Managing marine environments: an introduction to issues of sustainability, conservation, planning and implementation

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ABSTRACT

The capacity of human activities to have significant impact on marine environments was not regarded as a serious issue until the middle of the 20th century. It is now regarded as a matter of increasing urgency but the evolution of appropriate management measures presents several challenges. This paper discusses the nature and scale of marine ecosystems, their linkage through the water column and how these raise management requirements that are not easily addressed through terrestrial concepts of jurisdictional boundaries and individual rights of access or ownership. It concludes by presenting the case for a marine implementation of multiple use management characterised by a core component of highly protected reference or sanctuary sites within a larger ecosystem-scale area managed for verifiably sustainable use and providing effective buffering for highly protected coresites.

Key words: Marine ecosystem, marine biodiversity, marine environment management, scale and linkage, conservation, sustainable use,Marine Protected Area

Introduction

From at least the 16th century people involved in resource management were aware of and increasingly concerned at the impact of human activities on what we now call sustainability, conservation and cultural amenity of terrestrial environments. Grove (1995) provides a discussion of the origins of environmentalism from 1600 – 1860, covering concepts of conservation, preservation and protected areas developed through the work of landowners and managers. By the second half of the 19th century these were reflected in the concepts of National Parks and the beginnings of scientific approaches to sustainability of agriculture and forestry.

An appreciation that marine environments could also be vulnerable to human impacts came much later. T. H. Huxley headed a Royal Commission into the collapse of the British North Sea Herring fishery in the late 1890s. In his report he denounced as absurd the suggestion that humans were able to have significant widespread impacts upon marine environments (Cushing 1988). Since the 1960s, new technologies have removed many of the dangers and most requirements for skill in finding marine resources. The nature and volume of wastes, by products and incidental runoff from human terrestrial activity were such that PCBs are found in the body fats of animals and plants in the remotest oceans. Kurlansky (1999) made it chillingly clear that by the close of the 20th century humans had and were determinedly applying the capacity to have significant impacts on marine environments.

Despite the accumulating history of impacts, the cargo cult concept of the seas as the last frontier on the planet, unexplored, under-exploited and a source of salvation in the face of depleted or overburdened terrestrial systems, is still widely held. For countries such as Australia that have claimed large Exclusive Economic Zones the issue of identifying, managing and maximising the benefits of those zones has national significance. A series of reports and inquiries such as McKinnon *et al.* (1989) and the Resource Assessment Commission (1993) have underpinned progress from cargo cult to national policy (Commonwealth of Australia1998). Despite this progress, Australia's Oceans Policy is not widely known and many of the concepts are not intuitively obvious for people with little or no experience of the dynamics of marine environments.

The purpose of this paper is to introduce and discuss a number of the key concepts as well as the issues of scale and process that arise when seeking a sustainable balance in the management of marine environments. In many cases the references are to textbooks that contain more detailed coverage of the issues.

The nature of marine environments

The supporting and linking medium of marine environments is seawater. It is 80 times as dense as air, enabling it to support and carry large amounts of biomass with little energy expenditure. The water column alone is a comprehensive environment or habitat providing

Pp 41 - 48 in *Conserving marine environments. Out of sight out of mind*, edited by Pat Hutchings and Daniel Lunney 2003. Royal Zoological Society of New South Wales, Mosman, NSW.

the complete support, food and reproductive needs for many species. While there are some insects, birds and bats that operate in a somewhat analogous manner in the air column, the scale and the processes differ. Energy expenditures for maintaining position in the air column are generally high. Food is derived from the land surface and is generally not produced or maintained within the air column. Critical stages including reproduction occur on the planet surface.

Seawater is a benign environment for biological cells. Seawater is chemically buffered and is a good solvent. It is physically buffered so that changes of 1 degree Celsius in a 24 hour period are unusual where daily changes of 10 or 20 degrees are common in continental terrestrial environments. In seawater complex mechanisms for conserving moisture, maintaining temperature, maintaining pH, expelling or neutralising toxic chemicals are not nearly as critical as they are in terrestrial environments, particularly for small organisms. For a fuller discussions see Open University (1987).

The water masses of major ocean current systems are very large. In the course of their movements, water masses may acquire nutrients or pollutants from land through river runoff or from deeper waters through upwelling. An object carried in a 1 knot current will travel 700 miles or more than 1000 kilometers in a month. The paths of water movement and the boundaries of water masses vary in complex 3 dimensional and multidirectional interactions between tidal, atmospheric and geostrophic factors. Seasonal and episodic reversals of dominant or common water flow directions are not unusual.

The upper layers within reach of sunlight are the sites of primary productivity by phytoplankton and each water mass contains the elements of several distinctive ecological communities. Within each water mass there are species that pass their entire life drifting or swimming in the water column without any contact with the seabed or geological substrate. They depend directly or through the food web on water column primary productivity. Water masses also usually transport and nourish eggs, larvae, juveniles and propagules of many species that have very different scales of adult range. At one extreme are pelagic or migratory species such as tuna and at the other are fixed or attached species such as corals.

When most seabed species settle or adopt a seabed territory – whether permanently or for critical life cycle stages - they continue to depend on the water column for nutrients, food, reproduction and development. For particular species there may be relatively limited sites within the area affected by a water mass where the conditions of depth and shelter and seabed substrate provide the quality of habitat required for their settled or territorial stage. The species compositions of seabed communities associated with mud are usually very different from those of gravel or rock substrates, yet the larvae for many different communities are transported and nourished and compete in the same water mass. However, where separate sites with suitable substrate exist within the area covered by a water mass, the same communities may occur at widely separated locations.

In terrestrial systems atmospheric linkages are important for transport of pollen, spores, seeds, birds, bats and insects but with no atmospheric primary productivity the nourishment, reproduction and development of aerial species depends on surface conditions.

Within catchments, downstream linkages are often substantial but they are essentially two-dimensional and unidirectional. There are very few examples of significant reversals of flow within catchments or of flows between catchments. The physical and chemical properties of land-forms, water courses and soils are fundamental to the primary productivity of most terrestrial ecosystems. The high levels of endemism in terrestrial communities arise because of functional isolation. Many habitats are confined to precise geographic locations because of soil distribution, catchment flows, or blockages by mountain ranges or water bodies.

While there are parallels for many of the processes in marine and terrestrial environments there are also major differences. In particular, geographic scale is generally more substantial and linkages are more pervasive. In the sea, the transport of nutrients, recruits, propagules and pollutants is often at such a vast scale that causes and effects, benefits and costs in interactions between human activities and natural environment processes are linked even though geographically they are widely separated. On land there may be large-scale linkages in major catchment systems but distinctive ecosystems, restricted to specific sections of catchments, or areas of particular soil types and rainfall regimes are relatively common. Such ecosystems may have linkages to more distant upstream areas but can reasonably be regarded as discrete entities.

Cultural views of marine environments

The sea is familiar to coastal people but the abundant microscopic plants and animals and most of the processes of marine ecosystems are invisible. Marine plants and animals are strange to those who are used to terrestrial ecosystems. Humans do not relate easily or intuitively to marine ecosystems and the scales of space and time underlying them. This may be illustrated by considering some common cliches relating to the sea.

The bountiful ocean and fishermen's luck

For many people living on the coast, the sea had been traditionally an abundant but mysterious source of food and other materials. There may be seasonal patterns in the arrival and abundance of fish and invertebrates, but even with limited technology for pursuit, capture or preservation many communities prospered thanks to an apparently endless supply of fish. For those prepared to face the physical or financial risks, fishing could provide a quick path to capital accumulation. Kurlanksy (1999) describes the importance of the Atlantic cod fisheries in providing food and capital for European and North American development. In modern economies, this is expressed in policies of nations that still subsidise national fishing fleets in order to achieve a source of food outside global currency trading.

Concepts of the bounty of the ocean, and of its inexhaustibility are captured in aphorisms of many coastal cultures such as "always plenty more fish in the sea". Other concepts recognise that all fishermen are not equally successful calling into play "fishermens luck" or even skill and experience. But the concept that human activities might have an effect or damage the traditional bounty by overfishing is not encompassed in many social traditions. Despite the evidence of 40 years of increasingly competent marine science, the catches of the best years are widely and wishfully considered "normal" and anything else is first explained by bad luck. There is an enduring mythology that fish are cunning secretive prey – making technical aids essential to combat bad luck.

For most of the history of fishing it has generally been the case that hard work, better equipment and the latest technology have improved catches. But the experience of the last two decades demonstrates that, for most marine stocks, fishing capacity now significantly exceeds the productive capacity of fish stocks. On the basis of United Nations Food and Agricultural Organisation calculations the global fishing fleet overcapacity was conservatively estimated to be 30% (Garcia and Newton 1997).

Peril on the sea

The sea has always been a place of danger with the risk of sudden death through drowning, shipboard accidents, shipwrecks, disease, attack by marine creatures, and piracy. Prayers for those in peril on the sea address the fear of seafarers and those farewelling sailors that a ship might never return and its fate might never be known. Modern technologies may limit or may give us the ability to avoid the worst of the dangers but the sea is still dangerous**.**

In many cultures men who went to sea were regarded with respect, even fear, and seen as somewhat apart from most normal terrestrial society. Young men in trouble would run away to sea to find their fortune. The relationship between the seafarer and the sea was expressed in phrases such as "the siren call of the sea", "the harsh mistress" and "the cruel sea". Seafaring has a long history of brutality and occasional acquisition of great wealth.

Cold, slimy and slippery fish

From the perspective of humans as members of a species that commits substantial investments of energy and resources in producing and rearing young, the processes of reproduction of marine fish and invertebrates are mysterious, counter-intuitive and even degenerate. Most fish and invertebrates produce vast numbers of eggs, with the larvae developing invisibly as part of the microscopic planktonic community. For the vast majority there is no parental protection or instruction of the young. Typically there is no contact between adult and larval generations and if it does occur the adults may cannibalise the young. Folk and children's stories anthropomorphise and identify with the characteristics of terrestrial mammals and birds. In contrast, "cold-blooded", "slimy", "slippery", "wet", "spineless" – words that describe fundamental characteristics of most marine animals - are used as expressions of insult or contempt in many cultures. Fear of the unfamiliar is compounded by the fact that some of the largest of sea creatures- "monsters of the deep" - can attack and kill people while some of the smaller creatures are venomous.

The fear is sublimated by demonisation of marine creatures and has been offset by mythologising the valour of those who pursue and vanquish monsters of the deep. Examples include The Old Man and the Sea (Hemingway 1952), Moby Dick, (Melville 1851) and Jaws (Benchley 1974). The process is maintained with such displays as Vic Hislop's Great White Shark Exhibition at Hervey Bay in Queensland (http://www.ozmagic3.homestead.com/VicHislopSharkExpo.html.

Common property resources

For much of history a ship on the high seas - beyond the reach of a cannon on land - has been largely beyond the reach of national jurisdictions. In Roman law, the concept was established that the sea, the seashore and their products are common to all, freely available to the bold and ingenious (Halsbury's Laws of England 1954). The concept of the sea as global commons underpins many modern legal systems.

The concept of managing marine environments brings substantial challenges to old patterns of thinking, especially to legal systems built over centuries of common and case law applied to concepts of the ownership of land and natural resources, with permanent clearly identifiable boundaries between properties and jurisdictions. To manage large marine ecosystems, with scales and linkages that cross the boundaries of several nations, requires concepts and practices that can reach across national and sectoral partitions.

In some coastal areas and countries around the world there are continuing traditional group rights and practices of management of access to and sustainability of marine areas and resources (e.g. Johannes 1981). They reflect concepts of individual or collective ownership, stewardship, rights and limitations on access or fishing that do not sit easily with the concept of common property. In response to fisheries collapses under open access, similar concepts of rights and limitations have emerged in the development of modern fisheries management regulations with licences, permits or quotas limiting fishing effort to levels that are predicted to be sustainable.

The reward and retreat from urban realities

In the late 19th century, sea bathing, boating and sea fishing ceased to be simply the lot of the coastal poor but were welcomed as recreational activities for the leisured classes. The seaside became accepted as a place for holidays and summer retreats from crowded and diseased cities. In Australia, with almost all of its major cities on the coast, coastal leisure activities rapidly became part of national culture. Phrases such as "gone fishing", "seaside holidays", and "retire to the coast" became expressions of a paradigm of freedom with exciting and romantic activities very different from everyday life.

In 20th century Europe, America and Australia, a pattern was repeated of the "discovery" of unspoiled coastal towns and villages, acquisition of property for summer holiday retreats, the development of rental properties, hotels and resorts with the accompanying growth of the commercial and service infrastructure (Kenchington 1993, Gunn 1994). Increasingly the holiday homes became retirement homes with year round occupancy and the settlements and their impacts on the coastal environment continue to grow.

A consequence of this has been the development of an informed public enjoying the benefits of coastal amenity, identifying high cultural values in unspoiled coastal areas but recognising and becoming actively concerned at pollution and other impacts.

Managing for sustainability

Issues of coordination and scale

Underlying the structure and operations of most governments and businesses are concepts of rights and responsibilities relating to land and property. The owner or occupier of land generally has freedom to use or manage that land without restrictions unless neighbours or other parties can demonstrate actual or probable damage. The onus is on the affected parties to object and to demonstrate that their rights or amenity have been or are likely to be damaged. This may be summarised as "anything that is not prohibited is allowed", or from the perspective of containing impacts and minding one's own business, "good fences make good neighbours".

Flowing from these concepts are governance arrangements based on localised responsibility for land and resources management and clearly allocated sectoral responsibility for broader issues. Responsibilities are defined in relation to geographic boundaries that more often reflect cultural history of acquisition or definition of property than functional considerations of the physical or biological processes driving the natural resource base.

Most governance systems from local government to international government organisations are based on robust competitive sectoralism. Decision-making and agency responsibilities for sectoral activities are clearly defined. Such systems are often characterised by grudging interagency collaboration in an overarching framework for addressing contentious issues involving two or more sectors.

The common property assumptions of legal systems derived from Roman law confer rights to use or enjoy the common good, subject to the responsibility of not damaging it or preventing the access, use or enjoyment of others. The onus is on the intending user to consider these matters and, if required, demonstrate that the use will not damage the commons. This may be summarised as "anything that is not allowed is prohibited".

National maritime jurisdictions, resource entitlements and responsibilities are defined by arbitrary lines derived from national coastal baselines. They are rarely at a scale that bears any functional relationship to the processes of large marine ecosystems. As technologies have increased the reach and impacts of human activities beyond the coast and shallow seas to the deep oceans, the jurisdictions of coastal states have extended further seaward. In many parts of the world, particularly enclosed marine areas such as the Mediterranean, Baltic and South China Seas, multiple national jurisdictions intersect in single large marine ecosystems. Regional and international mechanisms have been developed that provide the basis for governance.

In many nations marine matters are a responsibility of national or federal government, while management of land may be a responsibility of local or state government. In most marine jurisdictions governance has been provided by extension of the concept of sectoralism although, until relatively recently, the only substantial sectoral interests have been those of fisheries and shipping. New technologies, and national responsibilities for sustainability of activities in marine jurisdictions and economic zones, have increased the spread of sectoral interests in marine areas.

The scale and processes of marine ecosystems, their linkages to the land and the intertwined interests of sectors and jurisdictions raise the need for effective mechanisms of coordination or integration of policy and management for human activities and impacts.

Environmental goods and services

Marine ecosystems provide some goods and services that are obvious and easily valued such as wild-caught food, rocks and sediment for construction materials and shallow areas that can be alienated or reclaimed to create more land. Other goods and services may be less obvious and their value or cost only appreciated when they have been damaged or removed such as coastal protection from sand dunes or shallow reefs. Others, such as disposal of wastes by dilution in coastal waters, may have costs that are indirectly reflected, for example in the decline of local fisheries because of pollution of nursery or breeding areas.

Because they have been long-standing benefits, environmental services have tended to be taken for granted. There has been a long history of unrecognised environmental subsidy to terrestrial economic activity with environmental costs being implicitly accepted as reasonable. Examples include collapsed fish stocks and degraded marine ecosystems from the pursuit of cheap food and marine pollution from inadequate treatment of terrestrially-derived wastes.

Before it was accepted that human activities could have significant impacts on marine ecological systems, there was little appreciation of their economic or social importance. Only recently have studies such as Cesar (2000) attempted to identify the full range of values and benefits of marine ecosystems and of the costs that are likely to be incurred to maintain or substitute for them.

There are still immense and increasing human pressures on marine ecosystems. The issues of overcapitalisation and perverse subsidies in the global fishing fleet are recognised. The same is true of the issue of meeting the costs of waste management. In the plan of implementation of the World Summit on Sustainable Development (WSSD 2002) the global community has committed to achieving sustainability of fisheries and marine ecosystems, but it may take many years to achieve.

The long-term goal of management of marine ecosystems should be sustainability in environmental, social and economic terms. The immediate issues are to achieve the objectives of conservation and maintenance of biological diversity and ecosystem processes. For a discussion of the issues involved in seeking a sustainable balance see Lawrence *et al.* (2002).

The role of protected areas in managing marine environments

In 1988 the IUCN adopted the following resolution calling for the establishment of a global representative system of marine protected areas.

> "To provide for…the 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 marine protected areas and through management in accordance with the principles of the World Conservation Strategy of human activities that use or affect the marine environment."

This resolution links the issues of marine area protection and sustainability. It places marine protected areas (MPAs) as part of the central machinery of management for sustainable use, understanding and enjoyment as well as biodiversity preservation.

MPAs are now recognised as a mainstream management tool for conserving biodiversity in the world's oceans and seas. Several international, national, and local level mechanisms promote them as vehicles for addressing the needs for long-term conservation of biodiversity, and verifiably sustainable use of marine resources (Kelleher and Kenchington 1992; Agardy 1997; Crosby *et al* 2000; National Research Council 2000).

The first MPA was proclaimed in 1879 over intertidal areas associated with Royal National Park, on the southern outskirts of Sydney, Australia (Brown 2002). Several more were proclaimed early in the 20th century and 430 MPAs had been created by 1985 (Silva *et al.* 1986) but most covered relatively small coastal areas. Many more MPAs were proclaimed in the last two decades of the 20th century. By 1995 there were globally at least 1,306 sub-tidal MPAs with a median size of 1,584 hectares and virtually every coastal country had implemented some form of MPA (Kelleher *et al.*1995).

The objectives of MPAs have covered a very wide range of objectives from total exclusion other than for scientific research to management of recreational and commercial fisheries. On the basis of permitted and prohibited activity, the range and combination of controls and the legal basis of protection, Silva *et al.* (1986) listed 91 different categories of protected area. The complexity of the marine environment and resource management issues has increased in the last 20 years and a similar analysis today would yield a much higher number.

It has been clear since the review of Silva *et al.* (1986) that the array of goals for MPAs, and their order of priority, varies enormously from place to place. While some MPA advocates have sought a single, simple, specific, yet broadly accepted definition of what constitutes a marine protected area, this goal has not been achieved. However, it is practical to adopt the single, general umbrella term - marine protected area - which can apply to a wide range of different habitat protection strategies, with a broadly accepted typology of terms that clearly define each individual MPA according to objectives and allowed purposes of use and entry.

The most commonly used definition of MPA internationally is that provided by IUCN:

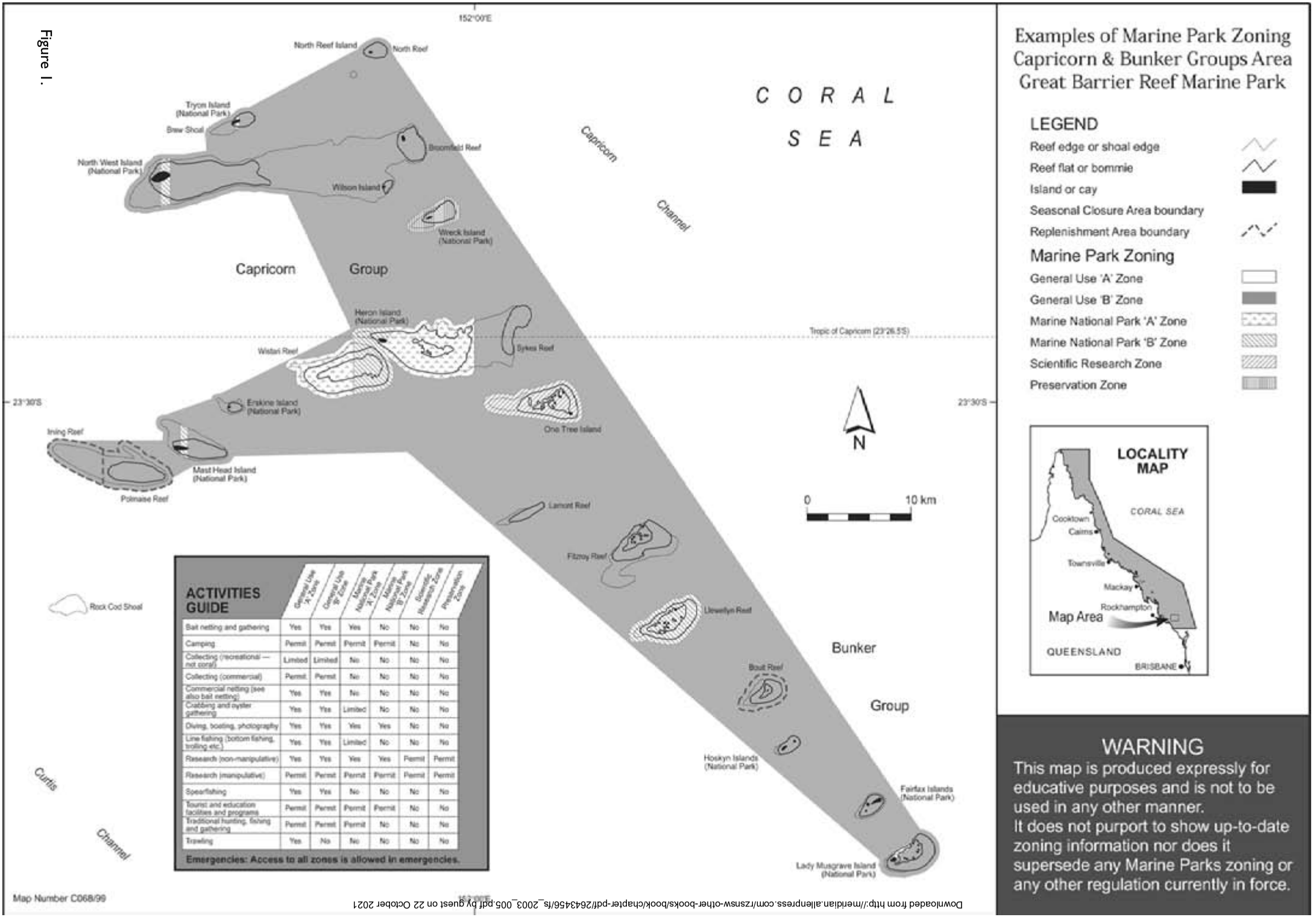
> "any area of inter-tidal or sub-tidal terrain, together with its overlying water and associated flora, fauna, historical, or cultural features, which has been reserved by law or other effective means to protect part or all of the enclosed environment" (Kelleher and Kenchington 1992).

The IUCN has divided Protected Areas both marine and terrestrial into six categories depending on their objectives (IUCN 1994; Kelleher 1999).

Table 1. IUCN Protected Area Categories

Category	Title	Main Protected Area Management Objective
I	Strict Nature Reserve	Science or wilderness protection
II	National Park	Ecosystem protection and recreation
III	Natural Monument	Conservation of specific natural features
IV	Habitat/Species Management Area	Conservation through managed intervention
V	Protected Landscape/Seascape	Landscape/seascape conservation and recreation
VI	Managed resource Protection Area	Sustainable use of natural ecosystems

Figure 1.



Examples of Marine Park Zoning Capricorn & Bunker Groups Area Great Barrier Reef Marine Park

LEGEND

- Reef edge or shoal edge
- Reef flat or bommie
- Island or cay
- Seasonal Closure Area boundary
- Replenishment Area boundary

Marine Park Zoning

- General Use 'A' Zone
- General Use 'B' Zone
- Marine National Park 'A' Zone
- Marine National Park 'B' Zone
- Scientific Research Zone
- Preservation Zone

WARNING

This map is produced expressly for educative purposes and is not to be used in any other manner.
It does not purport to show up-to-date zoning information nor does it supersede any Marine Parks zoning or any other regulation currently in force.

Any of the categories can have a role in marine biodiversity management. However, there are two essential elements in a comprehensive strategy for management of marine biodiversity and ecosystem processes. One is large area ecosystem scale management of resources, uses and impacts to ensure that they are sustainable. The other, incorporated within the strategy, is the establishment of site scale management through strictly protected areas, national parks or no-take reserves in which no harvesting of resources is permitted at any time. In terms of the IUCN categories this equates to overall category VI with core areas of category I or II.

The overall category VI provides a framework within which uses are permitted provided that they are managed on a basis of objectives that address demonstrable sustainability. Whether these objectives are achieved through conservation legislation or fisheries legislation makes little difference provided they are rigorously defined and enforced and that there is a systematic evaluation of performance in achieving them.

The category I or II inclusions address protection of representative areas of marine biodiversity and of sites critical for breeding, feeding or migration of rare, endangered or economically significant species. They may also provide refuges for intensively exploited species, breeding stock buffers against recruitment failure and centres for dispersal of eggs and larvae and for spillover emigration of adults.

The other categories also have a role in marine ecosystem management. Thus, category IV – Habitat/ Species Management Area can play a significant role in protection of seasonally important breeding grounds of turtles or fish or feeding areas for migratory species.

Categories II, III and V have roles in managing recreation and tourism so that they do not damage the resources. They can also contribute to the important tasks of education of visitors about the importance and value as well as the beauty of marine ecosystems.

Conclusion

True sustainable use approaches depend in large part on minimizing user conflicts through multiple use zoning (Lawrence *et al*. 2002; Eichbaum *et al*. 1996; Crosby *et al*. 2000) and empowering local communities in decision-making for managing local areas.

Many MPA management plans propose zoning schemes that can divide the MPA into various areas with different degrees of protection (fig. 1). They reflect the concept that has been long articulated by the UNESCO biosphere reserves (Batisse 1982, Kenchington and Agardy 1990; Bridgewater 1999). Multi-use zoning is a way to accommodate multiple users in areas where coastal populations, tourism, and resource use conflicts are on the rise (Kenchington 1990). Arguments supporting zoning within multiple use MPAs include those put by Pressey and McNeill (1996) who consider broad-area integrated management more effective than a series of small, isolated highly protected areas because:

- ecologically speaking, zoning recognizes temporal/spatial scales at which ecological systems operate and ensures the entire area remains viable as a functioning ecosystem;
- practically speaking, it is easier to manage; it buffers and dilutes the impacts of activities in areas adjacent to highly protected 'core' areas; and
- socially speaking, zoning helps to resolve and manage conflicts in the use of natural resources and ensures all reasonable uses can occur with minimal conflict.

In terms of costs and practicality of implementation, clearly designed integration of Category I/II MPAs within larger multi-use Category VI MPAs will generally have lower infrastructure, social and administrative costs per spatial area than a series of separately and competitively administered small Category I and larger Category VI MPAs.

Arguably, the most important tasks are to identify and report to the management and scientific communities on the characteristics of successful examples of integrated, equitable marine and coastal management and to translate these into culturally appropriate enforceable forms for other situations that can meet the objectives of maintaining biodiversity.

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