Evolution in action: Are voles shrinking?

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Abstract

It is not easy being small. Especially when nature seems to favor larger individuals. But why don't all animals evolve to be bigger? Is it sometimes better to be small? Or are some incapable of evolving?

To answer these questions, we studied a wild population of snow voles (a small rodent species) in their alpine habitat. Genetic analysis indicated a hidden evolutionary change: voles evolved to become smaller but the average body size of population stayed the same. To understand the underlying causes, we separated genetic and environmental influences on vole body size.

We found that young voles with genes for small bodies developed faster. This allowed them to survive better when environmental conditions changed (earlier arrival of winter). As a result, the population evolved towards a smaller body size. Our study shows that populations can evolve rapidly. But without a genetic perspective and understanding the underlying causes, we may not be able to detect these changes.

Introduction

Do you ever wonder why organisms seem to fit their environments? It happens through an often slow and gradual process called *adaptive evolution*. It has a key role in shaping long-term features of wild plant and animal populations. Individuals that survive and reproduce pass on their genes to future generations, while the genes of those that do not survive and reproduce are eliminated. Over multiple generations of elimination, a.k.a. *natural selection*, genes that improve survival and reproduction become more common in the *gene pool* of the population.

Human-induced climate change impacts environmental conditions all around the world. *Adaptive evolution* might help animals and plants fit their new environment and avoid extinction. But we still do not know how common or how fast it is in nature, because it is hard to see *adaptive evolution* in action. For example, body size is influenced by genes (it is passed on from generation to generation) but also by the environment (individuals who are better fed when young will grow up to be bigger). So if we see that larger animals have more offspring, why don't we see the average snow vole within the population evolving to be larger?

There are two possible answers:

1) The population is really not evolving (*evolutionary stasis*)

Or:

2) Adaptation is happening, but the genetic changes are swamped out by environmental changes. (Better fed individuals grow larger, even if they have genes for small bodies).

Because body size is a *quantitative trait* (which means it depends on the cumulative actions of many genes *and* the environment), we need more effective methods to separate the effects of these two factors.

Methods

Snow voles are small rodents that live between loose rocks on mountains (Figure 1). They reach their adult sizes in one to two years, and can live up to four years. Between 2006 and 2014, we studied a wild snow vole population in their alpine habitat. Since their habitat was *geographically isolated*, we were able to monitor each vole throughout its lifetime.

Every summer, we trapped and marked the voles to collect the following data:

- *Phenotypic data*: we weighed and measured the voles.

- *Genotypic data*: we took DNA samples from ear tissues, and determined genotypes and parent-offspring relationships within the population. We created an 11-generation *pedigree* (a family tree).

Figure 1:
Snow vole is a small rodent inhabiting mountainous and rocky areas. Adults weigh 27 to 58 g.

Typical snow vole habit

We separated the contributions of genetics and environment on phenotypic trait with the help of a mathematical model with two parts:

1. A "fixed effect" part: this measures how much the phenotype varies depending on age and gender, without accounting for genetic effects.

2. A "random effect" part: to measure how much related individuals look the same and therefore estimate *heritability*, the relative importance of genes versus the environment in shaping differences in size.

Results

Our results revealed interesting facts:

Body size was a heritable trait: large parents tend to have large offspring.

Relatively heavy individuals both survived better and produced more offspring per year. However, larger body size did not directly cause an increase in *fitness* (it only correlated with).

Voles changed genetically over a few generations only. They became smaller and lighter. Especially in years when the first winter snow fell earlier than usual, lower body weight caused higher survival and fitness (Fig. 2).

Despite the genetic change towards lighter body size, average body size of the population did not change much.

Do longer or shorter summers select for smaller voles? How do you think this will change with a warmer climate?

Figure 2 :
Here you can see vole size in relation to season for both vole types (big body genes = dark purple vole, and small body genes= light purple vole) for two different time periods and their respective survival rates.

From 2006 to 2007 (left panel), the summers (leaf symbol) were long and snow started late. So there was lots of time for both types of voles to eat, grow and fully develop. Thus, their survival was the same.

Between 2008 and 2014 (right panel), the summers were short and winter (ice symbol) started early. This left voles with genes for large bodies, who need a longer development time, less time to grow into adults. Their chances of survival were therefore lower than those of the voles with genes for small bodies (who can develop faster). In this case, natural selection favored small bodied voles
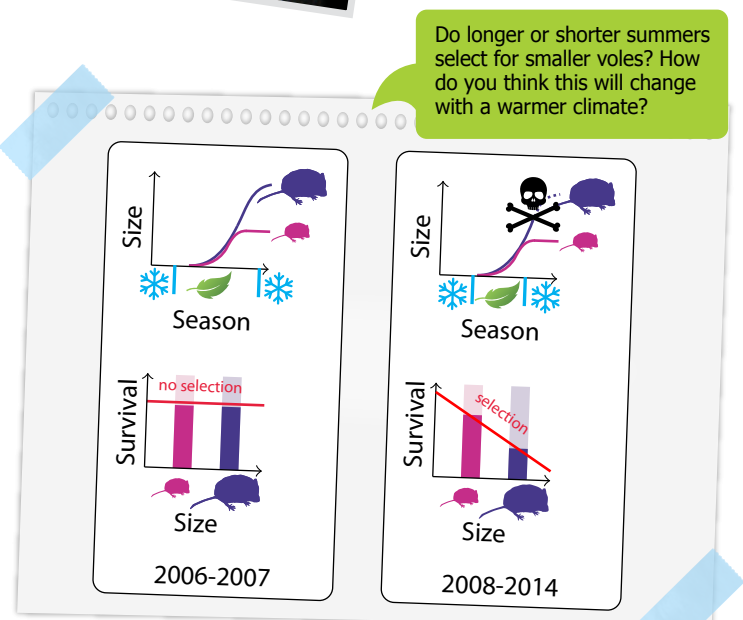
Discussion

Our genetic study of a wild snow vole population revealed adaptive evolution in action towards a smaller and lighter body size. Due to the isolated location of their habitat, natural selection (and not immigration) was the main cause of this evolutionary change.

To understand why nature selected small voles over large ones, we separated effects of genes and the environment on vole body size. We discovered that young voles with genes for large bodies require a longer development time. When snow fell earlier in the season, these individuals could not complete their development in time and died. On the other hand, young voles with genes for small bodies were more likely to develop before the winter came and food became scarce. Therefore they survived better and were fitter compared to their counterparts.

And here comes the tricky part: Over the same decade, the number of voles in the population decreased. Thus, more food was probably available for the remaining animals, and they grew bigger. This kept the average body size of the population the same, even though the voles were evolving to be smaller in the long run. As a result, genetic change towards small body size wasn't visible from the outside. If we restricted our study to simply measuring the change in average body size, we couldn't have exposed this adaptive evolution in action that was going on at the genetic level.

Conclusion

When environments are changing, wild animals and plants face the risk of extinction. In this study, we used genetic methods to reveal a rare case of hidden adaptive evolution. Adaptive evolution can help species cope with changing climatic conditions.

Our understanding of evolutionary dynamics is vital in predicting when or if evolution will occur and in identifying evolutionary winners and losers. We can use this information to preserve species that cannot adapt. Down the line, we can incorporate evolutionary processes into wildlife management programs and minimize biodiversity loss due to rapid climate change.

Glossary of Key Terms

Adaptive Evolution – evolutionary changes that make a population fit its environment better. Darwin's finches have different bill shapes, each working best on a different types of food. Adaptive evolution makes the average bill in the population match the food available on a given year.

Biodiversity – variety of life in the world or in a particular habitat or ecosystem. To increase the biodiversity in a garden, plant different trees, shrubs, and flowers.

Evolution – change in the genetic composition of a population or a species over generations. Dogs evolved from grey wolves.

Evolutionary Stasis – lack of evolutionary change over a long period during the history of a species or a population.

Extinction – End of a species, dying out. About 65 millions year ago, a mass extinction killed off dinosaurs.

Fitness – how well an organism can survive and reproduce in its environment. *Survival of the fittest*.

Gene pool – Set of all genes, or genetic information of a population of individuals of the same species. A large gene pool indicates high genetic diversity.

Genotype – complete heritable genetic identity of an organism. Examples of genotype are the genes responsible for eye color, hair color, or certain diseases.

Heritability – The measure of a trait being passed on to the next generation. High heritability implies high resemblance between the parents and their offspring.

Natural Selection – A process in nature in which organisms possessing favorable traits are more likely to survive and reproduce.

Pedigree – a chart, list, or record of ancestors. Breeders keep their dog's pedigree to prove that they are purebred dogs.

Phenotype – the set of observable, physical characteristics of an individual resulting from the interaction of its genotype with the environment. Hair color, eye color, height are examples of phenotype.

Quantitative trait – a measurable phenotype that depends on the combined actions of many genes and the environment. Examples: height, weight, blood pressure.

REFERENCES

Bonnet T, Wandeler P, Camenisch G, Postma E (2017) *Bigger Is Fitter? Quantitative Genetic Decomposition of Selection Reveals an Adaptive Evolutionary Decline of Body Mass in a Wild Rodent Population.* PloS One.
http://journals.plos.org/plosbiology/article?id=10.1371/journal.pbio.1002592

Kovach RP, Gharrett AJ, Tallmon DA (2012). *Genetic change for earlier migration timing in a pink salmon population*. Proceedings of the Royal Society B.
http://rspb.royalsocietypublishing.org/content/279/1743/3870

Understanding Evolution
http://evolution.berkeley.edu/evolibrary/resourcelibrary.php

Check your understanding

1 Explain how the change in selective pressures led to the evolution of small snow voles?

2 How would the vole population respond if winters started later and later due to climate change?

3 Why did the average body size of the population remain unchanged?

4 Why is it important to predict evolutionary responses of a population?