MARINE CONSERVATION

Mixed management boosts reef shark abundance

A global survey using baited cameras on coral reefs demonstrates a near two-fold increase in the relative abundance of reef sharks in Marine Protected Areas that are also embedded within areas of effective fisheries management. Such conservation benefits however, were not evident for wide-ranging sharks or rays found on the reef.

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What makes an effective Marine Protected Area (MPA)? And what do we mean by protected area effectiveness? These complex and debated questions underpin how we understand and measure marine conservation goals. They are challenging because MPAs range in size and age, and from minimal to full protection[1]. It seems however, that effective MPAs combine some or all of five key features: large, old, no-take protection, well enforced and isolated. It is predicted that these characteristics lead to substantial increases in fish size and biomass when compared to areas under fishing pressure[2]. Yet it remains difficult to quantify the effectiveness of MPAs and other conservation solutions at scale. Writing in *Nature Ecology & Evolution*, Goetze et al.[3] use data from more than 18,000 video surveys in 36 different countries, to compare the relative abundance of wide-ranging and reef-associated sharks and rays from inside and outside 66 fully protected areas. They show unequivocal benefits of a mixed-management approach of MPAs embedded in areas of effective fisheries management for reef-associated sharks, but mixed results for other elasmobranch species.

Fishing has had profound negative impacts on large-bodied, predatory elasmobranchs, which include sharks and rays, round the world[4,5]; Yet other human

impacts also affect these species. As a tool for shark conservation, MPAs tend to be most effective in remote places far removed from human activities[6]. But anthropogenic effects are often more nuanced than this, as Goetze et al. demonstrate. Using the metric 'gravity' (a measure of human population size and distance to a fully protected area), they show us that in low gravity, remote fully protected areas where human impacts are low, abundance of top predator species is high both inside and outside the protected area. As gravity increases however, the abundance of sharks increases inside the fully protected area relative to outside (Fig. 1). In short, the conservation benefits of fully protected areas are greatest where the human impacts are high, as well as where reefs were distinct (isolated reefs more than 20 km to their nearest neighbouring reef). Goetze et al. show that, if these areas are also situated in locations where catch limits are imposed and gillnets or longlines prohibited through fisheries management in the area surrounding the MPAs, then the abundance of reef sharks doubles compared to locations where there is no effective fisheries management (Fig. 1). This provides a significant advance in our broad understanding of the key factors that influence successful reef shark conservation.

Perhaps unsurprisingly, these mixed management effects do not hold for wide ranging sharks capable of spending prolonged periods of time outside protected area boundaries. More surprising, however, is Goetze and colleagues' finding that they also do not hold for either large or small bodied rays, themselves subject to considerable fishing pressure. The authors suggest this reflects a potential methodological bias causing reduced detection of these flattened elasmobranchs on the baited remote underwater video stations (BRUVS) used in the surveys.

Of course biotic factors cannot be ignored, and reef sharks are an ecologically and demographically diverse assemblage. The authors offer an intriguing hint that in some areas and species complexes, ecological traits and even behaviour may explain some of the variation in relative abundance seen between sites. For example, they describe more heterogeneity and lower confidence in the conservation

benefits for Blacktip reef sharks (*Carcharhinus melanopterus*), implying that BRUVS sampling fails to capture certain interspecific interaction effects such as competitive exclusion, which are known to influence space use in this species in particular locations[7]. Integrating species-specific standardised movement metrics derived from tracking data, with predictive models to explicitly inform marine spatial planning, is undoubtedly offering exciting and important developments in research and policy implementation[8–11].

One message that becomes clear reading Goetze and colleagues' work is that both geography and culture can contribute to bucking the global trends. MPAs can have both positive and negative social, cultural, political and economic impacts on local communities[12] and the notion of 'success' can vary between stakeholders[13]. Outlier locations in these global analyses, such as Marovo in the Solomon Islands, therefore warrant careful attention. Outliers reflect areas where other factors such as culture significance, low effort or demand, or geographic factors can lead to low catch and high abundance of sharks, without the need for effective fisheries management or fully protected areas. Crucially, these geographic and cultural factors also influence enforcement and compliance in protected areas[14]. A lack of quantitative data on patrol effort, infringements or community support for regulations, meant compliance was assigned by park authorities or scientists as simply high, moderate or low in Goetze and colleagues' model. Given the importance of compliance in driving conservation success in teleost fishes[2], including it as a qualitative factor, which explained none of the model variation, may unintentionally mislead us to assume that compliance has no influence. What we should take from this though, is that in advocating the benefits of a mixed management approach, we need to work harder across disciplines and with local managers and users, to accumulate long-term, standardised data on MPA efficacy post designation, and at scales appropriate for global assessments such as this.

The Global FinPrint survey, which provided the data used by Goetze and colleagues, has already generated fundamental insight into the shifting state of elasmobranch assemblages on our world's coral reefs[4,11]. This study not only adds weight to the recommended expansion of networks of highly protected areas, it also highlights the

numerous fully protected areas that do not confer significant benefits to elasmobranchs; areas in need of improved management or design. As a taxonomic superorder rays (Batoidea), are known to be more imperilled than sharks, with 36% of species now threatened[15]. Importantly, Goetze et al. provide the first global assessment of protected area effectiveness on rays and in doing so emphasise the need to better understand, and perhaps better measure what drives conservation benefits in this group.

Using this remarkable data set, Goetze and colleagues deliver the evidence that mixed management approaches to reef shark conservation can achieve benefits much greater than the sum of their parts. In doing so, they provide another reminder that conservation targets based purely on area, are unlikely to be sufficient to reverse the decline in marine biodiversity and predator biomass in hyper-diverse coral reef ecosystems.

Competing interests statement: The author declares no competing interests.

Figure Legend

Fig. 1 Relative abundance of reef-associated sharks is influenced by social, geographic and management factors. Goetze and colleagues show that reef shark abundance in fully protected areas (PAs) is most strongly influenced by three characteristics of the PA (in order of their explanatory power): it's gravity (a measure of human disturbance), distinctiveness (a measure of PAs that contain isolated reefs more than 20 km from one another) and PA size. They also show that embedding fully protected areas within areas of effective fisheries management (for example, where catch limits and bans on gillnets and longlines are imposed), can nearly double the conservation benefits of the PA for reef-associated shark species.

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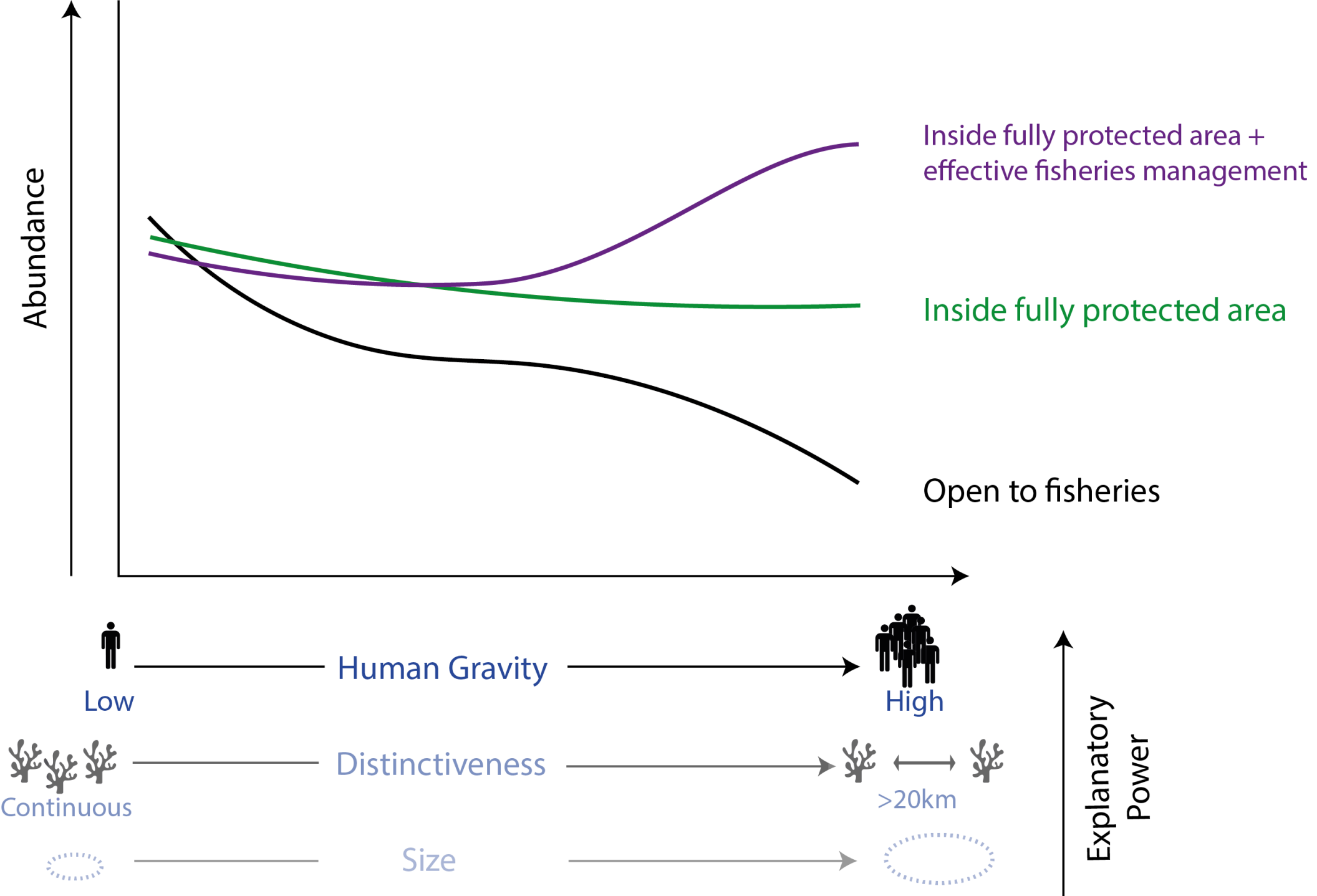
Abundance
Inside fully protected area +
effective fisheries management
Inside fully protected area
Open to fisheries
Human Gravity
Low
High
Distinctiveness
Continuous
>20km
Size
Explanatory
Power