Population fluctuations in Rock Ptarmigan in high-arctic Greenland

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(Med et dansk resumé: Populationssvingninger i bestande af Fjeldrype i højarktisk Grønland)

Abstract Cyclicity in population fluctuations has been described in a number of tetraonid species. Also, synchrony in these fluctuations – both between and within species – has been found in several bird species and other animals. The present study analyses data of the northernmost subspecies of Rock Ptarmigan *Lagopus mutus captus* in Greenland. The material has been collected by the Danish military dog sledge patrol *Sirius* in North and Northeast Greenland during the period 1977-2006. The material from three of the subareas was of sufficient quality for statistical analyses. Additionally, we present data from the Zackenberg Research Station and the Karupelv Valley Project within the same general study area. We checked for cyclicity in the population fluctuations by testing the significance of the parameters in an autoregressive log-linear model fitted to the time series, but failed to detect cyclicity in any of the time series. Some level of synchrony in population fluctuations between neighbouring subareas was detected, although this was statistically significant in only one pair of neighbouring subareas.

Introduction

Ptarmigan population cycles have been described from many areas, involving various species and subspecies. The duration and amplitude of these cycles vary from region to region, even within species (e.g. Cattadori & Hudson 1999). However, not all ptarmigan populations seem to be cyclic, some not even fluctuating to any noticeable extent (e.g. Switzerland, *Lagopus mutus helvetica*, Glutz von Blotzheim et al. 1973).

Rock Ptarmigan occurs throughout Greenland. It is one of the few avian species that over-winter within the high-arctic zone, in Northeast Greenland as far north as Wollaston Forland (75ºN; Boertmann 1994), while more northern populations migrate southwards in late autumn and return in spring. At Danmarkshavn (78ºN; subarea C in Fig. 1), the first birds return in the second half of January or the first half of February, but spring migration does not peak until around 1 April (Meltofte 1975, 1977, Forchhammer 1990). The populations in subareas A and B (Fig. 1) are thought to be resident except, perhaps, in years where the population peaks (Salomonsen 1950, 1967).
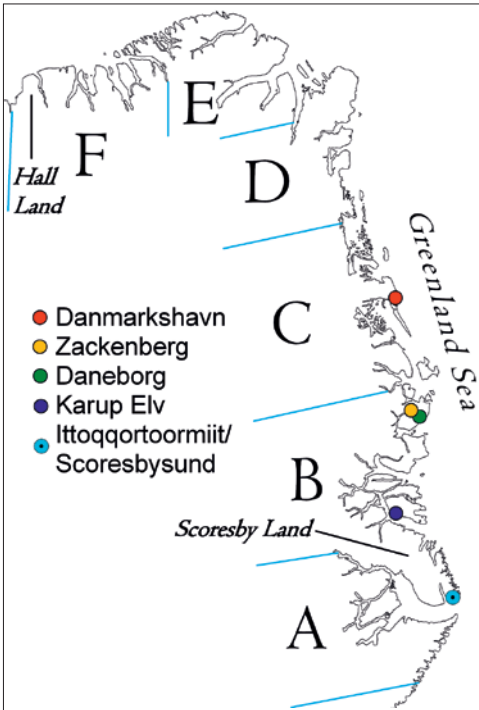
Fig. 1. Map of North and Northeast Greenland with subareas A-F and place names used in the paper. The position of the northernmost settlement in East Greenland, Ittoqqortoormiit/Scoresbysund, is also given.
Kort over Nord- og Nordøstgrønland med delområderne A-F samt udvalgte stednavne.

The present study focuses on population fluctuations of the high-arctic subspecies of *Lagopus mutus captus* (see Browning 1979) and examines to which extent these fluctuations are cyclic and synchronous between subareas. Rock Ptarmigan cycles have previously been suggested from central arctic Canada (Cotter 1991), Svalbard (Løvenskiold 1964, Pedersen et al. 2005), Iceland (Guðmundsson 1960, Garðarsson 1988, Nielsen 1999) and West Greenland (Bræstrup 1941, Vibe 1967). The reports from Iceland and Canada are based on biological surveys, those from Greenland and Svalbard on trapping and hunting data (sales statistics or logs).

Traditionally, attempts to identify the mechanisms governing population cycles have focused on predator/prey relationships (Elton 1924). For Rock Ptarmigan, some authors (e.g. Cotter et al. 1992, Nielsen 1999) have found that predation specifically by avian predators was a crucial factor, while others (Weeden & Theberge 1972) have identified mammalian predators as more im-

portant. Alternative or contributing factors that have been suggested are periodic lack of minerals in food plants (Bræstrup 1941), winter losses of juvenile ptarmigans (Garðarsson 1988), varying recruitment of young birds into the local population (Hörnell-Willebrand 2005), and parasite loads (Holmstad et al. 2005). Recently, the disappearance of population cycles in formerly cyclic populations, coinciding with the occurrence of shorter winters, suggests that climate has the potential to synchronize the dynamics of populations over large geographical areas (Ims et al. 2008). Species exhibiting such spatial synchrony in their dynamics are particularly vulnerable to local and global extinction (Heino et al. 1997, Post & Forchhammer 2002).

Synchrony in fluctuations of different populations has been found in several tetranoid species (Lindström et al. 1996). The aim of our study was to investigate how Rock Ptarmigan numbers varied in Northeast Greenland in order to determine if population fluctuations were synchronous between populations (or subareas), and whether they were cyclic.

Materials and methods

Data on ptarmigan numbers in Northeast Greenland were compiled by the military dog sledge patrol *Sirius* during 1977-2006 (except 2002). Each year, six dog sledge teams survey nearly 20000 km of coast, lowland and valley floor in North and Northeast Greenland between Scoresby Land (subarea A; Fig. 1) and Hall Land (subarea F; Fig. 1), with the most intensive coverage of subareas B and C. During these surveys, records are kept of species, number of individuals, date and position of all mammals and birds encountered.

The main survey effort is from mid February to early June, when each team (consisting of two men with a dog sledge) covers 30-60 km per day. Depending on latitude, the sun first rises above the horizon between early and late February; from early June, rivers begin to flow, making dog sledging cumbersome. In the southern part of Northeast Greenland surveys are also made in winter during November-December, but since it is dark all day during this period, only few birds are seen, and we have not used these data.

Due to the long survey period each year, the ptarmigans recorded by *Sirius* include late-winter flocks, which probably contain both local birds and migrants from other subareas.

The subareas chosen for the present analysis are the same as used by Meltofte (1985), where

The population of ptarmigan at Zackenberg is censused in June when pairs are found, or males mark their territories by displaying their white plumage from high points. Photo: Lars Holst Hansen.

details on the geographical definitions are also given. Most observations are from subarea C (average = 13.4 ptarmigans per year; range 0-107), but substantial numbers were also recorded in subareas B (average = 7.7; range 0-42) and D (average = 11.9; range 0-103). Data from subareas A, E and F were also included in the totals, but they were too scarce for statistical comparisons between subareas. Due to military confidentiality, we did not have access to the number of days spent or the distance covered within each subarea. Consequently, we cannot calculate densities (birds per kilometre) and have to use the total number of ptarmigans recorded within each subarea. However, time spent and routes taken within subareas by the *Sirius* teams do not vary much from year to year.

We tested the *Sirius* data from subareas B, C and D for cyclicity by fitting a second order log-linear autoregressive model to each of the three time series (cf. Ims et al. 2008 and references therein). The model has the form $X_t = \beta_0 + \beta_1 X_{t-1} + \beta_2 X_{t-2} + \varepsilon_t$, where X_t is the logarithm of the population index (*Sirius* count) in year t, β_1 and β_2 are the coefficients of the direct and delayed density-dependence, respectively, and ε_t is the error term. If $(1 + \beta_1)^2 + 4 \times \beta_2 < 0$, the model generates

cyclic time series. We omitted data from the years 2003-2005 from this analysis due to the missing value from 2002, since broken time series cannot be handled in autoregressive models.

The degree of synchrony between subareas was estimated by cross-correlation of time series. We also investigated cyclicity and synchrony in the first and last part of the time series separately. This was done by splitting each time series into two, using all possible splits, but ignored results from the shortest section when it covered less than 10 years.

Two other ptarmigan time series from Northeast Greenland were available. One derives from the BioBasis monitoring programme at Zackenberg Research Station (74°30'N, 20°30'W (subarea B); Hansen et al. 2007), where during June 1996-2006 a census of a 19.3 km^2 bird monitoring area is carried out (Meltofte & Berg 2006). The other dataset comes from the Karupelv Valley Project which has monitored lemmings, predators and tundra birds during 1988-2006 within a 15 km^2 area on Traill Ø in Kong Oscars Fjord, c. 245 km south of Zackenberg (72°30'N, 24°W (subarea B); Meltofte et al. 2007). In addition to the described analyses of the *Sirius* data we also tested if ptarmigan numbers in these two areas
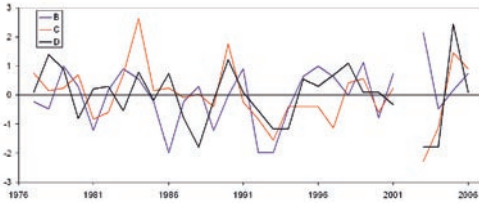
Fig. 2. The *Sirius* records of Rock Ptarmigans in sub-areas B, C and D, 1977-2006 (log-transformed and standardised records).
Sirius' registreringer af Fjeldryper i delområderne B, C og D, 1977-2006 (log-transformerede og standardiserede tal).
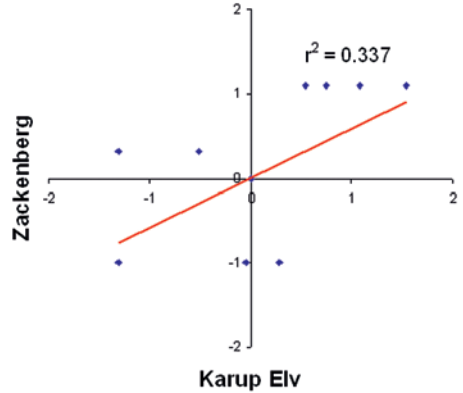

Fig. 3. Relationship between ptarmigan census results at Zackenberg and Karup Elv, Northeast Greenland 1996-2006. Log-transformed and standardised figures.
Sammenhæng mellem fjeldrypepopulationerne ved Zackenberg og Karup Elv, 1996-2006. Log-transformerede og standardiserede tal afbildet mod hinanden.

fluctuated synchronously. At both sites the records cover territorial pairs and males in June as well as females with broods later in the summer, i.e. all observations of birds likely to belong to the breeding population. In cases where a result was given as a range we use the midpoint in our analysis. Data were log transformed and standardised to zero mean and unit variance in order to make time series comparable and to stabilize variances. We used a significance level of 5%.

It should be kept in mind that the *Sirius* data are records of randomly observed ptarmigan during thousands of kilometres of dog sledging, while the census area data are potential breeding pairs per km^2 in well defined lowland areas.

Results

There was a pronounced year-to-year variation in the *Sirius* records (Fig. 2), but no indication of cyclicity in any of the time series: $(1+\beta_1)^2 + 4\times\beta_2$ was never less than zero. Actually, no direct or delayed density dependence at all was indicated for any of the three subareas (B, C, D), since none of the coefficients differed significantly from zero: $\beta_1 = 0.161-0.272$ (P = 0.140–0.468), $-\beta_2 = 0.143-0.307$ (P = 0.140–0.525). We did find significant

Table 1. Pearson correlation coefficients r between Rock Ptarmigan counts in subareas B, C and D (*Sirius* records during 1977-2006 except 2002).
Pearson korrelationskoefficienter r mellem Fjeldrype-tællinger i delområderne B, C og D (Sirius-patruljens registreringer 1977-2006 undt. 2002).

	B vs C	B vs C[1]	B vs D	C vs D
r	0.152	0.485	0.0137	0.549
n	29	19	29	29
P	0.43	0.035	0.94	0.002

[1] first 19 years *kun første 19 år*

synchrony between subareas C and D (Table 1), and the correlation between these two time series improved when the earliest years were removed from the analysis (whereas an opposite tendency was found in the other pairs of subareas). We also found a significant synchrony between subareas B and C, but only for the first 17-19 years of the time series (Table 1). Within subarea B, synchrony between the Zackenberg and Karup Elv data was suggested but not quite significant ($r^2 = 0.337$, n = 11, P = 0.061; Fig. 3).

Discussion

We found no evidence of population cycles in ptarmigan from Northeast Greenland. Indications of a 10-year cycle have previously been identified in populations of Rock Ptarmigan in Iceland (Garðarsson 1988). The time period covered by the Icelandic study differed from ours, and the population estimates in Iceland were based on transect counts of live birds and therefore probably represent a more accurate measure of population density. Both could conceivably explain the different results – it could be that ptarmigan numbers only intermittently fluctuate cyclically; and the *Sirius* data could track the ptarmigan population so poorly that existing cycles went undetected in our analysis.

We were unable to demonstrate synchrony in ptarmigan fluctuations across the entire high-arctic part of Greenland, but we did find significant synchrony between the central subareas C and D

and, during the first 17-19 years, between subareas B and C. In order to perform the analyses, we had to pool observations collected over large areas, so that synchrony occurring at smaller spatial scales would be masked. In addition, data collected by people with no experience in censusing ptarmigan or other wildlife could be very sensitive to the commitment and skills of the observers – a case in point is the year 2003 where numbers in subarea B indicate a peak year, whereas numbers in subareas C and D suggest a low year.

Our results suggest that fluctuations in Northeast Greenlandic Rock Ptarmigans are synchronous over scales of a few hundred kilometres, but that synchrony decreases with distance. Several other studies of tetraonid birds have shown a similar pattern: temporal synchrony in fluctuations decreasing with increasing distance between populations (e.g. Ranta et al. 1995, Lindström et al. 1996, Cattadori et al. 2000, Hammarström 2001).

Further studies on the population fluctuations discussed here could focus on the influence of the weather, on which data from our study period should be available from the weather stations along the coast of North and Northeast Greenland. The monitoring at Traill Ø and Zackenberg continues, as does the note-keeping by *Sirius*, and should in time yield data of sufficient quality for further investigation.

Resumé

Populationssvingninger i bestande af Fjeldrype i højarktisk Grønland

Cykliske svingninger i bestandsstørrelsen er beskrevet for flere årfugle og andre hønsefugle, lige som der i flere tilfælde er konstateret synkroni i bestandssvingningerne over større områder, og mellem bestande af forskellige arter.

I denne undersøgelse sammenligner vi data vedrørende forskellige bestande af Fjeldrype *Lagopus mutus captus*, den nordligst forekommende underart i Grønland. Materialet er indsamlet af Siriuspatruljen i årene 1977-2006. For tre delområder (B, C og D; se Fig. 1) i patruljens virkeområde var der tilstrækkelige data til at muliggøre statistiske analyser. Hertil kommer data fra Zackenberg Forskningsstation og fra Karupelvprojektet, begge i delområde B.

Vi undersøgte, om bestandssvingningerne kunne betragtes som cykliske, ved at teste signifikansen af parametrene i en log-lineær autoregressiv model. I ingen af tidsserierne kunne det imidlertid påvises, at svingningerne var cykliske.

Vi kvantificerede graden af synkroni mellem bestandssvingningerne i delområderne B, C og D. Det viste sig, at der var synkroni mellem naboområder (dog kun statistisk signifikabt for C og D), men ikke mellem B og D (som ligger længst fra hinanden). Der var nogen tendens til synkroni mellem bestandene ved Zackenberg og Karup Elv (Fig. 3).

Disse resulater for Fjeldryperne i Nordøstgrønland stemmer fint overens med resultater for andre fugle og pattedyr i nordlige eller alpine egne. Eksempelvis har svenske Dalryper *Lagopus lagopus*, italienske Fjeldryper og tre arter årfugle i Finland alle vist tilsvarende sammenhænge (Ranta et al. 1995, Cattadori & Hudson 1999, Hammarström 2001).

Photo: Hans Meltofte.

References

Boertmann, D.M. 1994: An annotated checklist to the birds of Greenland. – Meddr Grønland, Biosci. 38.

Browning, M.R. 1979: Distribution, geographic variation, and taxonomy of *Lagopus mutus* in Greenland

and northern Canada. – Dansk Orn. Foren. Tidsskr. 73: 29-40.

Bræstrup, F.W. 1941: A study of the arctic fox in Greenland. – Meddr Grønland 131(4).

Cattadori, I.M. & P.J. Hudson 1999: Temporal dynamics of grouse populations at the southern edge of their distribution. – Ecography 22: 374-383.

Cattadori, I.M., S. Merler & P.J. Hudson 2000: Searching for mechanisms of synchrony in spatially structured gamebird populations. – J. Anim. Ecol. 69: 620-638.

Cotter, R.C. 1991: Population attributes and reproductive biology of Rock Ptarmigan in the central Canadian Arctic. – M.Sc. thesis, University of Alberta, Edmonton.

Cotter, R.C., D.A. Boag & C.C. Shanks 1992: Raptor predation on rock ptarmigan (*Lagopus mutus*) in the central Canadian Arctic. – J. Raptor Res. 26: 146-151.

Elton, C.S. 1924: Periodic fluctuations in the numbers of animals: their causes and effects. – Brit. J. Exp. Biol. 2: 119-163.

Forchhammer, M. 1990: Ornithological observations in Germania Land and Dove Bay, Northeast Greenland 1986-88. – Greenland Home Rule, Department for Wildlife Management, Technical Report, No. 12.

Garðarsson, A. 1988: Cyclic population changes and some related events in Rock Ptarmigan in Iceland. Pp. 300-329 in A.T. Bergerud & M.W. Gratson (eds): Adaptive strategies and population ecology of northern grouse. Vol. 1. Population studies. – University of Minnesota Press, Minneapolis.

Glutz von Blotzheim, U.N., K.M. Bauer & E. Bezzel 1973: Handbuch der Vögel Mitteleuropas. Vol. 5. – Akademische Verlagsgesellschaft, Frankfurt am Main.

Guðmundsson, F. 1960: Some reflections on ptarmigan cycles in Iceland. – Proc. XII Int. Orn. Congr.: 259-265.

Hammarström, A. 2001: Long time fluctuations of three willow grouse populations in Sweden. – M.Sc. thesis, Swedish University of Agricultural Sciences, Department of Animal Ecology, Umeå. Available at http://www.szooek.slu.se/swe/examensarb/VisaPub.cfm?1263.

Hansen, J., A.P. Tøttrup & N. Levermann 2007: Birds. Pp. 44-58 in A.B. Klitgaard, M. Rasch & K. Caning (eds): Zackenberg Ecological Research Operations, 12th Annual Report, 2006. – Danish Polar Center, Danish Agency for Science, Technology and Innovation, Ministry of Science, Technology and Innovation, Copenhagen.

Heino, M., V. Kaitala, E. Ranta & J. Lindström 1997: Synchronous dynamics and rates of extinction in spatially structured populations. – Proc. Royal Soc. Lond., Ser. B 264: 481-486.

Holmstad, P.R., P.J. Hudson, V. Vandvik & A. Skorping 2005: Can parasites synchronise the population fluctuations of sympatric tetraonids? – Oikos 109: 429-434.

Hörnell-Willebrand, M. 2005: Temporal and spatial dynamics of Willow Grouse *Lagopus lagopus*. – Ph.D. thesis, Swedish University of Agricultural Sciences, Department of Animal Ecology, Umeå. Available at http://diss-epsilon.slu.se/archive/00000850/01/MHWfin0050511.pdf.

Ims, R.A., J.-A. Henden & S.T. Killengren 2008: Collapsing population cycles. – Trends Ecol. Evol. 23: 79-86.

Lindström, J., E. Ranta & H. Lindén 1996: Large scale synchrony in the dynamics of capercaillie, black grouse and hazel grouse populations in Finland. – Oikos 76: 221-227.

Løvenskiold, H.L. 1964: Avifauna Svalbardensis. – Norsk Polarinst. Skr. 129.

Meltofte, H. 1975: Ornithological observations in Northeast Greenland between 76°00' and 78°00' N. lat. 1969-71. – Meddr Grønland 191(9).

Meltofte, H. 1977. Ornithological observations in Germania Land, Northeast Greenland, 1975. – Dansk Orn. Foren. Tidsskr. 71: 81-94. (In Danish, with English summary)

Meltofte, H. 1985: Populations and breeding schedules of waders, Charadrii, in high arctic Greenland. – Meddr Grønland, Biosci. 16, 43 pp.

Meltofte, H. & T.B. Berg 2006: Zackenberg Ecological Research Operations. BioBasis: Conceptual design and sampling procedures of the biological programme of Zackenberg Basic. 9th edition. – National Environmental Research Institute, Department of Arctic Environment. Available at http://www.zackenberg.dk/documents/BioBasisManual2004.pdf

Meltofte, H., B. Sittler & J. Hansen 2007: Breeding performance of tundra birds in High Arctic Northeast Greenland 1987-2007. – Arctic Birds 9: 45-53.

Nielsen, Ó.K. 1999: Gyrfalcon predation on ptarmigan: numerical and functional responses. – J. Anim. Ecol. 68: 1034-1050.

Pedersen, Å.Ø., Ø. Overrein, S. Unander & E. Fuglei 2005: Svalbard Rock Ptarmigan (*Lagopus mutus hyperboreus*) – a status report. – Norsk Polarinst. Rapportserie 125.

Post, E., M.C. Forchhammer 2002: Synchronization of animal population dynamics by large-scale climate. – Nature 420: 168-171.

Ranta, E., J. Lindström & H. Lindén 1995: Synchrony in tetraonid population dynamics. – J. Anim. Ecol. 64: 767-776.

Salomonsen, F. 1950: Grønlands Fugle. The Birds of Greenland. – Munksgaard, Copenhagen.

Salomonsen, F. 1967: Fuglene på Grønland. – Rhodos, Copenhagen. (In Danish)

Vibe, C. 1967: Arctic animals in relation to climatic fluctuations. – Meddr Grønland 170(5).

Weeden, R.B. & J.B. Theberge 1972: The dynamics of a fluctuating population of Rock Ptarmigan in Alaska. – Proc. XV Int. Orn. Congr.: 90-106.

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