



Protecting biostructure

Biodiversity researchers have focused on diversity at the cost of ignoring the networks of interactions between organisms that characterize ecosystems.

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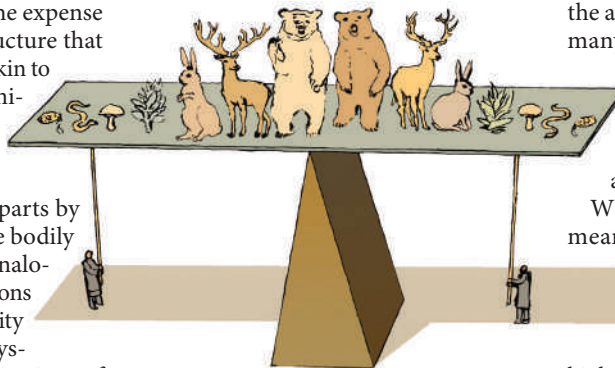
That biodiversity is in sharp decline is no longer in question, but scientists still heatedly debate the functional consequences of this loss. Attempts to tackle the problem have mainly involved trying to establish a direct link between species diversity and the sustainability of ecosystems. But in taking this approach, scientists have concentrated on diversity at the expense of ignoring the biological structure that maintains ecosystems. This is akin to the physiologist cataloguing animal parts and ignoring the anatomical structure that connects them. Clearly it is the underlying architecture, not just the parts by themselves, that maintains the bodily functions necessary for life. Analogously, the network of interactions between organisms, not diversity per se, breathes life into ecosystems. To understand the implications of biodiversity loss, it is crucial to monitor changes to the underlying 'biostructure'.

Perhaps the main reason why researchers have tended to focus on diversity is that it is easier to count species than to document their interactions. Empirically mapping biological networks such as food webs is no small chore. Like realist painters, some intrepid scientists have attempted to render the topology of these wildly complex webs by meticulously piecing together stomach-content analyses and many hours of field observations. But stomach contents are difficult to decipher, so it is often impossible to quantify energy fluxes that pulse through these networks.

Recently, ecologists have begun to use stable isotopes to trace the flow of energy through food webs. Because the concentration of the ^{15}N isotope tends to increase by a certain amount with each step of the food chain, patterns in ^{15}N fractionation provide a wonderfully simple measure of a species' position in the web. Similarly, signatures in ^{13}C can be used to determine a given predator's prey — although only prey organisms that have very different carbon sources can be differentiated (for example, C3 versus C4 plants).

A fuzzy but fluid empirical sketch of a food web emerges from stable-isotope analyses. Importantly, these 'sketches' can reveal changes in major network attributes across ecological gradients; for example, increased omnivory by fish as lake size decreases.

On the horizon, DNA-barcoding may soon provide a more highly resolved and precise understanding of both network topology and energy flux, by allowing ecologists to rigorously identify and quantify prey species taken from a predator's stomach. Here, bits of mitochondrial DNA are used to identify species, much like a barcode is used to identify the price of an item in a grocery store.



To establish how structural properties of an ecological network change with human impact, an obvious starting point is to sketch ecological networks across a gradient of human-induced diversity. I know of only one study that has directly explored network patterns across such gradients, but the early results suggest that clear patterns may exist. By using stable isotopes to sketch food webs, our group has shown that human-induced diversity gradients consistently correlate with changes in the structure of tropical seagrass food webs.

Intact seagrass beds are wonderfully diverse and productive coastal ecosystems, but natural variation in human densities around different beds has repeatedly created gradients in species diversity. As human density increases, these ecosystems lose top predators, detritus, specialist consumers and edible seagrass. At high enough human densities the systems are reduced to a very homogenized habitat dominated by a single, relatively inedible seagrass and an explosion of sea urchins. The reason for this changing structure is not fully known but early findings suggest that generalist urchins consume increased algal production driven by an increased load of nutrients in the water. The human-induced nutrient subsidy, and the loss of top-level predators, promotes an elevated density of urchins that drives habitat homogenization.

Results from long-term ecological research are consistent with the seagrass

story. Fisheries researchers, for example, have used historical catch records to argue that humans preferentially harvest large organisms in the higher levels of food webs. Similarly, terrestrial ecologists have found that habitat fragmentation and culling has led to the extirpation of many large mobile terrestrial organisms. Thus, indirect evidence is accumulating that humans are exerting a strong top-down force on the apex of food webs. At the same time, many studies indicate that humans are homogenizing the base of aquatic and terrestrial food webs, through nutrient run-off, the introduction of invasive species, urbanization and agriculture.

What does structural deterioration mean for ecosystem function and sustainability? Recent food-web theory predicts that the homogenization of habitats and the loss of mobile predators from high trophic levels is seriously threatening nature's balance. In the most simplified sense, this theory argues that the variation in species occupying lower levels in the food webs allows an ecosystem to elicit a range of responses to a variable world. The mobile larger organisms interact with this landscape of species variability in a way that prevents any single species from monopolizing space and energy. The large organisms, in other words, promote the balance and maintenance of a diverse and variable assemblage of organisms, which in turn buffers against an ever-changing world.

According to this theory, nature is a beautiful balance of bottom-up (driven by habitat heterogeneity) and top-down (driven by predators) forces. By homogenizing habitats and truncating higher-order predators, we may be inadvertently testing this theory — it remains to be seen whether the balance of critical ecosystem functions survives.

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FURTHER READING

Ecological Effects of Biodiversity. http://en.wikipedia.org/wiki/Ecological_effects_of_biodiversity.
Food Webs. www.foodwebs.org
Barcode of Life Data Systems. www.barcodinglife.com
Tewfik, A., Rasmussen, J. B. & McCann, K. *Ecology* **86**, 2726–2736 (2005).

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