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Fisheries productivity

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Resilience of reefs to overfishing

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Many coral reefs suffer from the effects of overfishing, which threatens biodiversity and erodes human livelihoods. A study now reveals where fished reefs boost their total productivity, providing a means of resilience.

Coral reefs are ecosystems of spectacular diversity and productivity, possibly harboring a third of the world's marine species, most of which remain undiscovered[1]. They also sustain millions of people living in their vicinity, many of whom depend on reef fisheries for food and income[2]. Such dependence is particularly pronounced in small island developing states, which have few alternative means of domestic food production. However, with growing human populations, export to foreign markets and loss of traditional management approaches, many reef fisheries are now overexploited[3,4]. Writing in *Nature Sustainability*, Renato Morais and colleagues[5] provide some hope for recovery, by quantifying the compensatory ecological responses triggered by fishing on coral reefs. The 'buffering productivity' they document reveals an important aspect of reef resilience that appears to be linked to habitat quality and complexity, among other factors.

While fisheries scientists have long been aware of the capacity of individual fish populations to modulate productivity in the face of fishing[6], this concept has not commonly been applied to reef fisheries characterized by dozens, if not hundreds, of interacting species[7]. Most biologists working on reefs regularly quantify this diversity and associated fish biomass through underwater SCUBA surveys, organized along replicated sections of reef and the species living thereon (see Fig. 1a). Such work has shown many times that fished sites tend to have much lower biomass compared with unfished ones, as well as changes in species composition driven largely by the loss of large-bodied predators and other preferred target species[3,4].

Morais and colleagues add a layer of complexity to this picture by tracking changes in productivity – the rate of new biomass production (kg ha^{-1} day^{-1}) – across entire reef systems, using over 1,000 underwater fish surveys spanning the entire Kingdom of Tonga in the South Pacific. They inferred productivity by calculating biomass per fish species from their average length and abundance and then matching these estimates with published information on taxon- and length-specific growth and mortality rates. Unsurprisingly, more heavily exploited sites featured less fish biomass overall (see blue line in Fig. 1b), but calculated productivity rates declined much more slowly than biomass did (red lines in Fig. 1b). Interesting contrasts emerged between the three main archipelagos that make up Tonga's territory, with remote areas in the Ha'apai archipelago showing much greater resilience, with productivity even showing a slight increase under light to moderate fishing (Fig. 1b). By contrast, Vava'u and Tongatapu are more heavily exploited regions closer to population centres that displayed much lower buffering capacity (Fig. 1b). A secondary analysis that tested for differences among individual sites showed that more complex habitats in wave-exposed, shallow environments displayed the greatest productivity boost, on average.

These results suggest that much like individual populations subject to fishing, entire reef communities can withstand moderate fishing pressure by boosting their productivity and compensating extra mortality via increased growth and possibly through improved recruitment of larvae, although the latter process was not quantified in the present study. This implies that some reefs are inherently more resilient than others and that this property may be predictable from easily measured habitat features.

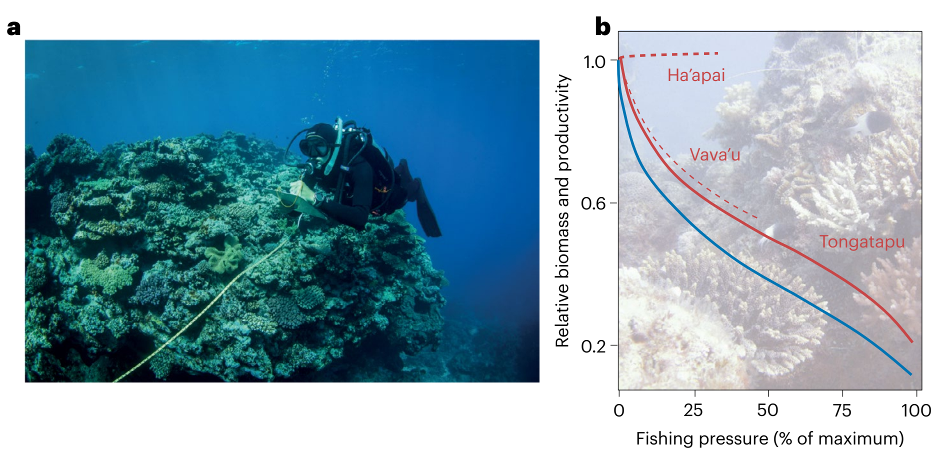

Fig. 1 | Quantifying changes in reef fish biomass and productivity. a, Divers use underwater transect sampling to survey a coral reef community in the South Pacific Kingdom of Tonga. **b**, Reef fish biomass (blue line) declines quickly and uniformly across a fishing pressure gradient, but three different regions in Tonga show marked contrasts in how productivity (red lines) responds to increasing fishing pressure, displaying varying degrees of compensatory 'buffering' capacity. Morais and colleagues suggest that this represents an aspect of reef resilience that is tied to habitat quality and complexity, among other factors. Data from ref. 5.

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But this inherent resilience may also erode as habitat quality is diminished and overfishing becomes more intense. In Tongatapu (Fig. 1b), biomass and productivity begin to decline more steeply at around 50% of maximum fishing pressure, suggesting an inflection point in reef resilience, possibly similar to the canonical dome-shaped response in classic surplus production models[8]. Future work might reveal whether this downturn is unique to reefs with specific assemblages and structural characteristics or a more general pattern. If the latter, it could represent a potentially important reference point for ecosystem-based management of reef fisheries.

How then can the results of Morais and colleagues be used to inform efforts to protect and restore overfished reefs and to safeguard their productive capacity? This study provides evidence that the studied reefs can sustain light to moderate fishing pressure by means of elevated productivity. It also suggests that habitat quality and complexity are important correlates and potential drivers of reef resilience to fishing. Safeguarding habitat complexity thus appears important not just for maintaining species diversity but also productivity.

Lastly, the study by Morais and colleagues is limited by excluding the human dimension of fishing and treating fishing pressure as a static external driver of biomass and productivity. Yet, in reality, fishing is a complex adaptive process that is dynamically shaped by individual and collective decisions[9]. It would be interesting to pair the results of Morais and colleagues with a more in-depth understanding of changing fishing practices across their three study regions, to understand patterns of productivity in the context of differing approaches to management and conservation. For example, the outstanding resilience of fished reefs in Ha'apai (Fig. 1b) coincides with a larger proportion of reefs safeguarded by unfished marine reserves, known to elevate nearby productivity through export of larval and adult biomass. Including the effects of such management measures into the study of reef productivity would bring further insights into how to maintain resilient reefs over the long term.

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Competing interests

The authors declare no competing interests.