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Conservation of seamount ecosystems: application of the MPA concept

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Abstract

Scientific appreciation of the unique properties of seamount ecosystems has grown markedly in recent years. With this growing body of knowledge has come the realisation that the targeting of fish populations supported by these ecosystems is inherently unsustainable. For the most part, the target species are long lived and slow to mature, with low fecundity. At current levels of exploitation, some populations are already showing signs of reduced genetic diversity. The exploitation of seamount fish stocks also seriously impacts the benthic communities disturbed by the fishing gears employed in the industry. Benthic communities could also be disturbed by exploration for, and exploitation of, marine mineral resources.

At current levels of knowledge concerning the structure and integration of seamount ecosystems, it is not possible to envisage that these systems can be exploited in a sustainable manner. Accordingly, an holistic conservation strategy is required. This paper explores the elements of such a strategy based upon defining seamounts as fishery "no-take" zones and as areas protected from the full spectrum of human activities. Given the apparently individual character of the seamount systems studied to date, this paper makes the case that a protective regime should encompass all seamounts in order globally to conserve biodiversity.

Introduction

As noted by Roberts (2002), the world's deep oceans are among the last remaining wilderness areas. Waters of over one kilometre in depth cover an estimated 62% of the surface of the planet. Despite research efforts dating back to the voyages of *HMS Challenger* in the early 1870's, it is only relatively recently that the complexities of deep sea systems have begun to be elucidated. In the mean time, following declines in shallow water fish stocks, the fishing industry has increasingly turned its attention to deep water environments. Developments in technology made such waters more accessible, and it is currently estimated that some 40% of the world's trawling grounds now lie in waters deeper than those overlying the continental shelves. Koslow *et al.* (2000) state that, since 1964, deepwater fisheries have contributed between 0.8-1.0 million tonnes per year to landings of marine fish. Added to the disturbance potentially and actually attributable to fishing activities, deep water resources of minerals, oil, gas and gas hydrates are increasingly likely to be targeted in the future by the mining and the oil and gas industries respectively. Currently, much of the commercial activity underway, or planned in the short term, in deep water environments is taking place against a background of very poor knowledge of baseline ecological conditions. Understanding of the way in which these ecosystems are likely to respond to perturbation, or subsequently recover from anthropogenic impacts, is practically non-existent.

Within deep water systems, seamounts are one of the most common topographic features. Seamounts are commonly defined as formations rising at least 1000 metres above the sea floor. They generally arise through volcanic activity, and often occur as ridges or chains. (Axys Environmental Consulting Ltd., 1999). Although the 1000m classification is far from rigid, on this arbitrary basis the Atlantic Ocean is estimated to contain 810 seamounts, while the Pacific Ocean may contain anywhere between 30-50 thousand such features. The best known are found in the waters around Hawaii, Australia, New Zealand, Africa and the Philippines.

Seamounts have somewhat special characteristics, further eroding the myth that deep sea ecosystems are depauperate. In common with hydrothermal vents and cold seeps, seamounts are known to be highly productive centres of biodiversity. Indeed, they attract significant commercial interests largely as a result of the aggregation of exploitable populations of bentho-pelagic fish around them. The unique properties of seamount ecosystems as a whole define the extent of conservation measures required to ensure their sustainability.

Seamounts as Productive Systems

Being essentially large obstacles placed in the path of an oceanic current, seamounts can cause substantial modification of flow patterns of the large ocean currents, although in most cases flow effects are more local. Effects include the formation of eddies, trapping of waves and the amplification, distortion or reflection of internal waves. An upwelling of cold, deep water can appear as a dome over the seamount. Turbulent mixing can also result together with strong internal tides. Under certain conditions, a clockwise eddy, known as a Taylor eddy, can be localised above the seamount. Precise conditions appear to be specifically determined, as evidenced by a study of seamounts off the coast of South America (Travassos *et al* 1999). Upwelling effects, in turn, can cause appreciable increases in water concentrations of phytoplankton nutrients as deep, nutrient-rich waters are brought close to the surface.

The physics of water flow coupled with local biological processes appear to play a pivotal role in determining productivity of the system. The advection and entrainment of productivity from other areas, however, may also be important. In general, the more shallow the water over the seamount, the more productive the system, although each level of the ocean food chain appears to be impacted by the presence of a seamount *via* different mechanisms. These aspects require further research to characterise and comprehend them fully. Nonetheless, the enhanced productivity around, in particular, shallow seamounts is reflected in a very diverse and abundant benthic fauna, dominated by suspension feeders, as well as in the highly aggregated fish populations found in their vicinity (Axys Environmental Consultants Ltd., 1999).

Diversity of Benthic Communities

As a "rule of thumb", community structure on a seamount reflects that found on nearby continental shelves. Shallow seamounts tend to have a greater component of regional species in comparison to the deeper seamounts, which understandably harbour assemblages of more cosmopolitan species (see e.g Gillet & Dauvin 2000). In terms of biodiversity, however, an important aspect is the degree of endemism of organisms found in these systems. An early biogeographic study of 92 seamounts suggested that some 15% of the species collected were endemic to individual mounts (see: Axys Environmental Consultants 1999). This early work has been superceded by a more exhaustive study of seamounts in the Southwest Pacific, which suggested that levels of endemism (among 850 species of macro- and mega-faunal species) could be as high 29-34% (de Forges *et al.* 2000). The relatively low species overlap suggests that seamounts function ecologically as island groups or chains, leading to localized species distributions, and with apparent speciation between such groups and/or chains. Despite some 30 years of studies directed at seamounts, however, the knowledge base remains poor. Hence the findings of high levels of endemism associated with seamounts could conceivably be an artifact of the limited research base. The gaps in knowledge of benthic biodiversity clearly need to be resolved.

Seamount Fisheries

It has been known for some decades that fish are often abundant over seamounts, particularly shallow seamounts. Prior to the development of fisheries over these areas, primarily by the former Soviet Union, the benthopelagic fish taxa found in these environments were regarded as somewhat obscure. Nonetheless, the aggregation of these fish over these topographical features allows them to be readily targeted and they render high yield per unit effort. Pelagic armorhead (*Pseaudopentaceros wheeleri)* have been exploited over seamounts in the central North Pacific since the late 1960s. More recently, orange roughy (*Hoplostethus atlanticus*) has been exploited over a variety of seamounts and marine plateaux since the early 1980s where initial catches could exceed 60 tonnes from a single 20 minute trawl (Roberts 2002). Reproductive strategies of fish associated with seamounts (in common with other deep water species) are at the far end of the K-selected spectrum. They are exceptionally long-lived, slow growing and slow to mature. Orange roughy can live to 150 years old, mature at 20-30 years of age and produce relatively few large eggs. Some *Sebastes* species can reach an age of 200, while the Icelandic roundnose grenadier live well into their 70s, maturing at around 14-16 years old (Roberts, 2002).

Vulnerability of seamount ecosystems

Despite growing understanding, the development of seamount fisheries has largely taken place against a background of relative ignorance of biological and ecological parameters. The highly K-selected life histories of these exploited species, coupled with somewhat sporadic recruitment, have significant implications in relation to conservation of species and management of associated fisheries. Excessive fishing pressure led to the commercial extinction of pelagic armorhead stocks over the Pacific seamounts in less than 20 years. These populations have never recovered. Orange roughy landings have been sustained through the serial depletion of stocks between south-eastern Australia and New Zealand. Typically, newly discovered stocks were fished down to 15-30% of the initial biomass in only 5-10 years (Koslow *et al.* 2000). Catch and effort data show very strong declines in catch rates over time (Clark 1999). Studies of the fished populations in New Zealand have revealed that male fish now show a reduced size at maturity, and possibly also reduced genetic diversity, although the evidence for these changes is conflicting (Clark *et al.* 2000; Clark & Tracey, 1994).

Overall, orange roughy fisheries should be regarded as largely outside "safe biological limits". Establishing and managing these seamount fisheries on a sustainable basis would require a very substantial (and probably unenforceable) reduction in fishing effort, combined with a much deeper understanding of the biology and ecology of these fish. The problems of establishing a sustainable fishery are generally similar to, but more intense than, those for shallow water fisheries (see: Pauly *et al.*2002).

In addition to the population level impacts identified in targeted seamount fish species, community and ecosystem-scale impacts may also be expected (Koslow *et al.* 2000). While evidence for community shifts due to fishing activities is considered, at best, highly equivocal (see: Jennings & Kaiser 1998), it must be stressed that this judgement is based for the most part upon data from shelf fisheries. The influence of the relatively longer time scales over which biological processes operate in the deep ocean is unknown, and the onset of fishery activity too recent to allow such changes to be identified.

The clearest impacts identified to date have been on benthic habitats. The natural intensification and modification of water flow patterns around seamounts give rise to a fauna dominated by suspension feeders, including various coral types. Some impacts have resulted directly from the targeting of these corals, though extensive changes have also been identified in benthic communities trawled over in connection with fishing activity. One study of Tasmanian seamounts showed that benthic biomass per dredged sample was reduced by 83%, and species number per sample reduced by 59%, in comparison with un-fished areas. Moreover, bare rock characterised 95% of the seafloor in trawled areas, as opposed to only 10% on the most comparable undisturbed area surveyed (Koslow *et al* 2000; Koslow *et al.* 2001). The high degree of endemism of the fauna associated with these habitats renders the possibility of extinctions extremely high (Roberts 2002), though such extinctions likely to remain undetected.

Conservation Options

Concerns about the vulnerability of seamount ecosystems have led to widespread discussion of conservation strategies. Marine reserves, or Marine Protected Areas (MPAs), have become a popular tool for marine conservation and marine resource management over the past decade. Nonetheless, many have been established without a clear view of the baseline conditions to be conserved, or how the designation is likely to affect the areas (Halpern & Warner 2002). It is clear, however, that biological responses often develop quickly and persist.

Some 1300 MPAs have now been designated worldwide (Boersma & Parrish 1999), designed to provide refugia and to allow spillover of threatened species into adjacent waters. To be effective as a conservation device, however, MPAs need to be both large and networked, and be representative of all biogeographic zones. Some modeling studies suggest that, for an MPA to operate effectively as part of a fisheries management strategy, around 50% of the productive habitat needs to be closed to fishing, implying the set-aside of very large tracts of the worlds oceans (Parrish 1999; Mangel, 2000). Even then, some negative fishery impacts may be exacerbated through the intensification of activities outside the MPA. Nevertheless, evidence exists that positive benefits accrue in some habitats, such as coral reefs, designated as MPAs (Jennings *et al.* 1996) and can allow depleted species to recover significantly (Kelly *et al.* 2000). Some difficulties exist in applying MPAs to migratory species, though even for these some degree of protection is afforded (Guenette *et al.* 1998).

Relatively few seamount systems have so far been designated as MPAs. Some 14 are protected in this way in Tasmania (Koslow *et al* 2000), covering a total area of some 370 square kilometres. New Zealand has protected 19 seamounts to some extent, while the US has designated an area encompassing two of these features off Alaska (Roberts 2002), as well as the Cordell Banks, a seamount off the Californian Coast. Saba Marine Park in the Netherlands Antilles includes two offshore seamounts, while the Port Foster SSSI in Antarctica incorporates an undersea volcanic caldera.

The high degree of endemism associated with the fauna of seamounts surveyed to date implies that any conservation strategy based on designation of MPA status will require a network of reserves both within areas of national jurisdiction and on the high seas, the latter currently falling outside any relevant regulatory scheme. The size and location of these reserves will require a greater understanding of the biogeography, ecology and reproductive strategy of the seamount associated fish and other fauna. Changes in fishing practice, i.e moving from trawling to line-fishing could also contribute to reducing current levels of human impact (Koslow *et al.* 2000).

Nonetheless, it is clear that with the current state of knowledge of seamount ecosystems, any prescribed conservation strategy which permits some continued exploitation of these poorly characterized biogeographic “islands” is associated with a high risk of failure. The substantial uncertainties and indeterminacies, coupled with evidence of widespread over-fishing over seamounts, suggest that a highly precautionary approach is merited. The only sure way of conserving the biodiversity of these unique ecosytems would be to prohibit the targeting and marketing of seamount-associated benthopelagic fish. Although illegal fishing might exert some residual impacts, such a prohibition would undoubtedly contribute substantially to the conservation of the benthic species found in these habitats.

Conclusions

1) Seamounts are poorly characterised as regards location, numbers and associated ecological systems

2) Seamounts support a rich and diverse benthic fauna with a high degree of endemism

3) Seamount associated fish are, in general, extreme k-strategists, highly vulnerable to exploitation and with long projected recovery times

4) Seamount fish and benthos are known already to have been seriously impacted by fishing activities

5) Conservation through designation of MPAs will require a mixture of national and supra-national measures effective in law and realistically enforceable.

6) Taking into account the characteristics of seamount ecosystems, coupled with the associated uncertainties and indeterminacies, the simplest way of assuring adequate conservation would be to cease all fishing activities targeting these populations.

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