JAKUB OSTAŁOWSKI

It Pays to be Small in Winter

Dr. Paulina Szafrańska from the PAS Mammal Research Institute in Białowieża explains why weasels range so greatly in size.

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ACADEMIA: **What kind of extremes are encountered by biologists working in ecophysiology?**
PAULINA SZAFRAŃSKA: Ecophysiology is the study of physiological processes under natural conditions in species living in the wild. Ecophysiologists are especially interested in extreme environments, such as deserts, high mountain ranges and ocean depths. Extreme conditions make limitations more visible, and they reveal physiological adaptations which help animals survive. At our latitude, the greatest challenge posed to animals – especially small mammals – is winter, when temperatures are low and there is precious little to eat.

Your research into weasels – small predatory mammals – noted a certain peculiarity.
That's right. Weasels show extreme characteristics, especially males whose size ranges from a tiny 50 g to a whopping 150 g – an enormous difference! If we were to compare weasels to humans, it would mean we would be as likely to meet a man weighing 70 kg as one weighing 210 kg. In our research we have tried to find out how it is possible for the population of a single species to maintain such a huge range.

Weasels are also very interesting because of their high metabolic rate – much higher than in other mammals of a similar size. This means they need to feed frequently, which is unusual in predators. Yet food is scarce in winter and the animals have to contend with low temperatures whenever they venture out to hunt. Weasels really live on the edge – as shown by their high mortality rates in winter.

Why such a great difference in body mass in weasels?
It pays to be small in winter, because a small individual needs less food. Hunting requires an energy expenditure, and weasels which can survive on, say, one vole are better equipped than those which need one and a half. Larger individuals need to hunt more frequently, which means more effort and longer exposure to low temperatures, all of which require more energy. I know from my own experience that it's much easier to go for a single walk during a winter's day than to go out twice. And of course weasels are very small, only up to 20 cm in length, and they have their own predators. Every time they leave their den to hunt they are at risk of becoming prey themselves.

However, larger weasels have an advantage in summer, because they are more likely to chase away smaller individuals from their territory and mate with more females, giving them a higher likelihood of reproductive success.

Can a single individual adjust their body mass during the year?
Male weasels tend to have a very stable body mass once they reach adulthood – they reach their full size around the time they leave the nest. In any case their lives are short, an average of around 11 months in the wild. The variation we're talking about is observed on the population level. In the summer, most males reach around 100 grams, which drops to 70–80 in autumn, although on the population level we see the full spectrum of sizes. The largest weasels most likely die out in the autumn.

We also see variation depending on the environment. Weasels whose territories are mainly open spaces such as meadows tend to be larger because their prey is larger – for example root voles. In forests, smaller weasels hunt smaller animals such as bank voles. The energy expenditure for hunting is likely similar in both cases, but that doesn't extend to the energy gain, which explains the differences in body mass in different environments.

Can you explain the notion of an organism's metabolism? We often think of it as referring to digestion, but physiologically speaking things aren't that simple, are they?
Digestion means converting food into energy, so that part is correct. The metabolic rate describes the speed at which an organism consumes and convert matter into chemical energy, heat and work. In ecophysiology we use the basal metabolic rate (BMR), measured in the lab on the basis of oxygen consumption per unit

of time in an animal which is not expending energy on digestion and is at a neutral temperature, which means it doesn't need to cool or warm itself. This standard measurement allows us to compare different individuals and species and the effects of environmental conditions.

> It pays for an animal to be small in winter, because it needs less food, but big in summer, because it can chase smaller rivals out of its territory.

Let me explain the difference between organisms with a high or low metabolism using cars as an example. Imagine two cars waiting at a red light – a little runaround and a Ferrari. Although they are stationary and appear the same, they are using different amounts of fuel just to keep idling, with the little car using much less. When the lights change, the Ferrari accelerates away rapidly and reaches a far greater speed, while the small car pulls away more slowly. Both have their pros and cons. The little car represents a low metabolic rate: it requires less energy to maintain basic function, but it doesn't manage as well when it needs to do something very quickly. In nature, this could mean having to escape a predator, or spending a prolonged period using more energy, such as bearing and rearing young. The Ferrari has a high metabolism: it can expend a lot of energy when it needs to, but it doesn't cope so well when the fuel is low.

What strategies do animals employ to cope with extreme winter conditions?

They have three options: migrate to a warmer region where there is more food, hibernate over the winter, or remain active and manage the best they can despite the difficult conditions. I'm especially interested in the third scenario. Weasels, shrews and many other animals with a body mass under 1 kg reduce their metabolic rate in winter, which in turn reduces their energy demands. Shrews are an especially interesting example. In the late 1940s, Prof. August Dehnel, founder of the Mammal Research Institute where I work, observed that the average body mass in the shrew population drops by 20% in winter. This fact has come to be known as the Dehnel phenomenon. However, until recently it wasn't clear whether larger individuals simply die out, or the animals are able to adjust their body mass. A few months ago, a team from the Max Planck Institute in Germany published its fascinating research into the seasonal changes in the common shrew. They discovered that the animals shrink their heads, including their brains, by around 15% in winter, and then increase them back by about 9% in spring. The difference can partially explain the reduced body mass and metabolic rate.

Certain animal species are able to temporarily reduce their metabolic rate to preserve energy. The red deer and the Przewalski horse use such a mechanism on freezing winter nights. Another strategy is adopting a torpid state – with reduced body temperature and metabolic rate – during adverse environmental conditions. It's a more common strategy than many people realize. For example, swift chicks can fall into a semi-torpid state to survive periods of bad weather in the summer when their parents aren't able to catch sufficient numbers of insects to feed them.

So we know that other mammals are able to adjust their metabolic rates relatively easily – what about humans?

According to anecdotes, Tibetan monks are able to slow down their metabolism to the extent that they can survive on minimal food. However, both in humans and other mammals, physiological traits change in response to external conditions. At times we can influence those conditions, for example by adjusting our body mass by changing the amount of food we eat or by exercising under different conditions to improve our immune system function. Athletes regularly train at high altitudes before major competitions. The lower oxygen levels in the atmosphere cause their bodies to produce more red blood cells to supply more oxygen to muscles and organs. The ability is maintained for a period of time after returning to a lower altitude, improving the athlete's performance and therefore their chances of obtaining better results.

Do changing environmental conditions lead to similar adaptations across species?

Not necessarily. Recent research compared two species of geese. One migrates over the Himalayas, while the other lives at a high altitude in the Andes. In the former, the bar-headed goose, the adaptation to high altitudes and low oxygen levels manifests itself in increased respiration and a faster heartbeat. The lungs of the latter, the Andean goose, absorb more oxygen, while their hearts have a higher stroke volume.

High mountains are a fascinating environment from the physiological point of view. Europeans are poorly adapted to cope with altitudes over 2400 meters above sea level and are at risk of altitude sickness, which manifests as headaches, vomiting, insomnia and dizziness. This is the physiological response to an external stimulus of low atmospheric pressure and low oxygen levels. However, after spending some time at high altitudes, human bodies generally adapt to the new conditions. This is commonly experienced by mountaineers climbing high peaks such as the Himalayas. They are frequently accompanied by local guides and porters, for example Sherpas. Sherpas don't suffer from mountain sickness and they are far better adapted to high altitudes than white climbers. For example, Lhakpa Tenzing and Phurba Tashi have each ascended Mount Everest 21 times.

However, research shows that people who live at high altitudes don't have a single specific trait responsible for their adaptation to extreme conditions. They tend to have a higher lung capacity, higher numbers of red blood cells and a higher affinity of hemoglobin for oxygen in the lungs and lower in other tissues. The traits are partially hereditary in people who have lived at high altitudes for many generations. Of course, people who live at low altitudes are able to adapt to high altitudes; however, this takes time, and generally speaking Europeans will not become as well adapted as Sherpas.

And of course there are more specific differences: some individuals are better able to adapt to different conditions or obtain better results following training than others.

That's right – there is variability in populations. Metabolic rate and body mass are determined genetically, but they are the result of the action of several genes. Some of those genes are only activated under certain conditions.

> In terms of physiology, it's possible to adapt to extreme conditions as ong as they don't arise too suddenly.

The ability to respond to environmental conditions is key when it comes to major challenges such as climate change, even though from the physiological perspective short-term but extreme changes, such as a rapid temperature increase, present a greater problem than slow, gradual shifts. The heatwave which hit Australia in the 1930s led to a mass extinction of zebra finches – sparrow-sized birds which are extremely well adapted to high temperatures. Tragically, people die during heatwaves in Poland and elsewhere in Europe, especially if the temperature rises rapidly. So when it comes to physiology, it's possible to adapt to extreme conditions as long as they don't arise too suddenly.

Interview by Agnieszka Kloch

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