nature

NEWS & VIEWS

E. LESLIE

POPULATION BIOLOGY

Case of the absent lemmings

Tim Coulson and Aurelio Malo

Changing weather patterns, producing the wrong kind of snow, have transformed the population dynamics of lemmings in northern Scandinavia. The knock-on effects have been felt throughout the ecosystem.

A colleague from Oslo once told me that when the Bible was translated into Norwegian, mention of plagues of locusts was replaced with plagues of lemmings. The logic behind this change was that most Norwegians knew nothing of locusts, but were all too familiar with periodic explosions in lemming numbers. The story is apocryphal, with references to lemmings only scrawled by the translator in the margin. Yet these scribbles suggest that lemming outbreaks have been a feature of northern ecosystems for the past millennium. But now the outbreaks, at least in some areas, have stopped. On page 93 of this issue, Kausrud *et al.*[1] explore the underlying reasons.

Norway lemmings (*Lemmus lemmus*) are remarkable animals. These rodents can live for three or four years, spending their winters beneath the snow and feeding mostly on moss. A female can produce up to three litters a year, with as many as 12 young per litter. Lemmings occasionally become super-abundant when large numbers of young survive[2]. In northern Norway in 1970, lemmings were so common that snowploughs were used to clear the vast numbers of squashed animals from roads. Outbreaks don't last long: food becomes scarce, and lemmings will then often disperse en masse in search of greener pastures. On occasion, desperate to find food, they jump into water and start swimming. This behaviour led to the myth that lemmings commit suicide.

In northern Scandinavia, lemming outbreaks typically occur once every three to five years. Or they used to. In the past 15 years, localized outbreaks have either stopped or occur less frequently[3]. The cause of this change is the subject of debate, partly because the reason that rodent populations often show periodic outbreaks is itself controversial[4–8]. Fluctuating predation, food availability or quality, and climate variability have all been proposed as plausible mechanisms generating these population cycles. Whatever the cause, it is clear that in parts of northern Europe something is now preventing these rodents from periodically producing large numbers of surviving young[3].

Kausrud *et al.*[1] analyse a 27-year time series of lemming numbers from one site in Norway. They first demonstrate statistically that climate change means that Norway now gets a lot of the wrong sort of snow. Lemmings do well when warmth from the ground melts a small layer of snow above it, leaving a gap between ground and snow. This subnivean space provides warmth and allows lemmings to feed in relative safety from many of the animals that eat them. Climate change now means that the subnivean space does not exist for as much of each year as it used to. Worse still, the space itself is less likely to form: warmer temperatures mean that snow melts and refreezes, producing a sheet of ice that prevents lemmings from feeding on the moss.

The wrong sort of snow therefore means that food is hard to come by, keeping warm is challenging, and being eaten is more likely. Kausrud *et al.* use their statistical associations to construct a predictive model of lemming dynamics. This model, fitted to data from before the outbreaks stopped, predicts the observed cessation, providing compelling evidence that changing snow conditions are a major factor in the change in lemming population dynamics.

The researchers then go on to show that the reduction in the frequency of lemming outbreaks has knock-on consequences for the wider ecosystem. They argue that the scarcity of lemmings means that predators such as foxes turn their attention to other species, including willow grouse and ptarmigan, adversely affecting their populations. Evidence for changes in the numbers of species other than lemmings in these northern ecosystems is convincing. But although the mechanism that Kausrud *et al.*[1] propose — a shift in predation patterns — is plausible, it is speculative.

The critical reader will complain that the story is based on correlations. Although this is true, it is often the only way to study populations and the consequences of changing climate for ecosystems[9]. The collection of detailed long-term data on the dynamics of free-living populations of animals and plants rarely attracts the same excitement as genomics or particle physics, yet such data are vital in characterizing the consequences of climate change for the natural world on which we depend. Describing and predicting such effects of climate change will help us prepare for, and possibly minimize, adverse affects. Kausrud *et al.*[1] elegantly show the value of detailed long-term ecological data, and demonstrate the benefits of maintaining existing studies and instigating new ones.

By the time the Norwegian translator of the Bible got to the book of Revelations, he had stopped making references to lemmings, so we do not know whether the cessation of outbreaks foretells the imminent arrival of the four horsemen of the apocalypse. However, we do now understand that climate change has made lemming outbreaks much less common, which has in turn affected the fragile ecology of northern ecosystems. This research[1] provides a striking example of how climate change can modify the workings of the natural world — raising the question of what consequences such change might have for us. ■

Tim Coulson and Aurelio Malo are in the Department of Life Sciences, Silwood Park Campus, Imperial College London, Ascot, Berkshire SL5 7PY, UK.
e-mail: t.coulson@imperial.ac.uk

1. Kausrud, K. L. *et al. Nature* **456,** 93–97 (2008).
2. Turchin, P. *et al. Nature* **405,** 562–565 (2000).
3. Ims, R. A., Henden, J.-A. & Killengreen, S. T. *Trends Ecol. Evol.* **23,** 79–86 (2008).
4. Aars, J. & Ims, R. A. *Ecology* **83,** 3449–3456 (2002).
5. Lambin, X. & Krebs, C. J. *Oikos* **61,** 126–132 (1991).
6. Angerbjorn, A., Tannerfeldt, M. & Erlinge, S. *J. Anim. Ecol.* **68,** 34–49 (1999).
7. Seldal, T., Andersen, K. J. & Hogstedt, G. *Oikos* **70,** 3–11 (1994).
8. Hanski, I. *et al. Ecology* **82,** 1505–1520 (2001).
9. Coulson, T. *et al. Science* **292,** 1528–1531 (2001).

ASTROPHYSICS

An illuminating dark halo

Stéphane Colombi

A large simulation reveals that most of the detectable signal from dark matter in our Milky Way probably comes from the main, smooth Galactic halo, rather than from small clumps.

Most of the mass of the Universe is believed to be in the form of dark matter — an invisible component that has so far been only indirectly detected through the effects of its gravity on visible matter. In the theory of supersymmetry in particle physics, there is a corresponding dark-matter-particle candidate that interacts only very weakly with the rest of the Universe, and is thus very difficult to detect directly. There is, however, a general feeling in the astronomical community that the search for dark matter is now at a turning point. This feeling stems from the recent start of the largest particle accelerator in the world (the Large Hadron Collider), which could provide clues about the nature of dark matter, and from the advent of high-energy astrophysics observations, such as γ-ray observations carried out by NASA's Fermi Gamma-ray Space Telescope. Such observations are potentially able to detect dark-matter particles indirectly through their annihilation radiation. On page 73 of this issue, Springel *et al.*[1] show that the primary and probably most easily observable annihilation signal is produced by the diffuse dark-matter component rather than the very small clumps in the main halo of our Galaxy (Fig. 1).

The challenges in determining the nature of dark matter are not only experimental. At a time when observations are about to start providing data, it is necessary to understand in detail how dark matter is distributed in our neighbourhood, in particular in the halo surrounding our Galaxy (an extended, ellipsoid-shaped dark-matter structure), in order to make predictions about the expected annihilation signal. During the past few years, there has been controversy about the nature of the clustering of dark matter inside galactic haloes, and particularly the mass and distance from our Solar System of the dark-matter structures that are likely to contribute to the annihilation signal that could be measured by the high-energy astrophysics experiments.

There are two ways to predict the properties of dark matter inside galactic haloes. The first involves simplifying the geometry of the problem, and making predictions using relatively simple but robust analytical calculations[2]. Although these calculations are rigorous and free from any numerical artefacts, the oversimplification of the geometry can lead to questionable results. The second approach, used by Springel *et al.*[1], involves performing sophisticated numerical experiments on supercomputers.

Springel *et al.* study the dynamics of dark matter in a cosmological background — the expanding Universe — by modelling the dark-matter distribution with a set of macroparticles that interact which each other only through gravitational forces. Each macroparticle represents a huge number of actual dark-matter particles. Because the gravitational force is very long-range in nature, the authors simulate a large volume of the Universe and zoom in on a region where a halo similar to that of our Galaxy is formed. In that smaller region, the resolution of the simulation is increased, enabling many macroparticles of smaller mass to trace all the fine details of dark-matter dynamics.

Springel and colleagues' simulations are developed in the framework of the cold dark matter (CDM) hypothesis, which is now the commonly accepted model for the formation of large-scale structures in the Universe. One of the hurdles to performing simulations in CDM models is achieving numerical convergence at small scales, or equivalently at small masses. Within the CDM hypothesis, the consensus is that the smallest dark-matter structures formed

V. SPRINGEL

Figure 1 | Dark matter around the Milky Way. The Galactic dark-matter halo contains a remarkable hierarchy of structures of different sizes. But according to Springel *et al.*[1], it is the diffuse, smooth component of dark matter in the halo that is likely to dominate the expected annihilation radiation of the corresponding dark-matter particles. (More pictures and movies are available at www.mpa-garching.mpg.de/aquarius.)