

News & views



Figure 1 | A sea otter (*Enhydra lutris*) eating a crab.

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Ecology

Ecosystem effects of sea otters limit coastal erosion

Johan S. Eklöf

Conservation is bringing back certain predators that are high in the food chain, but how this affects an ecosystem overall is debated. Rigorous fieldwork provides strong evidence that sea otters help to mitigate coastal erosion. **See p.111**

Whether food webs are regulated by resources in a bottom-up manner or by consumers in a top-down way is a long-standing debate¹ that is relevant to an even broader fundamental question in ecology. Namely: to what extent are ecosystems influenced by interactions between organisms (such as predation) compared with the effect of environmental conditions? On page 111, Hughes *et al.*² report data that provide insights into the fundamental

effects of a predator in the wild and highlight a system that benefits plants and their influences on coastal landscapes.

Over the past three decades, the rapid recovery of some populations of large 'top' predators – those high in food webs – after hunting bans, pollution abatement or reintroduction programmes, is helping ecologists to investigate the role of predators in ecosystems. However, there has been

considerable debate about how strong the effects of predators on an ecosystem really are.

Perhaps the most well-known example of this is the reintroduction of grey wolves (*Canis lupus*) to Yellowstone National Park in the United States. There, subsequent increases in plant cover and riverbank stability have been put forward as a landscape-wide example of a 'trophic cascade' – an indirect effect observed when predators, by reducing the density or behaviour of their prey, enhance the survival and activity of organisms at the next, lower level of the food web^{3,4}. In the Yellowstone case, wolf predation of elk (*Cervus canadensis*) was proposed to reduce elk grazing pressure, resulting in taller and more-dense plant communities that stabilized riverbanks by reducing soil erosion, thereby altering the landscape⁵. Yet the lack of controlled experiments needed to provide rigorous scientific evidence of this complex cascade effect has made it impossible to determine whether wolves or other factors caused the observed changes^{4,5}.

Hughes and colleagues report results gathered from another type of ecosystem, which provide strong evidence for the idea that the recovery of top-predator populations can

benefit plant communities and aid ecological processes regulated by such plants, including shoreline protection. The authors conducted their study in salt marshes at Elkhorn Slough, one of California's largest remaining coastal wetlands. At this site, intense land development, excess nutrient input (eutrophication) and sea-level rise has caused coastal erosion, and more than 60% of the marsh area found in 1870 has either been lost or converted into other habitat types⁶.

Over the past 40 years, the number of sea otters (*Enhydra lutris*) – a top predator that was once hunted to near extinction – has gradually increased in the area, from a few individuals in the 1980s to more than 100 identified animals by the late 2000s, as the authors note. Hughes and colleagues were inspired by previous findings from their team indicating considerable effects from sea otter recovery on food webs in nearby seagrass beds⁷. Sea otters (Fig. 1) need to consume an amount of food equivalent to more than 20% of their body mass per day in these cold estuarine waters⁸, and their diet includes the commonplace striped shore crab *Pachygrapsus crassipes*. The authors hypothesized that, in tidal marsh creeks where otters had become abundant, their intense predation of these crabs should reduce crab burrowing and feeding on roots of the dominant marsh plant, pickleweed (*Salicornia pacifica*). This plant is an effective 'ecosystem engineer' that stabilizes shorelines. Therefore, sea otter recovery should have triggered a trophic cascade that mitigates salt-marsh erosion, similar to the proposed effect of wolves on the landscape in Yellowstone.

To test their hypothesis, the authors combined four approaches, each of which could have been a study in its own right. First, Hughes and colleagues used time-series data partly extracted from aerial and satellite imagery from the 1930s to the present day. They combined these data with advanced statistical modelling to assess the influence of sea otter abundance on tidal creek widening (a measure of creek-bank erosion). The model output suggested that, despite a sustained increase in factors known to cause erosion of the shorelines (such as eutrophication or sea-level rise), marsh erosion instead abated alongside the recovery of the sea otters.

The second, and in my view major, feat was to experimentally test the effect of otters on the ecosystem at this site. This was done by excluding otters from fenced plots measuring 1 × 2 metres and comparing these enclosures with unfenced controls in five tidal creeks over the course of an impressive timespan of three years. This type of field experiment is usually run for just a couple of months because of the regular need for maintenance and the risk of damage to the enclosures – a period that can be too short to capture effects that build up over time.

The authors' results indicate that sea otter predation strongly suppressed crab numbers and crab burrowing, which increased pickleweed root biomass and soil density; factors known to reduce the risk of erosion on creek banks. The authors also demonstrate that common side effects of enclosures, such as shading or the alteration of water flow, did not affect their results. Consequently, this proves that the otters have an effect on coastal plants and soil stability through a trophic cascade.

For the other two approaches, the authors used field surveys covering both time (comparing the periods before and after the otter population increased) and space (across 13 creeks) to scale up their experimental results. This involved more than three years of daily observations of sea otter foraging and diet composition by trained observers. As predicted, otter-predation rates on crabs rose over time with increasing otter abundances, whereas marsh-creek erosion decreased. Compared with creeks that had the highest predation rates, creeks with the lowest measured predation rates had more than twice as many crabs, half the amount of plant-root biomass and three times faster marsh-erosion rates – data that again support the trophic-cascade hypothesis.

Hughes and colleagues' study is notable for at least three reasons. First, it experimentally confirms the theory that abundant top predators can strongly influence both ecosystem structure and processes. This adds to a large body of work showing that predation,

similar to factors such as nutrients and temperature, matters for ecosystem functioning⁹. Second, the powerful combination of methods used raises the bar on the evidence needed to support claims of strong effects of organisms on ecosystem functioning in the wild. Finally, the findings should intensify discussions on the role of conservation of large animals to help mitigate the environmental effects of stressors such as eutrophication and global warming¹⁰. This is especially important in times of rapid climate change and increasing calls to again limit coastal top-predator populations as a way to reduce conflicts between wildlife and fisheries¹¹.

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- Hairston, N. G., Smith, F. E. & Slobodkin, L. B. *Am. Nat.* **94**, 421–425 (1960).
- Hughes, B. B. et al. *Nature* **626**, 111–118 (2024).
- Eriksson, B. K., Bergström, U., Govers, L. L. & Eklöf, J. S. in *Reference Module in Earth Systems and Environmental Sciences* <https://doi.org/10.1016/B978-0-323-90798-9.00006-8> (Elsevier, 2023).
- Ripple, W. J., Larsen, E. J., Renkin, R. A. & Smith, D. W. *Biol. Conserv.* **102**, 227–234 (2001).
- Beschta, R. L. & Ripple, W. J. *Ecohydrology* **12**, e2048 (2019).
- Van Dyke, E. & Wasson, K. *Estuaries* **28**, 173–189 (2005).
- Hughes, B. B. et al. *Proc. Natl Acad. Sci. USA* **110**, 15313–15318 (2013).
- Costa, P. *Physiol. Zool.* **55**, 35–44 (1982).
- Koske, A. K. et al. *Integr. Comp. Biol.* **51**, 644–646 (2011).
- Malhi, Y. et al. *Curr. Biol.* **32**, R181–R196 (2022).
- Tixier, P. et al. *Fish Fish.* **22**, 31–53 (2021).

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Quantum information

Mobile atoms power up logical qubits

Barbara M. Terhal

Small groups of mobile neutral atoms have been manipulated with extraordinary control to form 'logical' quantum bits. These qubits can perform quantum computations more reliably than can individual atoms. **See p.58**

Over the past 20 years, scientists have been developing ways of using neutral atoms for quantum computing¹. On page 58, Bluvstein et al.² demonstrate how far these methods have come: the authors' efficient optical techniques enabled them to control tens to hundreds of atoms in parallel, maintaining the quantum state of the atoms, and allowing them to execute logical operations on an unprecedented scale.

Bluvstein and colleagues' quantum-

computing platform uses lasers to trap atoms in arrays that are hundreds of micrometres wide. Two of the possible energy levels of the electrons in each atom form a quantum bit (qubit). Before any computation can begin, a cloud containing millions of extremely cold atoms is loaded into the optical array, and atoms are removed and reshuffled until they are positioned in an organized grid.

The authors first subdivide the grid into three zones (Fig. 1). One section is designated