Constraints of terrestrial protected area solutions in protecting marine biodiversity

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ABSTRACT

Traditionally the concepts of terrestrial protected areas have been used in designating marine protected areas. We discuss the differences between marine and terrestrial protected areas and highlight the need to consider the movement of species through marine protected boundaries. The source of most productivity differs; in terrestrial systems it is all attached whereas in the marine environment much occurs in the water column and cannot be restrained by artificial boundaries. This has major implications for the management of marine protected areas.

Key words: Marine Protected Area, marine biodiversity, ecosystem management, larval distribution, water column, primary productivity, life strategies

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Introduction

In 1988, IUCN Resolution 17/38 on protection of the coastal and marine environment called for "protection, restoration, wise use, understanding and enjoyment of the marine heritage of the world in perpetuity through the creation of a global representative system of MPAs and through the management, in accordance with the principles of the World Conservation Strategy, of human activities that use or affect the marine environment."

The concept of a global representative system of Marine Protected Areas (MPAs) has been pursued particularly through the United Nations Convention on Biological Diversity through a percentage of coverage targets – most recently in Aichi target 11 calling for 10% of coastal and marine areas to be conserved in protected areas by 2020 (http://www.cbd.int/sp/targets/rationale/target–11/). However, although the role of MPAs within broader management for conservation of marine biodiversity (Allison *et al.* 1998) and the values of such targets were questioned by Agardy *et al.* (2003), these matters have received relatively little recent attention.

While progress has been made towards the MPA target, Devillers *et al.* (2014) observed that the majority of the percentage coverage of MPAs consists of residual areas, very large, remote, little used or little impacted areas. They are relatively easy to designate but can they be effectively policed or monitored? Such areas have substantial values of scale and pre–emption of impacting activities within their boundaries but, as Allison *et al.* (1998) pointed out, just establishing marine reserves is not in itself a sufficient strategy for marine conservation. Discussion of residuality (Devillers *et al.* 2014) raises the question of how well the established practices of terrestrial Protected Area biodiversity management transfer to marine environments.

In this paper we briefly address the constraints and opportunities of protected area options for conserving marine biodiversity and ecosystem processes. We consider the extent that various forms of MPAs are able to contribute to maintaining biodiversity in the face of direct and indirect anthropogenic impacts and threats.

The terrestrial context

Primary production by macroscopic plants, animal dependence on social groupings and the need to care for their young resonate with human cultures, concerns and experience. From childhood, people are familiar with terrestrial plants and animals through direct experience, through urban landscapes and agriculture, national parks, nature based recreation, and culturally through education, narrative and images of iconic species, their young, and unmodified landscapes. People can walk and spend substantial time in natural areas and can experience and record much of the biota directly.

Although familiar to humans, terrestrial environments and the atmosphere above them are physiologically very challenging to biological cells. Desiccation, large diurnal and annual thermal ranges, ultraviolet and solar radiation present major physiological challenges. This is addressed by complex anatomical, physiological and behavioural mechanisms to maintain cellular function, and reproductive strategies that involve expensive energy investment in regulation of body fluids, thermal regimes, seeds, eggs or viviparity and caring for vulnerable young.

In terrestrial ecosystems there may be cross–boundary issues relating to the impacts of upstream activities, but freshwater flows provide generally unidirectional connectivity from hilltop to ocean. Together with surface geology, they establish the constraints and isolation of ecosystems through soil and moisture regimes, often resulting in localised high levels of endemism. The third dimension of the overlying atmosphere enables connectivity through drifting pollen, spores, seeds and small animals and energy intensive flying by arthropods, birds and mammals. This connectivity is important for many terrestrial surface communities, but the biological material transported in the atmosphere all derives directly from and depends on primary production at the terrestrial surface.

Terrestrial protected areas are sectorally managed to address conservation of biodiversity primarily through management of direct activities and impacts within their defined boundaries. While their creation is often contentious, it sits easily as a form of title and authority for a particular form of land use within designated boundaries that can be easily seen and may be fenced to manage entry and cross boundary issues. Terrestrial protected areas are a major strategic means to address conservation of biodiversity sustained by the soils and water regimes provided by geological structure, particularly where ecosystems and habitats are endangered or at risk of destruction through other forms of land use.

The security of land or aerial migration routes of species with ranges greater than designated boundaries can be a substantial management issue, but for the many species with smaller ranges a Protected Area can be an effective sample or island of naturalness maintaining biodiversity values and processes that have otherwise been lost or are threatened by human use or impact.

The marine context

For much of history and even for most coastal people the sea has been regarded as dangerous and unpredictable, marine creatures as monstrous or strange, and fish as an abundant resource for those skilful and brave enough to venture to sea. Adjectives that describe marine creatures, such as slimy, slippery, cold–blooded, spineless and fishy are used as insults. Few marine animals care for their young and in many cases there are no obvious young, although there are exceptions like marine mammals and some fish. Most of the life in the water column is microscopic and invisible. Even with sophisticated equipment such as scuba most people can only observe or experience shallow marine ecosystems for very short periods of time. Studying seabed fauna and flora is much more challenging logistically than working in terrestrial environments and the costs increase with increasing depth and distance offshore.

The largest component overlooked in marine biodiversity management is typically the extremely diverse benthic sedentary and infaunal communities which exhibit a tremendous range of time and spatial scales. These communities are dominated by species which are sedentary as adults but have a pelagic larval stage of varying duration. So different factors are important for each life stage; for adults suitable substrates are critical whereas water quality, salinity and supply of phytoplankton are critical for larval stages. Severe storms and associated flood plumes can have major consequences for benthic species with restricted spawning periods and may result in the complete loss of a year's recruitment with larvae being transported away from sites suitable for settlement (David *et al.* 1997). We also know from long term studies of benthos in places like Jervis Bay, NSW (Hutchings and Jacoby 1994; Hutchings and Knott in prep) how dynamic these systems are and how they are largely driven by fluctuations in recruitment. This certainly complicates devising monitoring programs but we need to ensure the long term viability of such communities which are very sensitive to changes in water and sediment quality.

Basically, the reasons why these macrobenthic and associated meiobenthic communities are largely ignored in the planning and management of marine protected areas are the cost, even in shallow waters, of systematic surveys and analysing their sheer diversity, and the challenges of understanding and conveying the importance of creatures so different from those on land. These communities include many phyla, representing many undescribed species, ranging in size from a few millimetres to many centimetres in length. They exhibit a range of feeding strategies, life spans varying from weeks to years with an amazing variety of reproductive biologies. They are difficult to categorise, they represent various levels of the food chain but without this benthos, functioning marine ecosystems will not be maintained. Thus they are critical to conserve and manage.

In contrast to the atmosphere where the third dimension of the atmosphere is hostile, the water column is a benign environment for biological cells. It is dense, wet, thermally stable, chemically buffered and provides physical support with little or no expenditure of energy for life forms from single celled organisms to whales. It sustains most marine primary productivity, supporting pelagic species and planktonic communities that are not dependent on the seabed. In addition, it supports the larval development and distribution of many seabed–living species.

Eggs and sperm or fertilised eggs of most marine animals are discharged into the planktonic community of the water column with no further parental role in development from larva to establishment in adult habitat. Many species produce hundreds of thousands of eggs. Larvae developing in the plankton are part of the water column food web, and the odds of individual survival to maturity are minute. Planktonic larval life from spawning to settlement in adult habitat ranges from a few days to many weeks for different seabed habitat species. During this time the larvae are transported with ocean and tidal currents, and larval settlement behaviours that provide genetic linkage between widely separated adult populations of attached or limited–territory species (Scheltema 1986; Allison *et al.* 1998; Pineda *et al.* 2007). Recent studies on kelp (Coleman *et al.* 2011; Coleman 2013) and on polychaetes (Smith *et al.* 2015) have highlighted the connectivity of disjunct populations along the NSW coast with propagules and larvae being transported southwards by the East Australian Current as well as larvae being transported in the opposite direction by coastal vectors. Hilario *et al.* (2015) have reviewed planktonic larval durations (PLD) of 305 species representing seven phyla that show mean medium PLD of 27.68 (SD 28) days for shallow species and 96.63 (SD 85) days for deep water seabed species. The importance of such connectivity has been demonstrated by studies showing the widespread dispersal of coral larvae in a southerly direction along the Great Barrier Reef with so called source and sink reefs (Hughes *et al.* 1999). Similar studies of fish populations also support this concept (Sale *et al.* 1984; Booth *et al.* 2007; Feary *et al.* 2013).

Water masses move and mix through variable multi–directional interactions of currents, tides, weather systems and inputs of terrestrial runoff to nearshore waters. Title and responsibility for marine protected areas may be assigned within boundaries defined by locations on the surface of land or sea, but many crucial issues for marine environments are not substantially addressed by management within spatial boundaries. The locations of seabed structures and associated communities such as coral reefs, seagrass and macroalgal beds, sedimentary or rocky seabeds may be precisely defined, but many of the species within their communities derive their nutrition and maintain recruitment and genetic diversity from the water column. The management of seabed or territorial communities can raise the problems of cross jurisdictional integration because of the mobility and multidirectional cross boundary biological and pollution linkages through the third and fourth dimensions of water column space and movement over time.

Undisturbed areas of seabed habitat are a crucial component of marine biodiversity conservation, but their viability may be limited without the capacity to manage factors affecting the water column that overlies and links food webs and genetic distribution of species of discontinuous

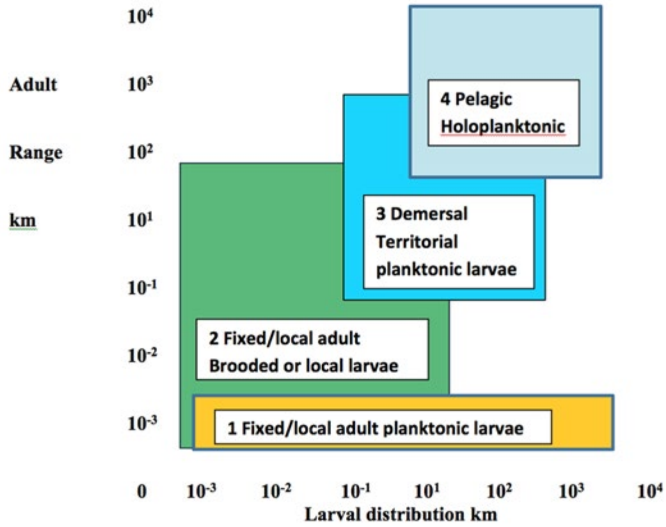

Figure 1. The geographic scales of life–cycle ranges of groups of marine species (adapted from Kenchington 1990).

seabed habitats. The importance of the water column as a sustaining linking habitat and the relationship between adult and larval ranges and seabed habitats is reflected in the observation by Allison *et al.* (1998) that marine reserves or protected areas are necessary but not sufficient for marine conservation, which suggests that they should be conceived and managed effectively as a crucial component within integrated ecosystem–based management rather than islands of naturalness.

Kenchington (1990) identified four groups of marine life–cycle ranges that have important implications for the applicability of spatially – based management of marine biodiversity (Fig. 1).

An area of seabed and the water column above it may have species of all four life–cycle groups with the seabed communities depending on the water column productivity and food web.

Terrestrial protected area concepts of protection of areas of high conservation significance as reasonably self–sufficient islands of naturalness can transfer most directly for type 2 species that are fixed or have a limited range and which brood their young or have limited larval distribution. Protected area networks are relevant for maintaining adult populations of type 1 fixed or territorial species that have lengthy planktonic larval or juvenile phases. They are also relevant for protecting areas of particular significance as spawning, nursery or migratory feeding sites for type 3 or type 4 pelagics, and large–ranged demersal species with long planktonic or juvenile phases. Effective exclusion of direct human uses from part of the range of type 3 or type 4 species can provide valuable protection from and contribute to understanding of the fourth dimension transboundary linkages to distant events over time. In addition, conservation of type 3 or type 4 species requires effective multiple use management tools for long term sustainability of fisheries and of the operational and potential accidental impacts of direct uses of marine resources and space such as shipping, mining, terrestrial runoff and energy and aquaculture installations.

Issues of water quality, coastal land management and climate change affecting marine waters are typically beyond the jurisdiction of an agency with responsibility for biodiversity conservation within marine spatial boundaries, and require integrated strategic management systems. Thus, the Great Barrier Reef Outlook Reports (2009 and 2014) identified the quality of external terrestrial runoff waters that enter the Great Barrier Reef Marine Park as a substantial threat to the Great Barrier Reef which is controlled by a variety of land–based agencies and authorities. Similar scenarios exist all around Australia adjacent to urban or agricultural lands.

So how can spatially defined Marine Protected Areas (MPAs) best contribute to conservation of functioning marine ecosystems?

MPAs can provide a spatial framework to address the crucial primary objective of conserving marine biodiversity. They are not designed as a fisheries management tool. Fisheries management provides a spatial framework to address crucial primary objectives of conserving fishery resources addressing food security, but this is not designed as a biodiversity conservation tool. While there are different primary objectives there are areas of common ground in the spatial measures used to protect species and habitats of interest. There are also shared concerns over the implications for an increasing range of extractive industries in the marine environment that affect or may affect the diversity, productivity and ecosystems of marine space and in many cases have impacts that are largely unknown.

MPAs in Australia are reported nationally and globally in terms of the IUCN categories of protection (Dudley 2008) but their design, management and allocation of categories reflects the legislative and policy framework of the jurisdictions that create them. There is confusing inconsistency between jurisdictions in the naming and allocation of categories for purposes of use and entry which has resulted in 32 named types of marine protected area (e.g. marine reserve, marine park, marine sanctuary, marine national park etc; CAPAD, 2014).

There are three broad strategic spatial management approaches relevant to marine biodiversity and natural resource conservation and these can be related to IUCN Protected Area categories (Dudley 2008). The first is exclusion of extractive and damaging activities, either totally to serve as sanctuaries, control or reference sites for scientific research that cannot be undertaken elsewhere (equivalent to IUCN Category I Strict Nature Reserve), or controlled to provide conditional access for nature based recreation and tourism activities (Category II National Park).

The second is seabed habitat protection by permanent exclusion of activities such as trawling, dredging, mining and installation of seabed structures but controlled to provide conditional access for consistent uses of the water column or sea surface. Depending on other objectives, this may be addressed within IUCN categories III (Natural Monument or Feature), IV (habitat/species Management Area), V (Protected Landscape) or VI (Protected Area with Sustainable Use of Natural Resources).

The third is an integrated strategic sustainable multiple use management framework (IUCN Category VI Protected Area with sustainable use of natural resources) with conservation as a primary objective such as the Great Barrier Reef Marine Park. This will contain highly protected (Category I/II) zones buffered as far as practicable by zones of intermediate (Category III–V) protection (Kenchington 2010; Kenchington *et al.* 2014).

No–take protected areas IUCN Categories I/II are essential components of a science–based strategy for ecologically sustainable marine management.

Such marine protected areas should generally be established as a network within a strategic framework to allow for the connectivity of larval recruitment at a number of scales and off–set the risk of catastrophic local impacts within a large geographical region. The importance of such connectivity has been demonstrated by studies showing the widespread dispersal of coral larvae in a southerly direction along the Great Barrier Reef with so–called source and sink reefs (Hughes *et al.* 1999). Similar studies of fish populations also support this concept (Sale *et al.* 1984; Booth *et al.* 2007; Feary *et al.* 2013)

Achieving effective marine conservation requires an integrated ecosystem–based multiple use framework providing for conservation and sustainable levels of human use and impact. The central element of such a system is a network of effectively protected sanctuary or reference areas, that should be buffered by surrounding areas of use consistent with protection of core sites while the rest of the area should be managed on a basis of demonstrable sustainability of use consistent with maintaining biodiversity and ecosystem processes.

The establishment of seabed habitat protection areas and networks of highly protected areas brings the need to address conservation issues within management of different uses of the sea surface, water column and seabed. It should also provide for linkages of marine areas through primary productive ecosystems and food webs of the water column and through nutrients and pollutants arising from land and freshwater uses.

The challenge of MPA creation is that it is not simply a process of defining areas that can be set aside and sectorally managed for biodiversity with relatively little overlap with management of sectoral activities and impacts beyond designated borders. In the Australian context most estuarine, intertidal and shallow subtidal marine ecosystems are in internal waters of state or territory jurisdictions, reflecting the extent of the three nautical mile territorial State at the time of federation. Further seaward, Commonwealth waters extend to 12 nautical miles and are surrounded by an Exclusive Economic Zone encompassing continental shelf and oceanic habitats. Ideally, protected area networks should include areas in State and Commonwealth waters if they are to address estuarine, nearshore and offshore habitats and linkages, but this has to be addressed through jurisdictional and sectoral solutions in different environmental and social contexts. The complexity of this challenge is reflected in the 32 named types of marine protected area used by Australian jurisdictions to address different specific regulatory approaches and allocations of IUCN categories (CAPAD, 2014).

Despite increasing recognition of the complexity and linkages of marine ecosystems in three dimensional space and in water column connectivity over the fourth dimension of time, the information for design and implementation of management is patchy and or sparse. The predominant sources of biological information come from fishery exploration and production data and studies of charismatic megafauna which are increasingly augmented by mapping seabed geology and some accompanying remotely imaged data of benthic meso– and megafauna. These and oceanographic data have been applied through surrogacy to develop IMCRA (Commonwealth of Australia 2006), which provided a reasoned spatial basis for Commonwealth Marine Protected Area planning within the constraints of time and available data. The current challenge is to develop the information base for non–commercial species, benthic meiofauna and infauna, in order to ensure that all components of the biodiversity and representatives of all parts of complex food chains are better understood, conserved and managed in the context of zonal changes occurring through ocean warming.

While very large, remote areas, relatively undisturbed, are attractive targets for addressing international MPA targets, they require substantial recurrent funding for management, surveillance and monitoring if they are to function as effective MPAs and not just paper parks. Focus on such areas may distract attention from estuarine, nearshore and continental shelf waters and habitats which are most substantially impacted in most ocean fringes and have complex sectoral and jurisdictional interactions (Devillers *et al.* 2014).

The IUCN resolution that called for "the establishment of a global network of representative marine protected areas" also called for "the management, in accordance with the principles of the World Conservation Strategy, of human activities that use or affect the marine environment" (IUCN 1988). Experience of the Great Barrier Reef Marine Park Act (1975) implementation and amendment "illustrates an evolution from broad protected area concepts of conservation and reasonable use to address concepts of areas of high conservation value, world heritage values and provision for ecologically sustainable use by traditional owners, consistent with traditional practice." Spatial management is an important component but is of limited effect without an explicit strategic framework to address sustainability of cumulative and cross boundary impacts of multiple and increasing uses and activities affecting the biodiversity of marine space.

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