

**Figure 1 Building regulation** — a Lego version of the superlattice structure shown in Fig. 1d (page 396)<sup>2</sup>. The base constitutes the substrate, including the SrRuO<sub>3</sub> electrode, and the Lego wall is made of layers of three different bricks: SrTiO<sub>3</sub> (red), BaTiO<sub>3</sub> (yellow) and CaTiO<sub>3</sub> (blue). Lee *et al.*<sup>2</sup> demonstrate that an artificial material with favourable ferroelectric properties can be constructed by using these three perovskite building blocks.

the structure, which is caused by differences between the lattice parameters of the layers. This effect influences the properties of the layers and the structure as a whole, and Lee *et al.* have exploited this phenomenon to increase the ferroelectric polarization of their material. The epitaxial strain decreases the in-plane lattice parameters of the BaTiO<sub>3</sub> layers, producing an increase in the ferroelectric polarization.

Lee and colleagues' ferroelectric superlattice is impressive, because it shows that such structures can be built with atomic precision and possess properties that surpass those of the individual building blocks. It also underlines the potential of designing artificial superlattices with unique properties. For example, most ferromagnetic materials show no ferroelectricity. But what would a superlattice made from ferroelectric and ferromagnetic building blocks be like? Would it show ferroelectric or magnetic behaviour, or have a mix of properties? New phenomena might even emerge. Here, then, is an invitation to materials scientists to design and build their own superlattice. ■

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## Ecology

# Paradise sustained

Shahid Naeem and Andrew C. Baker

**Biodiversity stabilizes ecosystem functioning in small-scale, short-term experiments, but do such findings scale up to the larger world? A global study of fossil reefs from the past 500 million years suggests they do.**

A watershed ecosystem that produces a steady volume of water may be more valuable than one that unpredictably alternates between flood and drought. A coastal ecosystem that provides a regular but modest supply of fish serves a community better than one that booms then busts. In most cases, then, the absolute magnitudes of ecosystem functions — such as the production of potable water and nutritious food — may matter little if they are unsustainable.

Over the past decade, some of the most intense research ever conducted in ecology has examined how the magnitudes and sustainability of ecosystem functions are governed by biodiversity, and whether a loss of biodiversity is a major cause of ecosystems becoming less productive and less stable<sup>1–4</sup>. In this debate, the 'ayes', who advocate a strong role for biodiversity in governing ecosystem function, point to the congruency of findings from the full triad of scientific methods (theory, observation and experiment). The nay-sayers find the evidence flimsy — weak effects derived from studies too small and too short-lived to be convincing.

On page 410 of this issue, Kiessling<sup>5</sup> provides evidence that may sway some nay-sayers — but there's a catch. Making use of an extensive palaeoecological database on thousands of reefs, spanning some 500 million years, Kiessling tested whether the local species richness of reef-builders on a given reef (and, by extension, the diversity of the entire community) could predict ecological change on these reefs. Using reef type, density, architecture and construction style as proxies for reef ecology, Kiessling found that higher-than-average species diversity in one time interval led to lower-than-average changes in reef ecology in the next. In other words, biodiversity may indeed govern sustainability. The catch is that this epoch-spanning data set cannot detect fluctuations in reef ecology of less than a few million years, which may disappoint some ecologists and ecosystems biologists following the debate.

For the ayes, the good news is that the positive biodiversity–stability relationship

predicted from theoretical and empirical work may scale up — way up. Although some may quibble with Kiessling's use of both absolute and relative measures of species richness in his analyses, and others may question whether the variables he chose are appropriate measures of reef ecology, no one is likely to dispute the depth and scope of his perspective. Kiessling's study is global and covers an extraordinary length of time, one that spans three entire geological eras and witnesses the wholesale turnover of reef-building consortia, from cyanobacteria to calcified sponges, bryozoans, molluscs, calcareous algae, and corals both ancient and modern (Fig. 1). Given this, it is remarkable that Kiessling's findings agree with those derived from mathematical models, bottles, Petri dishes, aquaria, growth chambers and field plots, which often run for only a handful of generations.

However, the 'deep time' approach to the diversity–stability debate is not without pitfalls. In Kiessling's study, some data points that documented major ecological change following periods of relatively high biodiversity were excluded from the analysis. These data, which contradict the diversity–stability hypothesis, are from three out of the five major mass-extinction events covered by the study.

Kiessling rightly argues that some external influences (such as asteroid impacts) really are beyond the scope of biology to buffer. However, in recognizing and excluding these legitimate outliers, we should take care not to throw the evolutionary baby out with the ecological bathwater. Many of these mass-extinction outliers are superimposed on a backdrop of major evolutionary milestones, such as the rise of predation and herbivory as lifestyle strategies, and the acquisition of algal photosymbionts in today's stony corals<sup>6</sup> — events that are themselves likely to result in dramatic ecological shifts in reef communities. Resolving this debate over extended timescales will therefore require us to distinguish between ecology and evolution in determining stability and

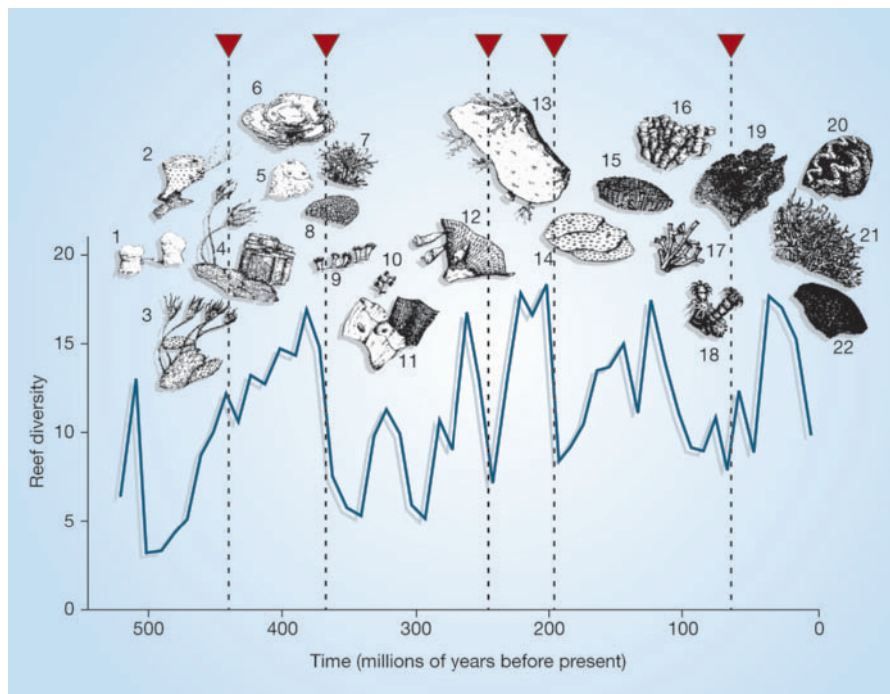


Figure 1 Reef-builders: diversity and stability. Over the 500-million-year time frame studied by Kiessling<sup>5</sup>, the diversity of species in coral reefs has fluctuated, and the dominant reef-building organisms have included cyanobacteria, sponges, molluscs, algae and corals. Kiessling used many ecological indicators to show that periods of high biodiversity are followed by periods of lower-than-average ecological change — in other words, biodiversity leads to stability. The red arrowheads represent times when major extinctions occurred. Diagrams drawn by John Sibbick, from ref. 6. Graph from ref. 5, supplementary information. Stromatolites: 1, 5; sponges: 2, 5–7, 12, 13; crinoids: 2–4; cyanobacteria: 2, 3, 6, 7; tabulate corals: 3, 4, 8, 10; rugose corals: 9; foraminifera: 11; bryozoans: 11, 12; rudist bivalves: 16; algae: 11, 12; scleractinian corals: 14, 15, 17, 18, 21, 22; gorgonian coral: 19; giant clam: 20. Organisms not drawn to scale.

productivity. Either evolutionary innovation drives ecological change, and the coupling of biodiversity and stability are ancillary, or the two are so tightly linked that it takes mass extinctions and dramatic evolutionary innovation to decouple them.

These ecological and evolutionary findings<sup>5</sup> are extraordinarily important to the diversity–stability discussion. Those who follow the debate because of its contemporary environmental implications, however, may find this study’s multi-million-year time frame frustrating—but there is an important message. The latest rounds in the biodiversity–stability debate have been fuelled by studies of current rates of species loss and their impacts on current ecosystem function. Kiessling’s finding that, given a few million years, species-rich ecosystems will tend to look the same as they do now, won’t do much to settle this argument. Indeed, given that today’s reefs are relatively diverse, one might inadvertently conclude that they will persist in the face of environmental perturbation.

Kiessling’s data, however, show that only 5–58% of ecological change is predicted by diversity, leaving plenty of scope for environmental impacts to have a dramatic effect. If history provides some basis for predicting the future, coral reefs may show less variability over the next few million years than their

less-diverse predecessors, but they might also collapse relatively easily. Threatened by climate change and coral bleaching, as well as by overfishing, the spread of marine diseases, nutrient pollution and habitat destruction<sup>7</sup>, reefs lie at the threshold of these alternative futures. The diversity of coral reefs may make them productive, and it may sustain their function over time, but these reef paradises can still be lost in the face of environmental change.

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#### 100 YEARS AGO

“Compulsory Greek at Cambridge.” When I decided to go up to Cambridge to study mathematics and philosophy I was living abroad, and I crammed Greek... But on going in for the “Little Go,” though I passed easily in translation, I failed by a few marks in Greek grammar. It was so near a thing that I thought I might pull through in December with a few hours more grind; but unfortunately I ran it too fine, and again failed by a few marks. This meant that I had to get up a complete new set of translation books for the following June, and to prevent further mistakes I went to a coach for the grammar part. I then passed, getting a second class... I can only say my present knowledge of the language is *nil*, although I had a double dose of it... But this may have been due to my resentment at being forced to waste time in an uncongenial study, when I was keen to get on to something else.

Edward T. Dixon

From *Nature* 26 January 1905.

#### 50 YEARS AGO

The declared aim of the Central African Federation is a partnership between the races, European and non-European; and to the attainment of this ideal a university, with the goodwill of the people and the support of the government, can make a tremendous contribution... The Moffat Resolutions adopted by the Legislative Council of Northern Rhodesia on July 29, 1954 (*The Times*, August 14, 1954), began the task of defining partnership in a more precise way than has hitherto been attempted: “(1) The objective of policy in Northern Rhodesia must be to remove from each race the fear that the other might dominate for its own racial benefit and to move forward from the present system of racial representation in the territorial legislature towards a franchise with no separate representation for the races. (2) Until that objective can be fully achieved a period of transition will remain during which special arrangements in the Legislative and Executive Councils must continue to be made so as to ensure that no race can use either the preponderance of its numbers or its more advanced stage of development to dominate the other for its own racial benefit...” The significance of education, and particularly the education of the African, in the working out of such a plan must be clear to all.

From *Nature* 29 January 1955.