How can science inform the design and management of marine protected areas?

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ABSTRACT

There is incongruity between much of the research that is ostensibly directed at improving marine conservation outcomes, and the effort that is actually needed to generate better outcomes. I argue that this is partly due to inadequate critique of basic assumptions by marine researchers. One assumption that is frequently made (explicitly or implicitly) is that marine reserves need to contain representatives of all species if they are to be effective. This assumption is not supported by evidence: many (perhaps most) species of marine organisms do not need the protection that marine reserves confer, because they are not threatened by processes that can be effectively managed by marine reserves. Better conservation investments are likely to be made if researchers critically evaluate basic assumptions, and design their research to address real information needs. Improved recommendations are likely to be achieved by research directed at understanding which species need protection most, and on how marine protected areas (MPAs) can be designed and managed to conserve viable populations of those species.

Key words: protected areas, marine reserves, conservation biology, reserve design

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Are Marine Reserves Succeeding?

Protected areas should be periodically evaluated to assess whether management actions are effective, and whether changes to management practices are needed (Agardy 1994; Vanderklift *et al.* 2000). This process should be guided by their objectives — that is, why a particular protected area was established (or, if its objectives have changed, why it is still needed). Failure to explicitly recognise and define objectives can lead to conflict, because evaluations then rely on *a posteriori* decisions that are retrofitted to prevailing ideology. The presence of clear objectives does not obviate the potential for conflict, but it does provide a framework against which effectiveness can be measured.

Marine protected areas (MPAs), like protected areas on land, often have multiple objectives: these can include conservation or restoration, recreation, improved sustainability of fisheries, research and provision of areas dedicated to traditional uses (Jones 2014). For example, the Convention on Biological Diversity (CBD) set out a framework in which signatory nations committed to "*Establish a system of protected areas or areas where special measures need to be taken to conserve biological diversity*" (Secretariat of the Convention on Biological Diversity 1992), and biodiversity conservation was listed as a primary goal of Australia's National Representative System of Marine Protected Areas (Australian and New Zealand Environment and Conservation Council Task Force on Marine Protected Areas 1999). One of the principal objectives of 'no take' marine reserves (a class of MPAs in which all extractive uses are prohibited) is conservation of biodiversity. Here, I provide a critique of the way research is currently done to meet this objective, and provide some suggestions for ways in which researchers can improve the advice that they give.

Notwithstanding the difficulty in measuring success of biodiversity conservation in its broadest sense (the definition of biodiversity is so broad — encompassing the diversity of all genes, species and ecosystems on earth — as to be essentially impossible to measure), most applications tend to use species as the key ecological unit for conservation targets: for example, the CBD indicated that a fundamental target was "*… the maintenance and recovery of viable populations of species in their natural surroundings*". As a taxonomic unit, the definition of what a species is tends to be considered obvious — for example the CBD defines what an ecosystem is, but not what a species is — despite the challenges and ambiguities involved in defining and describing species (Pimm *et al.* 2014). The focus on species as the key ecological unit for conservation is sometimes explicit, such as when species distributions are used to design protected areas (e.g. Carvalho *et al.* 2010), but it is often implicit, such as when surrogates like habitats are used in the (typically untested) expectation that they will reliably predict species distributions (Ward *et al.* 1999). A common approach to identifying candidate areas for protection is to identify which combination(s) of areas are required to ensure inclusion of representatives of all species (Caro 2009). However, in the ocean, this approach is likely to be inefficient, and might have the unintended consequences of providing poor protection for the species that need it the most (Hughes *et al.* 2014; Pressey *et al.* 2007).

Not all species need MPAs

The aspiration to include all species in marine reserves ignores the fact that not all species need such protection. That not all species need marine reserves is self–evident: there are many species that not only are present outside MPAs, but are present in equivalent abundances (Claudet *et al.* 2010). This is because the threats that can typically be effectively managed within marine reserve boundaries — most notably fishing and habitat loss — tend to affect the abundances of some species disproportionately: for example fishing tends to affect species that feed at higher trophic levels, while habitat loss tends to affect species that rely heavily on the resources (shelter, food, and so on) provided by the habitat. Other threats, such as climate change or pollution, do not respect reserve boundaries. Because of this, approaches that consider all species equally are likely to be poor conservation investments. In some cases they might even be detrimental because the distribution patterns of threatened species does not always match overall patterns of species richness (Pimm *et al.* 2014).

Presence alone is insufficient

Even if marine reserves were designed with a focus on the species that would benefit, they will likely fail to meet their objectives if they do not consider the processes that ensure persistence of populations (Pressey *et al.* 2007). Ensuring that a given species is present in a reserve does not guarantee that it will persist. To achieve persistence, protection needs to encompass enough individuals, and the habitats in which they acquire resources, to ensure viable populations. Here again, approaches that focus only on patterns of presence or richness will likely yield poor outcomes, and are misguided.

Science Can Be More Helpful

The pages of scientific journals are replete with analyses of 'gaps' in reserve networks that are based on species distributions, of algorithms that select sets of areas that include part of the distribution ranges of all species, and of analyses that demonstrate that various surrogates have good correlations with species distributions (e.g. Fox *et al.* 2005; Harris *et al.* 2008). Most of this research is not useful for managers who are seeking to find ways to protect species. Worse, it could even lead to poor conservation outcomes if the advice given were followed, because the recommendations might be incongruent with the actions needed to ensure persistence of species that would benefit from protection. Wiser recommendations would account for the fact that many species will not benefit from such protection, and focus instead on those that will. Scientists can help by directing their research efforts at solving problems that hamper effective conservation practices: two areas of research that would help are (a) identify species that would (and species that would not) benefit from area–based management, and (b) define the characteristics of an MPA that would maximise the probability of effective protection of those species.

What species need protection?

Relatively few species of marine fish or invertebrates are threatened with extinction, although many marine mammals and reptiles are (although information to enable assessment of a large proportion of species are lacking: www.iucnredlist.org), but the abundances of many species have been severely reduced. Conservation efforts are therefore likely to be better directed at rebuilding abundances of these species, rather than preventing extinction (Hughes *et al.* 2014). In some cases, such as when populations of a fish are reduced by fishing, or populations of a coral are reduced by bleaching, restoration is a more appropriate objective. Ideally, we would try to identify each of the species that needs such attention. However, we do not have complete information to identify all the relevant species: for many places historical data – and even current data — are not available. In such cases, conservation efforts would therefore greatly benefit from research that identifies what the traits of these species are, and — by extension — which traits render species vulnerable.

How can we protect them?

Designing protected areas solely on the basis of ensuring that part of the distribution of each species (or on the basis of 'protecting' an arbitrarily–defined percentage of some habitat or biogeographical area) is encompassed by a protected area is likely to be inadequate — surveys of terrestrial protected areas show that population declines in protected areas can occur if reserve design is inadequate for a species' needs (Geldman *et al.* 2013). To be effective marine reserve design needs to accommodate sufficient area, and the necessary habitats, to ensure a viable population is protected (Babcock *et al.* 2012). Researchers can help by trying to understand how many individuals are required for maintaining a viable population, by finding out what area is encompassed by the foraging and migratory movements of those individuals, and by determining what are the habitats that are required to sustain those individuals. In the latter case, where individuals rely on resources that are transported from farther afield, this might encompass an area broader than that encompassed by the population itself.

A New Perspective

The objectives of biodiversity conservation are many, but invariably include conservation of species. A focus on selecting and designing marine reserves to meet targets based on protecting an arbitrarily–defined proportion of ocean, and the method of doing so on the basis of including a proportion of the distribution of all known species (or of the distribution of some surrogate) is likely to yield outcomes that do not meet biodiversity conservation objectives. Not all species need the protection conferred by reserves, and those that do likely have different distributions and different requirements from those that do not. In addition, some species (including many species of endangered marine mammals and reptiles) move such great distances that they move between national jurisdictions, or even into the high seas where such jurisdictions are absent, rendering most MPAs inadequate. Effective conservation of species therefore requires a new perspective that includes clear objectives for which metrics of success can be unambiguously defined (such as the maintenance of viable populations of all species), identification of the species that would benefit from marine reserves, designing reserves to maximise the likelihood of persistence of populations of those species, and implementation of complementary mechanisms to ensure the conservation of threatened species that will not benefit from MPAs.

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