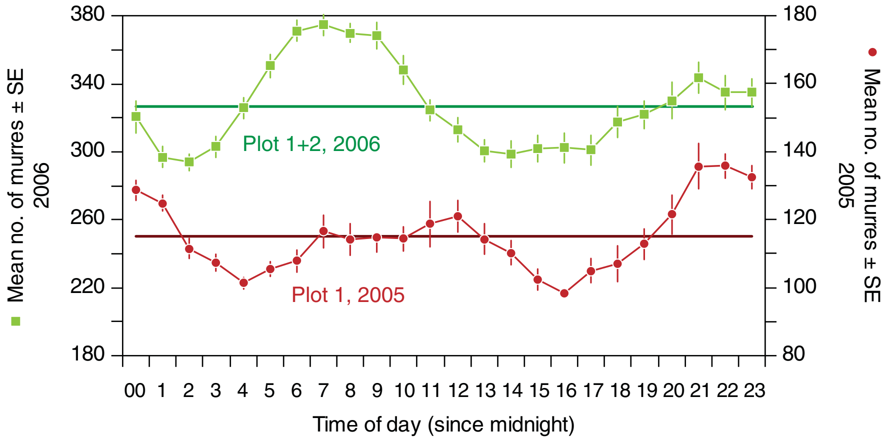
2.3.2 Colony attendance

Colony attendance in 2006, as measured by the daily mean number of birds present in study plot 1 and 2, was relatively constant from the beginning of the study period (9 July) until ca. 21 July. For this period, the average coefficient of variation (CV) for day-to-day fluctuations (calculated for every hour), was 7.7% (range: 4.3-13.8) for plot 1 and 8.6% (5.4-12.0) for plot 2. After 21 July there was a steep decline in the number of attending murres (Fig. 2.4), which according to breeding status information from study plot 2 corresponded with massive fledging activity (Fig. 2.3). The survey period was shorter and started later in 2005 (Fig 2.4), but at least for the period 19–25 July (plot 1) the level of day-to-day variation in attendance was about the same as in 2006 (CV=8.0%, range: 3.0-13.8). Subsequently, there was marked decline in the number of attending murres, indicating that fledging in 2005 peaked approximately one week later than in 2006 (Fig. 2.4). Direct observations at various sites in the colony in 2005 confirm massive fledging activity on 25-26 July and it was noted that the colony that was close to empty on 28 July.

Diurnal variation in attendance in 2006 followed a rather consistent pattern until fledging, with a distinct peak in numbers between 6 and 9 in the morning. In contrast, the number of attending birds was below average throughout most of the afternoon and also shortly after midnight.

This was the case in both study plots and numbers are therefore pooled in Fig. 2.5. In 2005 the attendance was also below average in the afternoon, however, no morning peak of attendance occurred (Fig. 2.5). Calculated for the period before fledging started, the average CV for diurnal fluctuations in attendance was 9.5% (range: 7.4-14.0) for plot 1 and 11.1% (7.3-13.8) for plot 2 in 2006 and 10.7% (7.7-13.3) in 2005 for plot 1. Thus, diurnal variation in attendance in the Ritenbenk colony exceeded the level of day-to-day variation.

Figure 2.5. Diurnal variation in the number of murres attending two study plots in the Ritenbenk colony in 2005 (19-25 July) and 2006 (8-21 July) (local time). Mean number of birds/hour based on photo counts every hour throughout the period. Horizontal lines indicate the overall mean no. of birds in the study plots.



The magnitude of the diurnal variation was intermediate compared to other murre colonies studied in West Greenland. In 2006, the Ritenbenk colony had on average 28% more birds when comparing maximum and minimum attendance periods. In 2005, the difference was 38%. From the most northern colony in West Greenland (Hakluyt Island, Qaanaaq) a difference of ca. 20% has been reported (Falk & Kampp 1997, Merkel *et al*. 2007), while a difference of 100% between maximum and minimum was detected for colonies in southern Upernavik (Merkel *et al*. 1999). The tendency of low attendance during the afternoon appears to be a general pattern for most of the colonies studied in Northwest Greenland, including the Ritenbenk colony, while the peak of attendance seems to be more variable, but usually occurring during night or morning hours (Falk & Kampp 1997, Merkel *et al*. 2007). The pattern detected in the Ritenbenk colony in 2005, differing by the low or medium attendance throughout most of the night and morning hours, underlines that patterns of colony attendance may change between years.

2.3.3 Population estimates

The total number of murres counted in the Ritenbenk colony in 2005-2006 varied between 1,761 and 2,399 individuals (disregarding a count made under unfavourable weather conditions). For future references to the present population size we recommend using the direct count estimate of 2,447 birds from 19 July, 2006 (Tab. 2.1). This is adjusted for both day-to-day variation and diurnal variation in attendance, and therefore represents the average number of murres present this year (day-to-day variation was not studied in 2005 at the time of the colony survey). When using a K-factor of 0.75 to convert from the mean number of individuals to the number of breeding pairs (Kampp 1990), we arrive at an estimate of 1,835 breeding pairs in the Ritenbenk colony in 2006. In this case we prefer the direct count estimate over the photo count estimate mainly because the first one is the higher one. Both methods are likely to underestimate the true number of birds, since some birds will be hidden in blind angles at the cliff or behind other birds, and therefore it seems reasonable to choose the highest estimate. When a colony census is conducted from a boat/ship, a photo count is usually considered more accurate than a direct count, however, from a land-based position (being able to use a spotting scope) the pros and cons for each method balance more equally.

The raw count estimates from Ritenbenk indicate a population increase from 1,963 individuals in 2005 to 2,399 individuals in 2006 (22%, Tab. 2.1). Whether this apparent change represents a genuine population increase is not clear, however, both surveys were equally affected by diurnal variation and both surveys were counted by the same observer (David Boertmann). Furthermore, the 24-hour photo counts in study plot 1 also indicate more birds in 2006. A mean number of 129.3 birds (N = 277 counts, 8-21 July) was counted in 2006, while a significantly smaller number of 116.4 birds (N = 111, 19-25 July) was counted in 2005, suggesting an increase of 11% from 2005 to 2006 (t-test: T = 8.73, P < 0.0001). What remains unknown is whether diurnal or day-to-day variation in attendance changed in between the colony census (5 July) and the start of the monitoring activity in study plot 1 (19 July). The date of the census (5 July) approximately represented the peak hatching period in 2005, which is within the recommended monitoring period from late incubation to early fledging where numbers usually change only little (Gaston & Nettleship 1981, Hatch & Hatch 1989, Merkel *et al*. 1999). However, it is a possibility that the pattern or the magnitude of the diurnal variation changed around hatching when parents started bringing food to the chicks, and this may have influenced the 2005 estimate for Ritenbenk. Such a change in attendance was observed in a murre colony in southern Upernavik (Merkel *et al*. 1999).

The previous survey of the Ritenbenk colony is from 1998 when the population was estimated at 3,415 birds (Merkel *et al*. 1999). Compared with the higher estimate from 2006 of 2,447 birds this is a decline of 28% or an annual decline of 4%. The 1998 estimate of 3,415 birds was adjusted for diurnal variation in attendance and day-to-day fluctuations were close to zero at the specific dates (July, 3+8) of the survey (Merkel *et al*. 1999). Thus, there seems to be little doubt that the change in numbers from 1998 to 2006 reflects a substantial population decline. Surveys conducted prior to 1998 also witness about a declining trend in the Ritenbenk colony: 3,655 birds estimated in 1994; 4,500 in 1984; 5,500 in 1980 and 7,000 birds in 1960 (Falk & Kampp 1997).

Table 2.1. Thick-billed murre counts in the Ritenbenk colony, 2005-2006.

Date	5 July 2005	5 July 2005	6 July 2005	19 July 2006	19 July 2006
Method	Direct count	Photo count	Direct count	Direct count	Photo count
Time of day	17:00-19:00	17:00-19:00	11:00-12:30	15:10-19:00	16:00-17:00
Murres					
Northern section	709	749	515	606	582
Southern section	705	880	526	1,042	1,011
Annex	347	334	377	751	649
Total birds counted	1,761	1,963	1,418	2,399	2,242
Diurnal var., correction	+8%	+8%	-4%	+7%	+8%
Day-to-day var., correction	-	-	-	-5%	-5%
Corrected no. of murres	-	-	-	**2,447**	2,309
Breeding pairs (K = 0.75)	-	-	-	**1,835**	1,732

3 Population modelling and harvest

3.1 Introduction

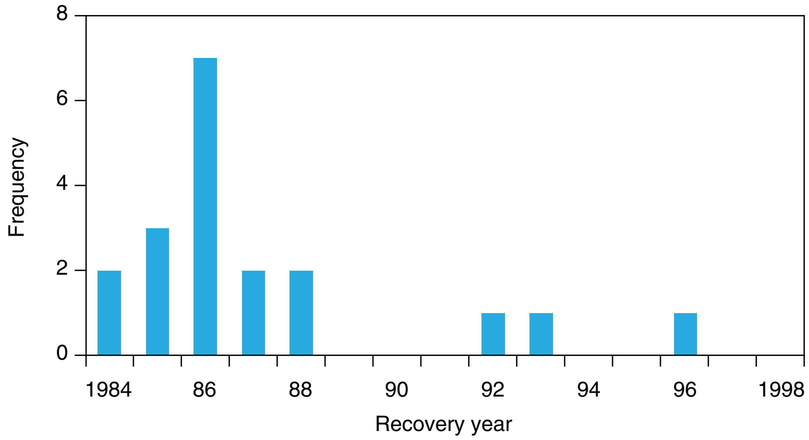
After documenting the decline of the Ritenbenk murre population, the next logical step is to attempt to identify why this decline has happened. This question can be split into two aspects: identifying the demographic mechanism responsible (i.e. is the decline due to high mortality, low reproduction or both), and identifying the underlying cause (e.g. climate change, hunting etc). In this context, a stringent mathematical framework provides the most reliable basis for sound inference, and is also useful for flagging up important data gaps. Demographic modelling is thus a useful tool for diagnosing causes and mechanisms of population change, particularly declines of threatened populations. Modelling tools can also be used to provide approximate guidelines for the maximum sustainable harvest of a population.

3.2 Methods

Several modelling approaches of varying complexity exist, but for the current data and purpose, matrix models are the most suitable. Matrix models project the demographic consequences (i.e. whether a population is likely to increase or decline) of specific values of the basic demographic parameters (survival and fecundity). Ideally, input parameters for such models should be estimated based on data collected from the study population, but when such data are unavailable, estimates from other populations or similar species can be used. In the case of the Ritenbenk murre colony, the only demographic parameter that can be estimated from colony-specific data is annual adult survival, and this estimate is somewhat dubious (see Results). The model we present here is therefore mainly based on data from the literature.

In 1984, 297 adult murres were ringed at Ritenbenk by Kaj Kampp and Knud Falk (Kampp 1991b), and 19 of these have since been recovered as shot. None of these birds were seen during fieldwork at the colony in 2005 and 2006, although the same ledges were visited. Most recoveries occurred during the first few years, and the most recent recovery dates are from January 1997 (Fig. 3.1). These data allow survival to be estimated using the models described by Brownie et al. (1985) and the software package MARK (White & Burnham 1999). These models estimate two types of parameters, namely annual probabilities of survival of birds and recovery of rings (i.e. the probability that a dead ringed bird is retrieved and the ring number reported to the ringing scheme). This is the so-called Seber parameterisation, but for this data set results are identical using the alternative Brownie parameterisation, which is often used for hunted species. Because of the sparse data (only one cohort of ringed birds), it is not possible to estimate annual variation in probabilities of survival or recovery. Only models with constant parameters or very simple temporal variation (e.g. a linear trend over time or two periods with different probabilities) are possible.

Figure 3.1. Temporal distribution of 19 recoveries of 297 adult murres ringed at Ritenbenk in 1984. Recovery years go from 15 July in year x until 14 July in year x+1.



[1] Ringing and recovery data kindly provided by The Copenhagen Bird Ringing Centre, Zoological Museum, National History Museum of Denmark.

Matrix models provide a simple and flexible tool for exploring how variation in demographic parameters affects population growth (Caswell 2001). They predict an asymptotic (i.e. long-term) growth rate and stable age structure of the population, given the model structure and specific values of demographic parameters. Because current population levels are far below historical levels, we did not include density-dependence in the model. We constructed a model with 5 age classes and a pre-breeding census, using basic parameter values from the literature listed in Table 3.1 and adjusting these as described under Results. The model was constructed in the software package ULM (Legendre & Clobert 1995).

Table 3.1. Parameters used in the demographic matrix model. Note that values for first- and second-year survival are derived from the closely related common murre (*Uria aalge*).

Parameter	Value	Source
Fecundity (chicks/pair)	0.68	Gaston & Hipfner (2000)
Sex ratio	0.5	
First-year survival	0.56	Harris et al. (2007)
Second-year survival	0.79	Harris et al. (2007)
Adult survival (after second year)	0.90	Gaston & Hipfner (2000)
Age of first breeding	5	Gaston & Hipfner (2000)

Dillingham & Fletcher (2008) describe a simple approach to estimate the maximum sustainable harvest (or other additional mortality) of a population when data are sparse. 'Potential biological removal' (PBR) is estimated as PBR = $0.5*R_{max}*N_{min}*f$, where R_{max} is the maximum annual growth rate (under ideal conditions), N_{min} is a conservative estimate of total population size, and f is a 'recovery factor' between 0.1 and 1, chosen to reflect the conservation status and concern of the population. R_{max} can be derived e.g. from a demographic model and N_{min} from population counts, whereas f has to be set by managers according to their perception of the status of the population. Here, we use a range of values of f for illustration and in order to compare PBR with reported harvest levels from the Greenland hunting statistics (Dept. of Fishery, Hunting and Agriculture, Greenland Home Rule).

3.3 Results and discussion

Mean annual survival was estimated as 0.761 (95% confidence limits: 0.652-0.845). This value is very low compared to other studies of the same species, e.g. 0.90 in Arctic Canada (Gaston & Hipfner 2000) and 0.916 in N Norway (Sandvik *et al.* 2005). Kampp (1991b) used recoveries of murre chicks ringed at Ritenbenk during 1946-1963 to estimate (under strict assumptions) a mean adult survival of 0.898. Mean survival may have been underestimated if the assumption of constant recovery probability (i.e. the probability that a dead ringed bird is retrieved and the ring number reported to the ringing centre) has been violated. The available data do not allow this assumption to be tested. However, if an arbitrary linearly declining trend in recovery probability from 0.12 in 1984 to 0.005 in 2007 is forced into the model (the estimated constant value is 0.064), survival is estimated as 0.869 rather than 0.761. This results in a poorer fit to the data (increase in deviance of 3.39), and is thus not a realistic model, but it serves to illustrate the potential for bias in mean survival if the recovery probability has in fact declined. Declines in recovery probability have been reported for a wide range of species, including seabirds (Wanless *et al.* 2006), and it is thus possible that the survival estimate presented here is too low. A more realistic model allows a different recovery probability for two periods, namely 1984-89 and 1989-present. This hypothetical change in recovery probability coincides with the change in hunting legislation which took place at that time. Under this model, the recovery probability was 0.117 in the first period and 0.021 in the second period, and survival is estimated as 0.885 (95% confidence limits: 0.586-0.976). This model has a better fit to the data than the constant model (decrease in deviance of 2.98 for one extra parameter). The first and third models are thus approximately equally supported by the data, but the very low precision of the survival estimate under the two-period model indicates that this model may be overparameterised.

With the basic parameter values in Table 3.1, the population is projected to be approximately stable (0.7% annual increase). Sensitivity to changes in adult survival is very high, and changing this value to 0.76, as estimated above, results in a projected annual decline of 13%. On the other hand, decreasing fecundity to 0.36 (the lowest mean value recorded for this species (Gaston & Hipfner 2000)) while keeping all other parameter values at their original level results in a projected annual decline of 3.3%. This value is close to the observed average annual decline from 1980 to 2006 of 2.8% (using counts listed in chapter 2). However, it is unrealistic that mean fecundity at Ritenbenk has been as low as this over several decades. Although it seems likely that adult survival is underestimated in this particular case (see above), reduced adult survival is thus the most credible mechanism for the observed population.

For murres at Ritenbenk, R_{max} can be estimated by substituting optimal values of demographic parameters in the matrix model. If fecundity is set to 0.8 and adult survival to 0.94, values which are probably close to optimal, the projected annual growth rate is 5.7% (a value very close to the 5.9% used by Falk & Kampp (2001)). Total population size is unknown, but the stable age structure of the matrix model provides a conversion factor by which the number of breeding pairs should be multiplied to get total population size. This factor is 3.55 for base values of the demographic parameters (as in Table 3.1), and 3.99 when survival is reduced to 0.76. For comparison, Falk & Kampp (2001, p. 17) give a conversion factor of 3.6. Total population size can thus be estimated as approximately 3.6*1835 = 6600 individuals. The recovery factor *f* should be set to reflect the conservation concern: 0.1 for threatened species, 0.3 for near-threatened and 0.5 for 'least concern' species (Dillingham & Fletcher 2008). For these three values of *f*, PBR can thus be estimated as respectively 19 (0.5*0.057*6600*0.1), 56 and 94 birds per year. It should be noted that this estimate assumes that the additional mortality is evenly distributed among age groups proportional to their abundance. However, mortality of juveniles (or pre-breeders in general) is much less critical for population persistence than adult mortality in long-lived species (Lebreton & Clobert 1991), so if e.g. hunting is concentrated on juveniles, the number that can be safely taken is higher than PBR. Conversely, if only adult breeders are taken, the sustainable annual take is lower than PBR. From 1993 to 2001, the annual number of murres reported shot in Ilulissat municipality in June and July was 100-206 (except 40 in 1998), see Fig. 3.2. As these birds are likely to have been primarily adult breeders, this harvest level was probably well above the PBR and thus unsustainable, particularly since neither autumn and winter harvest in Greenland and Canada nor harvest in Disko Bay other than in Ilulissat in June-July is included. Since 2002, the reported illegal June-July harvest in Ilulissat has been 0-16 murres per year (0-35 in Disko Bay in total), a level that is more likely to be sustainable, at least if reported harvest levels are reliable.

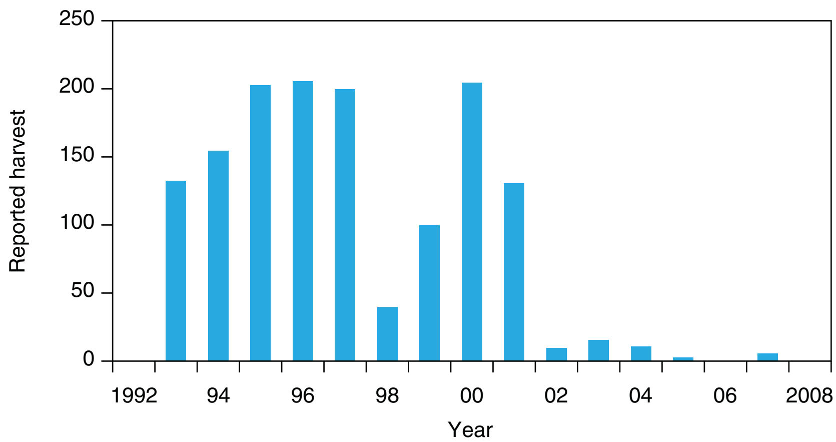


Figure 3.2. Reported harvest of thick-billed murres in Ilulissat municipality in June and July 1993-2007. Source: Dept. of Fishery, Hunting and Agriculture, Greenland Home Rule.

In conclusion, it is highly likely that hunting, especially of adult birds, during the breeding season has been responsible for the decline of the Ritenbenk murre colony, at least up to 2001. If (illegal) harvest during the breeding season as well as winter harvest remains at the current low level, there is a chance that the colony will stabilise at the current size. Detecting whether this happens will require regular monitoring.

4 Migration patterns based on ringing recoveries and satellite telemetry

4.1 Introduction

Due to a long-term bird ringing effort in Greenland from 1946 (Salomonsen 1967, Nielsen 1979), ringing and recovery data have accumulated over several decades; this includes records from thick-billed murres originating from Ritenbenk. The spatial and temporal patterns in the recoveries provide insight into the migration and wintering areas of juvenile, immature and adults. Since the murres are preferred game in Greenland as well as eastern Canada, the recoveries at the same time indicates where and when the harvest takes place.

The ringing recoveries however do only give information on bird presence in the area and periods where the birds are harvested, while satellite tracking gives full migration routes for the tracked birds. Satellite tracking is therefore a unique tool for studying dispersal and habitat use in the post-fledging period when the murres conduct a swimming migration through the Disko West Area where there is oil exploration.

4.2 Methods

4.2.1 Ringing recoveries

Thick-billed murres have been ringed at/near Ritenbenk regularly between 1946 and 1963. The total numbers ringed are a little uncertain, but amounts to approximately 2500 birds, of which the vast majority were chicks (21 known older birds). Since then only two expeditions have added to the pool of data: a ringing expedition targeting adult breeders ringed 297 birds in 1984 (Kampp 1984), and the research teams from NERI/GINR ringed 22 adults captured for other research purposes in 2005/2006. In total, ringing efforts at Ritenbenk across a 60-year time span have produced a total of 372 recoveries.

This summary is based on the comprehensive study by Lyngs (2003), but with an updated analysis specifically for the Ritenbenk data set (data kindly provided by The Copenhagen Bird Ringing Centre, Zoological Museum, National History Museum of Denmark). Prior to reanalysis, some minor errors and inaccuracies in recovery year have been corrected (by the curator of the Greenland ringing scheme, Kaj Kampp pers. com.).

For this analysis we have selected among the 372 recoveries according to the following criteria and order:

- Excluded 32 birds with unknown/doubtful ringing year
- Further excluded 30 birds where recovery date inaccuracy exceeded ± 2 weeks
- Excluded one bird with too imprecise recovery location (“W Greenland”)

- Among the remaining 309 recoveries, 59 birds (from 1946-1963) have 'unknown' age at ringing; however we have treated them as chicks, because less than 1% of the known-age birds from that period were *not* chicks.

The murres are generally present in the breeding area (Disko Bay) between May and August, here called 'summer', while the non-breeding migration and wintering period from September to April here is lumped as 'winter'.

4.2.2 Satellite tracking

We implanted satellite transmitters (Platform Transmitter Terminals) in thick-billed murres to follow them during migration. We used implanted PTTs because we have had good experience with these in diving seaducks where we have received locations for more than a year (Mosbech *et al*. 2006). External attachment of PTTs on the feathers will only last for few weeks because of feather moult.

Because of suboptimal results with abdominal implanted PTTs reported from Alaska (Hatch *et al*. 2000) we also used a PTT version for dorsal subcutaneous implantation (developed with Microwave Telemetry Inc.). In 2005 we implanted 8 subcutaneous and 2 abdominal pressure proof (65 m, 100psi) Model PTT-100 weighing 22 g. In 2006 we implanted 15 abdominal and 2 subcutaneous PTTs, and the PTT models were modified to make them more pressure resistant (>500 m 1000psi). However, this also increased the PTT weight to 27-29 g.

Figure 4.1. Thick-billed murre with implanted satellite transmitter.

The PTTs had an expected battery life of 400-550 hours. They were programmed to transmit with either a fast or a slow duty cycle. The slow duty cycle should potentially give locations for a full year while the fast duty cycle would give detailed information on the swimming migration. The fast transmission duty cycle PTTs started with 4 hours of transmission and 24 hours off for 60 cycles, and the slow duty cycle PTTs started with 4 hours of transmission and 48 hours off for 40 cycles. For both the fast and the slow PTTs the first 60 and 40 cycles respectively were followed by a duty cycle with 4 hours of transmission and 100 hours off, for the rest of the PTT life.

In the analysis of the migration with the PTT location data we have used the best-pick locations (from the Douglas SAS Argos-Filter, Version 7.03) consisting of the location with highest precision (best Argos location class) in each duty cycle.

Birds were caught on ledges using noose poles. Birds with large chicks were selected because they were easier to capture and more likely to return to the young after implantation. We were especially interested in following the swimming migration of the adult males accompanying the young. However, we could not determine sex in the field but blood samples were taken for later sexing in the lab.

Table 4.1. Specifications and performance of 27 satellite transmitters.

Ring#	PTT ID#	Year	Sex	PTT program	PTT Type	Status at last signal	All LC	BP_All LC
4137510	6932	2005	m	slow	S	Battery ok, bird ok	159	20
4137511	6938	2005	f	slow	S	Battery ok, bird dead	108	12
4137509	7794	2005	f	slow	S	Battery ok, bird ok	133	15
4137513	23166	2005	m	slow	S	Inconclusive	285	33
4137508	23168	2005	f	fast	S	Battery faliure	195	35
4137507	23169	2005	f	fast	S	Battery ok, bird ok	455	61
4137506	23170	2005	f	fast	S	Battery faliure	314	35
4137512	23324	2005	f	fast	S	Battery ok, bird ok	370	41
4137514	30055	2005	m	slow	A	Battery faliure	123	15
4137515	30057	2005	m	slow	A	Battery ok, bird ok	91	22
4137534	30059	2006	m	slow	S	Battery ok, bird ok	5	4
4137523	41177	2006	m	fast	A	Battery faliure	25	15
4137535	41178	2006	f	fast	A	Battery faliure	165	41
4137538	41179	2006	m	fast	A	Battery faliure	365	58
4137536	41180	2006	m	fast	A	Battery ok, bird ok	125	33
4137526	41181	2006	f	fast	A	Battery ok, bird ok	21	7
4137520	41182	2006	f	fast	A	Battery ok, bird ok	40	12
4137537	41183	2006	m	fast	A	Battery ok, bird ok	56	34
4137540	41184	2006	m	slow	A	Battery ok, bird ok	132	28
4137541	41185	2006	m	slow	A	Battery ok, bird ok	107	24
4137542	41186	2006	f	slow	A	Battery ok, bird ok	86	17
4137543	41187	2006	m	slow	A	Battery faliure	19	6
4137544	41188	2006	m	slow	A	Battery ok, bird dead	15	9
4137545	41189	2006	m	slow	A	Battery ok, bird dead	16	11
4137531	41190	2006	m	slow	A	Battery ok, bird dead	45	12
4137532	41191	2006	m	slow	A	Battery ok, bird dead	11	2
4137518	41196	2006	m	fast	S	Battery faliure	385	56

Slow: 4 h on 48 h off in 40 cycles, Fast: 4 h on 24 h off 60 cycles, Both 2. season: 4 h on 100 off
A: Abdominal implant, S: Subcutaneous implant
All LC: Total number of locations after DAR-filtering (rate 100 km/h, LC 1)
BP_all LC: Total number of locations classified as "best pick pr duty cycle"

Pre-surgical preparations followed Korschgen *et al.* (1996a, 1996b) with some modifications. Transmitters were sterilized in 70% medical ethanol/isopropyl (12h) prior to the implantation and a peritoneal DuPont® dacron cuff was afterwards attached at antenna basis and fixed with ca. 5

mm heat shrink tubing. Prior to anaesthesia, neutral liniment (80% vaseline, 20% paraffin oil) was used to prevent corneal dryness. To prevent post-release heat loss, feather removal was avoided at the abdominal Alba line and cervical incision sites (feathers aligned aside). The surgical procedure followed Korschgen *et al.* (1996a, 1996b) with few modifications. Birds were anaesthetised through a mask with Isoflurane® (Schering Plough) and compressed medical oxygen (induction: 3% in 2000 ml O2 /min; maintenance: 1.5-4.5% in 2000ml O2/min) in a modified Bains' system (Dameca Cyprane Limited; Fluotec). At the antenna exit site - as dorsa-cranially to the ischia bone as possible - a haemostasis was used to penetrate the subcutis, peritoneal muscle layer, and peritoneum. Then the antenna was pulled through the skin and the cuff was fixed tight to the cutis and peritoneum with two single interrupted knots. Thereby only the heat shrink coated antenna penetrated the skin.

Surgeries were performed in a tent with temperature raging from 16.9 to 24.2 °C. The BCT was measured through an anal probe (OBH®), and used for control and compensation of birds' heat loss and overheating. Heat loss was compensated by using an electric heating pad (OBH®, 50 W) placed below birds and a few times, the instant heating was boosted with a heat gun (Black & Decker, 2000 W) and anti chock blankets (www.falck.dk). Overheating was compensated by applying plastic bags with melting snow and ice (0 °C) to the feet. The ECG (electrocardiography, Schiller®) was employed to monitor HR and excitability used for regulation of anaesthesia. Isotonic Ringer-acetate was used as vascular transmitter between electrodes and skin. Finally, the sites were inspected and the patients were given 15 mg i.m. Enrofloxacine® (Baytril®) i.m. and medical oxygen until consciousness.

After implantation the birds were held in a padded box in a quiet environment for about 1 hour for wakeup and preening. After wakeup the birds were released without further handling as the box was put on the ground at the edge of the top of the bird cliff and the sea-facing side of the box was opened. All birds took off to sea in normal flight. In most cases birds were not re-sighted on the ledge where they had been caught and if so only after several days. To increase the chance of having the tracked birds returning to their ledges and taking up parental care we placed murres in a box with an opening on one side, on a broad breeding ledge. Birds were sedated with Stesolid after wakeup prior to placement to prevent instant flight when released in the box. In this set-up the murre could emerge from the box after waking up listening to the calls of chicks. In four cases birds were waking up in this setup and two of these birds were observed back on their ledge. One of them was taking part in parental care and it was observed leaving the ledge with a young (PTT ID#41196). It was generally not possible to use the box-setup close to the birds own nest-site because ledges were too narrow and it would create too much disturbance. In one instance a sedated murre was put near its own chick without the box but supported by stones on the ledge. However, this bird was harassed by neighbour murres and an Iceland gull during wakeup and departed the ledge. We did not observe it back on the ledge during the next days and the box setup seems to be a better solution.

4.2.3 Satellite transmitter performance

In both 2005 and 2006 the PTTs stopped prematurely (Table 4.1) to the potential battery life, and we suspected that either 1) batteries failed (it appeared from other studies that battery failure was not uncommon in Microwave PTTs in 2005) 2) PTTs were worn out because of the intense deep diving activity 3) Subcutaneous PTTs were rejected or 4) the implanted birds died.

After the 2005 season we suspected that the PTTs were worn out because of frequent deep dives, since we had two shot murres handed in after the PTTs had stopped working - so in these cases the PTTs died before the birds. Both murres, which had subcutaneous implants, appeared to have been healthy at the time of shooting. One murre was shot 16 September near Aasiaat and the other further south in West Greenland, south of Sisimiut 10 November. The murre shot after 6 weeks had increased in weight since implantation (from 880 g to 925 g) while the murre shot after 15 weeks had lost weight (form 810 g to 769 g). The autopsy showed that for the murre shot after 6 weeks the PTT was in an early stage of rejection while for the murre shot after 15 weeks the PTT was sitting ok imbedded in the peritoneum.

To improve the performance the pressure proofing was improved on the PTTs used in 2006 (>500 m 1000psi). However, the PTT performance did not increase significantly (Table 5.1)

In 2008 an elaborate pressure test of two PTTs (model 2006) was conducted at FORCE Technology Institute. The PTT pressure test simulated murre dives in feeding bouts: 0-20 bar with 1 cycles pr. 3 minutes and a total of 1000 cycles. The PTTs were put on a roof after the test and performed normally indicating that at least in 2006 the premature stop of locations was not due to transmitter failure.

The fate of the implanted PTTs has been classified in four groups based on interpretation of the general trend for voltage, temperature and activity counter during the last locations we have received (Table 4.1). Out of the 27 PTTs, 8 had low battery and 5 birds appeared to be dead at last signal received, while both bird and battery appeared to be ok at the last location for 13 birds. Among the birds that appeared to be dead at last signal there was a tendency for overrepresentation of abdominal PTTs (4) versus the subcutaneous PTTs (1), and males (4) versus females (1) though the small sample size prevented meaningful statistics.

4.3 Results and discussion

4.3.1 Spatial and temporal patterns of ringing recoveries

Ninety one percent of all 309 recoveries included here derived from Greenland, and 72% were reported as shot in the Disko Bay area (Table 5.1, Fig. 5.1). This included 89% of all adults – 80% in the summer months alone – 70% of immatures, and 28% of first year birds. 303 of the recoveries were reported as ‘shot’, and 2 birds as drowned in fishing gear (4 unknown). Six birds were shot within 3 weeks after ringing; three of them being adults reported at or near the colony, and three of them chicks shot in the Vaigat sound on the swimming migration. Eight birds

– ringed as chicks – reached age 20 years old or more, the oldest two were 24 years.

The wintering grounds include West Greenland – mainly from Nuuk northwards, although one juvenile was recovered from Nanortalik in southernmost Greenland (Fig. 4.1) – and Canadian waters around Newfoundland. Among first-year birds, 38% were shot in Newfoundland during the winter months November to April.

Table 4.2. Temporal and spatial distribution of recoveries of thick-billed murres ringed at Ritenbenk, 1946-2005 grouped according to age at the time of recovery. 'Area' refers to Greenlandic municipalities (order north to south) or provinces in Canada: Quebec or Newfoundland (= NFLND). Municipalities in Disko Bay – near the ringing location – are in italics.

Age	Area	Month												
		Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Total
Adults	UPV										1	1		2
(>4 years)	UMQ									1	2		2	5
	ILU				*2*				*3*	*32*	*20*	*26*	*8*	*91*
	QEQ	*1*	*2*			*1*			*1*	*6*	*1*	*11*	*11*	*34*
	AAS	*1*	*1*											*2*
	KAN					1								1
	SIS			1				1						2
	MAN					1								1
	NFLND			1		1		3						5
Ad sum		2	3	2	2	4		4	4	39	24	38	21	143
Immatures	UPV										1	4	1	6
(2-3 years)	UMQ					1				2	10	4	3	20
	ILU			*1*						*13*	*24*	*22*	*3*	*63*
	QEQ			*1*							*1*	*4*	*4*	*10*
	AAS			*1*			*1*			*1*		*2*	*1*	*6*
	KAN	1												1
	SIS				1									1
	NUK				1				1					2
	NFLND	1		1		1	1							4
Imm sum		2		4	2	2	2		1	16	36	36	12	113
Juveniles	UMQ	2									3	4		9
(1 year)	*ILU*		*1*									*2*		*3*
	QEQ			*1*								*2*	*1*	*4*
	QAS		*1*											*1*
	AAS	*1*	*3*		*1*						*1*	*1*		*7*
	SIS		1	3	2									6
	MAN			1			1							2
	NAN				1									1
	NFLND			4	2	5	6	1	1					19
	Quebec				1									1
Juv sum		3	6	9	7	5	7	1	1		4	9	1	53
Total		7	9	15	11	11	9	5	6	55	64	83	34	309

In spring and summer, first year birds disperse and reach north to Uummannaq, while immatures and a few adults (up to 6 years old) reached as far north as Upernavik (Table 4.3, Fig. 4.2). Older birds (4Y+)

returned earlier to the general breeding area in Disko Bay than immature birds (Fig. 1, Table 98 in Lyngs 2003).

Murres from colonies further north in Greenland (Avanersuaq/Thule, Upernavik, Uummannaq) and high-arctic Canada (three colonies in Lancaster Sound) migrate through the Disko Bay area and mix with the local birds from Ritenbenk. More than 40,000 murres have been ringed in these areas (30,000 alone in Upernavik), and have provided 235 recoveries from the Disko Bay (and Ritenbenk) area (Table 4.3). In Ilulissat (near Ritenbenk), 22 murres ringed in the more northern areas have been shot within Ilulissat municipality, i.e. close to Ritenbenk. However, in Disko Bay the largest harvest of murres take place in Aasiaat in the autumn, and overall 18% of the recoveries derived from the autumn. Compared to the birds ringed at Ritenbenk, relatively few 'northern' murres are shot in the summer, so a large share of the birds hunted close to the Ritenbenk colony are likely to be local breeders.

Table 4.3. Recoveries in the four Disko Bay municipalities of thick-billed murres ringed in areas north of Ritenbenk: Uummannaq, Upernavik, and Lancaster Sound (3 colonies) in high-arctic Canada

Area		Month												
Ringed	**Recovered**	**Sep**	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Total**
UPV	QAS		6	2							1			9
	AAS	11	39	18			3			5	2	7		85
	ILU	1	4	2						1		5		13
	QEQ	15	18	5	1				1	4		3		47
UMQ	AAS	1	1									1		3
	ILU		1								3			4
	QEQ		1								1			2
Lanc. Sound	QAS				1					1				2
	AAS	3	13	15	4	1	1	4		13	1			55
	ILU						1	1	1	2				5
	QEQ	1	5		1		1			2				10
Total		32	88	42	7	1	6	5	2	28	8	16		235

Birds originating from northern West Greenland (Upernavik, Uummannaq and Ilulissat) winter partly in the Open Water Region along West Greenland and partly off Newfoundland south to Nova Scotia in Canada (Lyngs 2003) – as also indicated for Ritenbenk birds alone (Fig. 4.2). First-year Greenlandic murres tend to arrive in the Canadian wintering grounds and be harvested mainly from November onwards, whereas recoveries of second-year birds peak in January, and those of older birds in February (Donaldson *et al*. 1997). Although the data set from Ritenbenk alone is too limited to verify this, the recoveries do fit the general pattern.

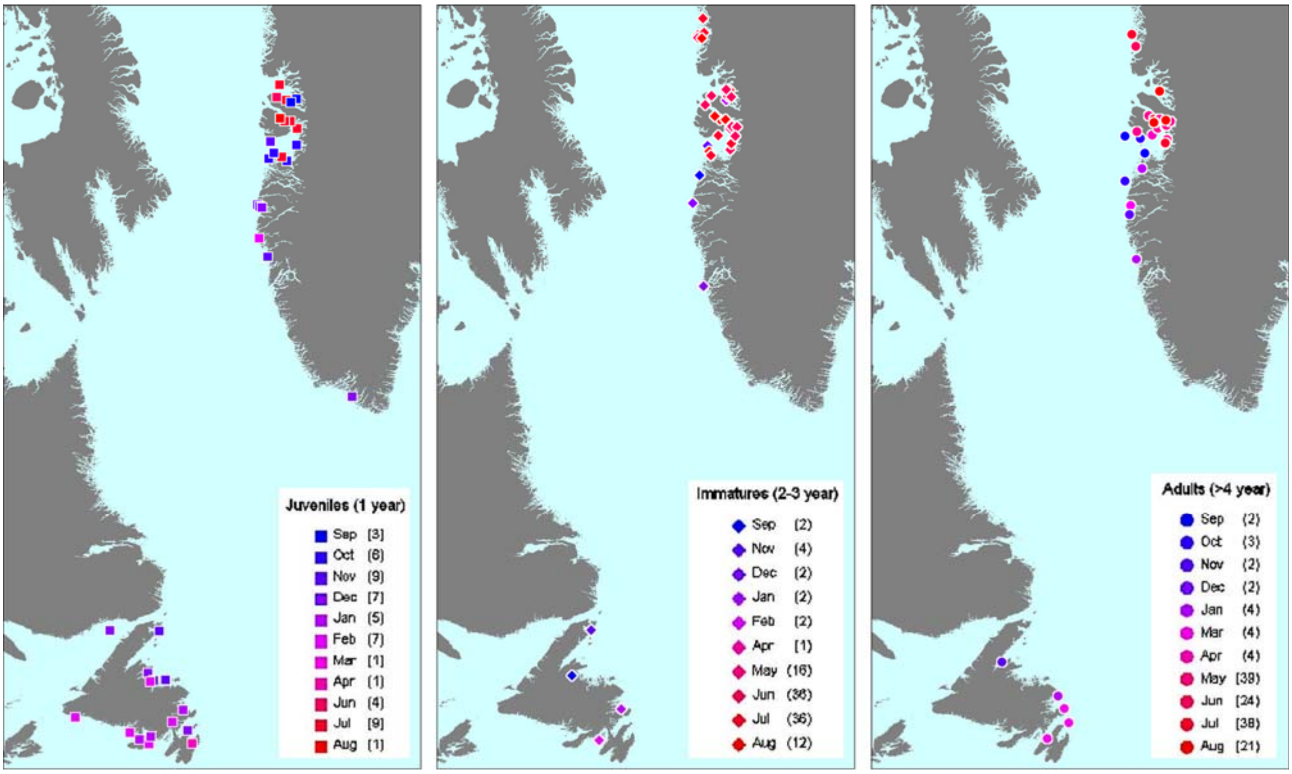


Figure 4.2. Distribution by month of recoveries of A) juvenile, B) immature, and C) adult thick-billed murres ringed at Ritenbenk; numbers in brackets are number of birds (cf. Table 4.1).

Clearly, most of the birds ringed at Ritenbenk are also recovered shot from the Disko Bay, i.e. the general breeding area. As indicated in Fig. 4.2 B & C, a few of the immature and adults were shot in the Disko Bay area on the autumn migration (blue symbols) in September, but the vast majority (red symbols) are shot in the breeding season, usually close to the colony.

Hence, the local hunting in the general breeding area has been a major mortality factor for the older cohorts, leading to conclusions (Kampp 1991a, Kampp *et al*. 1994) that the summer hunt is the most likely explanation for the observed population declines, including the diminished colony at Ritenbenk (and the loss of 5 very small colonies in its neighbourhood). See also chapter 3.

4.3.2 Migration and wintering based on satellite telemetry

On average, the 27 satellite tracked murres provided locations for 49.8 d (range 5-112 d (n=27)) covering the movements in most of August and September. The duration of the PTTs did not vary significantly with program for PTT transmissions (fast or slow) or PTT type (abdominal or subcutaneous) (GLM ANOVA for unbalanced data (factorial 2x2 model) $F = 0.34$ $P > 0.80$) neither with sex and PTT type (abdominal or subcutan) (GLM ANOVA for unbalanced data (factorial 2x2 model) $F=1.34$ $P> 0.30$) though there was a tendency for males PTTs to last longer than females (55 d and 41 d respectively).

Table 4.4. Results from tracking of 27 thick-billed murres with implanted satellite transmitters from the colony at Ritenbenk.

Ring#	Sex	weight	Year	Route	Last location	Days transmitted	Sum of movements*	Direct distance**	Average speed***
		g		Disko Isl.	Date	days	km	km	km/day
4137510	m	900	2005	South	19-10-2005	89	985	147	11
4137511	f	920	2005	South	16-08-2005	25	476	266	19
4137509	f	880	2005	South	23-08-2005	32	434	255	14
4137513	m	920	2005	North	06-10-2005	76	1380	384	18
4137508	f	810	2005	North	20-09-2005	61	1695	141	28
4137507	f	900	2005	South	05-10-2005	76	2787	2161	37
4137506	f	890	2005	South	31-08-2005	41	1433	167	35
4137512	f	880	2005	South	19-09-2005	59	869	176	15
4137514	m	860	2005	North	25-08-2005	33	1187	588	36
4137515	m	1000	2005	North	13-09-2005	52	1415	448	27
4137534	m	900	2006	North	03-08-2006	21	453	296	22
4137523	m	880	2006	n.d.	04-10-2006	81	914	264	11
4137535	f	870	2006	North	02-09-2006	49	1251	215	26
4137538	m	870	2006	North	24-09-2006	70	979	300	14
4137536	m	n.d.	2006	North	26-08-2006	42	604	206	14
4137526	f	870	2006	North	29-07-2006	13	173	161	13
4137520	f	1000	2006	North	03-08-2006	18	330	211	18
4137537	m	920	2006	North	21-09-2006	67	808	102	12
4137540	m	915	2006	North	14-09-2006	59	1718	1141	29
4137541	m	945	2006	North	15-09-2006	60	987	289	16
4137542	f	1030	2006	North	21-08-2006	35	450	259	13
4137543	m	940	2006	North	31-07-2006	14	138	132	10
4137544	m	890	2006	North	03-09-2006	48	196	110	4
4137545	m	845	2006	North	06-11-2006	112	244	160	2
4137531	m	985	2006	North	29-08-2006	42	198	75	5
4137532	m	860	2006	North	23-07-2006	5	100	98	20
4137518	m	950	2006	North	17-09-2006	65	1325	202	20

* sum of distance between ‘best pick’ locations (see text)
** direct distance from colony to last location received
*** calculated as ‘sum of movements’/’ days transmitted’

The murres left Disko Bay and the Vaigat Strait at the end of July and occurred dispersed in the south-eastern Baffin Bay in the following weeks including the wing moult period (Fig. 4.3 and 4.4). Males tended to migrate north of Disko Island through Vaigat (15 of 16 birds) when they left the colony, while female tracklines were distributed equally with 5 north of Disko and 5 south of Disko (Fig. 4.3). Though this difference between sexes is significant (Fishers exact test P = 0.02) it is confounded by unequal distribution between the two years as all birds took the northern route in 2006. However, that the main swimming migration of males and chicks follow the northern route is supported by the earlier recovery of 3 chicks shot in Vaigat (Lyngs 2003) and it fits well with the direction of the genral surface current in Vaigat. The northern route was also taken by a male which was observed to leave the colony with a chick (Fig. 4.6). The rate of movement for this bird was below 2.25 km/hour and it most likely performed the swimming migration with a chick.

Figure 4.3. Routes for the 27 thick-billed murres tracked from the Ritenbenk colony in 2005 and 2006. Blue lines = males, red lines = females.

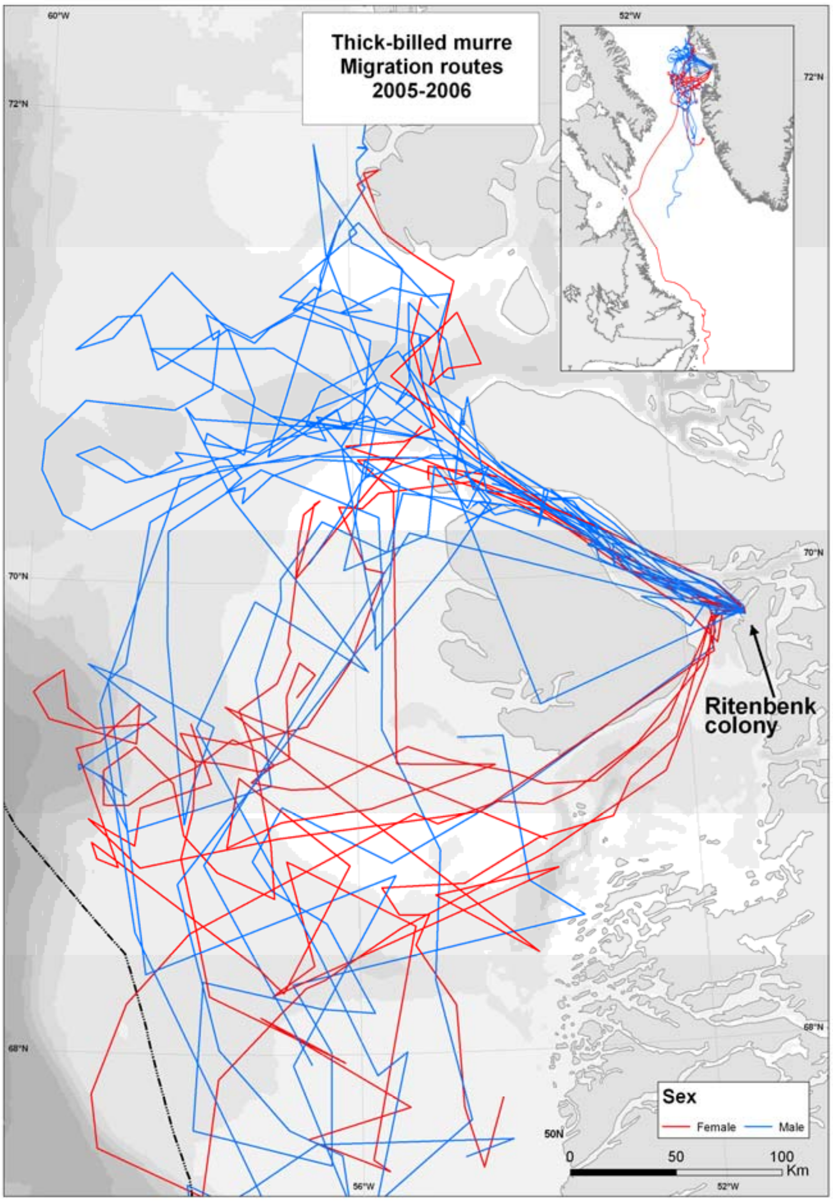
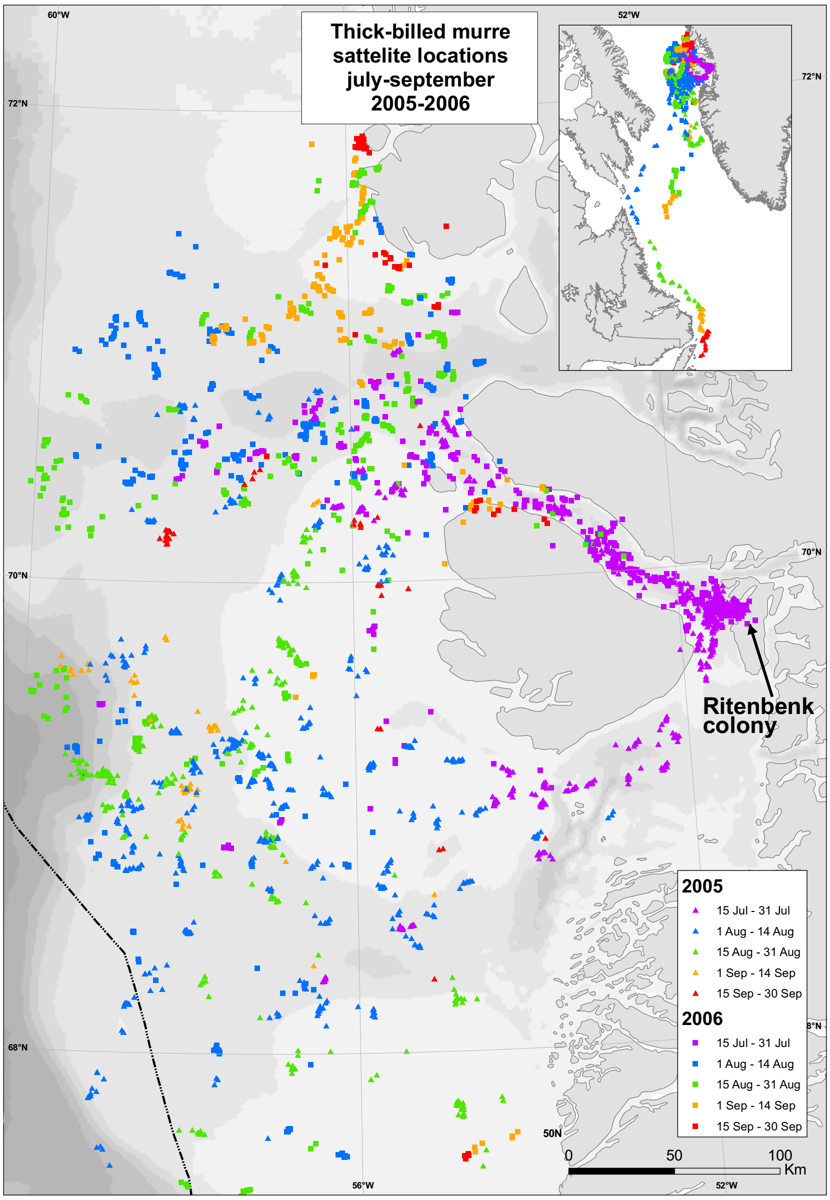


Figure 4.4. The temporal and spatial distribution of locations from 27 thick-billed murres tracked from the Ritenbenk colony.



To extrapolate the distribution of locations of tracked murres in the southeastern Baffin Bay in August – September, we did an exploratory modelling of the potential distribution using the variables: distance to coast, bathymetry and slope (Fig. 4.6) (MaxEnt approach: Phillips *et al*. 2006, Edrén *et al*. in press). Among the variables included in the model distance to coast contributed most to the predictions (93%), and there is a significant drop in concentrations of murres about 200 km west of the Greenland coast. Slightly elevated concentrations occur north of Store Hellefiskebanke and north of Hareø.

While most of the murres stayed and performed wing moult in southeastern Baffin Bay two murres migrated towards the Labrador coast. One of them, a female, migrated to Newfoundland in the first half of August (Fig. 4.7) where it lowered the rate of movement after arrival and most likely performed wing moult here.

Figure 4.5. The route tracked for a male thick-billed murre which took up parental care on the breeding ledge after the implantation of a subcutaneous PTT and later left the ledge with a chick and started swimming migration. The average rate of movement is calculated between the best quality locations in consecutive PTT transmission periods (Best Pick location in each of 56 28 hour cycles).

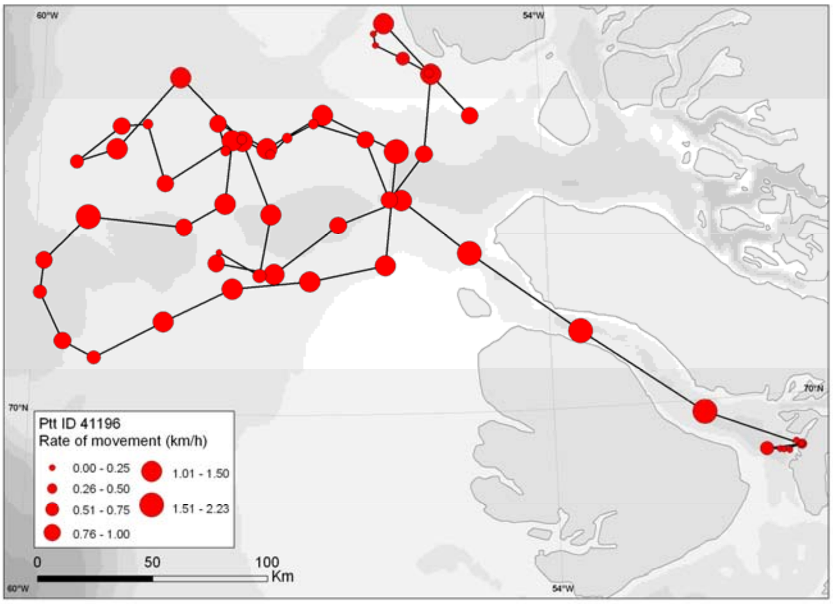


Figure 4.6. Offshore distribution of thick-billed murres from Ritenbenk in August – September (a). The distribution is based on a MaxEnt model of bootstrapped samples of locations from 15 individuals with more than 10 locations (best pick of location accuracy class in each duty cycle) in the offshore area. Predictions of standard deviations (b) in each pixel were calculated over 10 bootstrap samples.

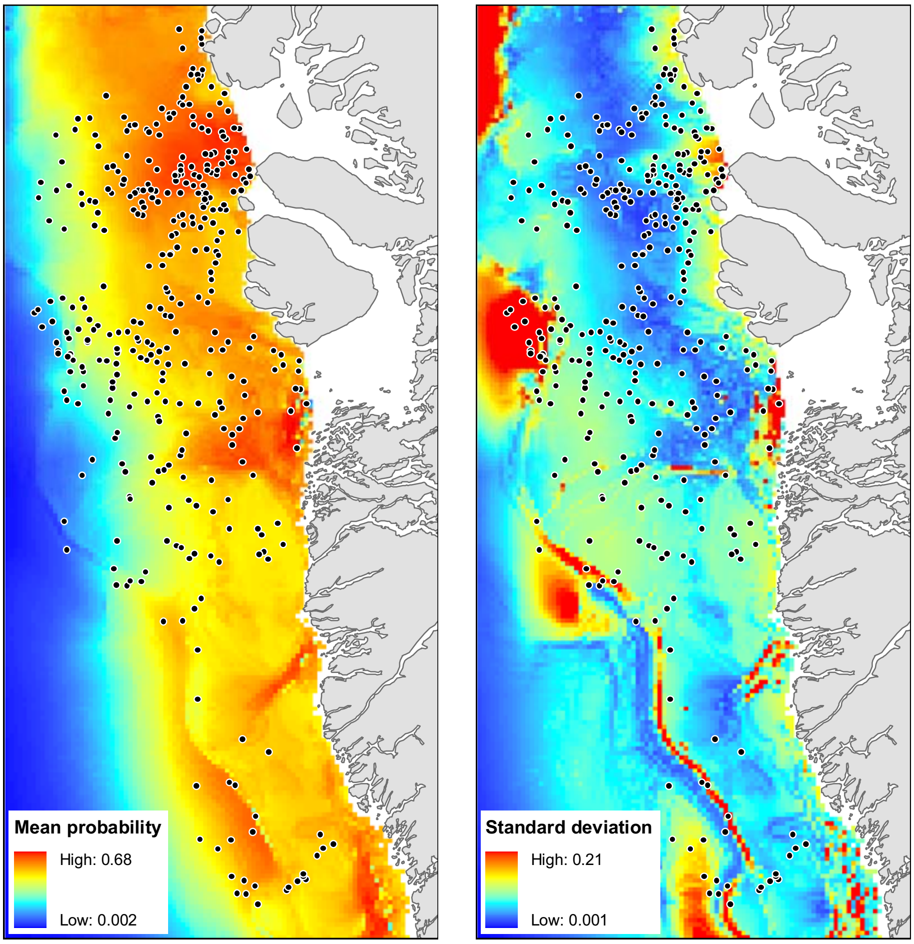
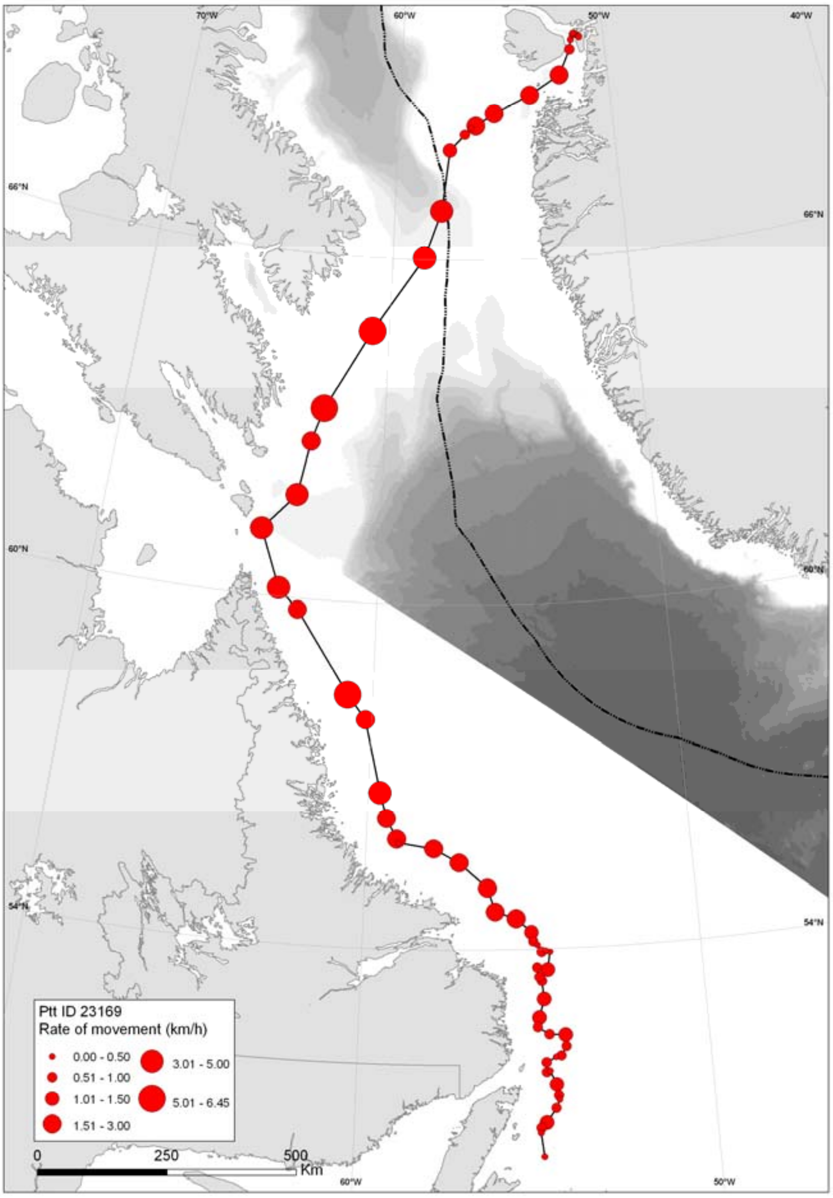


Figure 4.7. The route of a female thick-billed murre (#4137507) tracked from Ritenbenk and arriving in northern Newfoundland in the first half of August. The average rate of movement was calculated between the best quality locations in consecutive PTT transmission periods (‘best pick’ locations). At the coast of Labrador the average rate of movement fell below 3km/h indicating that most likely wing moult started here.



Based on the satellite tracking it can be concluded that the Innaq population to a large extent migrate through Vaigat and a large part of the population will pass through the Vaigat - Hareø area around 1 August. An oilspill coinciding with this can have a serious impact on the colony. Later in the autumn and winter the birds from the Innaq colony occur more dispersed and the colony will be less vulnerable to an oil spill. Based on the ringing recoveries the adult birds from the Ritenbenk colony are back in the Disko Bay in May, at this time they may also occur aggregated at good feeding spots.

5 Foraging behaviour and chick feeding

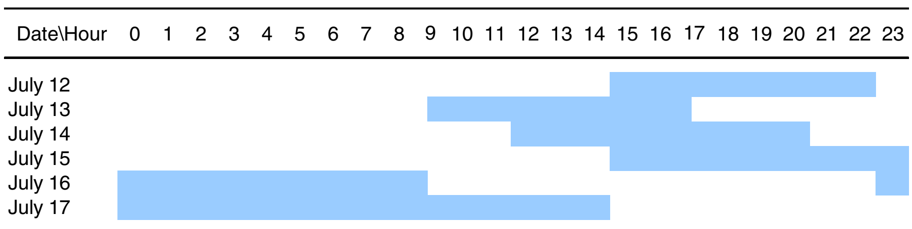
5.1 Introduction

In this chapter we combine traditional methods of observing feeding activity directly in the colony with the more advanced technology of small data loggers (Time-Depth-Recorders; TDRs) to examine the foraging behaviour of thick-billed murres in the Ritenbenk colony. Over the recent decades, miniature data loggers have been successfully used to investigate time budgets and diving behaviour of the larger wing-propelled pursuit diving seabirds such as the penguins (*Aptenodytes forsteri*) (e.g., Kooyman & Kooyman 1995, Trembley *et al*. 2003). Gradually these devices have become smaller and lighter, to an extent where leg attachment is now possible on murres (Croll et al. 1992, Benvenuti *et al*. 2002, Mehlum *et al*. 2001 and Falk *et al*. 2002). Knowledge about at-sea activity, including the diving behaviour, is limited for thick-billed murres, despite the fact that this constitutes a large component of the time/energy budget during the breeding season and may be important for understanding the general status of the breeding populations.

5.2 Methods

Direct observations of feeding rates in study plot 2 (A-D) were carried out as continuous observations in blocks of 8-16 hours, spread over the period 12-17 July, 2006 (Fig. 5.1). The observations added up to ca. 60 hours in total and covered the full diurnal cycle, although effort was slightly higher during afternoon and early evening (Fig. 5.1). Feeding rates were recorded for 21 breeding pairs and as far as possible additional arrivals (no food) and departures were also recorded. Some food items were identified by visual cues and sized in relation to the bill length of the adult bird. When calculating feeding rates, both feedings that were recorded as "food seen" and as a "likely feeding" (behavioural cues) were included.

Figure 5.1. Effort distribution of direct observations of murre chick feeding rates in the Ritenbenk colony in 2006 (study plot 2, A-D).



TDR Data loggers were deployed on thick-billed murres with chicks (Table 5.1). The adult murres were caught on the nest site with an 8-m noose pole. In 2006 6 data loggers were successfully deployed and retrieved on breeding murres attending chicks. In addition one data logger (ID # 830) was deployed late in the breeding season in 2005 where it logged for 5 days mostly during the migration and it was retrieved in 2006 (Table 5.1). We used small StarOddi DST Micro data loggers, (25 mm long cylinder, diameter 8 mm , weight 3.3 g in air and 1.9 g in water) attached with two cable ties and silicone glue to a metal tarsus band where four holes were drilled for the cable ties (Fig. 5.2).

The Time Depth Recording (TDR) data loggers recorded pressure and potentially temperature at predefined intervals (sampling rate). We used mostly 10 seconds sampling rate for pressure data (Table 5.1) which give a rather accurate description of the depth distribution in each dive while temperature was only sampled at 30 s intervals to save logger memory. A dive was defined as a series of records with depths (pressure) greater than 3 m, to eliminate data noise from display and comfort behaviour at the sea surface. Thick-billed murre foraging behaviour occur in feeding bouts which is a series of dives followed by a longer pause before the next feeding bout or by another behaviour (Croll *et al*. 1992). Based on a preliminary data analysis of dive distributions we defined feeding bouts as a series of dives with less than 5 minutes in between each dive. We used both temperature and depth data to estimate the number of feeding trips. When birds were brooding on the ledge logger temperature generally exceeded 30 °C while the sea surface temperature was about 5 °C, and air temperature generally above 10 °C (Fig.5.8).

Figure 5.2. Data logger attached to a metal tarsus band on a Thick-billed murre.

Table 5.1. Deployment of Time Depth Recorder (TDR) data loggers on chick-rearing thick-billed murres in the Ritenbenk murre colony.

ID #	Pressure Sampling rate (seconds)	Logging started	Deployment time (days)	Feeding bouts recorded (N)	Sex	Chick age at deployment (days)
1473	10	11-07-2006 17:00:00	3.6	24	m	10-14 d
1474	10	11-07-2006 12:36:00	3.8	44	n.d.	< 7
1476	10	11-07-2006 15:30:00	3.7	33	m	10-14 d
1479	10	11-07-2006 16:40:00	2.8	31	m	18+ (jumps 16-07)
1489	10	11-07-2006 12:36:00	1.9	16	f	< 7
1502	30	11-07-2006 17:00:00	6.9	53	m	n.d.
830	12	26-07-2005 23:31:00	5.0	50	f	18+

We defined it as a feeding trip (roundtrip from the ledge) if there were one or more feeding bouts between two 30 °C threshold values. Likewise we calculated an estimate of the total number of relocating flights either between feeding locations or to or from the ledge using a 10 °C threshold value for the logger being exposed to air. Some of these trips could have been chick feeding trips with only a short stop on the ledge (Elliot *et al.* 2008).

5.3 Results and discussion

5.3.1 Feeding observations

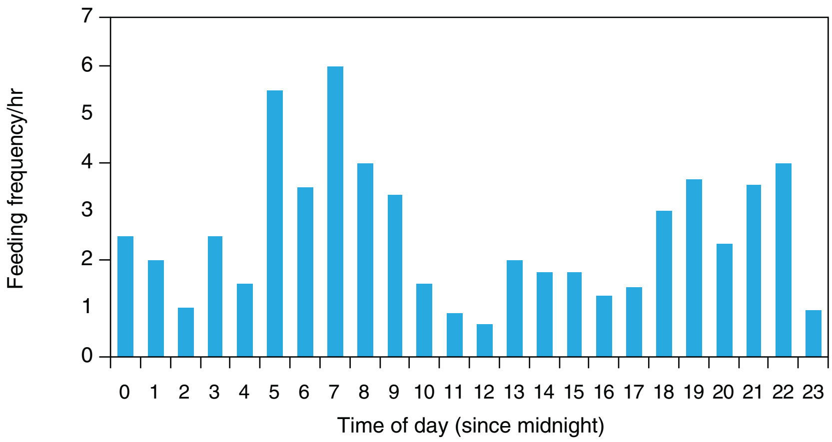
Among 143 feedings recorded the food was identified as either "fish sp." (N=63), capelin (N =55, Fig. 5.3), sea scorpion (N =5), polar cod (N =1) or as sandeel (N =1). In 18 cases the food was unidentified. Apart from the capelin, which clearly was important diet for the murre chicks in 2006, the frequency distribution of the prey species should be treated with care, since the visual identification is difficult and easily biased. No previous information about chick diet is available from the Ritenbenk colony.

On average, the feeding rate was 2.72 meals/chick/day, ranging from 0 to 6 meals. This is identical to the feeding rate observed in the Kippaku murre colony in northern Upernavik in 2008 (mean 2.73, N = 47 chicks), but less than observed further north at Saunders Island (mean 4.92, N = 24 chicks) in Qaanaaq, 2008 (NERI & GINR, unpubl.). At breeding locations outside Greenland chicks were fed an average of 2–6 meals/day (Gaston & Hipfner 2000).

The feeding frequency of the chicks in the Ritenbenk was highest in the morning from 5 to 9 and also above average in the evening from 18 to 22 (Fig. 5.4). This bimodal feeding pattern is similar to the diurnal attendance pattern (Fig. 2.5), indicating that simultaneous attendance by both parents is closely linked with the feeding events.

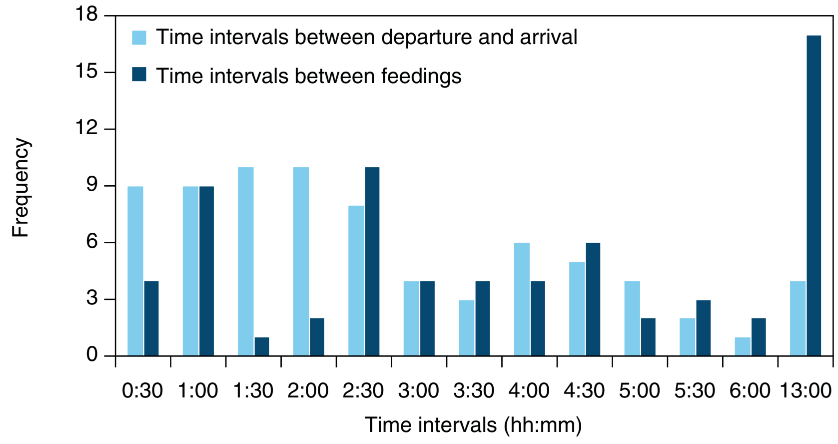
Figure 5.3. Thick-billed murre arriving at nesting ledge with capelin for its chick at Ritenbenk, July 2005.

Figure 5.4. The feeding frequency/hr for 21 chicks in the Ritenbenk murre colony (study plot 2, A-D) in 2006 (12-17 July) in relation to time of day (local time).



The duration of the feeding trips (from departure to arrival) show that murres were capable of finding food for the chicks relatively close to the colony in 2006. More than 50% of the recorded feeding trips were shorter than two hours and 12% were shorter than 30 min. (Fig. 5.3). A rougher estimate of the duration of the feeding trip is the time interval between two subsequent feedings, which ignore periods where both parents attend the breeding site simultaneously. This study roughly quantifies the magnitude of this bias (Fig. 5.5). In 2006 the mean interval between departure and arrival was 2.47 hrs (N = 75), while the mean interval between subsequent feedings was 3.78 hrs (N = 68), implying that the parents spend on average 1.32 hrs together at the breeding site after feeding the chick.

Figure 5.5. Frequency distribution of the duration of feeding trips in the Ritenbenk murre colony (study plot 2, A-D) in 2006, 12-17 July, determined as the time interval between departures and arrivals (N = 75) or as the time interval between subsequent feeding observations (N = 68).



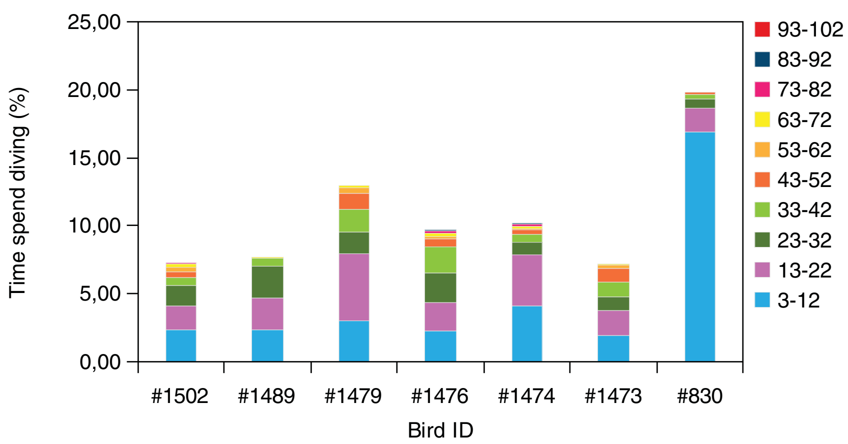
5.3.2 Dive recordings

From the data loggers we got diving information for 7 birds covering a total of 27.7 days with 251 feeding bouts. For six of the birds the recorded data were entirely from the chick-rearing period in 2006 while data from one bird (ID# 830) mainly represents the diving behaviour after the chick had left the breeding ledge in 2005 (Table 5.1 and 5.2). The chick-rearing birds used on average 9.2% ± 2.3% (mean ± SD) of the total time budget diving (Table 5.2 and Fig. 5.6).

Table 5.2. Diving behaviour for seven thick-billed murres in the Ritenbenk murre colony deployed with Time Depth Recording (TDR) dataloggers during chick-rearing.

ID #	Dive Time %time below 3 m	Feeding bouts/day	Feeding trips/day 30 °C treshold	Feeding trips/day 10 °C treshold	Deployment time (days)
1473	7.2	6.7	2.5	4.5	3.6
1474	10.2	11.7	1.6	2.6	3.8
1476	9.7	9.0	1.9	3.0	3.7
1479	13.0	11.0	1.8	5.3	2.8
1489	7.7	8.5	7.4	8.5	1.9
1502	7.3	7.6	2.6	3.6	6.9
830	19.8	10.0	n.d	n.d.	n.d.

Figure 5.6. The relative time spend diving for 7 birds (see table 5.1 for bird details). The colour coding of the columns show the different depth intervals from 3 m to 102 m.



The chick-rearing birds were estimated to have 3.0 ± 1.9 feeding trips per day (mean ± SD) using the 30 °C threshold, and 4.6 ± 2.1 trips per day using the 10 °C threshold which includes relocations between foraging areas (Fig. 5.8). The number of feeding trips per day per bird estimated from the logger data (using the 30 °C threshold) is about the same as the direct observed chick feeding frequency (2.72 meals/day). However as there are two parent birds feeding the chick this indicates that there are two feeding trips for each time the chick is fed. There may however be sex differences as the only female among the 5 chick-rearing birds, where we identified the sex, was an outlier with a relatively high number (7.4) of feeding trips per day while the other foraging parameters were within range (Table 5.2 and 5.3).

On average the chick-rearing birds had 9.1 ± 1.9 feeding bouts per day (mean ± SD) with an average duration of 24.8 ± 16.5 minutes and 10.3 ± 7.5 dives per feeding bout. The average of the maximum depths recorded in each feeding bout were 41.0 ± 18.4 m (Fig. 5.7). It was not possible to identify significant differences among the six chick-rearing birds in relation to sex or chick age as the range in values among birds was relatively limited and the sample size small (Table 5.2 and 5.3).

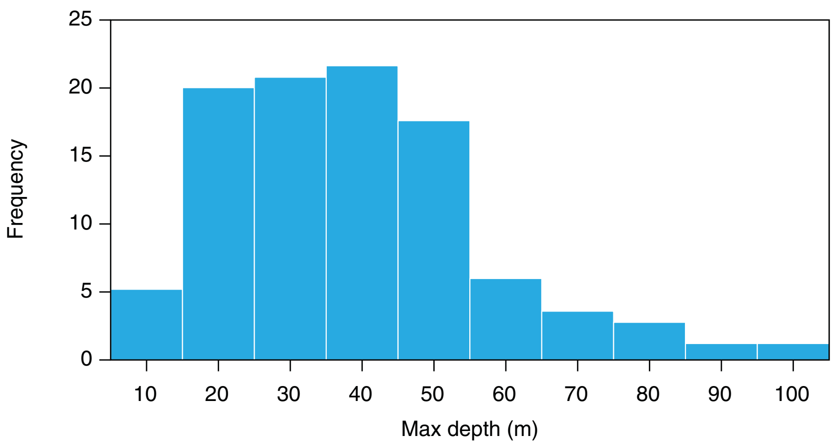


Figure 5.7. Frequency distribution of the maximum depths recorded in each feeding bout (N=251).

Table 5.3. Feeding bout characteristics for seven thick-billed murres in the Ritenbenk murre colony deployed with Time Depth Recording (TDR) data loggers during chick-rearing.

TDR ID #	Feeding bouts recorded (N)	Feeding bout duration Mean (minutes)	SD	Dives per Feeding bout mean	SD	Maximum depth during feeding bouts (m)	SD
1473	24	29.1	25.9	9.5	10.0	48.4	12.9
1474	44	22.8	16.8	11.6	9.5	37.6	24.9
1476	33	24.9	14.1	10.8	6.3	47.7	18.3
1479	31	25.4	14.8	12.4	7.6	42.3	17.1
1489	16	20.4	8.2	7.8	3.5	32.4	7.0
1502	53	25.5	14.9	8.9	5.3	38.1	14.8
830	50	12.1	9.2	8.7	6.7	27.8	13.3

Figure 5.8.a. Diving behaviour recorded with TDR for a thick-billed murre on a foraging trip the night between 13 and 14 July 2006. Between 11 PM and 8 AM the murre made 9 feeding bouts. Most dives (blue) went to about 40 depth but in the last feeding bout dives exceeded 80 m depth. The temperature (red) at the sea surface was ca. 5 °C, decreasing to ca. 1 °C at 40 m and remaining at that level down to 80 m.

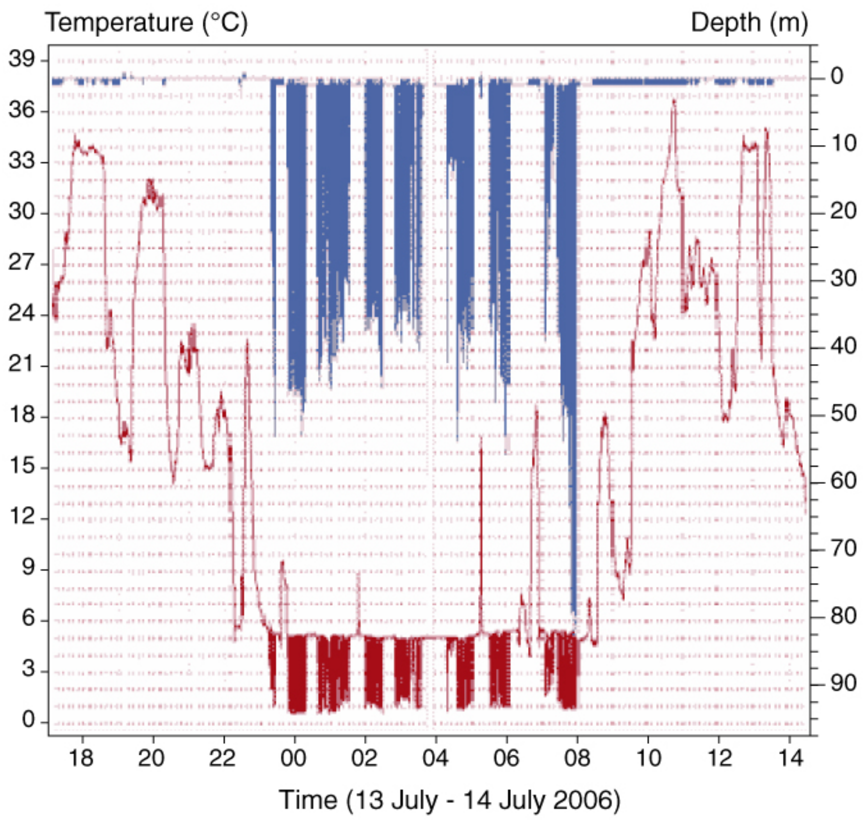
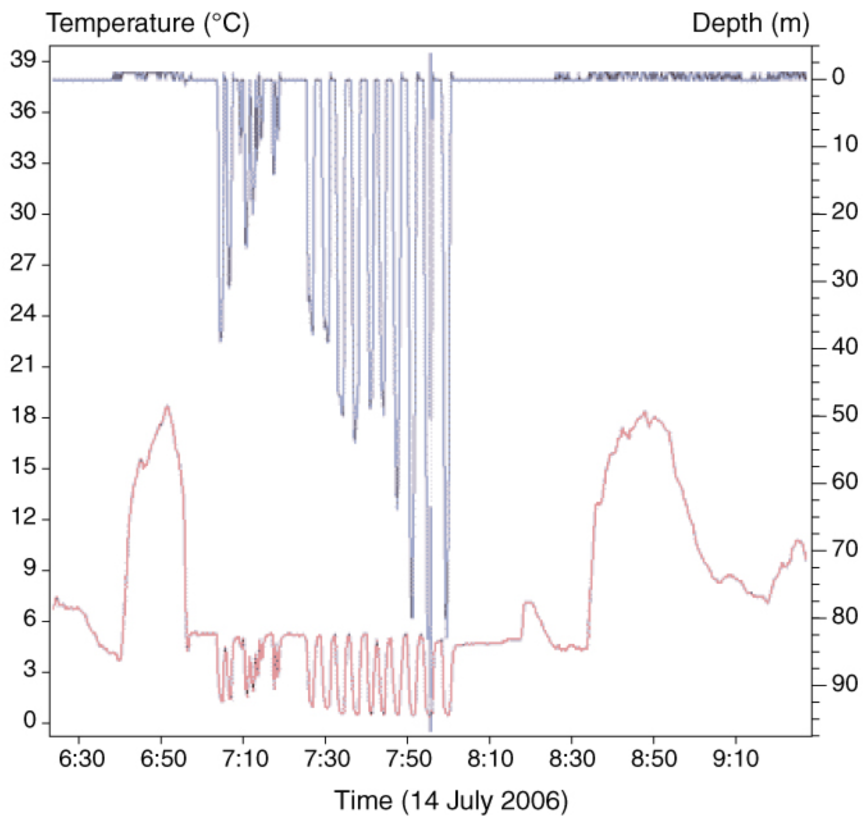


Figure 5.8b. Enlargement of the last feeding bout in fig 5.8a.

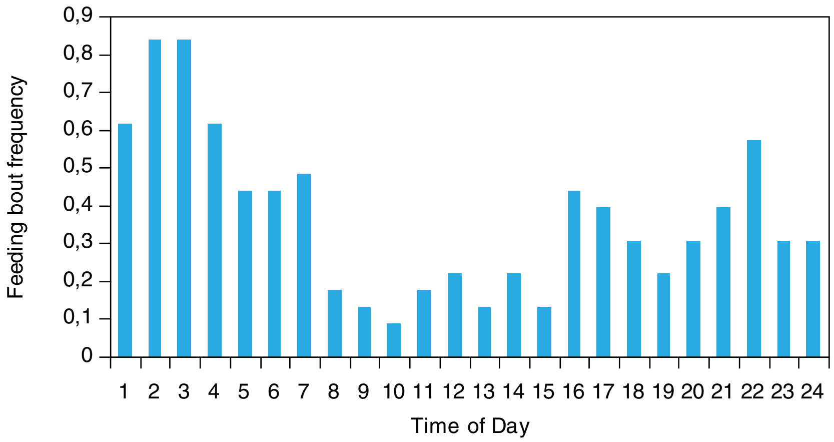


Murres can only carry a single prey item held lengthwise in the bill (single prey loaders), and thus feed the chick with only one item per meal. It is therefore important for the provision of the chick that the murres can catch large nutritious prey like capelins, especially if there is a significant travel distance to the foraging area. There were more feeding bouts recorded per day (9.1 bouts/day) than feeding trips (Table 5.2). Thus some feeding bouts did not result in a single food item brought to the chick either because the murre was feeding itself or because the murre had to use several feeding bouts to catch a suitable prey item for bringing back to the chick.

In one occasion we sailed in the opposite direction of the incomming murres which were returning to the colony from feeding trips. This lead us to an area with intensive foraging activity about 20 km west of the colony. Supporting that the observations of relative short feeding trips indicate that good foraging areas were close to the colony.

There were a maximum in feeding bout frequency at night (Fig. 5.9) which preceded the maximum in chick-feeding during morning (Fig. 5.3) with about 3 hours, indicating that murres mainly provided for themselves first during late night/early morning foraging. Both the diurnal distribution of feeding bouts (Fig. 5.9) and the chick-feeding frequency had the lowest level at noon and the early afternoon.

Figure 5.9. The distribution of feeding bout frequency in relation to time of day (local time) for six birds assumed to feed chicks on the ledges. Feeding bout frequency is based on logging of diving activity for six birds for a total of 200 feeding bouts in 544 hours. The feeding bouts frequency is given as number of feeding bouts per hour per bird.



5.3.3 Conclusion

The relative time the chick-rearing murres spend forage diving (9.2%, Table 5.2) is in the lower end of the range reported from other localities (Gaston & Hipfner 2000). For example Falk *et al.* (2000) found 16.6% of total time were used diving at the Hakluyt colony in the North Water Polynya. Overall the limited time spent diving and the chick-feeding observations indicate that forage conditions were rather good in 2006.

6 Kittiwake population estimate, phenology and breeding success

6.1 Introduction

The Ritenbenk cliff is also home to a breeding population of black-legged kittiwakes. There is no national monitoring plan for kittiwakes, but since they often breed in the same colonies as the murres, monitoring is often combined.

The kittiwakes were subject to less detailed studies than the murres, and the data collection was limited to a survey of the breeding population, the rough timing of breeding, and breeding success (brood size).

The kittiwake can have up to three young, so the span in breeding success (number of chicks per nest) is larger in the kittiwake than in the murre. In areas of poor oceanographic production, three-egg clutches may be very rare. Even if early-season production allows for a large clutch, chick food may be limited and chicks may die, starting with the smallest. Hence, brood size and breeding success of the kittiwakes are rather sensitive indicators of overall food availability within the adult birds' foraging range, integrating over the pre-laying and chick feeding period.

Black-legged kittiwakes and an Iceland gull (upper left) at Ritenbenk, 2005.

6.2 Methods

The kittiwake population was counted directly (not photo count) as Apparently Occupied Nests (AON) on 5 July 2005 and 19 July 2006 (Tab. 3.1). The kittiwake count was conducted along with murre counts from the small peninsula on the opposite side of the bay at a distance of 1000 –

1,100 m from the colony (Fig. 1.1). We used a Zeiss Diascope 85 TFL (20x-60x) spotting scope.

Kittiwake breeding phenology was assessed by screening a sample of 'Apparently Occupied Nests' (AON) in seven different sub-colonies using a 32x telescope. The same observer conducted the survey in both years (on 27 July 2005 and 23 July 2006) and recorded the approximate age of the chicks, in this case roughly classified in four groups: as downy young, feathers with no/little black markings visible, clear black markings (mainly on neck, but also wings), and large, feathered young. These categories were subsequently converted into rough estimates of age in number of days (cf. Walsh *et al*. 1995): 6, 10, 16 and 25 days, respectively, and the figures used to estimate approximate timing of breeding for the two years.

When screening 'Apparently Occupied Nests' of kittiwakes for breeding success, only nests where all chicks can be counted are included in analysis, whereas when assessing chick age, just some chicks have to be visible for the nest to be included in estimate of timing of breeding.

The crude categories used in aging in this case makes the estimates of phenology very rough, but nevertheless does provide an impression of the typical timing of breeding in the Ritenbenk colony.

6.3 Results and discussion

6.3.1 Population estimate

The kittiwake population was counted once in 2005 and once in 2006, both as direct counts of Apparently Occupied Nests (AON, Tab. 3.1). The number of nests differed hugely between the two years, indicating a reduction of 35% from 2005 to 2006. A possible bias due to varying degree of attendance should not be of major concern since we counted nests and not individuals. Furthermore, the AONs were counted by the same observer (David Boertmann) in both years and major bias due to disagreement in the interpretation of AONs can also be disregarded. The number of prospecting individuals in a kittiwake colony is known to increase over the chick rearing period (Boulinier *et al*. 1996, Cadiou 1999), and if the presence of such individuals are mistaken for AONs this could result in overestimation if surveyed late in the breeding season. This does indeed not explain the much lower estimate in 2006, which was generated two weeks later than the 2005 survey.

In theory, the small number of nests in 2006 could be explained by breeding failure. In case of a massive breeding failure, a large proportion of the breeders perhaps abandoned the nests prior to the survey on 19 July. However, various productivity counts conducted in 2005 and 2006 does not support such a scenario (see below). On the contrary, breeding success suggests approximately equally favourable conditions in both years. Alternative explanations for the observed decline include large-scale non-breeding by established breeders, emigration to other colonies, and high adult mortality. There are examples of kittiwakes skipping breeding seasons or moving to other colonies in large numbers (Danchin & Monnat 1992, Suryan & Irons 2001), but this usually happens when food conditions are very poor or predation/parasitism at the colony is high, resulting in low reproductive success. Given the high observed breeding success in 2005, none of these explanations seem very likely, and the most obvious mechanism behind the population decline thus seems to be high adult mortality. However, further colony counts are necessary to draw any firm conclusions.

Table 6.1. Direct counts of Black-legged Kittiwake 'Apparently Occupied Nests' (AON) in the Ritenbenk colony, 2005.

Date	5 July 2005	19 July 2006
Time of day	17:00-19:00	15:10-19:00
Northern section	1,125	772
Southern section	1,380	803
Annex	278	236
Total nests	2,783	1,811

As with the murres, previous estimates of the Ritenbenk kittiwake population indicate a severe population decline over the past two or three decades. In the period 1994-1998 the breeding population was twice estimated to ca. 6000 nests (NERI 2007), implying an annual decline of 10-14% up to now. In 1984 a breeding population of rough 22,000 pairs (35,000 birds) was estimated and indicate a similar rate of decline between 1984 and 1994.

6.3.2 Phenology

The assessment of chick age in each nest indicated that mean hatch dates were 11 July and 6 July in 2005 and 2006, respectively, with an apparently slightly larger spread in hatching dates in 2005 (Tab. 3.2, Fig. 3.1). The difference in timing between the two years is small – and in the same direction as also shown by the murres: 2006 being slightly earlier than 2005.

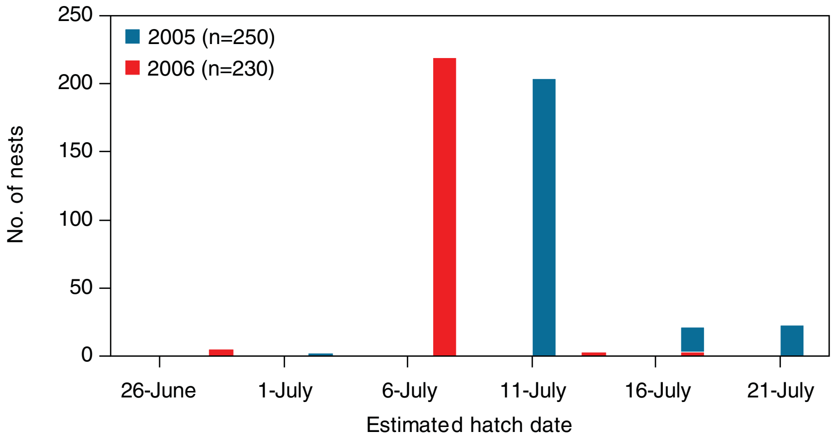


Figure 6.1. Distribution of Kittiwake hatching dates at Ritenbenk in 2005 and 2006; note rough categories used (see methods).

Table 6.2. Hatching dates of Kittiwakes at Ritenbenk.

Parameter	Year	
	2005	2006
Mean hatch date	11 Jul	06 Jul
Late	21 Jul	17 Jul
Early	02 Jul	28 Jun
SD	2.7	2.0

6.3.3 Breeding success

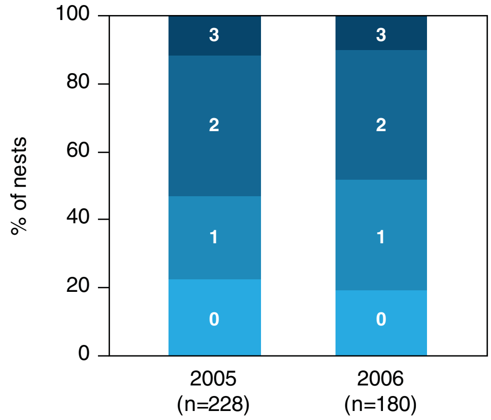
The reproductive performance of kittiwakes was very similar in the two years: Breeding success was slightly higher in 2005 than in 2006 – both measured as brood size (chicks per successful nest) and chick per nest (Tab. 6.3). The distribution of brood size was very similar in the two years with 11.8 and 10% of nests with three young in 2005 and 2006 (Fig. 3.2), respectively, and the equivalent figures for unsuccessful AONs of 22 and 19%, respectively.

Table 6.3. Breeding success of Kittiwakes at Ritenbenk.

Parameter	Year	
	2005	2006
Chicks per succesful nest	1.84	1.72
SD	0.67	0.67
Sample size, N	177	145
Chicks per AON	1.43	1.39
SD	0.97	0.91
Sample size, N	228	180

AON = 'Apparently Occupied Nests'

Figure 6.2. Distribution of kittiwake brood size at Ritenbenk in 2005 and 2006.



The number of young/successful nest is high, and so is the proportion of broods with 3 young; for example the northernmost kittiwake colony in West Greenland (Hakluyt Island) produced 0.55 to 0.98 chicks per successful nest over three years (Falk unpubl. data), and the northernmost in East Greenland produced 1.4 young/successful nest (Falk & Møller 1997).

Most chicks were large at the time of survey, so mortality between survey and fledging is likely to have been relatively low. Hence, the overall breeding success is relatively high, and – along with the mere presence of a significant proportion of nests with three young – suggests fairly favourable foraging conditions in the area in both years.

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