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# Divide and Diminish

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Olivia Judson on the influence of science and biology on modern life.

**Tags:**

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Jacques Descloitres, MODIS Land Rapid Response Team, NASA/GSFC In Indonesia, the smallest islands are home to many fewer species than the largest.

This week, I want to dust off my crystal ball and make a prediction: in the future, the biggest land animals will be smaller than they are now.

Here's why I think so. As a rule of thumb, larger animals need more food than smaller animals; they also need more space. Obviously, it takes more land to grow 100 rhinoceroses than it does to grow 100 rabbits. One hundred tigers require more land than 100 foxes. Indeed, meat-eaters, being higher in the food chain, need even more space than plant-eaters. For land mammals, every kilogram of prey supports just 9 grams of carnivore. So to feed one tiger of 180 kilos, you need 20 tonnes of prey. To support a breeding population of tigers, you need rather more. (For non-metric types, 2.2 pounds of prey feeds one third of an ounce of carnivore; a tiger weighs about 400 pounds and needs 22 tons of prey.)

When we break up rainforests or steppes, or build roads through pristine landscapes, we start to fray the fabric of nature.

Which has the following consequences. On islands, there's a relationship between the size of the island and the size of the largest animals that live there. Enormous animals don't live on tiny, or even medium-sized islands — they can't. Moreover, an island of a given size will be home to more large herbivores than large carnivores. The pattern even extends to continents: the biggest animals on big continents outsize the biggest animals on small continents. (In general, large animals that find themselves on islands either go extinct — or shrink. For example, continental tigers are bigger than those on large island of Sumatra, which are, in turn, bigger than those on the small island of Bali.)

As a corollary of this, smaller islands are also home to fewer species than larger islands; hence, the ecosystems tend to be simpler. There are fewer niches for organisms to occupy, and fewer organisms of other species to interact with. Predators may be few, or entirely absent, for example.

O.K., fine. But what does this have to do with the future of large animals?

A lot. Although "island" tends to conjure images of small bodies of land surrounded by water, such as Bermuda, or the Falkland Islands, this is not the only kind of island out there. Lakes are islands of water surrounded by land. Caves are islands of darkness surrounded by light. Oases are islands of fertility surrounded by sand. In short, an island is any self-contained patch of habitat within some larger sea. Looked at this way, the garden outside my window is an island of parkland in an ocean of bricks and concrete.

For we humans are island makers. We routinely fragment former "oceans"— be they tracts of forest or prairie, or some other vast ecosystem — leaving remnants here and there. These remnants are, from a biological point of view, islands.

Before humans began building roads and cities, damming rivers, and hacking down forests, islands formed in one of two ways. The first is exemplified by Hawaii. Here, volcanic activity in the middle of the ocean has created islands where, before, there was nothing but water. On islands like this — call them Clean Slates — the ecosystem gets assembled from scratch by the various organisms that arrive there.

Alternatively, islands form when, say, sea levels rise so that pieces of land that were previously connected become separated. For example, as recently as 12,000 years ago, much of what is now Indonesia was part of the Asian mainland. Then, the glaciers retreated, sea levels rose, and what had been one large landmass became an archipelago of separate islands. Human-made islands tend to be of this second type — let's call them Splinters.

Islands of both kinds are famous for being home to weird and wonderful organisms found nowhere else: isolation on an island allows the evolution of new and distinct forms — such as the marine iguanas of the Galápagos. But three things are worth pointing out. The first is that the evolution of new forms takes time — the island needs to remain isolated for thousands of years.

Second, the relative simplicity of island ecosystems means that they are vulnerable to disruption by competitors that have evolved in the more intense environments of the mainland. Third, many of the most spectacular episodes of island evolution — finches on the Galápagos, cichlid fishes in the Great Lakes of central Africa, bees and snails in Hawaii, and so on — occur on the Clean Slate type of island. This makes sense: the combination of few competitors plus empty niches presents massive evolutionary opportunities.

A different process goes on when an island forms by splintering. Here, the ecosystem is pre-existing: the island is created with a set of residents already in place. But it is now too small to support them all.

What happens next is a kind of unraveling, a fraying, a disassembling such that the ecosystem becomes simpler, so as to fit the space that is now available. On those recently-created islands of Indonesia, for example, the smallest islands

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are home to many fewer species than the largest islands. And, as you'd expect, you don't find big animals on the smallest islands either.

When we humans burn tracts of forest, or make islands in some similar way, the immediate impacts depend on a suite of factors, including how many islands there are, how big they are, and how close they are together. It also matters what is between them. Fields may be more hospitable to wildlife than roads or water; under some circumstances, life forms may be able to flit from one fragment to another, and the "island" nature of the fragments will be reduced. Perhaps we can use such patterns to shape how we use land, to try and minimize the impact we have.

Perhaps.

Or perhaps we should stop getting mired in details, and reflect on what we know: small islands are simpler, less ecologically interesting places than big islands. When we break up rainforests or steppes, or build roads through pristine landscapes, we start to fray the fabric of nature. We may not see the full impact today, tomorrow, or next year. But we know what the long-term effects will be. By fraying nature we make the planet a simpler, duller, diminished place.

*Notes:*

*For the tonnage of prey that carnivores need, see Carbone, C. and Gittleman, J. L. 2002. "A common rule for the scaling of carnivore density." Science 295: 2273-2276. For the relationship between body size and island size, see Marquet, P. A. and Taper, M. L. 1998. "On size and area: patterns of mammalian body size extremes across landmasses." Evolutionary Ecology 12: 127-139. For a fascinating paper on the relationship between big animals and continent sizes, see Burness, G. P., Diamond, J., and Flannery, T. 2001. "Dinosaurs, dragons, and dwarfs: the evolution of maximal body size." Proceedings of the National Academy of Sciences, USA 98: 14518-14523. I took tiger body sizes from page 825 of Nowak, R. M. 1999. "Walker's Mammals of the World." Sixth edition; volume 1. Johns Hopkins University Press.*

*The study of islands has a long history in evolution and ecology. See, for example, "Island Life: or, The Phenomena and Causes of Insular Faunas and Floras", by Alfred Russel Wallace, which was first published in 1880. Another landmark book, about ecological processes on islands, is MacArthur, R. H. and Wilson, E. O. 1967. "The Theory of Island Biogeography." Princeton University Press. For the formation of Hawaii, and the evolutionary history of its animals, see, for example, Cowie, R. H. and Holland, B. S. 2008. "Molecular biogeography and diversification of the endemic terrestrial fauna of the Hawaiian Islands." Philosophical Transactions of the Royal Society of London B 363: 3363-3376. The greater simplicity of island ecosystems has been well documented; the size effect is well known. It is my observation that the most flamboyant evolutionary radiations happen on Clean Slate islands; however, this needs testing.*

*For disassembly on Indonesian islands, see Okie, J G. and Brown, J. H. 2009. "Niches, body sizes, and the disassembly of mammal communities on the Sunda Shelf islands." Proceedings of the National Academy of Sciences, USA 106 (supplement 2): 19679-19684.*

*Habitat fragmentation is the subject of a voluminous literature, much of which is devoted to analyzing specific cases. But for the possible importance of the "matrix"—the kinds of habitat that lie between different habitat fragments—see Prugh, L. R. et al. 2008. "Effect of habitat area and isolation on fragmented animal populations." Proceedings of the National Academy of Sciences, USA 105: 20770-20775. For an excellent, and sobering, analysis of the ecological and evolutionary trajectories of human-created fragments, along with an analysis of the vulnerability of fragments to invasive species, see Leigh, E. G. Jr, Vermeij, G. J. and Wikelski, M. 2009. "What do human economies, large islands and forest fragments reveal about the factors limiting ecosystem evolution?" Journal of Evolutionary Biology 22: 1-12.*

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