The intention of this column is to throw a *spotlight* on individual organisms — not to blind you with science but to reveal important and fascinating aspects of specific plants, animals and microorganisms.

# The Svalbard rock ptarmigan

## Survival of the fattest


**Figure 1** Male Svalbard ptarmigan looking out across the unique Svalbard landscape.

Rock ptarmigan belong to the group of birds that live on the ground. The group also includes turkey, chicken, quail, grouse and pheasant. Rock ptarmigan live in the alpine regions of the northern hemisphere and a sub-species of these birds — the Svalbard rock ptarmigan (see Figure 1) — is found only on the High Arctic islands of Svalbard, about 400 miles north of Finland. The Svalbard ptarmigan are bigger than rock ptarmigan in mainland Europe — they are about 35–40 cm long and weigh, depending on the season, between 490 and 1000 g.

**Key words**

Arctic
Locomotion
Adaptation

Because of the harsh winter conditions they are the only land birds that inhabit these islands all year round and local people hunt them for food. Recently they have been listed as an indicator species for monitoring the biodiversity of the Svalbard region — a region at high risk from the impacts of climate change. So how do these small unassuming birds manage to survive the winter? This *Spotlight* highlights the **adaptations** of the Svalbard rock ptarmigan that enable them to survive in one of the harshest environments in the world: the Arctic.

### Life in the High Arctic

Svalbard is a group of islands that covers an area of 61 000 km$^2$ and is recognised as a centre for scientific excellence. It houses the **doomsday seed vault** and international scientific research stations from ten different nations. Situated high up inside the Arctic circle, Svalbard experiences extremes in environmental conditions. From late April to August each year the sun doesn't set and maximum temperatures hover around +5°C. From mid-November to January the region is blanketed in continual darkness and temperatures regularly drop as low as –30°C. These differences in the amount of daylight and darkness are important and serve as triggers for many of the behavioural adaptations seen in the animals that make this region their home.

The landscape on Svalbard is unique. Glaciers cover around 60% of the land, and because it lies above the **tree line** there are no trees or large bushes, only small (<10 cm) plants (see Figure 1). The Arctic, with its widely fluctuating weather conditions, is a unique and challenging

environment for animals and they must adapt in order to survive, reproduce and move around.

## Adaptations for life in the Arctic

The Svalbard ptarmigan are well adapted to live in the High Arctic. The most obvious adaptation is the seasonal change in their plumage. In the winter both sexes are pure white — the male can be distinguished by the black stripe running from his beak through the eyes (see Figure 2). In summer, however, the male has intermittent brownish black feathers with yellowish spots over a background of white feathers. The female has yellowy flecks over a more uniform brown background (see Figure 3). These differences in plumage allow the birds to blend into their environment, providing protection from predators at different times of the year. The female (see Figure 4) has better all-over camouflage than the male — it is particularly important for her to be able to hide because she protects the nest and eggs.

However striking these changes in plumage are, the most remarkable adaptation these birds have for life in the Arctic is their changing body mass. In preparation for the harsh winter months, these birds double their body mass (see Figure 5 on p. 28). In summer the birds normally weigh about 0.5 kg but by the beginning of winter their mass has increased to around 1 kg. When these birds are at their heaviest, more than 30% of their body weight is fat.

Seasonal changes in day length on Svalbard trigger these changes in body mass. Increase in day length during the spring months, together with the increased availability of food, means that the birds deposit increasing amounts of fat in their bodies. These huge fat stores play an important role in providing insulation against the Arctic winter and serve as emergency fuel reserves for the birds when food may be hard to find.

Most animals gain some weight before the winter, when food is plentiful. Some, such as bats and bears, gain large amounts of weight like the Svalbard rock ptarmigan. But bats and bears hibernate throughout the winter, living off their fat reserves, whereas the ptarmigan do not hibernate at all. They continue to forage and move around throughout the year.

The extreme unpredictability of the weather in the Arctic means that it is nearly impossible to predict the harshness and, more importantly, exactly when the winter will end. This unpredictability means that hibernation cannot be relied upon as a successful over-wintering strategy. The ptarmigan's fat stores, therefore, are conserved as much as possible throughout

Tommy Dahl Markussen

**Figure 2** Male Svalbard rock ptarmigan moving on snow.

Jan Haugseth

**Figure 3** Male (in the foreground) and female Svalbard rock ptarmigan in summer.

Jonathan Codd

**Figure 4** Female Svalbard rock ptarmigan showing well camouflaged summer plumage.

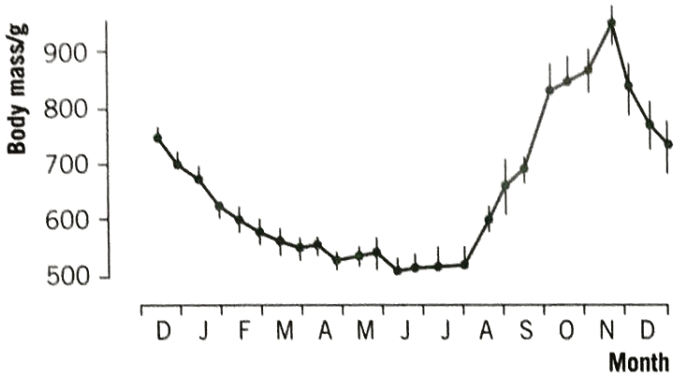


**Figure 5** Seasonal changes in body mass of the Svalbard rock ptarmigan during a year, showing the doubling of body mass before winter (Nov–Dec) compared with summer (July). Modified from Stokkan, K-A et al. (1986) *Am. J. Physiol.*, Vol. 20, pp. R264–R267.

the winter to enable the birds to survive short periods of starvation brought on by the extreme cold and conditions that restrict their ability to feed on the plants hidden below the snow and ice. However, this adaptation to survive in the Arctic represents a real challenge for these birds because they must continue to move around despite this huge increase in body mass.

## Studying bird movement

When we think of birds moving we naturally think of them flying through the air. Bird flight requires remarkable adaptations — feathers and light skeletons and the huge oxygen supplies required to provide the energy necessary to fly. However, many birds, including the Svalbard ptarmigan, when breeding and feeding, rely not on their ability to fly but on how well they are able to move on the ground. For a considerable part of the year Svalbard ptarmigan cannot fly, partly because they are simply too heavy and partly because they cannot orientate in total darkness.

So biologists are interested in measuring the energy it takes for Svalbard ptarmigan to move around on the ground and in understanding their associated adaptations. This study will provide knowledge that is fundamental to understanding the ecology and energetics of these birds.

When an animal moves, it uses oxygen to provide the necessary energy, and the faster an animal moves, the more oxygen it requires. Therefore, by measuring the amount of oxygen used by an animal as it moves at different speeds on a treadmill, we can calculate the overall energetic **cost of locomotion** under different conditions. Experiments have been performed on Svalbard ptarmigan where the birds run inside a clear plastic box (see Figure 6). The air that they breathe out is collected and analysed.

## Energy savings

The predictions seem obvious — that the birds will run fast when they are lean and much more slowly when they are heavy. Following on from this we might expect that the

Jonathan Codd

**Figure 6** Male Svalbard ptarmigan on a treadmill inside an energetics chamber used to measure the amount of oxygen it is consuming.

energy used to move around will be less when they are lean and more when they are heavy. But experiments with the birds have given surprising results. The speeds of a series of Svalbard ptarmigan running on a treadmill were measured when they were light, at the beginning of summer, and then checked again later in the year when the birds were at their heaviest. Their energy expenditure (oxygen consumed per distance covered per unit body weight per unit time) when they were on the treadmills was also measured.

The first part of the results confirmed the predictions. During the summer months, when the birds are lean, the Svalbard ptarmigan are able to run very fast — at speeds of well over 2.5 $m s^{-1}$. When the birds were fat, they could achieve only half their summer top speeds. But when efficiency rates (energy used per unit body mass) were considered there was a surprise. If you have ever carried shopping bags or walked with a large backpack, you will know that walking or running with extra weight costs more energy, right? Well not in the case of the Svalbard ptarmigan. These birds are actually able to move around more efficiently during winter when they are heaviest than in summer when they are at their lightest (see Box 1).

Exactly how the ptarmigan are able to achieve this remarkable feat is not yet fully understood but it may have something to do with the tendons in their legs. Think of a large truck: when it is empty, the truck will bounce around and give a rough ride. When it is fully loaded, however, the springs in the suspension begin to work better and allow the heavy load to be carried smoothly and more efficiently. Something similar may be happening with the ptarmigan. The tendons in their legs are thought to act as springs during locomotion, storing energy when they are compressed and releasing it when they move forwards. So when the ptarmigan are heavy, the larger amount of stored energy enables these birds to move around more efficiently than when they are light. In a similar sort of way, biologists have found that kangaroos are more energy efficient when they are bounding at high speed compared with when they are hopping at a more leisurely pace.

## Box 1 Reduced cost of locomotion in winter

Svalbard rock ptarmigan were trained to run on a treadmill at different speeds, and the amount of oxygen used and carbon dioxide produced was measured by sampling the air from a box surrounding the birds (see Figure 6). From these measurements we then calculated the energy needed for the birds to move. We tested for any differences in the cost of locomotion associated with the seasonal changes in body mass seen in the Svalbard rock ptarmigan. Figure 7 shows the results. The cost of locomotion (*y*-axis) is measured as metabolic power in watts per kilogram body mass ($W kg^{-1}$) at different speeds in metres per second (*x*-axis, $m s^{-1}$). You can see that during winter (blue line) the birds used less energy to move around than they did during summer (red line) — a remarkable adaptation to life in the Arctic.

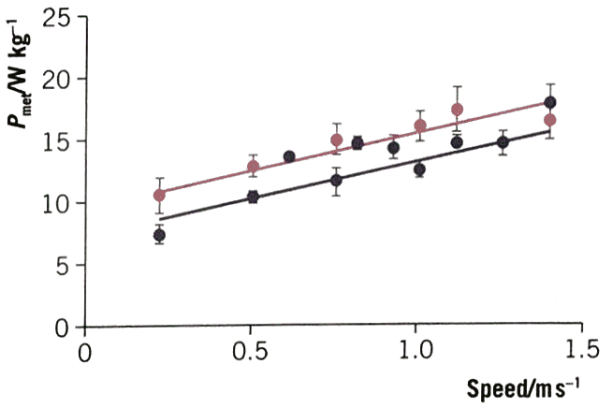


**Figure 7** Graph comparing the running efficiency of heavy and light rock ptarmigan. Modified from Lees, J. J. et al. (2010) *PLoS ONE*, Vol. 5, No. 11, e15490.

## For the future

There remains much to be discovered about Svalbard ptarmigan. The unique environment of the Arctic provides the opportunity to gain insight into the adaptations and evolution of different ways of surviving. In particular, there is a real need to conduct detailed field studies. The vast majority of zoological research takes place under laboratory conditions. It is often unclear how relevant the findings are to birds in the wild, and this should become an important area for future research. The polar environments are also at the forefront of the impacts of climate change and the Arctic is one of the fastest warming regions in the world. The species that live in these environments are at an increased risk of climate-change-driven extinction and it is only through further study that we may gain the insights necessary to ultimately protect and conserve them.

## Terms explained

**Adaptation** An advantageous trait that has been maintained by natural selection.

**Cost of locomotion** The amount of energy used to move a known distance at a given speed for a given body mass.

**Doomsday seed vault** The seed vault on Svalbard is a secure building where seeds of plants from around the world are preserved for future generations.

**Tree line** The edge of habitat that trees are capable of growing due to the harsh environmental conditions.

## Further reading

For further information on Svalbard, including advice on planning visits, see the Governor of Svalbard's website: **www.sysselmannen.no**.

Blix, A. S. (2005) *Arctic Animals and their Adaptations to Life on the Edge*, Tapir Academic Press.

**Dr Jonathan Codd** is a senior lecturer in the Faculty of Life Sciences at the University of Manchester. He is the programme director for the undergraduate zoology programme and researches the respiratory and locomotor adaptations of birds and bats.