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Svalbard Rock Ptarmigan *(Lagopus mutus hyperboreus)* – a status report

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(*Lagopus mutus hyperboreus*)
– a status report

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Preface

The Norwegian Polar Institute (NPI) was commissioned by the Ministry of the Environment to prepare a status report based on present knowledge of the Svalbard rock ptarmigan (*Lagopus mutus hyperboreus*) and further define future needs for research and monitoring. Dag Vongraven (NPI) and Jon Ove Scheie (previously with The Governor of Svalbard, now with the Norwegian Nature Inspectorate) initiated the work with the report. Later, the report draft was updated and completed by Åshild Ønvik Pedersen (University of Tromsø, Department of Biology), Øystein Overrein (NPI), Eva Fuglei (NPI) and Sigmund Unander (previously NPI, now the Municipality of Vennesla).

The species Svalbard rock ptarmigan is endemic and demands special management responsebilities for Norway. It is included in the Environmental Monitoring Programme for Svalbard and Jan Mayen (MOSJ), (http://miljo.npolar.no/mosj/start.htm).

The Norwegian Parliament's White paper "About environmental protection in Svalbard" (White paper no. 22, 1994-95) states: "Svalbard must appear as one of the best managed wilderness areas in the world". This objective was further strengthened in the White paper "Svalbard" (White paper no. 9, 1999-2000). The most important objective is ecosystem-based management where ecological knowledge about species and their habitats are known and monitored with regular intervals. The White Paper no. 9 also states that environmental concerns shall be predominant when they conflict with other interests.

We would like to thank Ian Gjertz (the Governor of Svalbard), Karl Arne Stokkan, Rolf Anker Ims and Nigel Gilles Yoccoz (University of Tromsø), Harald Steen and Geir Wing Gabrielsen (Norwegian Polar Institute), and Marie Lier (Directorate for Nature Management) for reviewing the report and contributing with valuable comments.

Tromsø 2005,

Åshild Ønvik Pedersen, Øystein Overrein, Sigmund Unander and Eva Fuglei.

Contents

Summary

The Svalbard rock ptarmigan (*Lagopus mutus hyperboreus*) is the only resident terrestrial bird in Svalbard. The ptarmigan is also by far the most important small game species for hunting in Svalbard. Research performed to date on the Svalbard rock ptarmigan has mainly been physiological studies focusing on adaptations to Arctic conditions. Current ecological knowledge is limited and available information focuses mainly on breeding biology including behavioure aspects of breeding and social ecology.

The Svalbard rock ptarmigan demonstrate different physiological and morphological adaptations. They are heavier and show substantial annual variation in body weight compared to the rock- and willow ptarmigan (*Lagopus mutus* and *Lagopus lagopus*) in mainland Norway. In September–October the Svalbard rock ptarmigan increase their body weight due to fat accumulation, and body fat may exceed 30% of body weight in November–December. The fat depot make them independent of a continuous access to food when feeding is restricted during winter, and contributes to the thermal insulation. A question still not answered is whether the ptarmigan puts on fat and double their body weight in autumn while they at the same time reduce their food intake. Or whether they increase both body weight and food intake, but reduce the activity level in autumn. In April they are almost fat-free even with the doubling of food intake from February until March. During summer they stay lean despite a high and stable food intake. The seasonal variation in body weight cannot be explained by variation in food intake and locomotor activity alone, though seasonal variation in daily energy expenditure must be taken into consideration. The Svalbard rock ptarmigan is able to reduce their energy consumption by 16% from summer to winter. They can also seek shelter in snow burrows to escape low temperatures and strong winds.

The only ecological study on the Svalbard rock ptarmigan was carried out in 1980-1986 and focuses on breeding biology, behaviour, social ecology and diet. In 2000 an annual monitoring project on spring densities of Svalbard rock ptarmigan cocks was started. In Svalbard the ptarmigans use separate habitats during the winter and breeding season. The wintering areas and the extent of true long-range migration of the Svalbard rock ptarmigan are not known. Flocks of migrating ptarmigans return to the breeding grounds in mid March, cocks arrive first followed by hens in early April. Altitude, terrain ruggedness and vegetation characteristics are the most significant landscape attributes that determine the presence of cocks. During breeding the cocks defend a territory varying between 3.5 and 50 hectare, which is significantly larger than found for rock ptarmigan in Alaska and willow ptarmigan in Norway. In Svalbard the cocks show periodically territorial behaviour throughout 24 hours due to continuous daylight in the breeding season. This is in contrast to willow ptarmigan and rock ptarmigan in mainland Norway showing territorial behaviour in the morning and evening. Currently there is very little information about the population size and variance in abundance of the Svalbard rock ptarmigan. Limited data on breeding density in Ny-Ålesund from 1981 and 1982 show a variation between 5.4 and 4.1 cocks per km². Results from the ongoing monitoring study in Adventdalen/Sassendalen (data from 2000-2004) shows that the population of territorial cocks vary between 2.7 and 4.9 cocks per km². These numbers are in agreement with breeding densities of rock ptarmigan in Iceland. Knowledge about population dynamics in Svalbard rock ptarmigan is limited due to lack of long-term time series data. Moreover, factors that could be responsible for ptarmigan population cycles are not studied in Svalbard. Both climate and predators are suggested as important factors that determine chick production; however, fluctuation in numbers may be caused by a combination of many aspects also including parasites, social factors and hunting.

Hunting in Svalbard requires a hunting license, and since 1997 annual harvest has varied between 824 and 1739 ptarmigans. The Svalbard rock ptarmigan show less marked fear behaviour to disturbances during incubation compared to willow ptarmigan in mainland Norway. Though the Svalbard rock ptarmigan is regarded to be extremely tame, the high Arctic climate makes them vulnerable to disturbances during incubation. The levels of persistent organic pollutants and heavy metals in the Svalbard rock ptarmigan are unlikely to cause physiological problems.

We suggests future research and monitoring needs based on existing research and monitoring data on the Svalbard rock ptarmigan presented in this report. The most important research topics are winter biology (wintering grounds and migration routes) and population dynamics.

Svalbard rock ptarmigan (*Lagopus mutus hyperboreus*).

Photo: Sigmund Unander.

1. Introduction

Aim of the report

The Svalbard rock ptarmigan (*Lagopus mutus hyperboreus*) is the only non-migratory terrestrial bird in the Svalbard archipelago (74-81°N, 10-30°E) (Løvenskiold 1954). Living at this high Arctic latitude with extreme periodically changing environment of light and temperature, the ptarmigan has developed several specific morphological, physiological and behavioural adaptations to its environment. Thus far the species has mainly attracted research interest from physiologists who have explored various adaptations to Arctic conditions. Central aspects have been seasonal variation in fat accumulation, food intake, body weight, locomotor activity, energetic, reproduction and biological rhythms etc. (i.e. Mortensen et al. 1983, Steen and Unander 1985, Mortensen and Blix 1986, Stokkan et al. 1986ab, Lindgård and Stokkan 1989). Current ecological knowledge is limited and restricted to the research done by Sigmund Unander in the Ny-Ålesund/Kongsfjorden area in 1980-1986. Only results from 1980 to 1982 are published (Unander and Steen 1985, Steen and Unander 1985, Unander et al. 1985). These publications focus on breeding biology, behavioural aspects of the breeding, social ecology of the species and dietary habits. Due to limited research on this sub-species many ecological aspects of the Svalbard rock ptarmigan's biology remain unknown.

The Norwegian Polar Institute (NPI) was given the task from the Ministry of Environment to provide a status report on the Svalbard rock ptarmigan. The main reason for this was the establishment of a new management strategy for wildlife in Svalbard. A new set of regulations concerning hunting periods and hunting/trapping in Svalbard was put into action in 1997.

Table 1. Body weight (BW) of the Svalbard rock ptarmigan, rock ptarmigan and willow ptarmigan from mainland Norway, showing annual average body weight in both sexes, and hen and cock body weights respectively.

Species	Both sexes BW (g)	Hen BW (g)	Cock BW (g)
Svalbard rock ptarmigan	650 ± 201[a]	634 ± 117[a]	675 ± 168[a]
Rock ptarmigan	487 ± 36[b]	470 ± 40[b]	478 ± 40[b]
Willow ptarmigan	598 ± 85[c]	517[d]	584[d]

a. Steen and Unander 1985
b. Mortensen et al. 1985
c. Mortensen and Blix 1986
d. Haftorn 1971

During this process, research and management authorities became aware of the lack of available data sources which could shed light into the dynamics of the Svalbard rock ptarmigan, for example hunting statistics or population monitoring data. The present report gives a status of published and unpublished research mainly from the early 1980s up to the present. Based on this information future needs for research and monitoring are suggested.

Species distribution

The Svalbard rock ptarmigan is a sub-species of rock ptarmigan (*Lagopus mutus*), which is a galliform bird of the family Tetranoidae. The rock ptarmigan has a circumpolar distribution also occurring in mountain areas. They are located in three continents with different sub-species. In Europe the species is found in Iceland, Greenland, Scotland, Norway (mainland), Sweden, Finland, Russia, the Alps and the Pyrenees. In Asia it is found in Siberia, in the mountain ranges of central Asia, on Commander Island, Kurile Island and in Japan (Hondo). In North America it occurs in Alaska (including the Aleutian Islands) and Canada (Løvenskiold 1964).

The sub-species Svalbard rock ptarmigan is only known in Svalbard and Franz Josef Land. It was first recorded in Svalbard in 1610 by Jonas Poole on his voyage to Spitsbergen (Løvenskiold 1964). Løvenskiold (1964) lists other early observations and gives a complete overview of these records. In Svalbard the species inhabits the entire archipelago with exception of Kvitøya, Kong Karls Land and many of the small islands in the eastern and northern parts of Svalbard. It breeds in all areas in which it occurs except on Hopen (Løvenskiold 1964). The species is rare or completely absent on Bjørnøya were it was observed only five times from 1921-1965 (Theisen 1997). Since then the only known observation is from the winter 2002 (H. Strøm pers. comm. 2005). The species is occasionally observed on Jan Mayen (Soglo 1995).

Morphology

Body size

The Svalbard rock ptarmigan shows large seasonal variations in body weight due to heavy fat deposition in autumn (500-550 g in summer and 900-1200 g in winter) (Mortensen et al. 1983, Steen and Unander 1985). More than 30% of the body weight in winter is fat. This is in contrast to their close relatives in mainland Norway. Both rock ptarmigan and willow ptarmigan (*Lagopus lagopus*) have a fairly constant body weight throughout the year, with fat contents rarely reaching 4% of the body weight (Mortensen and Blix 1989, Stokkan 1992). Furthermore, the rock ptarmigan in Svalbard are heavier than both the rock ptarmigan and the willow ptarmigan on mainland Norway (Table 1). The highest body weight of the rock ptarmigan (both sexes) on mainland Norway is 510 g in December with the lowest body weight in June and September of 455 g (Mortensen et al. 1985).

The mean hatching weight of chicks is 16.0 ± 0.5 g. The chicks are able to double their body weight every week, and after 40 days they reach more than 400 grams. During the first autumn chicks do not reach adult body weight (Steen and Unander 1985).

Figure 1. Svalbard rock ptarmigan cock in July. They frequently do dust bathing to improve their camouflage before moulting.
Photo: Eva Fuglei.

Figure 2. Svalbard rock ptarmigan hen (left) and cock (right) in winter plumage.
Photo: Sigmund Unander.

2. Adaptations

Resident animals in Svalbard must cope with extreme seasonal variations in light and temperature. The sun is below the horizon from late October to mid February, and there is virtually 24 hours darkness from November until the end of January (polar night). In contrast, the sun remains above the horizon from mid April to late August, resulting in 24 hours daylight (midnight sun). Average air temperatures are below freezing from September to May, and winds are ubiquitous in winter (Hisdal 1998). However, the climate is highly variable and rain may occur at any time during winter. When followed by sub-zero temperatures heavily icing of the tundra may occur to compromising feeding of terrestrial herbivores.

Plumage

Both sexes have a white winter plumage except for black outer tail feathers (Fig. 2). The winter plumage of both sexes consists of long feathers with a rich downy base (Johnson 1941). Cocks have a conspicuous black streak from eye to beak, and well-developed red colour supraorbital comb above the eye in the breeding season (Steen and Unander 1985). Also the hen has a red colour comb, but it is less visible (Ø. Overrein pers. comm. 2004). The summer plumage of the hen resembles more the golden-brown mottled plumage of the willow ptarmigan than the greyish plumage of the rock ptarmigan. The plumage gives the hen exceptionally good camouflage in the predominantly brownish nesting ground (Steen and Unander 1985).

The moulting cycle varies between the sexes. Hens moult in April and by the end of May, coinciding with the beginning of egglaying, their brown mottled summer plumage is fully developed (Fig. 3) (Løvenskiold 1964, Stokkan et al. 1986b). Adult hens start to moult about 10 days earlier than yearlings. Cocks moult in July and complete their pigmented summer plumage by late August. Frequent dust bathing gives the cock a shabby appearance (Fig. 1), which contributes to their camouflage before moulting. Both sexes moult into the white winter plumage at the same time starting in September. Hens with early-hatched chicks start to moult earlier than hens with late-hatched chicks (Steen and Unander 1985). The seasonal plumage changes are causally related to the simultaneous changes in daylength (Stokkan et al. 1986b, Lindgård and Stokkan 1989).

Parker et al. (1985) distinguished adult and yearling Svalbard rock ptarmigan by using the standard feather pigmentation method by Weeden and Watson (1967). The three outermost wingfeathers (primaries) are used for age determination. Typical young had noticeably more pigmentation on primary 9 (P9) than primary 8 (P8). However, Parker et al. (1985) found that about 10% of the young lacked these pigments. By looking at shaft pigmentation on P9 and P8 on the atypical young, they found that the pigmentation extends further towards the tip of P9 than P8. For adult birds the shaft pigmentation on P8 and P9 extends equally as far up along the tip (Fig. 4). With this slight modification of the method, they were able to estimate with 99% accuracy young and adult birds.

Figure 3. Svalbard rock ptarmigan hen (left) and cock (right) in June. The hens start to moult in April–May, while cocks moult in July.
Photo: Kerstin Lye.

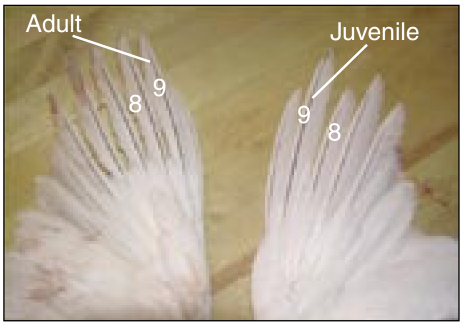

Figure 4. The age is determined by feather pigmentation of the wings. Adult feather (left) and juvenile feather (right).
Photo: Mathias Overrein.

Morphology

The unpigmented white feathers of the rock ptarmigan are unique because the barbules contain air-filled cavities, presumably having an insulative value and a visual resemblance of the winter plumage to snow (Dyck 1979). The Svalbard rock ptarmigan is shown to be substantially better insulated than other ptarmigan species and sub-species. However, the plumage insulation of the Svalbard rock ptarmigan does not change with season as found in willow ptarmigan. In both the Svalbard rock ptarmigan and the rock ptarmigan, the plumage weight does not change significantly with season (Mortensen 1985). Therefore, the better insulation of the Svalbard rock ptarmigan is due primarily to the seasonal deposit of subcutaneous fat (Mortensen and Blix 1986).

The winter plumage of the ptarmigan has heavily feathered feet, thus the name *Lagopus* meaning "harefoot". This reduces thermal conductance and equips the bird with "snowshoes", thereby reducing energy expenditure when walking on snow (Höhn 1977).

The Svalbard rock ptarmigan is heavier and has larger body size than their closest relatives, the rock ptarmigan (Table 1). This may be an adaptation to cold climate since cold tolerance increases with body size due to improved insulation. Moreover, large birds can store more subcutaneous fat, and have a more favourable surface to volume ratio (Herreid and Kessel 1967). Large body size may compromise flight ability, and increase vulnerability to avian predators, in particular. The lack of permanent populations of e.g. gyrfalcon (*Falco rusticolus*) in Svalbard may thus have played a role in the evolution of the large body size of the Svalbard rock ptarmigan.

Physiology

Biological rhythms

All animals living on the high arctic Svalbard archipelago experience extreme photoperiodic changes throughout the year. From mid-November until February the light intensity remains permanently below civil twilight, while from April until mid-August, the sun never sets. In spring, the daylength increases and in autumn the daylength decreases extremely rapidly. The timing and duration of seasonal biological events such as breeding and reproduction, migration, moulting, fat deposition for insulation and energy, body weight, food intake and feeding activity are of importance to animals living within the constraints of the high latitude environments in Svalbard. The Svalbard rock ptarmigan has a continuous 24 hours feeding activity in summer during continuous light conditions (Stokkan et al. 1986a, Reierth and Stokkan 1998a). In spring and autumn, during day and night cycles, the food intake is concentrated to the light part of the day. Then, in winter with continuous darkness, the feeding activity is spread over 24 hours cycles again, however, at a lower intensity compared to summer (Stokkan et al. 1986a). Thus, the Svalbard rock ptarmigan show an opportunistic feeding behaviour to meet conditions when the environment becomes arrhythmic and unpredictable, allowing the birds to forage whenever physical conditions are favourable. In addition to the important regulatory influence that the photoperiodic conditions have on the daily rhythm of behaviour (Stokkan et al 1986a, Reierth and Stokkan 1998a), the process of feeding in itself also appears to influence the pattern of behaviour in Svalbard rock ptarmigan (Reierth and Stokkan 1998b).

Lindgård and Stokkan (1989) suggested that the vernal increase in daylength triggers the annual cycle in body weight, food intake and plumage. It has also been suggested that gonadotrophic and gonadal activities are triggered by increased daylength in March (Stokkan et al. 1986b). Several hormones have been shown to change seasonally, presumably also under photoperiodic control. These are thyroide hormones and growth hormones, changing in close association with food intake and fattening (Stokkan et al. 1985). Gonadal hormones, gonadotrophic hormones and prolactin change in close association with the reproductive cycle (Stokkan et al. 1986b, 1988). Melatonin changes seasonally in close parallel with, and is causally related to the changes in the ambient light conditions (Reierth et al. 1999).

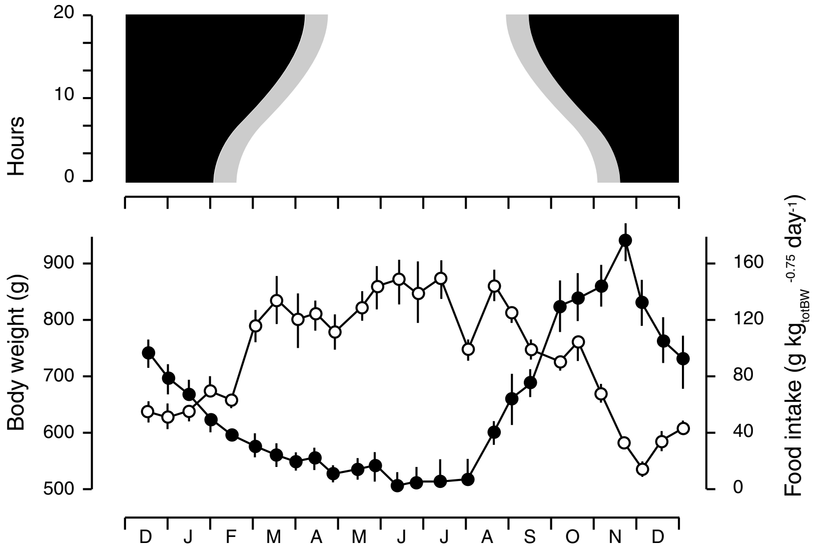

Figure 5. Seasonal changes in body weight (filled circles) and food intake (open circles) in captive Svalbard rock ptarmigan exposed to natural temperature and light conditions in Svalbard. Upper panel shows periods when the sun is above horizon (in white), polar night (in black), and civil twilight (in grey). From Stokkan et al. (1986a).

Body weight and body fat

Svalbard rock ptarmigan (both captive birds and birds shot in the wild) show substantial annual variation in body weight, which is low in summer and high in winter (Mortensen et al. 1983, Steen and Unander 1985, Stokkan et al. 1986a). The maximum body weight in wild Svalbard rock ptarmigan cocks range between 1000-1200 g in October. In March the body weight declines to 680-700 g and decreases further to the lowest level of 490-610 g in June. During July–September the body weight increases again up to the maximum level in October (Mortensen et al. 1983, Steen and Unander 1985). The hens experience two peaks in body weight during the year. In early May, coinciding with moulting, the hens start to put on weight until egglaying at the end of May (630-780 g), while the second peak occurs in October (880-980 g). The lowest body weight is recorded in July–August (490 g). During September and October both sexes increase their body weight due to fat accumulation (Fig. 5). Body fat exceeds 30% of body weight in November–December and individual fat depositions of 300-350 g have been measured (Grammeltvedt and Steen 1978, Mortensen et al 1983, Steen and Unander 1985) (Fig. 6).

The fat accumulation cycle seems to be regulated according to a changing set-point (Fig. 7). In birds fasted and re-fed during winter, Mortensen and Blix (1985) found that body weight was returned to the level recorded in control birds (fed normal) and not to the pre-starvation level. Large amount of fat stores during the Polar night may be of great adaptive significance for the Svalbard rock ptarmigan. The stored energy renders them relatively independent of a continuous access to food at time when feeding is restricted (Stokkan et al. 1985, Mortensen 1985), and contributes to the thermal insulation in winter (Mortensen and Blix 1986). The lean birds observed in summer for both sexes are due to high energy demands for defence of territory, incubation and rearing of young (Steen and Unander 1985).

Figure 6. Svalbard rock ptarmigan increase their body weight due to huge fat accumulation during autumn as an adaptation to survive the polar night (left). The body weight declines during March and leaves the ptarmigan lean in spring and summer (right).

Photo: Georg Bangjord (left) and Sigmund Unander (right).

Food intake and activity

The Svalbard rock ptarmigan put on fat and double their body weight in autumn despite the fact that they at the same time significantly reduce their food intake by one third (Stokkan et al. 1986a, Lindgård and Stokkan 1989, Mortensen and Blix 1989). The food intake reaches a minimum in November–December, shortly after the peak in body weight. Then, in April the birds are almost fat-free despite the doubling of food intake from February until March (Mortensen et al. 1983, Stokkan et al. 1986a). During summer they stay lean despite a high and stable food intake. The annual profiles of the food intake (high in summer, decreases during autumn, low in winter and increases in spring) appear to be inversely related to body weight (Fig. 5) (Stokkan et al. 1986a).

Also, locomotor activity varies annually in the Svalbard rock ptarmigan (Lindgård et al. 1995). The locomotor activity level was reduced from July to October, when the fat content is increasing, while it was at a constant low level from October to February. It was a vernal increase in activity to a peak in April, while it decreased from May to July. The decreased activity in May–July does not agree with the high food intake and reduced body weight found in the same period by Stokkan et al. (1986a).

It has been suggested that food intake is of moderate influence on the fat accumulation during autumn. The seasonal changes in body weight may not be determined by food intake alone, but depend heavily on seasonal changes in locomotor activity reflected in the changes of feeding activity. Associated with decreased energy expenditure this is suggested as the most important factors (Mortensen 1985, Stokkan et al. 1986a, Mortensen and Blix 1989). In contrast Lindgård et al. (1995) found that food intake increased during autumn, in association with increasing body weight and decreased activity, and suggested that food intake may be more important for autumnal fattening than previously assumed. In spring on the other hand, when the ptarmigan are at their leanest while at the same time their food intake increases, elevated food intake and increased energy expenditure may be associated with the decline in body weight (Lindgård et al. 1995). Later Dragøy (2000) found activity levels comparable with those of Lindgård et al. (1995), but the activity level could not alone explain the annual variation in body weight. A combination of changes in resting metabolic rate, specific dynamic action (increased metabolism due to food intake), energy consumption for thermoregulation is presently thought to explain the annual cycle in body weight in the Svalbard rock ptarmigan (Dragøy 2000). However, a more refined explanation requires further research.

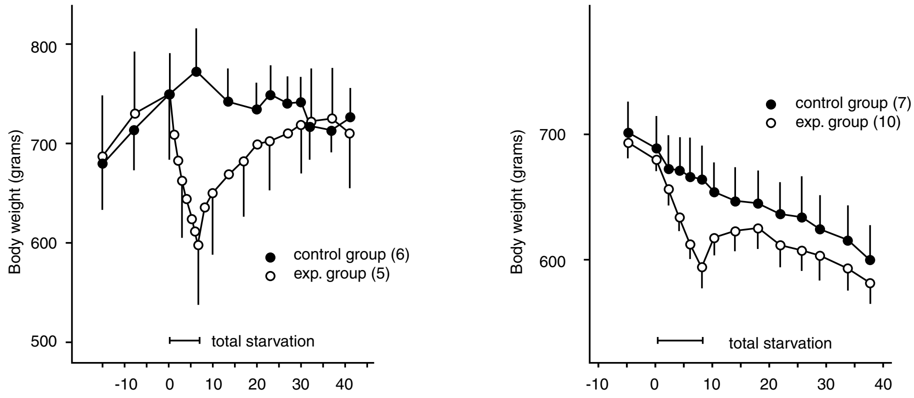

Figure 7. Changing set point of body weight. Left: Body weight before, during and after total starvation in September. Right: Body weight before, during and after starvation in December. Both control groups were fed throughout the experimental period. From Mortensen and Blix (1985).

Energy consumption

The heat production of an animal varies with its use of chemical energy for different functions (internal or external work). Energy consumption is often termed heat production. The term resting metabolic rate refers to the energy consumption in a resting animal and gives information about how fast an animal burns off its energy stores. The Svalbard rock ptarmigan exhibit a significant decrease in mass specific resting metabolic rate of 16% from summer to winter (5.5 W/kg and 4.6 W/kg, respectively) (Mortensen and Blix 1986). Such seasonal variation in resting metabolic rate is also found in the rock ptarmigan and the willow ptarmigan on the mainland of Norway.

Daily energy consumption reflects the total daily heat production in an animal, and represents the sum of the energy consumption for resting metabolic rate, activity, digestion, and temperature regulation. The daily energy consumption measured in free-living animals is termed field metabolic rate, which has not been recorded in Svalbard rock ptarmigans, but experimental studies in captivity have been conducted (Mortensen and Blix 1989, Lindgård et al. 1995). The daily energy consumption measured in captive birds was also reduced from summer to winter in Svalbard rock ptarmigan (11.4 W/kg and 3.8 W/kg respectively) (Dragøy 2000). It is suggested that the inversely related annual variation of body weight and food intake mentioned earlier, could be explained by the seasonal variation in daily energy expenditure (Stokkan et al. 1986a, Lindgård et al. 1995, Dragøy 2000). Reduced metabolism during winter is probably an adaptation to cope with long periods of bad weather and low food availability.

Adaptation to food deprivation

Any herbivorous animal must be prepared to cope with periods of limited food resources. Such periods most often occur at a stage in life where the energy demand is high, combined with low ambient temperatures and wind chill (Stokkan and Blix 1988). If this coincides with wet periods and icing of grazing grounds, the birds are especially exposed to starvation and possibly death. During winter the ptarmigans are still not on the breeding grounds and can move over large areas. The icing is therefore probably only a local problem and does not affect the breeding population as a whole (Løvenskiold 1964). It is suggested that experimental food deprived birds do not reduce their resting metabolic rate, nor their energy expenditure as an adaptation to food depletion (Mortensen and Blix 1985, Lindgård 1996). The activity level was not increased during starvation in winter. Starved birds responded to re-feeding with increased food intake until body weight reached the body weight of normal fed control birds (Fig. 7). Furthermore, food deprived fat ptarmigans showed a better capacity to save body protein than lean birds. Fat birds effectively reduced protein catabolism and maintained this at a low level whereas starving and lean birds increased their protein catabolism (Lindgård et al. 1992).

Behaviour

Ptarmigans are known to seek shelter from wind and low temperatures in snow burrows during winter to minimize energy consumption (Fig. 8). The snow burrow provides a microclimate with higher temperatures than the outside air temperature thus creating a favourable thermal microclimate where they do not need to increase the heat production (Løvenskiold 1964). This behaviour may also have an anti-predator effect (Stokkan 1992).

It is observed that the Svalbard rock ptarmigan use feeding craters excavated by Svalbard reindeer (*Rangifer tarandus platyrhynchus*) in search for food (Pedersen et al. 2005). The utilization of feeding craters may be of importance to the Svalbard rock ptarmigan in snow-rich winters or after terrestrial ice-crust formation resulting from mild spells and rain-on-snow events. It is expected that such co-feeding may be of particular importance for saving energy in periods when demands are high for both sexes due to territorial defence and preparation for the breeding season.

Figure 8. Svalbard rock ptarmigan seek shelter from wind and low temperatures in snow burrows.
Photo: Sigmund Unander.

Another typical behaviour characteristic of the Svalbard rock ptarmigan is that they are extremely tame. As quoted by Løvenskiold (1954) "---they may almost be trodden on before they fly up". While feeding they usually move around walking slowly, not flying or running. This special behaviour makes them an easy game in the hunting season. Even if you shoot a bird that is feeding among other birds, the other birds continue to feed as if nothing has happened. Normally you may shoot the whole clutch/group on the ground at the same location. After some weeks of hunting in the easiest accessible areas some birds tend to show larger flight distances and start flying if a hunter appears in the near vicinity (Ø. Overrein pers. comm. 2004).

Figure 9. Svalbard rock ptarmigan hen lying on nest incubating eggs (left). The nest is placed in a shallow scrape in the ground, lined with dead leaves. The hen lays between 8 and 11 eggs (right).
Photo: Kerstin Lye (left), Sigmund Unander (right).

3. Population ecology

Life history parameters

The Svalbard rock ptarmigan mates in late May. The egg laying starts in early to mid June, coinciding with the ambient temperature above freezing and conditions suitable for nesting and survival of offspring (Steen and Unander 1985). Normally the 1 year old hen lays 8–9 eggs, while the two year and older hens lay 9–11 eggs (Fig. 9). The eggs resemble rock ptarmigan eggs in colour and shape, but the weight is slightly higher. The mean weight of newly layed eggs is 23.4 g (range 21.0–26.7 g). The incubation time is 21 days (Løvenskiold 1964, Steen and Unander 1985). The date for onset of incubation varies between years, hens of different age, body weight and quality of nesting grounds areas (Steen and Unander 1985). Hens with larger body weight normally start to incubate earlier than hens with lower body weight, and clutch size is positively correlated to the hen's body weight at the start of incubation. Thus, hens deserting their nests or whose nests are depredated have lower body weight compared to hens that hatch their eggs. If eggs are lost early in the incubation period, the hens normally lays new eggs, but in a lower number than the first time. This is also found in young hens (first time egg laying) compared to older hens (Steen and Unander 1985). Steen and Unander (1985) concluded that the physical conditions of the hens prior to the breeding season seem to be an important factor determining the chick production. During the egg laying period the hens lose up to 100 g of their body weight followed by an additional loss of 130 g during the incubation time.

The chicks hatch in late June to early July when the plants are most nutritionous, and the first weeks after hatching are the most important for survival of the offspring (Unander 1982, Steen and Unander 1985). The hen and her brood leave the nest 1-2 days after hatching (Fig. 10). After approximately two weeks the chicks are able to fly and daily movements of up to two kilometres have been recorded (Steen and Unander 1985). Studies by Unander and Steen (1985) show that only 1–2% of the young establish in the vicinity of the site were they were born. This indicates high dispersal rate among young birds. Unander (1985, unpubl.) found a mortality rate for territorial cocks and hens of 35–50% from one year to another. There is no present documentation for the importance of winter survival for the breeding population of the Svalbard rock ptarmigan.

Figure 10. The Svalbard rock ptarmigan hen and her brood leave the nest 1–2 days after hatching. The young are fledged after 10–12 days, but remain with the hen for 10–12 week before becoming independent.
Photo: Winfried Dallmann.

The Svalbard rock ptarmigan uses separate habitats during the winter- and breeding season. Habitat selection for all seasons, except the dark period of the winter (November-February) is known. In spring and summer shift in habitat selection coincides with the reproduction period (Unander and Steen 1985).

Breeding season

Flocks of migrating ptarmigan start to return to the breeding grounds around the middle of March (Fig. 11) (Steen and Unander 1985). Cocks arrive first followed by the hens in early April. A habitat quality gradient with the best breeding areas found in the south facing hillsides with early thaw in the inner fjord zone to the poorer sites along the coastline was found in the Ny-Ålesund area (Unander and Steen 1985). The development of a habitat model predicting spatial distribution of territorial males in April, indicate that altitude, terrain ruggedness and vegetation characteristics are the most significant landscape attributes determining the presence of cocks (Pedersen, Jepsen, Yoccoz and Fuglei unpublished a). The model allows for predicting spatial distribution of territorial males at larger scales and may be an important tool for management of the species on Svalbard.

Figure 11. The Svalbard rock ptarmigan migrate from their wintering areas and arrive in flocks to the breeding ground in March.
Photo: Georg Bangjord.

Territory characteristics

Shortly after arrival to the breeding grounds the cocks establish a territory (Unander and Steen 1985). A territory is defined as a stationary area where one cock dominates over all other cocks (Watson and Miller 1971). Territory borders often follow ridges including at least one steep area with rocks and crevices for shelter and predator avoidance. Flat homogenous areas, like valley bottoms, plateaus and areas adjacent to the sea, are not well suited for nesting due to late thaw and predator risk. The cocks use between two and four lookout points regularly in their performance of territorial behaviour (Unander and Steen 1985).

Cocks defend a territory varying between 3.5-50 hectare (mean 1981 = 18.5 ± 15 hectare; mean 1982 = 24.5 ± 25 hectare) (Unander and Steen 1985). Along with a decrease in the breeding population from 1981-82, Unander and Steen (1985) found that the territory size generally increased due to the lower breeding population. Average territory size was smaller on optimal than on marginal sites (Fig. 12). Territories occupied by adult cocks associated with sub-adult cocks were approximately of same size and territories occupied by pairs were in general larger than for a single cock. Compared to territory size of rock ptarmigan in northern Alaska (mean 4.0 ± 2.4 hectare) (Bart and Earnst 1999) and willow ptarmigan in Norway (6.0 ± 2.4 hectare in 1980; 7.8 ± 2.9 hectare in 1983) (Pedersen 1984), the Svalbard rock ptarmigan has significantly larger territory size.

Nest site characteristics

The nest site is placed in the upper part of the territory, always on a rather steep and rocky location, combining a good view of the surroundings along with wind shelter, cover and good drainage (Steen and Unander 1985). The nest is a rather shallow scrape (1–2 cm) in the ground lined with dead leaves, mostly *Dryas*, *Salix* and *Empetrum* (Løvenskiold 1964).

Figure 12. Svalbard rock ptarmigan hen feeding within a territory in April.
Photo: Åshild Ønvik Pedersen.

Winter habitat

In September and October the ptarmigans gather in groups of 10-15 birds (brood and adults) foraging under bird-cliffs or other areas with rich vegetation for 2–3 weeks. Typically, flocks move around foraging at different sites (S. Unander pers. comm. 2005). In the Ny-Ålesund area most ptarmigans left the breeding grounds during September and October. Only a few birds were seen in the vicinity of the Ny-Ålesund settlement during winter. Mark and recapture studies showed that none of the wintering birds bred in the study area (Unander and Steen 1985). Løvenskiold (1964) and Unander (1982) observed large groups of ptarmigan along the west coast of Spitsbergen in late autumn and winter. For instance, 100–200 ptarmigans were observed foraging under bird cliffs in Kongsfjorden in early 1980s, none marked in the local study area (S. Unander 1985, unpubl.). Hunters from Longyearbyen observe annually late in autumn the arrival of migratory birds to the vegetated feeding areas north, east and south of Isfjorden (Ø. Overrein pers. comm. 2004). This indicates that the Svalbard rock ptarmigan use different habitats in winter than in the breeding season. The wintering areas and possible migration routes are unknown and a large-scale telemetry study is recommended to give information about possible important wintering areas and migration routes. There is very little information about dispersal in rock ptarmigan in Fennoscandia. However, analysis from Iceland of grit in rock ptarmigan in winter suggests dispersal from Greenland (Gudmundsson 1972). In Iceland it is also shown that banded rock ptarmigan may move over large areas in winter. Dispersal seems to be greater in females than in males, and in Iceland female rock ptarmigan, especially juveniles, dispersed over longer distances than males (Gardarsson 1988).

Like for several other northern tetranoid species, including ptarmigans (for example in mainland Norway), the several anecdotal observations of flocks of Svalbard rock ptarmigan performing high altitude and directional flights resembling what normally characterise long-range migration. However, the occurrence of true long-range migrations distinct from more local seasonal habitat shifts needs clarification through new scientific studies designed for the purpose of verifying such phenomena.

Diet

The diet of the ptarmigan has been subject of several articles (e.g. Ekstam 1897, Høeg 1929, Løvenskiold 1954, Løvenskiold 1964, Byrkjedal 1975). Ptarmigan generally prefer food of high nutritional value, and great seasonal changes in diet results from the changes in availability and phenology of the ingested plants throughout the season (Unander et al. 1985). During mid winter (November–February) the crop content contains mainly herbs i.e. *Saxifraga oppositifolia* and *Saxifraga cespitosa*. In March and April *Salix polaris* makes up more than 50% of the crop content, and the contribution from this plant increases steadily from autumn to spring. During the pre-egglaying season (May-June), *S. polaris* makes up 65-90% of the crop content. *Polygonum viviparum* is the most important food resource in summer and autumn contributing more than 50% of the food intake for hens and chicks (Fig. 13). In late autumn and winter the crop content is mostly composed by pseudo-viviparous bulbils of grasses like *Poa alpina*, *P. arctica*, *P. pratensis s.l.*, and *Deschampsia alpina* (Unander et al. 1985). The rapid growth of chicks is based on a diet of almost 100% bulbils of *P. viviparum*, which proves to have a high content of protein and an excellent substitute for the insect diet of for instance rock ptarmigan (Spidsø 1980). Inadequate supplies of nutrients are more likely to be caused by restricted availability of foraging grounds than of poor quality (Unander et al. 1985). Local icing of habitat in spring can lead to inaccessible food resources, and cause effects locally for the ptarmigan population (Løvenskiold 1964).

Figure 13. *Polygonum viviparum* is an important food resource in summmer and autumn.
Photo: Elisabeth Cooper.

Social organization

Territorial behaviour and pair establishment

Cocks show periodically territorial behaviour throughout the 24 hours from primo March to medio July (Unander and Steen 1985). Compared to willow ptarmigan and rock ptarmigan in mainland Norway, which display territorial behaviour in the morning and evening, the Svalbard rock ptarmigan's territorial display throughout the 24 hours is anticipated to be a function of continuous daylight in the breeding season (Pedersen et al. 1983, Unander and Steen 1985). Postures, calls and aerial chases are the same as described for other rock ptarmigans (Fig. 14) (MacDonalds 1970, Watson 1972).

Mutual hostility between cocks develops gradually in late March and early April and continues throughout the incubation period. From mid-April the cocks start to court hens landing on their territory and as soon as the pair bond is established, other hens are forced out of the territory. During the establishment of a territory the cock changes between foraging, using his lookout-points and flying between them showing territorial behaviour with sequences of postures and calls. The territory borders in the optimal habitats (areas with many windblown ridges with vegetation, Fig. 12) are established first followed by sub-optimal and marginal territories. Once established on a territory, cocks always claim the same territory in subsequent years, whereas hens change territory (and cock) but always come back to the same breeding grounds. The fact that pairs usually occupy larger territories than single cocks indicates that hens prefer cocks with large territory size. After pair establishment, the cock shows less intense territorial behaviour and spends much of his time guarding the hen (Unander and Steen 1985).

The quality of the cock's territory is probably the most important selective criteria vis-à-vis the hen. In addition to time of establishment and size of the territory, the composition of available foraging grounds and suitable nesting sites are important factors in mate selection. Hens in

Figure 14. Svalbard rock ptarmigan cock showing territorial behaviour. The cock´s call is a characteristic burping "aarr — aa — ka — ka".
Photo: Sigmund Unander.

optimal territories are mated earlier than hens in sub-optimal and marginal territories. Polygamy among territorial cocks ensure that almost all hens breed every year. Despite this, the territorial behaviour of cocks may limit annual chick production and thereby the population, since the cocks' second hen laid eggs later than the first and usually produced fewer chicks (Steen and Unander 1985). The pair bonding is temporal and disbands after hatching when the hen leaves the nest with the chicks.

Family structure and brood activity

The hen usually leaves the cock's territory 1–2 days after hatching. Cocks display different degrees of brood attentiveness, depending on the year and time of the hatching. The cock normally leaves the breeding site in mid-July in order to find better foraging grounds for fat deposition (Unander and Steen 1985). Cocks with hens hatching late (late July and early August) usually leave the territory before hatching. Broods often trespass and feed on neighbouring territories without hostility from the territorial cock even when his hen still is incubating (Unander and Steen 1985). Daily movement of chicks can be up to 2 km as demonstrated by a 20 days old chick, and exchange of chicks was quite common on areas with high chick density in the study area of Steen and Unander (1985). Chicks were observed to stay with the new family for days and on one occasion a hen was observed with 16 chicks (Steen and Unander 1985). Broods usually move downhill from the nest site after hatching to find areas with later snowmelt. This simply indicates the chicks' preference for sprouting plants, i.e. plants low in fibre and high in nutrient (Unander and Steen 1985). Two days old chicks are foraging about 5% of the time for 3–5 minutes, while chicks at 10 days of age are active 25% of the time for 15–60 minutes periods (Steen and Unander 1985). Later in July–August broods are often seen at higher elevations with better foraging grounds (Ø. Overrein pers. comm. 2004). Of 146 banded chicks on five breeding areas in 1981 and 1982, only six were re-observed and none were found in the same area as they were born (Unander and Steen 1985).

Population dynamics

The understanding of population processes requires information about the production of young, survival, mortality and dispersal of juveniles and adults throughout the year, migration and recruitment into a population. In addition, information about changes caused by natural factors such as predation, suitable habitat, weather conditions, social organization etc., as well as anthropogenic effects such as hunting, needs to be known. Both local and more large-scale factors determine the spatial and temporal variation in the size of populations. The quantity and quality of available food in the winter and the egglaying period may vary locally due to the particular habitat composition in local areas. The general climate during the winter may differ vastly between years in terms of severity for terrestrial herbivores in Svalbard.

A striking feature of tetranoid birds is their cyclic variation in numbers. On the mainland of Norway the willow ptarmigan exhibit 3–4 years cycles in accordance with small rodent populations (Myrberget 1989). It is not well known to what extent the Norwegian mainland rock ptarmigan follow the willow ptarmigan cycles. However, Holmstad (2004) suggests that the two species are correlated regarding density and growth rate fluctuations. The rock ptarmigan in Scotland cycles with a period of 6 to 10 years (Watson et al. 1998). A periodicity of up to 10 years is also consistent with rock ptarmigan in Alaska (Weeden and Theberge 1972) and Iceland (Gardarsson 1988, Nielsen 1999). Løvenskiold (1964) reported in his early writings a qualitative record based on trapper's diaries from 1827 to 1955, showing fluctuations in the population of the Svalbard rock ptarmigan between years. However, absence of yearly registrations in the long time data series make them unsuitable for statistical analysis on temporal patterns, including cyclic dynamics.

Currently there is very little information about the population size and variance in abundance of the Svalbard rock ptarmigan between years. Only two studies, covering timeperiods over 2 and 5 years, have estimated the breeding population of rock ptarmigans in Svalbard. Unander and Steen (1985) expressed the breeding density as the number of territories occupied by pairs or cocks. In the Ny-Ålesund area the population varied between 5.4 cocks per km² (1981) and 4.1 cocks per km² (1982) . Current monitoring data from Adventdalen and Sassendalen (2000-2004) shows that the population of territorial cocks in April vary between 2.6 and 4.9 cocks per km² (Pedersen, Bårdsen, Yoccoz and Fuglei unpublished b). In comparison, the breeding density of rock ptarmigan in one location in Iceland varied between 7 and 34 cocks per km² (Gardarsson 1988). However, lower densities were found at other locations, 1–10 cocks per km² in the northeast, 0.4–2.5 cocks per km² in the southeast, and in the southwest of Iceland there were densities of 0.3-0.6 cocks per km² (Gardarsson 1988). A continuation of the data series in Svalbard and a more comprehensive scientific analysis will contribute valuable data for long-term monitoring purposes. Hunting statistics can also contribute with valuable indirect information about the population size.

More recent data (1997–2004) collected by the Governor of Svalbard show that the number of ptarmigans hunted per year varies between 824 and 1739 (Fig. 3). Production estimates (juveniles per pair) based on collected ptarmigan wings (1998–2004) vary in the same time period between 3.1 and 5.5 juveniles per pair (Pedersen, Aanes, Yoccoz and Fuglei unpublished c).

Predation

The 3 to 4 years cycles of the willow ptarmigan on mainland Norway seem to be driven through trophic interactions due to predators switching from their main rodent prey to alternative ptarmigan prey when rodents are scarce (herbivore–predator interactions) (Ims and Fuglei 2005). In Iceland, where no significant small rodents or hares are found, the alternative prey hypothesis regarding population cycles does not apply to the 10 years cycles of rock ptarmigans. Instead, the gyrfalcon predation seems to be an essential part of the rock ptarmigan cycle (Nielsen 1999). Compared to ptarmigans on the mainland of Norway, the Svalbard rock ptarmigan have few natural predators. Small rodents are lacking in Svalbard, except for a very restricted population of sibling voles (*Microtus rossiaemeridionalis*) in Grumant (Henttonen et al. 2001). Due to this, there are no small rodent specialist predators in Svalbard. Despite that breeding of the nomadic snowy owl (*Nyctea scandiaca*) has never been confirmed in Svalbard, they are frequently observed (Løvenskiold 1964, Steen and Unander 1985, Mehlum and Gjertz 1998). The snowy owl, a migratory small rodent specialist predator, seemed to exhibit 3-year cycles during 1959 and 1996 in Svalbard, coinciding with the 3-year lemming cycles in northern Siberia (Mehlum and Gjertz 1998). Løvenskiold (1964) claimed that the occurrence of snowy owl in Svalbard is correlated to fluctuations in the abundance of prey (ptarmigan). However, since no long-term time series is available on abundance of ptarmigan such a hypothesis cannot be tested.

The most important predators on Svalbard rock ptarmigan are the arctic fox (*Alopex lagopus*) and glaucous gull (*Larus hyperboreus*) (Fig. 15) (Steen and Unander 1985). Other species as arctic skua (*Stercorarius parasiticus*) are also known to take chicks (Løvenskiold 1964). Prestrud (1992) hypothesized that density fluctuations of Svalbard rock ptarmigan might affect the

Figure 15. Arctic fox and glaucous gulls predate on Svalbard rock ptarmigan. Photo: Christiane Hübner (left), Hallvard Strøm (right).

population dynamics of arctic foxes, however, he found no correlation between the abundance of species. Steen and Unander (1985) showed a decrease in the population size of ptarmigans in the Ny-Ålesund area from 1981 to 1982 due to reduced chick production. Poor climate conditions combined with predation were the most important factors deciding the chick production. In some areas arctic foxes depredated more than 50% of the nests. The arctic fox reproduction has been monitored since 1997 in Adventdalen/Sassendalen. In 2003 there was extremely low reproduction in arctic foxes in the monitoring area (E. Fuglei pers. comm. 2004), while the reproduction index in ptarmigan was high in the same year (Pedersen, Bårdsen, Yoccoz and Fuglei unpublished b). Predation is assumed to be the most important factor, in particular, in regulating the production of Svalbard rock ptarmigan chicks (Steen and Unander 1985, Unander and Steen 1985, Prestrud 1992).

Parasites

Specialist natural enemies like parasites are also thought to be responsible for population cycles. In a study of red grouse (*Lagopus lagopus alexandrae*) in northern England, Hudson et al. (1998) showed that application of anthelmintics prevented expected density declines and reduced variance both within and between populations. Holmstad (2004) studied how parasites affect population dynamics in willow ptarmigan and rock ptarmigan in the mainland of Norway. This study suggests that parasites might play a role in generating synchronous density fluctuations between ptarmigan populations. One master study on parasites in the Svalbard rock ptarmigan was once started, but never completed. As far as we know no data regarding parasites and population dynamics in the Svalbard rock ptarmigan exist.

Another factor that could imply population cycles is diseases (i.e. microparasites). However, to our knowledge, diseases in the Svalbard rock ptarmigan has never been studied.

Social factors

One of the main hypotheses explaining the generation of population cycles in ptarmigans invokes social factors like territoriality and kin selection (Moss and Watson 2001). Unander and Steen (1985) found that during the breeding season there was a surplus population of Svalbard rock ptarmigan that had not established territories. They conducted a removal experiment and found that other cocks quickly occupied the territories where the cocks were shot. The re-established population consisted of more sub-adults than the control population. This indicated that there are surplus birds in the population and that the population can be regulated by territorial strategies. In this way territorial behaviour can limit the productions of young and thereby also the population size of Svalbard rock ptarmigan. Similar mechanisms are documented for among others willow ptarmigan (Pedersen 1984, 1988) and red grouse (Watson and Jenkins 1968). Around the local settlement of Longyearbyen, it is most likely that the local population of ptarmigan in easy accessible hunting areas are almost completely removed early in the hunting season (September/October). Next spring, the same areas seems to be occupied by ptarmigans probably moving in from surplus populations in the surrounding region (Ø. Overrein pers. comm. 2004).

Unander and Steen (1985) also showed that when the ratio of sub-adult birds were high, all territories from optimal to marginal were occupied, while in years with a lower population only the optimal and sub-optimal territories were used. The optimal territories had dominant cocks while the sub-optimal and marginal territories were used by sub-adult cocks or cocks without hen.

Climate

The large fluctuations in numbers seen in most ptarmigan populations seem to be caused by a combination of biotic factors and climatic variation (Moss and Watson 2001). The systematic component of the fluctuation (i.e. cycles) most likely originates from biotic interactions (self regulation through e.g. social behaviour, predator–prey or host–parasite interactions). Also regular fluctuation in sun-spot activity has been invoked as cause of cycles in some northern vertebrate species (e.g. Sinclair et al. 1993). In willow ptarmigan and rock ptarmigan climate events like bad weather during the breeding season compromising breeding success is thought to be a vital factor in synchronizing the population dynamics at different locations, often called the “Moran effect” (Royama 1992). Watson et al. (2000) suggested that such events entrained rock ptarmigan cycles in Scotland. Poor climate conditions as heavy snow fall during egg laying caused delayed hatching in Svalbard rock ptarmigan (Steen and Unander 1985), but how important such conditions are in shaping population dynamics is at the present unknown.

4. Human impacts

Hunting

Ten species of birds and mammals are allowed to hunt in Svalbard. The Svalbard rock ptarmigan is one of these and commonly viewed as the most popular species for recreational small game hunting around the local settlements. In 1997 to 2004 between 824 and 1739 ptarmigans were harvested annually (Fig. 16).

The harvesting of ptarmigan is regulated by The Svalbard Environmental Protection Act and The regulations relating to harvesting of the fauna in Svalbard. The regulations state in § 1 (purpose): “The fauna shall be managed in such a manner that the natural productivity and diversity of species and their habitats are maintained, and Svalbard’s natural wilderness is protected for future generations. Controlled and limited harvesting may take place within this framework.” These laws work within the framework of controlled and sustainable harvest of wildlife species. Currently the hunting period is 10 September to 23 December (Fig. 17).

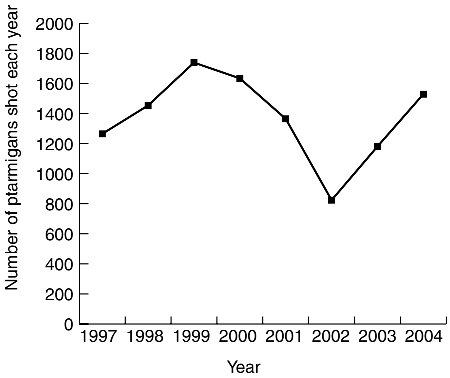

Figure 16. Number of Svalbard rock ptarmigans harvested in 1997-2004 (The Governor of Svalbard 2004).

Hunting of ptarmigan in Svalbard requires a hunting license. The Governor of Svalbard requires mandatory reporting of hunting data (e.g. date of hunting, number of ptarmigans harvested, geographic location of harvest). These data are yearly reported to the Environmental Monitoring Programme for Svalbard and Jan Mayen (MOSJ, http://miljo.npolar.no/mosj/start.htm). Hunters are also asked to deliver the outer part of one wing from each ptarmigan. The primaries (three outermost feathers) are used for age determination and calculation of production (juveniles per pair).

Trappers that used to operate in numbers spread around Spitsbergen in the first half of the 20th century most likely harvested a large number of ptarmigan locally for use in their household. In modern times with better guns and easier access to hunting grounds, the number of ptarmigans shot most likely increased quickly especially in the Isfjorden area. After experiencing some visiting hunters renting helicopters shooting hundreds of ptarmigans, the Governor of Svalbard immediately started to create a management strategy for ptarmigan. Specific guidelines/regulations were introduced in 1998. Visitors to Svalbard were allowed to shoot maximum five ptarmigans per year. Resident hunters got a bag-limit of 10 ptarmigans per day and a maximum of 30 ptarmigans per season. People living as trappers were excepted from the regulations. However, lack of knowledge about the biological needs for limiting the harvest led to a change in the regulations in 1999. The bag-limit for visitors became unchanged, but for resident hunters the maximum limit per season was removed. These bag-limits were confirmed in 2003 in separate regulations concerning quotas for hunting Svalbard reindeer and Svalbard rock ptarmigan.

Figure 17. The hunting season for Svalbard rock ptarmigans is between 10 September and 23 December. Photo: Trond Østvang.

Ptarmigan hunting in Svalbard is characterized by:

- The majority of hunters hunt without using a pointing dog (like rock ptarmigan hunting on the mainland.)
- The challenge is definitely to find the ptarmigans, not to shoot them. They have a perfect camouflage, apart from when they get a white plumage and the ground is still bare.
- Normally you may walk close up to ptarmigans and shoot them at the distance you prefer. Most often the birds are totally occupied with feeding and pay no attention to the hunter. Most birds are shot using a shotgun. Some hunters prefer to use a small calibre rifle like cal. 22LR.
- Most of the birds are shot in the areas accessible on foot from the roads around Longyearbyen. Some hunters go by boat to hunting grounds in the inner, northern and outer part of Isfjorden where the density of hunters is much lower and the density of ptarmigan is normally higher late in the hunting season.

The harvesting of the Svalbard rock ptarmigan has taken place without any information on population size and status. Furthermore, there is no data explaining the relationship, if any, between population- and habitat ecology and hunting of the ptarmigan.

Disturbances

Gabrielsen et al. (1985) found that wild incubating Svalbard rock ptarmigan hens disturbed by vocal human sounds showed a typical orienting response, i.e. inhibitions of movements, head raised and eyes open (a "what is it?" response, increasing its sensitivity to unusual stimuli). The same response was found when a glaucous gull or a fulmar (*Fulmar glacialis*) came close to the nest. The immediate response when a human became visible to hens was either "freezing" (inhibition of movements, heads down and eyes open, and up to 26 and 42% reduced heart and respiration rates respectively) or "flight" responses (restless behaviour, movements of head and eyes, and up to 46 and 60% increased heart and respiration rates respectively). In contrast to wild willow ptarmigan hens in mainland Norway, they did not leave the nest until they were pushed off or caught by a human. They were aggressive and made hissing sounds when taken off the nests. Rather than flying away from the nest or "playing injured" as willow ptarmigan often do, they remained close to the nests and returned immediately when humans left the nesting site. Steen and Unander (1985) found that when a brood was disturbed for the first time they did not show any anxiety. Only when the distance became less that 2–3 m did the chicks gather around the hen and walk away. If disturbed by an arctic fox or a dog they fly if necessary.

The less marked fear behaviour to disturbances in the Svalbard rock ptarmigan compared to willow ptarmigan is suggested to be due to few natural predators and fewer threats from humans during the incubation period in Svalbard (Gabrielsen et al. 1985). Due to the general impression that the Svalbard rock ptarmigan is extremely tame, the species is generally viewed as less vulnerable to disturbances. However, low ambient temperatures and precipitation make them vulnerable to disturbances during incubation. Despite that the Svalbard rock ptarmigan hens do eat through the incubation period, they use body fat as energy reserves and lose 18% of their body weight during incubation (Gabrielsen and Unander 1987). Gabrielsen and Unander (1987) documented that repeated heating of eggs after the hens leave the nests to forage costs extra energy and leads to stop in incubation. The effect of sustained disturbances would give similar results and increases the use of energy reserves, weakening the hens and influencing the chick production.

Persistent organic pollutants

Only one study has measured persistent organic pollutants in the Svalbard rock ptarmigan. Liver samples were collected from birds at four locations ranging from Hornsund in the south to Ny-Ålesund in the north during 1993 and 1994 (Severinsen and Skaare 1997). The levels of persistent organic pollutants in the Svalbard rock ptarmigan were low and within the same range as rock ptarmigan and willow ptarmigan from Canada (AMAP 1998).

Heavy metals

Two previous studies have measured levels of heavy metals in the Svalbard rock ptarmigan. Severinsen (1997) measured levels of aluminium (Al), lead (Pb), cadmium (Cd), copper (Cu), mercury (Hg), nickel (Ni), selen (Se) and zinc (Zn) in liver and muscle in 39 Svalbard rock ptarmigan. The birds were shot at three different locations in Spitsbergen in autumn 1993 (Brøggerhalvøya (west), Endalen (inland) and Hornsund (south)) and at one location in spring 1994 (Teistpynten, east). Eikrem (2002) studied seasonal variations in levels of Cd, Cu and Zn in 13 ptarmigans shot on one location (Longyearbyen) in autumn 1999 and spring 2000. Both studies documented low levels of accumulated heavy metals and almost at the same level or lower than willow ptarmigan in mainland Norway (Kålås and Lierhagen 1992, Pedersen and Hylland 1995) and willow ptarmigan from Canada (Langlois and Langis 1995). There was no variation in metal contamination between locations (Severinsen 1997). Low levels made it difficult to assess the impact of anthropogenic long-range transported contaminants versus local influence. Eikrem (2002) found higher levels in birds shot in spring than in autumn probably due to mobilization of fat reserves releasing accumulated metals throughout the winter. Both studies concluded that contamination of heavy metals might not cause physiological problems for the Svalbard rock ptarmigan.

5. Monitoring

The Svalbard rock ptarmigan is listed as an indicator species for monitoring of terrestrial biodiversity in Svalbard (Hop et al. 1998, Environmental Monitoring Programme for Svalbard and Jan Mayen (MOSJ) – http://miljo.npolar.no/mosj/start.htm). It is an endemic species with specific management responsibility for Norway.

Since 1997 hunters have reported data on date of hunting, numbers of ptarmigan shot and location for hunting to the Governor of Svalbard. At the end of the season the hunters are expected to deliver one wing of each ptarmigan to the Governor of Svalbard for age determination. All the wings from 1998 to 2004 were age-analysed in 2004 (Å. Ø. Pedersen pers. comm. 2004). As mentioned, NPI has since 2000 carried out yearly spring monitoring of territorial cocks in Adventdalen with adjacent valleys and Sassendalen in co-operation with the Governor of Svalbard (Fig. 18). A comprehensive analysis of the point transect sampling data from this work is started (Pedersen 2001, 2002, 2003, 2004, 2005, Pedersen, Bårdsen, Yoccoz and Fuglei unpublished a; Pedersen, Aanes, Yoccoz and Fuglei unpublished c). These data, together with unpublished data from S. Unander (pers. comm. 2005) will be used in order to develop suitable indicators for long-term monitoring of the population size of the Svalbard rock ptarmigan. Both the annual hunting statistics and spring density estimates of territorial cocks are reported to MOSJ.

6. Research and monitoring needs

The main focus of research on the Svalbard rock ptarmigan has so far been physiological studies. Therefore the following suggestion for future research and monitoring needs focus mainly on ecological topics. Winter biology (wintering grounds and migratory routes) and population dynamics, are suggested as most important fields of research

Winter biology movements and migration routes

- Identify possible migration routes, important wintering areas and dispersal of the Svalbard rock ptarmigan by using satellite telemetry.

Population dynamics

- Identify spatial and temporal patterns of population dynamics.
- Identify possible short or long-term ecological factors influencing the population dynamics (e.g. predation, parasites, diseases, climate etc.).
- Analyse and publish Unander's data from 1980-86 (S. Unander pers. comm. 2005) with respect to population dynamics and factors influencing the size of the breeding population.
- Continue the long-term monitoring of spring density of Svalbard rock ptarmigan.

Ecological impacts from harvesting

- Evaluate the relationship, if any, between hunting mortality and population size, at local and regional scales, and in particular whether hunting mortality influences in an additive or compensatory way. A premise for this is to maintain a high standard on reports and biological material from hunters.
- Evaluate the relationship between spring density index and harvesting data, and identify robust indexes for monitoring of the Svalbard rock ptarmigan population.

Habitat modelling

- Develop a robust habitat model in order to predict the spatial distribution of territorial males in spring indicating the size of the breeding population.

Environmental contaminants

- The data on persistent organic pollutants and heavy metals in the Svalbard rock ptarmigan by Severinsen (1997) need to be published.

Figure 18. Yearly spring monitoring of territorial Svalbard rock ptarmigan cocks has been carried out since 2000.
Photo: Sigmund Unander.

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Manuscripts in preparation marked as unpublished in the text:

Pedersen, Å.Ø., Jepsen, J.U., Yoccoz, N.G. & Fuglei, E. Unpublished a. Ecological correlates of territorial Svalbard rock ptarmigan (Lagopus mutus hyperboreus) in Svalbard.
Pedersen, Å.Ø., Bårdsen, B.J., Yoccoz, N.G. & Fuglei, E. Unpublished b. Evaluation of point transect sampling for density estimates of territorial Svalbard rock ptarmigan (Lagopus mutus hyperboreus) in spring.
Pedersen, Å.Ø., Aanes, R., Yoccoz, N.G. & Fuglei, E. Unpublished c. Spring density and harvest statistics of the Svalbard rock ptarmigan (Lagopus mutus hyperboreus).

8. Extended summary in Norwegian

Norsk Polarinstitutt har fått i oppdrag av Miljøverndepartementet å utarbeide en kunnskapsstatus for svalbardrype (*Lagopus mutus hyperboreus*). Hensikten med rapporten er å gi en oppdatert oversikt over kunnskap som foreligger. Rapporten viser publiserte og upubliserte arbeider hovedsakelig fra 1980 tallet og frem til i dag. På basis av denne kunnskapen oppsummeres framtidige behov for forskning og overvåking av svalbardrype.
Svalbardrype er en endemisk underart av fjellrype (*Lagopus mutus*) som Norge har et spesielt forvaltningsansvar for. Svalbardrype er en viktig småviltart som det har vært drevet utstrakt jakt på i flere hundre år uten at det har eksistert informasjon om bestandens størrelse eller status. En sentral nasjonal målsetting for forvaltning av naturmiljøet i polarområdene er å overvåke bestandsstatus for arter som i dag er jaktbare. Svalbardrype er oppført som en indikatorart i Miljøovervåkingsprogrammet for Svalbard og Jan Mayen (MOSJ), se http://miljo.npolar.no/mosj/start.htm.

Innledning

Hønsefuglen svalbardrype er den eneste plantespisende fugl som tilbringer hele året på Svalbard. Svalbardrypa er i hovedsak studert av fysiologer med vekt på tilpasninger til sesongvariasjoner i fettdeponering, matinntak, kroppsvekt, aktivitet, energetikk, reproduksjon og biologiske rytmer. Den økologiske kunnskapen om svalbardrype er meget begrenset og har hovedsakelig fokusert på hekkebiologi, ernæringsbiologi, atferd og sosial organisering, habitatstrategi og bestandsregulerende faktorer.

Svalbardrype er en underart av fjellrype som tilhører familien tetranoide. Arten fjellrype forekommer sirkumpolart i nordlige tempererte og arktiske strøk, foruten i Alpene og Pyreneene. Svalbardrype finnes kun på Svalbard og Frans Josef Land. Den er en vanlig hekkefugl over det meste av Svalbard bortsett fra i de nordøstligste deler. Den er ikke konstatert hekkende på Kvitøya, Kong Karls Land, Hopen og Bjørnøya.

Tilpasninger

Svalbardryper er, som andre arktiske dyr, utsatt for store variasjoner i lys, temperatur og mattilgang. Solen er under horisonten fra sent i oktober til midten av februar som resulterer i 24 timers mørke fra november til slutten av januar (polarnatt). Solen er over horisonten igjen i midten av april til sent i august, som resulterer i 24 timer dagslys (midnattssol). Lufttemperaturen er i gjennomsnitt under frysepunktet fra september til mai. Klimaet er imidlertid meget variabelt og perioder med mildvær og regn forekommer gjennom vinteren. Etter perioder med lave temperaturer oppstår det ofte tykke islag som dekker tundraen og gjør næringssøk vanskelig for plantespisende arter. Svalbardrypa har ulike morfologiske, fysiologiske og atferdsmessige tilpasninger til å leve så langt mot nord.

De upigmenterte hvite fjærene hos fjellryper er unike fordi fjærstrålen inneholder luftfylte rom som gir en isolerende effekt. Svalbardryper i vinterdrakt har fjærdekte føtter som reduserer varmetapet til bakken, derav det latinske navnet Lagopus som betyr "den harefotede". I vinterdrakt er begge kjønn hvite, bortsett fra de svarte halefjærne. Steggen har også en svart strek fra nebbroten og bakover til øyet. I hekketiden har den også en stor kjøttfull kam over øyet. Høna har også en rød kam, men den er nesten ikke synlig. Høna skifter til sommerdrakt i april og mai og er mer gyllenbrun enn skandinaviske fjellryper og likner mer på lirype i fargen. Steggen beholder den hvite drakten til midten av juli og får komplett brun sommerdrakt som hunnen først i midten av august. I løpet av september er begge kjønn igjen i vinterdrakt. Ungfuglen er mer gråbrun enn foreldrene og har brun hale.

Svalbardrype har store sesongmessige variasjoner i kroppsvekt som følge av stor evne til fettlagring gjennom høsten (500-550 g om sommeren og 900-1200 g om vinteren), i motsetning til sine nære slektninger på fastlands-Norge. Både liryper og fjellrypene her har samme kroppsvekt gjennom hele året. Svalbardrypene er noe større og tyngre enn både li – og fjellrypene på fastlandet. I løpet av september og oktober øker svalbardrypene kroppsvekten som følge av fettlagring, og i november–desember utgjør mer enn 30% av kroppsvekten fett. Fettlagrene gjør dem uavhengig av kontinuerlig tilgang på mat når det er vanskelig å finne næringsplanter om vinteren og bidrar til god isolering. Flere mulige forklaringsmodeller er fremsatt for den årlige sesongvariasjonen i kroppsvekt hos svalbardrype. En hypotese er at rypene legger på seg fett og dobler sin kroppsvekt om høsten, mens de samtidig reduserer matinntaket. En annen forklaring er at de øker både kroppsvekten og matinntaket, men reduserer aktivitetsnivået om høsten. Sesongvariasjonen i kroppsvekt kan ikke alene forklares ut i fra variasjonen i matinntak og aktivitet, men sesongvariasjon i daglig energiforbruk må også tas med i regnskapet. Svalbardrypene reduserer energi forbruket med 16% fra sommer til vinter. Redusert forbrenning om vinteren er sannsynligvis en tilpasning til lange perioder med lav temperatur og vind, og lite tilgjengelig næring. Når lyset vender tilbake i april er fettreservene og kroppsvekten lav selv om de dobler matinntaket fra februar til mars. Om sommeren fortsetter de å ha lav kroppsvekt til tross for høyt og stabilt matinntak. Vinterstid søker rypene ly ved å gå i "dokk" i snøen for å unngå lave temperaturer og sterk vind. Svalbardryper kan også utnytte beitegropene til svalbardreinen (*Rangifer tarandus platyrhynchus*) for lettere å komme til næringsplanter.

Bestandsøkologi

Svalbardrypene pares sent i mai, og reiret plasseres i øvre del av territoriet på tørr mark. Reiret består av en 1-2 cm fordypning dekket med ulike plantedeler. Eggleggingen starter i første halvdel av juni og det legges 9-11 egg. Omlegging kan forekomme hvis paret mister eggene, men antallet er noe mindre. Eggene har gulbrun bunnfarge og kraftige brunsvarte flekker og skjolder. Høna ruger i 21 dager og de nyklekkede kyllingene veier ca. 16 g. Kyllingene dobler kroppsvekten hver uke, og de kan nå en kroppsvekt på over 400 g etter 40-50 dager.

Høna forlater reiret sammen med kyllingene etter 1-2 dager. De er flygedyktige allerede etter 10-12 dager, men holder sammen med moren i 10-12 uker før de blir selvstendige. Parbindingen mellom stegg og høne oppløses etter at høna forlater reiret med kyllingene. Steggen forlater territoriet i midten av juli for å finne bedre beiteområder. Rypene blir kjønnsmodne etter ca. 10 mnd.

Steggene ankommer hekkeområdene i midten av mars hvor de raskt etablerer territorier ved å vise territoriell atferd gjennom hele døgnet. Territoriestørrelsen varierer mellom 3.5-50 hektar. De beste habitatene ligger i sørvendte skråninger der snøen smelter tidlig. Høyde over havet, grad av kupert terreng og vegetasjon bestemmer hvilke områder steggene tar i bruk. Territorier i optimale habitater (områder med mange vindblåste rygger med vegetasjon) etableres først, etterfulgt av mer marginale territorier. I år med en lav hekkebestand er territoriestørrelsen mindre. Steggene kommer tilbake og forsvarer de samme territoriene år etter år. Hønene ankommer tidlig i april og velger forskjellige territorier (og stegger) fra år til år, men returnerer til de samme hekkeområdene. Svalbardryper skifter habitat fra sommer til vinter. Mange steder forlater de hekkeområdene i september–oktober. Svalbardrypenes vinterområder og eventuelle migrasjonsruter er ikke kjent, men man antar at de søker til relativt snøbare områder som under fuglefjell eller andre områder med rik vegetasjon.

Dietten varierer gjennom sesongen. Harerug er viktigste fødeplante sommer og tidlig høst. Senhøstes og tidlig vinter er ulike arter rapp og fjellbunke viktig. Fra november til februar er rødsildre og tuesildre viktige fødeplanter, mens polarvier øker fra mars–april og utover våren.

Det er ikke kjent om bestanden av svalbardrype varierer mellom år slik det er vist hos fjellrype andre steder (6-10 års svingninger i Skottland, Island og Alaska). Hvilke faktorer som kan påvirke mulige bestandssvigninger er ikke studert på Svalbard. Både klima og predasjon kan påvirke produksjonen av kyllinger. Årlige variasjoner i bestanden kan også skyldes en kombinasjon av flere faktorer inkludert parasitter, sosiale faktorer og jakt. Svalbardrype viser svært lave nivåer av både persistente organiske miljøgifter og tungmetaller, og det er lite variasjon i verdiene mellom ulike lokaliteter på Svalbard.

Svalbardrype er en viktig småviltart som det har vært drevet utstrakt jakt på uten at det har eksistert informasjon om bestandens størrelse eller status. Rypa er kjent for å være ekstremt tam og lite sky. Denne atferden skyldes trolig få naturlige fiender og lite menneskelig forstyrrelse. Dette gjør rypa til et lett bytte for jegere. I 1997 startet registreringen av jaktuttaket på Svalbard, og frem til 2004 er det tatt ut mellom 824 og 1739 ryper i året. Jakttiden er fra 10. september til 23. desember.

Svalbardrype er oppført som en indikatorart i overvåkingsprogrammet for Svalbard og Jan Mayen (MOSJ). Siden 2000 er det gjennomført årlige registreringer av vårtetthet av territoriehevdene stegg i Adventdalen og Sassendalen. Så langt viser overvåkingen at tettheten i varierer fra 2.6 til 4.9 stegg per km². I forbindelse med jakten registreres jaktstatistikk, og jegere leverer inn vinger av skutt fugl slik at andelen eldre/ungfugl i jakttuttaket kan bestemmes.

Kunnskapsbehov

Med bakgrunn i oppsummeringen av eksisterende kunnskap om svalbardrype anbefales det at framtidig forskning og overvåkning fokuserer på økologiske problemstillinger. Det er store kunnskapshull med hensyn til vinterbiologi (overvintringsområder og migrasjon), bestandsdynamikk og mulige effekter av jakt på bestanden. Følgende forskningsområder anbefales:

- **Vinterbiologi og trekkruter**
  Identifisere mulige trekkruter, viktige overvintringsområder og utvandring ved bruk av satellitt-telemetri.

- **Bestandsdynamikk**
  Identifisere bestandsvigninger i tid og rom, og hvilke økologiske faktorer som påvirker eventuelle svingninger i bestanden mellom år (predasjon, parasitter, sykdom, klima etc.).

- **Økologiske effekter av jakt**
  Evaluere om det er en sammenheng mellom dødelighet som følge av jakt og bestandsstørrelse på lokal og regional skala. Videre bør sammenhengen mellom vårtetthet og jaktdata analyseres, for å finne robuste indekser for overvåking av rypebestanden.

- **Habitatmodellering**
  Utvikle robuste habitatsmodeller som kan forutsi den romlige fordelingen av vårtetthet av territoriell stegg som kan indikere størrelsen på hekkebestanden i et område.

Appendix 1

List of publications on the Svalbard rock ptarmigan not listed in the reference list, from 1964 to present. Løvenskiold (1964) lists references prior to 1964.

Bangjord, G. 1997. Pattedyr- og fugleregistreringer på Svalbard i 1995. Rapportserie nr. 99, Norsk Polarinstitutt, Oslo, 109 s. (In Norwegian).

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Gabrielsen, G.W. 1987. Reaksjoner på menneskelige forstyrrelser hos ærfugl, svalbardrype og krykkje i egg/ungeperioden. Vår fuglefauna nr. 3: 153-158. (In Norwegian).

Hanebrekke, T.L. 1998. Innvirkningen av melatonin på biologiske rytmer hos svalbardrypa (*Lagopus mutus hyperboreus*). Master thesis, University of Tromsø, Tromsø, Norway. (In Norwegian).

Houston, A.I, Welton, N.J. & McNamara, J.M. 1997. Acquisition and maintenance costs in the long-term regulation of avian fat reserves. Oikos 78: 331-340.

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Lindgård, K. & Stokkan, K.A. 1985. Photoperiodic control of body-weight and food-intake in the Svalbard ptarmigan (*Lagopus mutus hyperboreus*). Acta Phys. Scand. 124: 406.

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Reierth, E. 2001. Adaptation to arctic light conditions: shedding light on the chronobiology of an Arctic resident: the Svalbard ptarmigan. Dr. scient thesis, University of Tromsø, Tromsø, Norway.

Reierth, E. & Stokkan, K.A. 2002. Biological rhythms in Arctic animals. Biological Rhythms 216-223.

Stokkan, K.A. 1985. Feeding-activity in the high-arctic Svalbard ptarmigan exposed to natural light conditions. Acta Phys. Scand. 124: 405.

Stokkan, K.A., Lindgård, K. & Reierth, E. 1995. Photoperiodic and ambient temperature control of the annual body mass cycle in Svalbard ptarmigan. J. Comp. Phys. B165: 359-365.

Unander, S. 1984. Sosial organisering og adferd til Spitsbergenrypene. Rapport, Norsk Polarinstitutt, 7 s., unpublished. (In Norwegian).

Unander, S. 1985. Svalbardrypas populasjonsøkologi og populasjonsdynamikk. Årsrapport og status for 1984 og 1985. Rapport, Norsk Polarinstituttt, 8 s., unpublished. (In Norwegian).

Unander, S. 1987. Svalbardrypenes hekkebiologi. Vår fuglefauna, 1: 37-42. (In Norwegian).

Vongraven, D. & Scheie, J.O. 1997. Utkast til kunnskapsstatus for svalbardrype, unpublished. (In Norwegian).

Appendix 2

Ongoing monitoring and research projects on Svalbard rock ptarmigan.

1. Title: Monitoring spring densities of territorial Svalbard rock ptarmigan.
   Objective: Identify long-term patterns in spring density of Svalbard rock ptarmigan.
   Cooperation: NPI and the Governor of Svalbard.
   Funding: The Governor of Svalbard, NPI.

2. Title: Evaluation of point transects sampling for density estimates of territorial Svalbard rock ptarmigan in spring.
   Objective: Evaluate point transect sampling and how the underlying assumptions are met. Furthermore give recommendations about future use of point transect sampling as a sufficient method to monitor spring density of ptarmigan.
   Cooperation: NPI, the Governor of Svalbard and the University of Tromsø.
   Funding: The Governor of Svalbard, NPI.

3. Title: Are indirect measures of density a useful index of population density? Comparison of spring density of Svalbard rock ptarmigan and hunting statistics.
   Objective: Identify possible patterns in spring density of ptarmigan and hunting data. Further, suggest design of long-term monitoring programme of Svalbard rock ptarmigan.
   Cooperation: NPI and the Governor of Svalbard.
   Funding: The Governor of Svalbard, NPI.

4. Title: Ecological correlates of territorial Svalbard rock ptarmigan in Svalbard.
   Objective: Develop a habitat model for predicting spatial distribution of Svalbard rock ptarmigan males in spring.
   Cooperation: NPI and the Governor of Svalbard.
   Funding: The Governor of Svalbard, NPI.

Photo: Sigmund Unander.