nature

NEWS & VIEWS

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A North American bog, home to pitcher-plant communities.

ECOLOGY

A pitcher of things to come

Jonathan B. Shurin

Big conclusions can be drawn from the tiny ecosystems that flourish in carnivorous pitcher plants. Manipulating habitat size and predator abundance reveals which is more important to ecosystem dynamics.

The creation by humans of novel combinations of species and environmental conditions is rapidly driving Earth's ecosystems into uncharted territories. Information about ecological interactions can be gleaned only with great investment of time, effort and money. Thus, creative approaches are required to extract the greatest insight into these changes from the fewest data.

Writing in *PLoS Biology*[1], Gotelli and Ellison wrestle with this problem, and show how simple experiments can illuminate a network of community interactions. The immediate subject of their interest is pitcher-plant communities. These diverse groups of insects and microorganisms, living in tiny pools of water (phytotelmata) in the leaves of carnivorous pitcher plants, are found in bogs across North America (pictured). The authors subjected these communities to experimental tests, and used novel statistical approaches to disentangle the ensuing chains of indirect responses.

Reconstructing the response of organisms to past change is a sufficiently challenging task to occupy an entire discipline, palaeoecology. Predicting the effects of future changes is an endeavour so fraught with uncertainty that it demands a critical evaluation of the complexity required of ecological models. Biological communities display an intricacy that defies generalization, with diverse populations linked by interactions that may be cryptic, or exhibit unexpected or context-dependent behaviour. The number of potential interactions between species increases as the square of their number[2], so putting the pieces together through exhaustive experimentation is prohibitively time-consuming.

In addition, indirect interactions among species are crucial for predicting a community's response to environmental changes, and can sometimes overwhelm the direct effects of perturbations on individual species. For instance, mid-range ultraviolet light (UV-B) inflicts damage on algae in streams. Removing these harmful wavelengths might therefore be expected to enhance primary production. But it turns out that the insects that graze on the algae are even more susceptible to UV-B sunburn, and so sheltering streambeds from these rays enhances the insects' survival, resulting in reduced algal populations[3].

It has been argued[4] that such chains of indirect interactions are so minutely sensitive to environmental conditions that communities starting from very similar initial conditions may follow disparate paths, ending up with wildly different outcomes. The dynamics of ecological communities that are subjected to a changing environment might therefore be fundamentally unpredictable: it could be that future conditions can never be anticipated on the basis of models constructed in the present.

Gotelli and Ellison[1] show how an approach of intermediate complexity can extract the most important interactions in a community and so predict its dynamics. They manipulated the volume of their pitcher-plant habitat and the presence of dipteran larvae (the most important predators in pitcher plants), and measured the response to these changes of the aquatic mites, rotifers, protozoans and bacteria living there.

Rather than simply testing the direct effects of their manipulations, the authors compared their data with different proposed configurations of direct and indirect interactions among the target species. They used so-called path modelling to propose different routes by which the impacts of their manipulations were transmitted among competitors, predators and prey. The model that showed the best agreement with the data identified the most important interactions among species.

They found that a food-web model that included only the effects of predator density and indirect interactions always offered the best agreement with the data, and so the best predictive power. Surprisingly, including habitat volume did not improve the fit of the model to the data — even though this volume was varied over an order of magnitude, and had significant effects in analyses where it was the only variable. The implication is that the effects of habitat loss on the community can be explained entirely as the indirect consequence of its impact on the top predator. (The top predator is most likely to be affected by habitat loss, as it requires the largest volume to persist.)

Gotelli and Ellison's experiment[1] offers important lessons. First, given their small numbers, predators often exert a disproportionately strong influence over the communities in which they live, but their rarity makes them highly vulnerable to habitat loss. This finding agrees well with the cascade of effects observed in larger ecosystems, for example when top predators such as jaguars were lost from tropical forests on Venezuelan islands following habitat fragmentation[5]. Many plants that could themselves easily cope with the loss of habitat felt the impact of the changes from above, as the extirpation of carnivores led to increases in the herbivores that were the carnivores' prey, but the plants' predators. Bromeliad phytotelmata in Costa Rica tell a similar story. The water held inside the leaves of these plants provides a microenvironment similar to that of pitcher plants. Here, increased structural complexity of the habitat (a larger number of leaves) affected communities largely by reducing the foraging efficiency of predatory damselfly larvae[6].

Second, Gotelli and Ellison show how habitat and predator losses percolate through just a few strong community links, such as the interaction between bacteria and their single-celled predators. Communities can be dominated by many weak and a few strong interactions[7]; identifying these few strong interactions therefore points to a simpler path to predicting community dynamics. It offers some hope to those who despair of understanding ecological communities well enough to predict their behaviour in a rapidly changing global environment. ■

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CHEMISTRY

Hydrogen at the flick of a switch

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Before hydrogen can be used as a transportation fuel, a safe storage system for the gas must be found. Metal clusters that release hydrogen in response to an electric current may be a step in the right direction.

With mounting concern over the environmental impact of oil as a fuel, hydrogen increasingly looks like a useful alternative. In principle, hydrogen can be generated in a clean way from water by using sunlight in combination with solar cells. Moreover, it is non-polluting, and forms an environmentally benign by-product — water — on combustion. Hydrogen is thought to be an ideal fuel for vehicles, but its widespread use is limited by the lack of a safe, efficient system for onboard storage. The density and the condensation temperature of hydrogen are very low (−252 °C at 1 atmosphere), which makes it difficult to use conventional storage systems such as high-pressure gas containers or cryogenic liquid-gas containers. Therefore, the development of safe and convenient methods for hydrogen storage is an active research area[1]. In *Angewandte Chemie*, Weller and co-workers (Brayshaw *et al.*[2]) report that hydrogen may be stored and released using molecular clusters, in a process that is easily controlled by a simple chemical reaction or by an electric current.

One of the most successful and extensively studied methods for hydrogen storage is to keep the gas in a 'hydride' form[3,4]. In this approach, an alloy absorbs and holds a large amount of hydrogen by chemically bonding with the gas to form metal hydride compounds[4]. But although a hydrogen-storage alloy can absorb and release hydrogen without compromising its own structure, heating is required to promote the release, as this process takes up energy. The alloys studied so far usually require a temperature of about 300 °C to provide hydrogen at 1 atmosphere pressure.

In contrast, the method now reported by Weller and colleagues[2] enables hydrogen storage and controlled release without a large input of energy. Their system is based on an organometallic compound that contains a core of six rhodium atoms[5], as part of a complex that also includes 12 hydrogen atoms (Fig. 1). This cluster absorbs two molecules of hydrogen (H_2) to produce a compound holding 16 hydrogen atoms. The absorption process takes 10 minutes at room temperature under 1 atmosphere pressure of hydrogen, and is almost instantaneous under 4 atmospheres of hydrogen[6,7]. The absorbed hydrogen molecules are retained at room temperature for weeks without any external hydrogen pressure (under an inert atmosphere of argon), but can be removed under vacuum to quantitatively regenerate the 12-hydrogen cluster, although this takes a long time (several days) compared with the uptake process.

Remarkably, Weller and colleagues[2] have found that hydrogen release from the 16-hydrogen cluster can be dramatically accelerated simply by changing the cluster's oxidation state. Adding a reducing agent to a solution of the 16-hydrogen compound releases one molecule of hydrogen from each cluster, so yielding a product containing 14 hydrogen atoms (Fig. 1). The original 12-hydrogen cluster is then easily regenerated by treating the 14-hydrogen cluster with an oxidizing agent, liberating another hydrogen molecule and completing the hydrogen uptake–release cycle.

Another crucial finding by Weller and colleagues[2] is that a rapid hydrogen uptake–release cycle can also be accomplished electrochemically — that is, the reduction and oxidation steps are achieved directly by electron transfers at electrodes. Adding one electron to the 16-hydrogen cluster liberates a hydrogen molecule, giving the 14-hydrogen cluster described above. This rapidly loses another hydrogen molecule to yield a 12-hydrogen cluster, which differs from the original starting material by having only one positive charge — the original 12-hydrogen cluster has two positive charges. The electrochemical hydrogen-release process occurs in a matter of milliseconds on a glassy carbon electrode at ambient temperature and pressure. The product of this process is easily converted back to the original 12-hydrogen cluster by electrochemical oxidation (electron removal at an electrode; Fig. 1). The overall electrochemical process of hydrogen uptake and release can be repeated at will.

With the aid of theoretical calculations, the authors[2] inspected the electronic structures of the starting 12-hydrogen cluster and of the 16-hydrogen cluster in this hydrogen-storage system. They found that the energy level of