Marine gap analysis

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The marine environment is host to a broad array of biodiversity. In some respects it is even more diverse than terrestrial ecosystems, containing more orders or phyla and featuring a spatial and temporal complexity not found to the same extent on land. While marine, terrestrial, and freshwater species are all known to migrate in and out of protected areas, this movement can be particularly pronounced in marine environments and many species require different habitats for different life-cycle stages. Much remains to be learned and much of the biological diversity in marine environments has yet to be described. Most marine conservation to date has been focused on the need to protect places required for species reproduction or juvenile life-cycle stages[1] and marine resource management has concentrated particularly on protecting fisheries and maintaining sustainable yields of marine resources. However, there is now a clear shift towards ecosystem-based management (EBM) practices (e.g., COMPASS, USOPC, Pew). The emerging EBM paradigm draws on the principle that an ecosystem-based approach needs to consider management for ecological systems and ecosystem function, as well as for individual species.

When carrying out a gap analysis in marine environments, as is the case in freshwater and terrestrial systems, the "coarse filter"/"fine filter" approach is recommended to ensure that biological diversity is represented at multiple scales. Selection of focal biodiversity elements for a gap analysis therefore should draw on a range of species, ecosystems and surrogates.

Species targets
In most cases it will not be possible to draw up a comprehensive list of species in marine habitats. However, species which are threatened or are keystone species (having a disproportionate effect on their environment[2]) should be prioritized for inclusion, as should rare or endemic species. Species may sometimes be selected as focal biodiversity elements due to their vulnerability at a particular life stage, such as species that congregate for reproduction or migrate across environments. Where information is available, and in cases where it is ecologically applicable, habitats required for specific life-cycle stages should be included in gap analysis as distinct elements, targeted for representation.

Ecosystems
Corals, shellfish, sea grasses, salt marshes, kelp and mangroves are generally classified as ecological systems in regional conservation plans such as gap analysis exercises. While we are able to identify individual species of coral or shellfish and some of these species may be listed individually on a list of focal biodiversity elements for representation, ecological systems such as coral reefs, shellfish beds (e.g., oyster reefs), and sea grass meadows are generally also listed because they provide structure, habitat, and processes which support a suite of other species. For example coral reefs are often used as a conservation target in part to protect the diversity of hard and soft coral species, but also to represent the diverse group of reef fish associated with coral reef systems. By ensuring representation of coral reefs in protected areas, we are also hoping to include representation of the fish, invertebrates, and other species which live in association with corals.

There is a great deal of variation within an ecological system such as coral reefs. In some cases detailed information will be available on the species associated with reef systems and their habitat requirements within reef systems and beyond. However, in most cases such detailed information is still not available and the gap analysis instead needs to ensure that the full range of habitat variability is represented to "capture" species for which less detailed data are available. In reef systems this is often done by developing benthic habitat characterizations that can be used to represent different reef formations. Patch reefs, fore reefs, banks/shelves, reef crest, and spur and grove are examples of types of reef formations that may be tracked as individual ecological system targets. Additionally, coral reefs are sometimes classified based on exposure to wave energy since this is known to correspond to variations in species assemblages in certain cases. Topographic complexity has been shown to correspond to greater levels of species diversity and also to abundance in coral reef systems; for this reason topographically complex reefs are sometimes included as an additional biodiversity element for analysis.

Salt marshes and inter-tidal wetlands are important and highly productive components of the marine ecosystem. These should therefore be included in marine gap analysis as applicable and may also be included in terrestrial and/or freshwater gap analysis. In some cases they may be classified into categories according to different levels of salinity such as oligohaline, mesohaline, and polyhaline, which are expected to correspond to variations in associated species assemblages. In cases where significant variations of wetlands are known and recorded these ecological systems cam be included as unique focal biodiversity elements; where detailed information is unavailable it is recommended that efforts be made at least to indicate coastal areas where wetlands are present.

Shellfish play an important ecological role as filter feeders, by processing water to remove suspended nutrients. In cases where shellfish beds have been significantly reduced it is expected that the reduction in filtration services contribute to negative feedback cycles that damage ecosystem health and may lead to a greater susceptibility to harmful algal blooms. Oysters are particularly notable in their ability to construct reefs that create habitat for additional species, not only by increasing structure, but also by altering current patterns to create eddies. Sea grass meadows and mangroves are known to play an important role as nurseries for many species of fish and invertebrates. These species form habitats that provide shelter and protection for juvenile fish and invertebrates and are often included as targets since they are important areas for representing marine diversity. Similarly, areas where algae beds are present such as kelp forests provide important habitats for a range of associated species. Where kelp beds are present they are generally tracked as targets. In some cases submerged aquatic vegetation may be tracked as an ecological system, generally if it can be detected by remote sensing, but detail about species composition is unavailable. Recent advances in the processing of remote sensing information have led to new techniques for mapping the distribution of coral reefs, sea grass meadows, kelp forests, and other marine systems.

Surrogate targets

Surrogate targets are developed as a strategy to address critical information gaps relating to species distributions and habitat utilisation requirements. Three distinct classes of surrogate models are generally employed:

- ✓ **Inter-tidal Systems**: based on shoreline geomorphology and sometimes submerged biological features such as kelp forests, sea grasses, and shellfish beds.
- ✓ **Benthic topology**: mapping sea floor topography is typically used to delineate abiotic habitats (often substrate and landform types) that have strong correlations to species assemblages.
- ✓ **Pelagic models**: that characterize different habitats and habitat utilization patterns in the water column or at the sea surface.

Although detailed information exists relating to the distribution of a few species in the **inter-tidal zone**, many are still poorly described or not yet mapped. However, there are often strong correlations between species assemblage patterns and coastal geomorphology, substrate type, and wave energy. Based on these associations shoreline characterisations can be created to distribute and map these variables into significant categories, which while certainly not being 100 per cent efficient in capturing the biological variability can provide a reasonable first approximation of habitat variability. Surrogate targets are often employed to ensure that a broad range of habitat types is represented in protected areas design, but it is important to note that these "surrogates" are only estimations and it is recommended that this level of uncertainty be reflected in planning scenarios. Many surrogate target classifications are based on expected correlations between physical environments and species habitat utilization. As these assumptions are tested it is expected that the processes can be refined to increase accuracy.

Benthic topographic characterizations are often developed to enable the range of variability of abiotic habitats on the sea floor to be tracked. Benthic complexity or rugosity is well known to correspond to higher levels of species diversity and greater species abundance in many areas; for instance specific topology can indicate likely areas for spawning aggregations. While some benthic habitat characterizations are developed to track particular features of known biological significance, others are developed to define or categorize entire study areas. When developing benthic topographic surrogates, caution should be used in order to avoid overprotection or areas with uncertain biological significance.

In most cases the biology and hence the conservation needs of **pelagic environments** are not well known. Most of the management effort is focused on fisheries and sustainable fishing practices and in consequence current fisheries management models may offer the clearest avenues for establishing biodiversity representation in pelagic habitats. In addition to fisheries models, areas of cold water "upwelling" are generally nutrient rich and have high productivity, which often attract important biodiversity elements and these features are therefore often included in marine conservation plans as significant focal biodiversity elements. Similarly, primary productivity from algae can be tracked by satellite, and areas of high primary productivity can be employed as surrogates. Seamounts have often been found to harbour high levels of diversity and while many seamounts have not yet been surveyed, these areas are often used as surrogates for the diversity expected to exist there.

There are several species with habitat requirements in both marine environments and also in freshwater or terrestrial environments. These species may need to be targeted in gap analysis for each environment where they have habitat requirements. Similarly, the transition zones between marine and terrestrial, and between marine and freshwater should be considered for ecosystem targets in each analysis.

Tools – a range of international and national resources are available, for instance

- ✓ Oceanic Biogeographic Information System (OBIS): the information component of the Census of Marine Life, a network of researchers in over 45 countries engaged in a 10-year initiative to assess and explain the diversity, distribution, and abundance of life in the oceans - past, present, and future. OBIS is a web-based provider of global geo-referenced information on marine species [http://www.iobis.org/Welcome.htm]
- ✓ Application of Natura 2000 in the Marine Environment or other Natura marine reference [http://www.bfn.de/09/natura2000marin.pdf#search='Natura%202000%20marine']
- ✓ Marine Life Information Network for Britain and Ireland (MarLIN) [http://www.marlin.ac.uk/]
- ✓ Coastal and Marine Resources Information System (CMARIS): devoted to the collection, organization, storage, retrieval and dissemination of information on coastal and marine resources in GIS format and relational databases of non-geocoded data and information [http://www.cmaris.net/theproject.html]

Protected Areas

Marine resources have been negatively impacted by human use patterns in many areas. Habitat destruction, over exploitation, and pollution are all primary concerns and many more factors are also significant threats to marine diversity and productivity. To maintain and protect marine diversity, marine protected areas (MPAs) have been established in a diverse array of geographies and for a range of purposes. IUCN The World Conservation Union defines Marine Protected Areas as any area of inter-tidal or sub-tidal terrain, together with its overlying waters and associated flora and fauna, historical and cultural features, which has been reserved by law or other effective means to protect part or all of the enclosed environment. MPAs have been found to offer considerable value for the protection and management of marine resources[3 4] and offer one effective strategy for maintaining biodiversity in the marine environment. While most MPAs offer some form of protection for certain resources, many are not comprehensive in providing protection for all species and ecosystems found there. The IUCN management categories offer one approach to classifying the different forms of MPAs according to management objectives. Marine reserves general restrict extractive uses and activities which degrade biological habitats. They offer one important strategy for maintaining biological diversity, but should not be relied upon as a single solution for management. Reducing the effects of pollution from land and freshwater are important resource management strategies as are fishing gear restrictions, catch limits, and other fisheries management techniques, such as timed closures.

When reviewing existing MPAs, it is important to recognize the level of protection provided by each designation and any weaknesses of gaps in the protection provide to biological resources. There are more than 100,000 MPAs already in existence, and these management designations have great variability both in their mandate as well as their effectiveness.

Analysis
Marine reserves and other areas established with biological diversity conservation as part of their mandate should be included in marine gap analysis and should also serve as a starting point for developing future scenarios for marine biodiversity protection. Other forms of MPAs will need to be evaluated to determine their significance for measuring existing biodiversity representation and determining gaps. While many of the forms of existing marine protection designations may be considered inadequate for maintaining marine diversity, they do offer an existing commitment to management of marine resources and recognition of their value. With less than 1 per cent of marine habitats under protection nearly all targets will have representation gaps in initial assessments.

While identifying the needs for adequate representation should be the top priority, efforts should be made to recognize existing designations. The World Database on Protected Areas maintained by UNEP-WCMC contains information on an existing collection of marine managed areas, many of which have boundary definitions available. Additionally, this database offers a well developed information structure for recording and reporting management status and detailed information associated with MPAs.

Network Design
Given the urgent need for protection of marine biological resources it is recommended that high priority areas be identified and that the process of establishing management scenarios for marine resources be developed in areas where implementation can move forward. In many cases the benefits of MPAs are already well known and the need for increased marine management is recognized. Many coastal countries have already initiated processes for establishing MPAs.

The Ecology Centre of the University of Queensland and the Great Barrier Reef Marine Park Authority have developed a tool and process for designing representative networks of MPAs. The tool, MARXAN, uses geospatial information and a set of explicit representation criteria to develop alternatives for MPA networks. The process is highly adaptable and repeatable, enabling stakeholder participation and an on-going process for refinement. While there are several tools which are available to assist in MPA site selection, it is the process of establishing which species and ecological systems need to be represented, developing representation criteria and mapping the distributions of these resources which are expected to require the largest investment of time and resources.

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