Species are shrinking

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An ingenious experiment has revealed the physiological reasons why many species are becoming smaller in response to global warming, overhunting and overfishing.

Human-related impacts on natural ecosystems are driving many species to evolve smaller body sizes. This could be because fishing and hunting are disproportionally targeting larger individuals, or because increasing temperatures due to global warming increase the food requirements for species, and this limits their size. These shifts toward smaller size are very common in nature, but we don't yet know what the consequences are.

What happens when a species evolves to a different size? I have been addressing this question using a technique called "artificial selection": I evolve species toward smaller and larger sizes and evaluate the physiological and ecological consequences of the size shift.

There are predictable relationships between the size of a species and how it behaves, from small bacteria to giant elephants. Many variables change together with the size of a species: generation time, the number of individuals within a population, how fast they convert food into biomass, the rate at which they divide, their bioenergetic requirements, and so on.

This might indicate that body size is extremely important to the performance of a species in nature, but when multiple variables are correlated it becomes hard to tell what drives what. For example, it might just be that species with short generation times (that also happen to be small) grow faster. How can we tell what is the unique contribution of size?

If the problem is that body size correlates with multiple characteristics among species, why not look for the influence of body size within a species? Why not compare the performance of small against large individuals within a population?

Unfortunately, this approach does not exclude covariation among variables: small individuals are more likely to be younger or have had less access to resources, preventing us from drawing conclusions about the role of size alone. This issue with size co-varying with many variables is why we cannot really determine the direct effects of body size in biology.

We came up with a more direct way to evaluate the influence of size on the performance of a species. Microorganisms are amazing study species when you want to test how organisms evolve in time: they divide every few days, they need little space and they have large population numbers. We chose the microscopic algae *Dunaliella tertiolecta* as our model species, and evolved it toward different sizes.

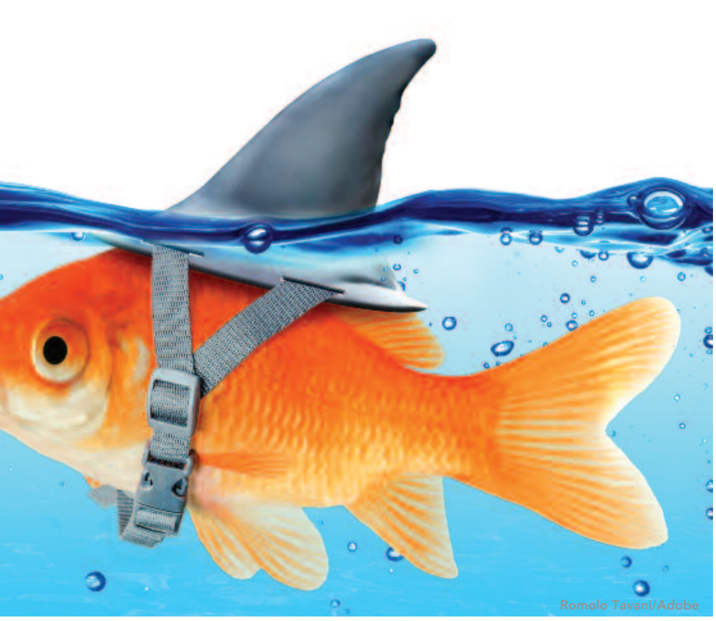
As individuals evolved toward larger or smaller sizes over many months, we measured how their performance changed. In this way we were only experimentally manipulating body size while keeping all other variables constant (environmental condition, body condition etc.). If the size of an individual was only correlated with the performance of a species, we would not have had any difference among our selection treatments. Instead, if size drives the performance of a species we would expect differences emerging between small- and large-evolved individuals.

As the organisms reproduced, we kept removing from the populations individuals that were either too big (small-selected) or too small (large-selected). This is called "artificial selection", and it leads species to evolve in the direction that we are selecting them to be. This approach is precisely what humans did to improve yields in agriculture and farming.

After repeating artificial selection for many hundreds of generations, the large-selected individuals were on average ten times larger than small-selected individuals. We found that this has important consequences for how individuals use energy, which is perhaps the most important currency in a living being.

Every time we eat, our metabolism breaks down complex molecules and absorbs the energy they release. This energy is then delivered throughout the body, so that every organ can carry out its duties. If our efficiency to assimilate energy decreases, we are less capable to function.

What this experiment found was that evolving the size of an organism also changes the ability of a species to use energy. We calculated that biomass production in populations of larger



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individuals was four times greater than the equivalent volume of smaller individuals.

By evolving smaller body sizes, species can improve their ability to persist when resources are limited, but this comes at a cost of lowered ability to convert food into biomass. So if the environment allows species to "acquire too much", it's best to grow bigger! If that's the case, it's better to desire little and be little. It works a bit like with cars: large engines are powerful but they are also less petrol-efficient than smaller cars.

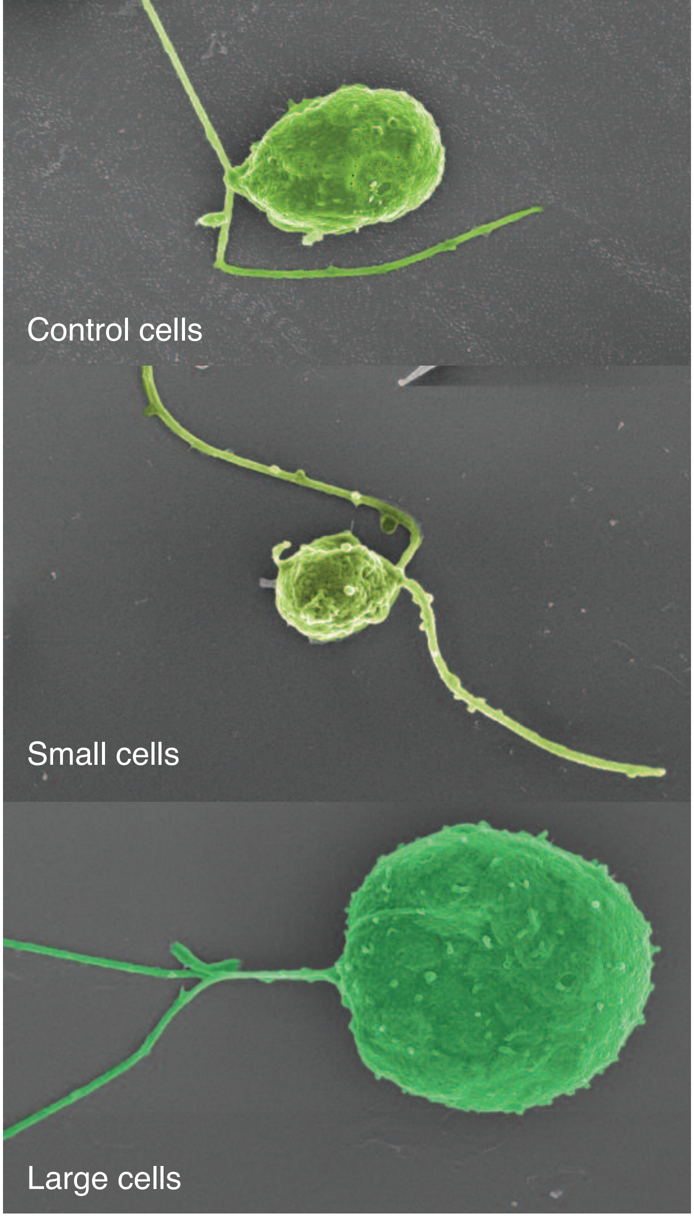
What does it all mean? Most likely it's bad news.

Open oceans are the most productive systems in the world, and photosynthetic algae dominate this productivity. Being among the most prolific primary producers and representing the base of most aquatic food chains, algae are extremely important in all ecosystems. Our study found that climate change can severely reduce their rate of carbon fixation by as much as 40%. This tells us that smaller species will have different performances compared with their original sizes, which should warn us of dangerous consequences when we alter the delicate equilibrium in nature.

Think of this: farmers at the end of the growing season collect seeds from their best-growing plants so that they can be planted for the next season. Generation after generation, only plants that grow well will contribute to the gene pool of the next generation, and the species evolves to be more productive. The same thing applies to livestock farmers: only the individuals showing the most desirable properties are selected to reproduce. This is why modern breeds of crops and livestock are far more productive than their ancestral types.

Compare this with the effects of fishing and hunting on natural populations. Every year, fishers and hunters aim to catch the biggest and largest animals they can find. Generation after generation, this process leads to the exact opposite result to what we do with farming: only small, young individuals are spared to reproduce for the next year. Over time, this process leads species to become smaller, weaker and less productive than what they used to be. Hence, the mortality imposed by fishing can act as a selective force that favours less productive individuals: slower growth, earlier maturation, and higher reproductive investment.

Global warming is also reducing the size of animals in nature.



Scientists have known for many years that species living in colder climates are on average larger than those living in the tropics. This is partly because larger body sizes are better insulated than smaller ones. But this is not all: an increasing in temperature leads to faster enzymatic reactions within our bodies, which means faster metabolism and higher energy requirements. This is known as the temperature–size rule, which states that organisms growing at higher temperatures mature at a smaller body size due to faster initial growth but lower adult body sizes. The development of an organism speeds up at higher temperature because of faster metabolic rates. But the development of an organism is also accelerated by higher temperature, which means that animals become reproductive sooner and at smaller temperature.

In conclusion, human actions are shrinking many species to smaller sizes, both directly through fishing and hunting, and indirectly through global warming. While we don't know what the consequence will be, these size-shifts are very likely to become a problem for the environment. In ecology, it is often true that a population with few, large individuals has a much larger influence on the environment than a population of many, smaller individuals of equivalent total biomass.

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