Marine Ecology: Reserve Networks Are Necessary, but Not Sufficient

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New work reveals that the large network of no-take marine reserves on the Great Barrier Reef is working splendidly. However, bold, global action is needed to eliminate threats that reserves cannot guard against.

On a hike in Western Australia, my wife and I met a man and his daughter, who was about 6 years old. We struck up a conversation, and when asked what I did, I said I was a marine biologist studying fish. His daughter turned to him and said, "Hey Dad, he's your friend!" I explained that I was testing whether no-take marine reserves (NTMRs) — places where fishing is banned — could support nearby fisheries. Like many Australians, he was an enthusiastic fisherman. He gave a little laugh, turned to his daughter, and said, "He's not my friend, darling."

NTMRs are just one of many ways we regulate fishing, but they seem to generate the most passionate responses. Everyone has an opinion about whether we need NTMRs, whether they violate our inherent rights and whether they work or not. Like the "debate" about whether humans cause climate change, there are wild-eyed true believers, vehement deniers and everything in between. Although not nearly as impressive as the staggering weight of evidence demonstrating that humans cause climate change, evidence that NTMRs can support fisheries is getting there. In this issue of *Current Biology*, Emslie and colleagues [1] evaluate the performance of the Great Barrier Reef NTMR network over 30 years and tip the scales a lot further in favour of their use.

The Great Barrier Reef Marine Park, encompassing more than 344,000 km^2, is the global gold standard for large-scale NTMR networks. Following a six-year re-zoning process, in 2004 the amount of the GBRMP inside NTMRs increased from 4.5% to more than 33% [2]. Primary objectives of the re-zoning were to protect biodiversity and assist in maintaining exploited fish stocks, while allowing for sustainable use by a range of people, such as fishers, tourists and tourism operators and traditional owners. Using a variety of monitoring data collected from across the Great Barrier Reef Marine Park since the 1980s and some innovative modelling, Emslie *et al.* [1] compared coral reefs within NTMRs to those in fished areas and asked whether the NTMR network is achieving its goals in terms of fisheries and biodiversity. In addition, they tested whether NTMRs provided any protection against a large, damaging cyclone that cut through the Park in 2009. Their results show that the NTMR network is performing as well as we had hoped, and in some cases even better.

Commercial and recreational fishing on reef in the Great Barrier Reef Marine Park is focused overwhelmingly on a small group of large, predatory fishes collectively known as 'coral trout'. Emslie *et al.* [1] found that there were more and larger coral trout inside NTMRs throughout the study period, adding further to the evidence from around the world demonstrating this effect [3,4]. But lots of big fish locked up inside reserves only helps sustain fisheries if NTMRs export fish to fished areas. They can do this either by some fish leaving the crowded NTMR ('spillover') or through the dispersal of planktonic larvae. Spillover does occur, but because most fish don't move far, it is most pronounced close to the NTMR boundary [5,6]. Of much greater value to fisheries is the increased production of larvae inside NTMRs and their export to fished areas [7]. Because egg production increases exponentially with body size in many fishes, NTMRs with lots of large fish produce far more larvae than an equivalent-sized area that is open to fishing, where fish are smaller on average. Recent studies show that many coral trout larvae disperse to fished areas within 1–30 km of where they were born [8,9]. As Emslie *et al.* [1] rightly point out, key questions remain, such as how much area or what fraction of a fished population should be protected given different levels of fishing pressure, but the usefulness of NTMRs as a fishery management tool now seems clear — they can work very well.

There were two surprising and very encouraging findings from the study. The first was how coral trout were affected by the cyclone: although density of fish decreased by 50% on both NTMR and fished reefs after the storm, biomass only decreased on fished reefs. Why larger fish inside NTMRs would be less affected by the cyclone is unclear, but this is a very important result. By retaining higher biomass, NTMRs can act as a source of larvae to rebuild populations damaged by the cyclone. The second encouraging result was that, apart from the cyclone, coral trout populations on fished reefs remained stable or increased between 1996 and 2012. The 2004 rezoning that dramatically increased the area within NTMRs also included a license buyout program to reduce fishing effort in the Park. Thus, the relocation of fishing effort caused by the establishment of new NTMRs was accompanied by a reduction in overall fishing effort. This seems to have successfully minimized the so-called 'squeeze effect' or the negative consequences of having the same fishing effort constrained to a smaller area after NTMRs are established [10]. It also seems likely that by protecting a greater fraction of the coral trout population from fishing, the more numerous and larger fish inside NTMRs contributed to the stability of fished populations through larval export [8–10], but this requires testing.

Emslie *et al.* [1] also compared NTMRs and fished areas using a number of biodiversity indicators, focusing on benthic community structure (percentage cover of hard coral, soft coral and algae) and the species richness and community structure of fishes not targeted by fishers. They found that biodiversity was similar inside NTMRs and fished areas. This might seem like a disappointing result. However, whether we should expect NTMRs to have greater biodiversity depends entirely on whether fishing affects biodiversity, either directly or indirectly. For the Great Barrier Reef Marine Park, as for many other developed countries, the answer is typically 'no'. That's because fishers target a limited number of species and destructive fishing methods, such as dynamite, chemicals or drive nets, are banned. Biodiversity in reef systems seems to be driven far more by geographic location — whether a reef is close to or far from the coast or equator. Location determines the particular environmental conditions that influence benthic community structure, which has a strong influence on reef fish species richness and community structure. Emslie *et al.* [1] demonstrate this effect of location: variability in benthic and fish community structure was far more related to reef location than whether the reef was inside or outside a NTMR. An exception is when fishery-targeted species also have strong impacts on lower trophic levels (e.g. herbivores) that, in turn, influence benthic communities — so-called trophic cascades [11]. But where fisheries primarily target just a few species of predators, trophic cascades in tropical reef systems are rare. Thus, the finding of Emslie *et al.* [1] that NTMRs do not have greater biodiversity than fished areas is entirely expected. In contrast, the situation is completely different in many other places in the tropics, where fishers target dozens of species (Figure 1), many of which are critical for healthy coral reefs, and may use destructive fishing methods. In this context, NTMRs should have greater biodiversity than fished areas, and we see this effect in places like the Philippines, Kenya and New Caledonia [3]. Furthermore, NTMRs in these places can export biodiversity to surrounding areas, much as they export fish to nearby fisheries [12].

Figure 1. What we should expect from networks of no-take marine reserves (NTMRs) depends on their fishery context.
In many developing countries, like in Manus Province, Papua New Guinea, fishers target dozens of species, many of which perform critical functions (e.g. herbivory) that keep coral reefs healthy. In contrast, fishers in developed countries target a limited number of highly prized, large, predatory species such as coral trout within Australia's Great Barrier Reef Marine Park. As a result, in developed countries NTMRs primarily affect fishery species, whereas in developing countries, NTMRs affect both fishery species and biodiversity (Photo: Glenn Almany).

The influence of context on NTMR network performance leads to a bigger question: what should we expect from NTMR networks? NTMRs only affect fishing. They do very little to guard against all the other threats to our oceans [13]. These threats include rising temperatures, ocean acidification and increasing storms, all resulting from climate change, as well as greater sedimentation, pollution and coastal development [14,15]. The Great Barrier Reef, even with its extensive NTMR network, is currently threatened by all of these stressors (see http://whc.unesco.org/en/soc/2867 and http://www.environment.gov.au/marine/great-barrier-reef/long-term-sustainability-plan). As Emslie *et al.* [1] show, large-scale NTMR networks can provide protection against regional-scale threats such as storms or flood plumes. That's because some areas of a large network are likely to be spared, and will serve as larval sources to help damaged areas recover. But climate change is a global threat. Yes, we need more NTMR networks. But more importantly, we need the courage and will to make the tough changes that eliminate these threats to ensure the future of life in our seas.

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Neural Evolution: Marginal Gains through Soma Location

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Unlike in most vertebrate neurons, the soma of many arthropod and mollusc neurons is placed at the end of a thin neurite. Multi-compartment computational modelling suggests this strategy may reduce the attenuation of signals from the dendrites, reducing the energy costs of signalling.

Since the earliest neuroanatomists revealed the morphology of single neurons from vertebrates and invertebrates over 100 years ago [1,2], a striking difference has been obvious: neurons in vertebrate brains typically have their soma interposed between their dendrites and axon (Figure 1A), whereas in the neurons of many invertebrates, such as arthropods and molluscs, the soma is placed at the end of a thin neurite (Figure 1B). In these invertebrate neurons the dendrites are in close proximity to the site of action potential initiation, linking directly to the axon [3]. The reason for this difference in morphology has been unclear but a new study by Hesse and Schreiber [4] in this issue of *Current Biology* demonstrates that by improving the efficiency of signal propagation an externalised soma may be advantageous over a central soma in some circumstances.

Hesse and Schreiber [4] compared the possible implications of a centralised or externalised soma using computational models of single neurons. Used in this way, computational modelling can be an invaluable tool for exploring the possible designs and configurations of biological systems. It is especially useful for studying systems such as single neurons in which the consequences of changing specific parameters can be quantified in functionally relevant ways (e.g., [5,6]). Using this approach, comparisons can be made among an array of designs with different combinations of parameters. Many such combinations may not exist, or have ever existed, in an actual biological system but their properties can still be quantified and compared. By coupling this approach with parameters measured from actual biological systems it is possible to determine the regions of parameter space that these systems occupy, revealing the inefficiencies inherent in certain parameter combinations and even biophysical constraints (e.g., [5,6]).

The alternative neural morphologies with a central or externalised soma were instantiated in multi-compartment computational models (Figure 1C,D) [4]. Such models approximate the morphology of neural dendrites and axons as a series of linked electrical compartments, each of which incorporates the basic biophysical membrane properties. The size and shape of each of these compartments can be altered, and they can be populated with various types of voltage-gated ion channels that modify their electrical

