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INTERNATIONAL EXPERIENCE OF MARINE PROTECTED AREAS AND THEIR RELEVANCE TO SOUTH AFRICA

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Marine protected areas (MPAs) have become necessary to counter modern threats to marine biodiversity and the sustainability of fisheries. Sensitive habitats, including coral reefs, estuaries and mangroves, have been effectively protected in large MPAs, which control resource use. Protection from pollution and physical destruction by fishing gear are important functions of MPAs in tropical and temperate regions. MPAs have been used to protect endangered species and to allow population recoveries. The advantages for fishery management include maintenance of spawner biomass, improvement of yield, simplified enforcement, research opportunity, insurance against stock collapse and maintenance of intraspecific genetic diversity. MPAs can be small with narrow, focused objectives, or large with core areas, buffer zones and exploitable areas to provide an integrated management approach. A variety of design considerations, based on ecological, fishery and socio-economic conditions, is presented. Optimal size and spacing have not been extensively tested and only theoretical arguments guide the choice of how much to protect. The process of establishing an MPA can be initiated by local communities or by governmental authorities. The former has better public support, whereas the latter promises a well planned system of MPAs. Community and industry involvement in the establishment process is essential for the effective functioning of MPAs. Successful MPAs are administered by national programmes and managed according to management plans. Monitoring, communication and enforcement are integral components of MPA management. South Africa is party to a number of international conventions which promote the designation of MPAs. Better protection of the physical marine environment, incorporation of MPAs in fishery management procedures and the management of MPAs are the major areas where South Africa can improve its marine protection.

Human activities around the world have decimated stocks of living marine resources and caused irreversible losses to marine biodiversity. The conservation of marine biodiversity is now a major international cooperative venture (de Fontaubert *et al.* 1996). Protection of terrestrial biodiversity is achieved largely by the designation of national parks, reserves and sanctuaries. In the marine environment, protected areas can play an equally important role, but the use of reserves and sanctuaries is relatively new. The first statutory marine protected areas (MPAs) in South Africa, the U.S.A., New Zealand and the U.K., for example, were established in 1964, 1975, 1977 and 1986 respectively (Ballantine 1987, Kayes 1987, Pritchard 1993).

An application of the terrestrial experience of reserves to the marine environment is inappropriate because the physical, biological and political nature of the two environments is fundamentally different (Kelleher and Kenchington 1992). Dispersal of pollutants and biota in marine ecosystems is more extensive than in terrestrial systems because seawater is an effective solvent and a carrier of propagules. Habitat alteration is the major cause of concern for terrestrial conservation, whereas in the marine environment, it is fishing (Boehlert 1996). In most marine environments, there is no functional equivalent of soil, that sensitive, biophysical medium that forms the basic habitat of terrestrial primary producers (Hockey and Branch 1994). Notable exceptions include coral reefs and estuaries. Within each country's Exclusive Economic Zone, territorial rights of ownership in the sea are rare, unlike on land, where they promote resource husbandry and facilitate the promulgation of nature reserves and parks.

MPAs are now at the leading edge of marine conservation for many countries. They are reservoirs of biodiversity and serve as a good base for marine research and education programmes (Gubbay 1995). In addition to conserving natural ecosystems, MPAs are advocated as a means to rebuild depleted stocks, to improve fishery yield and to provide insurance against stock collapse (Clark 1996, Roberts 1997). However, the use of marine reserves in fishery management is proving to be its most controversial application.

A Marine Reserves Task Group was established with the overall leadership of the Sea Fisheries Research Institute (SFRI) under the auspices of SANCOR, the South African Network for Coastal and Oceanic Research, in 1996 to draft a policy on the use of MPAs in South Africa. The current paper contributed towards the process by reviewing various aspects of

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MPAs, including functions, design, administrative structures, management procedures and international protocols. This is a vast subject, and therefore only a broad outline is presented here. Specific aspects are detailed in Salm and Clark (1984) and Gubbay (1995) for a discussion on planning and management of MPAs, Roberts and Polunin (1991) and Rowley (1994) for reviews on MPAs in fishery management, Bohnsack and Alt (1996) for a discussion of MPAs and the conservation of marine biodiversity, Kelleher *et al.* (1995) and Silva *et al.* (1986) for descriptions of all existing MPAs, Hockey and Branch (1994) and Carr and Reed (1993) for discussions on MPA design principals, and Farrow (1996) for an economic perspective.

"Marine Protected Area" (MPA) is the term used to describe the subject of this review, namely any part of the intertidal or subtidal terrain that is reserved by legislation for protection of biotic and abiotic resources. Various other terms are frequently used and reflect a great diversity of design and function, but their definitions are not consistent from one country to another. These include: biosphere reserve, fishery reserve, harvest refuge, marine reserve, marine park, marine sanctuary and no-take marine reserve.

FUNCTIONS OF MARINE PROTECTED AREAS

A MPA is nothing more than a particular management strategy applied in a defined area. Why can control measures, aimed at sustainable resource use, not be applied equally throughout equivalent habitats and socio-political systems? Why should some areas require special protection? Many of the reasons are obvious, but others are less intuitive, and have emerged from recent biological, fishery and socio-economic research.

The major functions of MPAs may contribute towards either the conservation of habitat, the conservation of species or the management of fisheries. These functions are discussed in the sections which follow. Other functions include scientific research, education and tourism. The value of undisturbed ecosystems for scientific research has been recognized for a long time. Most research conducted in MPAs can be regarded as supporting one of the managerial tasks listed above. Tourism and education are also served by MPAs and, reciprocally, they are necessary for the financial and popular support of conservation. However, these topics are not considered here because their scope goes well beyond any discussion of MPAs. They are detailed in Dixon (1993), Dixon *et al.* (1993) and Kaza (1995).

Many MPAs are large and serve multiple functions. Given the frequent opposition to the establishment of MPAs, only those that offer several benefits are likely to reach the stage of statutory proclamation. One of the functions of MPAs may be to integrate various activities of the coastal zone, to accommodate a diversity of usage without degrading the resources.

Protection of marine habitats

The ocean appears to be resilient to physical and chemical alteration, because of its large volume, turbulence and high flushing rates, but there are coastal ecosystems and deep-sea environments which have been severely impacted by anthropogenic activity. MPAs play a vital role by controlling activities in sensitive habitats and by preserving representative areas from development, to maintain biological diversity and ecosystem functioning. Marine ecosystems that are most susceptible are those with complex biophysical habitats, including coral reefs, seagrass beds, estuaries and mangrove forests, but severe damage has also been caused to physically dominated systems by pollution and destructive fishing gear.

CORAL REEFS

The degradation of coral reefs is of great concern because they support the greatest biodiversity of any marine ecosystem. Coral reefs need special protection because of their susceptibility to damage and disease. The recovery of coral is so slow that extensive damage is regarded as irreversible on a time-scale of decades. There is no single cause of reef damage, but a variety of problems have been experienced in the tropics of East Africa, the Indo-Pacific and Western Atlantic.

Siltation, trampling and destructive fishing methods are the main cause of coral reef degradation along East Africa and Madagascar (Salm 1983, Odendaal *et al.* 1995). Expansion of coastal communities has led to a profusion of traditional fishermen, which, collectively, present a serious threat to coral reefs. MPAs have been established to protect the reefs in Kenya, Tanzania, Seychelles and Madagascar. Kenyan marine reserves are zoned, with a core Marine Park, in which all biota are fully protected, and a National Marine Reserve, which acts as a buffer zone where traditional, non-destructive fishing practices continue. Reserves in the Seychelles protect reefs from poisoning, dynamiting and spearfishing. Tanzania also has MPAs designed to protect reefs, but poaching is widespread, possibly because traditional fishing practices were not considered in the design of the MPAs. Kimani (1995) notes that the establishment of exclusive nature reserves, where entry is only permitted for special purposes, may be the only way of preserving some of the coral reefs in the region.

More efficient gear has generally replaced traditional methods in South-East Asia, and many of these are extremely destructive. Heavy trawl gear and explosives are commonly used to exploit reef fish, but in the process they cause severe damage to the reef. MPAs have been established throughout South-East Asia to prevent these practices (Alcala 1988, White 1988, Russ and Alcala 1989, McManus 1994, Kelleher *et al.* 1995). Pollution and uncontrolled tourism have become problematic in the more affluent countries with large industries.

Coral reefs in the Caribbean are heavily utilized by fishermen and tourists. The latter have increased tremendously in the past decade and have been blamed for localized deterioration of reefs. Even non-consumptive activities, such as anchoring, SCUBA diving and the use of tripods to stabilize underwater cameras, cause visible deterioration to coral in the more popular areas (Dixon 1993).

Examples of successful MPAs designed to protect coral reefs can be found in Thailand, the U.S.A., Australia and South Africa. The common features of these MPAs are their large size, multiple objectives and zonation, and reef monitoring and education programmes. Their purpose is not to exclude human use, but rather to prevent reef damage. The coral reefs of Thailand's Phuket Island are zoned and managed to fulfil three separate objectives: meeting local subsistence needs, tourism and recreation, and conservation and scientific study (Hale and Olsen 1993). The enormous Florida Keys National Marine Sanctuary assigns reefs into five types of management zones. The overall management plan includes enforcement, monitoring and visitor education programmes and a reef-restoration plan (NOAA 1996a). Covering 350 000 km^2, with 120 core preservation areas, Australia's Great Barrier Reef Marine Park is recognized as a Biosphere Reserve (Kelleher and Kenchington 1982). A zoning plan serves the combined needs of conservation, commercial fishing and tourism, although some difficulties are still encountered with regard to non-sustainable fishing, land-based pollution and inadequate policing (Sobel 1993). South Africa's contiguous St Lucia and Maputaland Marine Reserves protect the country's tropical corals. All forms of bottom fishing are prohibited, whereas diving and game fishing are developed as important tourism attractions.

ESTUARIES AND COASTAL EMBAYMENTS

Estuaries are the nursery grounds for many coastal fish species; they support commercial, recreational and artisanal fisheries and mariculture. On a per-unit-area basis, estuaries are the most productive habitats on earth. Estuaries have a poor conservation status in most parts of the world, and the reasons are similar throughout. Human settlements usually develop at river mouths, probably as a result of the original productivity of these systems, and because estuaries form natural harbours with ocean access. Poorly regulated activities have destroyed many estuarine habitats by structural development in the estuary, canalization, land reclamation, pollution, mariculture, dredging and trawling. Estuaries are also at the receiving end of any malpractice in the river catchment, including pollution, erosion, excessive water extraction and impoundments. Coastal lagoons and embayments share many of the characteristics of estuaries – they are important for fisheries and are heavily utilized for industrial purposes. Low flushing rates make these areas very susceptible to pollution and eutrophication.

Estuaries fall on the boundary of the jurisdiction of management authorities. They are neither land nor sea and, being tidal, they are usually excluded from river management. In practice the management of all these zones affects the estuary, and unless it is specifically considered in management plans, its requirements are ignored. The U.S.A. system of estuarine protection is perhaps one of the most well developed worldwide. Their National Estuarine Research Reserve System (NERRS) is distinct from the National Marine Sanctuary Program, which by itself recognizes that estuaries are important and have special management requirements. Estuaries require integrated management of the entire river catchment, the coastal zone and the adjacent ocean. NERRS provides this, not by imposing restrictive legislation in estuaries, but rather by facilitating federal, state and local partnerships, which serve to promote informed estuarine management. Public stewardship, education and scientific monitoring are important initiatives of NERRS. Estuarine sites which meet certain criteria are designated for NERR-status, which elevates the estuary to a higher level of management, with access to financial, administrative and technical support. The U.S.A. has 26 NERRs.

Estuarine sanctuaries in Australia are not treated separately, but are lumped in the general category Marine and Estuarine Protected Area (MEPA), of which 228 have been established (Rigney 1990). MEPAs are based on a sustainable use principle, and controlled fishing is allowed in most. Less than 2% of MEPAs are closed to all forms of fishing.

Mangrove forests play a vital role in tropical estuaries by trapping silt and providing nursery areas for fish. Unfortunately, mangroves are frequently in areas which lack the expertise and institutional capacity to manage them and, as a result, there has been a widespread loss of mangrove forests (Salm and Clark 1984). Mangrove deforestation is a serious concern because of their vital role. The Sultanate of Oman's Q'urm Managed Nature Reserve is an example of a MPA which has succeeded in protecting a mangrove forest in the heart of a prime residential area from further urban development and road construction (Salm and Price 1995). Worldwide, there are 700 MPAs which protect mangroves (Kelleher *et al*. 1995), including many on the African continent, but not all of these have been successful. The Mida Creek Biosphere Reserve in Kenya failed to halt the degradation of mangroves, despite its designation as a Biosphere Reserve (Kennedy 1990). Traditional exploitation of mangroves for wood, still permitted in the reserve, is no longer sustainable: the expanding local communities having become increasingly poor and more dependent on natural resources. Kennedy (1990) recommends that a revised management plan should limit the extent of traditional exploitation. In addition, creeping development for tourism in the coastal zone has often proceeded without a sound management plan and stands of mangroves have been cleared in this way.

BENTHIC ENVIRONMENTS

Trawls and dredges modify the sea bed by ploughing, scraping, sediment resuspension, destruction of non-target species and dumping of processed waste (Jones 1992). The extent of the damage is related to the characteristics of the gear, trawling speed, and the rate at which the environment can recover. Deeper areas, unaccustomed to oceanic storm events, and high profile reefs are most severely impacted. In heavily fished areas, like parts of the North Sea, every square metre of ocean floor is trawled several times a year. Comparisons between trawled and untrawled areas have revealed differences in the structure of the benthic habitat and the community composition. Trawling creates a homogenous bottom, to the detriment of large and long-lived epibenthic species. Despite these deleterious effects, designation of "no-trawl areas" to conserve undisturbed benthic communities is rare.

One approach has been to designate no-trawl areas on the basis that trawling is damaging. For example, scallop dredging was shown experimentally to damage the benthic habitat and its fauna, and hence the Nature Conservancy Council of the U.K. proposed by-laws to prohibit dredging within the Skomer Island Reserve (Gubbay 1993). Another approach has been to close areas to trawling to allow fish recovery, with remarkable success in some instances (Pipitone *et al*. 1996), but ambiguous results in others (e.g. Armstrong *et al.* 1993).

Western Australia's Fishing Industrial Council referred to the extensive practice of terrestrial monoculture, and commented that a certain amount of environmental modification is an unfortunate byproduct of large-scale food production or capture (Rigney 1990). Nonetheless, the extent to which the benthic disruption might reduce the productivity of the fishery needs to be assessed. "No-trawl reserves" will be necessary for the study. In some cases, longlining is a viable alternative to trawling, but it has its own attendant conservation problems, notably the incidental mortality of seabirds (Barnes *et al.* 1997).

POLLUTION

Pollution in the ocean is considerably more difficult to contain than in the terrestrial environment, because of the dispersing nature of seawater. Therefore, MPAs must be large to counter pollution problems at the source effectively (Sobel 1993). Two examples of MPAs, from the U.S.A., in which anti-pollution measures are a priority, have the power to stop pollution at the source.

The Florida Keys National Marine Sanctuary (FKNMS) covers 8 899 km^2 of coastal water and one of the most utilized coral reefs in the world. Apart from having the necessary legislation to protect the coral reefs and seagrass beds from physical destruction, FKNMS has a water-quality protection programme as part of its management plan (NOAA 1996a). Water quality problems are controlled at the source, even where this may be inland and, therefore, FKNMS has provided effective control over residential run-off and riverine flow (Ehler and Basta 1993, Barley 1993). The 120 km^2 Stellwagen Bank National Marine Sanctuary was designed specifically to protect an important region for humpback whales, in response to concerns of water pollution and mining (Eldrege 1993). Activities prohibited in the sanctuary include sand- and gravel-mining, ocean dumping or discharging, vessel lightering, alterations of the sea bed, and disturbance of marine mammals, reptiles or seabirds. In addition, the sanctuary can take action against any outside source of pollution which affects it.

The traditional segmented approach to environmental management fails to address problems caused by fluxes across arbitrary boundaries. MPAs are effective in bridging separate authorities to form an integrated management plan. Fortunately, measures to control pollution usually carry widespread community support.

Conservation of species

The subject of marine protection is often more focused than protecting environments. The need to protect one or more species is a strong motivation for a MPA. Criteria which have been used to decide which species are in need of additional protection are seldom objective. Large, air-breathing marine predators easily qualify for protection, because they gain sympathy on the basis of their physical similarity to humans, whereas fish are more traditionally regarded as food (Bohnsack and Ault 1996). In practice, MPAs have seldom been created to protect species which are important in fisheries, but MPAs are slowly gaining acceptance in fishery management (Kelleher *et al*. 1995). MPAs that protect entire ecosystems remain a better and more consistent means of applying protection, because they maintain ecosystem functioning in an undisturbed state. Nonetheless, there are clearcut cases where protection is needed for species that are in danger of local or global extinction.

The threat to most endangered marine species is direct exploitation, or past exploitation from which the species is struggling to recover. In some cases, habitat loss or disturbance has been the cause of a species' decline. Numerous examples exist of MPAs which have been established to remedy these problems. For example, New Zealand established a protected area to exclude certain forms of fishing in the range of the endemic Hector's dolphin to reduce further incidents of mortality in nets (Dawson and Slooten 1993). Marine mammals are a common focus of protection in all seas. As for other groups, MPAs have been designated to protect turtle beaches, seabird breeding areas and shorebird stopovers, fish spawning and nursery areas, and exploited crustaceans and molluscs (Kelleher *et al.* 1995).

To protect species that are exploited for food, MPAs are typically established after the population has been reduced to such a low density that exploitation is no longer viable. MPAs established in this manner range from no-take reserves, for example the Sea of Azov, which was entirely closed to fishing following dramatic stock collapses (Zenyk 1988), to fishery reserves which are quite specific in their protection, for example, trawl reserves (Armstrong *et al.* 1993), prawn reserves (Klima *et al.* 1986a), lobster sanctuaries (Davis 1989) and shellfish reserves (Tegner 1993, Rice *et al.* 1989).

However, it is not a foregone conclusion that a MPA will adequately protect populations of fish or invertebrates from the effects of exploitation outside its borders, or allow populations to recover from previous exploitation. Poaching is perhaps the most common reason for the failure of a MPA to protect species. Tegner (1993) reported this as a likely reason for the failure of reserves to protect abalone in California. However, even where compliance with the MPA regulations is known to be absolute, MPAs might not have the desired effect on fish abundance. Polunin and Roberts (1993) cite two reasons for not finding any effect of a MPA on the mean size or abundance of 70% of target species at two sites in the Caribbean. One was the technical difficulty of detecting differences between exploited and unexploited sites, because of high variance in abundance estimates and the difficulty in counting cryptic and nocturnal species. The second was that some species are migratory or very mobile. With completely open seaward boundaries, the natural passage of animals is likely to be a major cause of loss from a reserve to exploited areas. Bennett and Attwood (1991) showed that six out of 10 fish species sampled in the De Hoop Marine Reserve, South Africa, recovered after six years of no fishing. These six species all include substantial resident stages in their life history, whereas three of the remainder do not.

Particularly in coral reefs, where ecosystem dynamics can become very complex, population recoveries are not a simple matter of allowing time to pass. Changes in predator-prey interactions and competitive effects can delay or prevent recoveries. Alcala (1988) and Russ and Alcala (1989) found that some populations failed to recover, whereas other non-targeted species increased in abundance following protection. MPAs in Kenya had the effect of protecting fish (abundances were much greater in MPAs) and keeping urchin populations under control (McClanahan and Shafir 1990). Outside the MPAs, the density of urchins was two orders of magnitude greater because of diminished predation by fish.

Despite these cautionary results, there is a growing body of evidence that suggests that MPAs do protect a range of organisms, including fish, molluscs, crustaceans and macrophytes (Table I). The most common response of a protected population is an increase in density and mean size. The effectiveness of a MPA in protecting fish stocks is a necessary precursor to advocating the value of the reserve for fishery management.

Fishery management

Only two generations ago it was considered that fishing could not seriously affect marine fish populations. Now it is beyond doubt that fishing can reduce stocks to well below the level of maximum productivity

Table I: A listing of the effect of MPAs on various exploited species

Locality	Species	Effect	Reference
Teleosts			
French Mediterranean	35 reef fish species	11 of 18 target species increased in abundance	Bell (1983)
Spanish Mediterranean	43 reef fish species	Species richness greater in reserve, larger mean size and greater abundance of target species in reserve	Garcia-Rubies and Zabala (1990)
De Hoop Marine Reserve, South Africa	10 fish species (Sparidae, Sciaenidae, Pomatomidae, Coracinidae)	*Cpue* of six species recovered 10 years after reserve estab-lishment	Bennett and Attwood (1991)
Tsitsikamma National Park, South Africa	Three temperate reef fish (Sparidae)	Greater density and healthier sex ratio in MPA	Buxton and Smale (1989)
Saba Marine Park, Netherlands Antllies	Coral reef fish community	59% of common targeted species had greater density and mean size in MPA	Polunin and Roberts (1993)
Hol Chan Marine Reserve, Belize	Coral reef fish community	45% of common targeted species had greater density and mean size in MPA	Polunin and Roberts (1993)
Sumilon and Apo islands, Phillippines	Coral reef fish community: 11 fish families	After reserve broke down, species diversity decreased, species of nine families declined in density, species of two families increased in density	Alcala and Russ (1990) Russ and Alcala (1989)
Goat Island, New Zealand	Reef fish: Red moki *Cheolodactylis spectabilis* and snapper *Pagrus auratus*	Increase in abundance after reserve was established. Larger mean size in reserve	Cole *et al. (*1990)
Molluscs			
Rhode Island, U.S.A.	Clams *Mercenaria mercenaria*	More than twice the density and twice the mean length in MPA	Rice *et al. (*1989)
Gouriqua, South Africa	Giant periwinkles *Turbo sarmaticus*	Greater density and mean size in MPA	Clark *et al.* (1996)
Chile	Keyhole limpets *Fissurella* spp.	Limpet density increased following reserve protection .	Oliva and Castilla (1986)
Chile	Loco *Concholepa concholepas*	Larger and more abundant in MPA	Castilla and Durán (1985)
Venezuela	Queen conch *Strombus gigas*	More abundant and greater mean size in reserve	Weil and Laughlin (1984)
Crustaceans			
Goat Island, New Zealand	Rock lobster *Jasus edwardsii*	More abundant in reserve	Cole *et al.* (1990)
Macrophytes			
Central Chile	Bull kelp *Durvillaea antarctica*	Greater density of kelp in unexploited areas	Castilla and Bustamante (1989)

(Huntsman 1994). Indeed, many stocks have collapsed and some are locally extinct (Roberts 1997). Sustained fishing pressure gradually erodes the resilience of fish populations by reducing genetic diversity, destroying habitat and altering community structure, in addition to simply reducing their numbers.

Overexploitation of fish can take several forms (Bohnsack and Ault 1996). Catching fish which are too young results in *growth overfishing*. Catching too many old fish reduces the reproductive capacity of the stock, resulting in *recruitment overfishing*. Fishing also removes superior genetic traits such as aggressiveness and rapid growth, causing *genetic overfishing*. History has shown that fisheries shift from large species to small, less-desirable species as the populations become depleted, a process termed *serial overfishing*. In some cases, the community structure can be altered, leading to reduced productivity, known as *ecosystem overfishing*. Bohnsack and Ault (1996) point out that MPAs are the most effective and practical means of overcoming these problems, whereas there are doubts about the ability of other approaches to manage fisheries sustainably (Ludwig *et al.* 1993).

MPAs are now regarded as a central component of precautionary fishery management (Clark 1996), but they may also be the key to enhancing fish yield, where single-species and spatially homogenous management strategies have failed (Roberts 1997). Fishery yield will increase as a result of the proximity of a MPA, if there is a substantial spill-over of fish. The increase in yield might be sufficient to offset the loss of the fishing ground to a harvest refuge (Roberts and Polunin 1991). This possibility has led to MPAs being considered by fishery management agencies (and by fishermen) in a more positive light. Rather than being solely a precautionary conservation measure, the MPA may translate into a greater and more stable fishery yield. At this stage, however, the evidence for enhancement of yield rests more on sound conceptual arguments and theoretical models than on direct observations of yield enhancement.

PROTECTION OF CRITICAL SPAWNER BIOMASS

Spawner-biomass models do not always account for the fact that old fish produce a disproportionately large quantity of gametes (in terms of mass) relative to younger fish (Plan Development Team 1990). Where fishing pressure is applied throughout the range of the population, few fish will reach full maturity, whereas a harvest refuge will allow a small part of the total population to reach their peak fecundity. Hence, the investment in a MPA may greatly improve recruitment.

Buxton (1993, 1996) provides an example of such enhanced recruitment. The seabream *Protogynous hermaphrodite* has a complex life history involving a sex change from female to male, and has a heavily skewed sex ratio when exploited. Under heavy exploitation, a paucity of males (sperm limitation) and large females (egg limitation) could lead to recruitment failure. A harvest refuge is required to maintain a healthy sex-ratio in such fish.

Abalone, like many other externally fertilizing sessile invertebrates, require a minimum density (or aggregation) for mates to have sufficient proximity for the production of fertile gametes (Shepherd and Brown 1993). This is only likely to be maintained in a harvest refuge. Even moderate exploitation may reduce the stock to densities below the threshold, thereby causing recruitment collapse.

ENFORCEMENT

Access to many coastal fisheries is difficult to control and a high level of policing is necessary to enforce regulations such as bag and size limits. There are problems related to the practicality of identifying, measuring and weighing fish. Fishery managers argue that, in contrast, MPA transgressions are easily spotted by surface or aerial surveillance, especially if the MPA has community support.

BYCATCH

While Total Allowable Catches (*TAC*s) and other fishery regulations are quite specific with regard to species, quantities and sizes, the fishing hardware (longlines, handlines, pots and nets) cannot deliver the required selectivity to meet these regulations without a substantial bycatch of unwanted or protected fish (Roberts 1997). In the process of filling quotas, large bycatches are taken, which are often not reported or dumped at sea. In most cases, unintentional catches cannot be returned alive. It is estimated that 26% of all fish caught at sea are discarded, but this figure reaches in excess of 80% for certain types of gear (Alverson *et al*. 1994).

SURVIVAL OF RETURNED FISH

Standard fishery regulations often require that captured fish are returned unharmed if they are below a size limit or caught in a closed season. Unfortunately, the survival rate of returned fish is not always good.

Some fish undergo barotrauma (rupturing of internal organs as a result of the expansion of gas), when brought to the surface from a great depth, and may not recover. Some shellfish are haemophiliacs and bleed to death, even if slightly wounded, and others die from wounds sustained during rough handling. For these reasons, it is considered good practice to select regulations that minimize the return of fish. Again, MPAs best achieve this.

REDUCED RELIANCE ON ACCURATE INFORMATION

Complete information about complex ecosystem interactions is not essential for MPAs. Multispecies management is based on the premise that interspecific relationships are important for the production of any species. These relationships may be difficult to identify and quantify, but MPAs operate by allowing the natural processes to survive. The system assumes that populations will reach natural equilibria. In this respect, refugia are superior to traditional catch restrictions for which it is necessary to have all sorts of information, such as the size of the *TAC*, the optimal mesh size, or when to close the season, etc.

PROVISION FOR FISHERIES RESEARCH

MPAs provide natural species assemblages for the measurement of fisheries parameters and the study of ecosystem effects, which are pertinent to fishery management. With such "benchmark" communities, scientists can learn by comparing the effects of fishing pressures on resources, and more easily identify the causes of anomalous events in a fishery. Undisturbed ecosystems thus act as vital controls in which natural fluctuations can be gauged and used to measure human-induced changes in harvested populations.

INSURANCE

When added to conventional effort and catch controls, MPAs provide a certain amount of redundancy in fishery management, making it less likely that any failure of traditional management techniques will lead to stock collapse. MPAs can be viewed as an insurance policy for fisheries.

CONSERVATION OF GENETIC DIVERSITY

A potentially important role for MPAs in fishery management is the maintenance of genetic diversity within a stock. Fisheries generally select large fish, creating a selection pressure favouring smaller fish size and slower growth (Ricker 1981). Other effects may be more subtle, like changes in behaviour (selection against aggressiveness) or alterations in migration patterns (Nuhfer and Alexander 1994, Boehlert 1996). All of these are undesirable for fisheries: smaller fish are less valuable and less fecund, and timid fish are less easily captured. Harvest refugia are considered a practical means to conserve biotic diversity by allowing natural (non-fishery induced) selection forces to apply, so preventing the stock from losing productivity or increasing its susceptibility to fishing. No fisheries regulation that applies equally throughout the range of the population can achieve this effect.

FISHERY MODELS

The benefits of harvest refugia for fisheries have been demonstrated with the use of a variety of analytical and simulation models. Quinn *et al.* (1993) gave one of the most elegant theoretical arguments for harvest refugia in a heavily fished system. Their model was applied to Red Sea urchin *Strongylocentrotus franciscanus*, but the generality of the model makes it applicable to any fish population that has an intrinsic growth rate and a dispersal phase. The model predicts, for high fishing effort, that the catch rate is greatest if the effort is not spread evenly over the entire range. In addition, the fishery is not driven to extinction under any effort level if a harvest refuge is applied. On the contrary, without a harvest refuge, fishery extinction is likely under great effort. The metapopulation model of tropical reef fish developed by Man *et al.* (1995) yields similar results.

Another approach has been to model "per-recruit" functions of a fishery regulated by harvest refugia. For a variety of fish, including species from the families Sparidae, Gadidae, Coracinidae, Carangidae, Pomacentridae and Acanthuridae, MPAs can improve spawner biomass-per-recruit, but not yield-per recruit (Polacheck 1990, DeMartini 1993, Attwood and Bennett 1995). Therefore, any increase in yield associated with the existence of harvest refugia is likely to be because of improved recruitment.

An age-structured simulation model developed by Nowlis and Roberts (in press) predicts that, for two coral reef species, a trigger fish (Balistidae) and a grunt (Haemulidae), the more heavily fished a stock is, the quicker fishermen will see an improvement in yield after a reserve is introduced. They found that large reserves usually produced the best long-term yield, but that the initial loss of catch, as a result of the removal of fishing ground before the resource recovered, could be an argument against the implementation of MPAs. By gradually phasing in a reserve, instead of closing a large area all at once, the initial loss experienced by fishermen could be reduced, but only at the expense of a corresponding loss of long-term yield.

Model results suggest that harvest refugia can improve yields of non-migratory fish, sufficient to compensate for the loss of the refuge as a fishing ground, if (i) fishing effort is greater than the optimal effort (i.e. the level of effort which produces the maximum sustainable yield) and (ii) there is export from the harvest refuge, in the form of larvae, pre-recruits or adults. The first requirement is met more often than not, and evidence for the last is emerging for a variety of exploited taxa.

EXPORT OF EGGS AND LARVAE

Most estimates of larval dispersal from a variety of phyla have relied on simultaneous surveys of larval density and current velocity. The use of more advanced techniques, e.g. chemical tracers to establish the origin of larvae (Levin 1990), is showing some promise, but they have yet to be widely applied.

Harvest refugia have been proposed to alleviate fishing pressure on abalone and to increase yield (Davis 1989, Dugan and Davis 1993, Shepherd and Brown 1993). Abalone larval dispersal is localized, estimates ranging from tens of metres to 4 km (Tegner 1993), with the implication that reserves should be small. Many reef fish are similar to abalone in that they are resident or territorial as adults, but have a larval dispersal phase, during which time they are at the mercy of currents. Based on an analysis of current-meter records from the Tsitsikamma National Park in South Africa, Tilney *et al.* (1996) projected dispersal distances of seabream larvae, and concluded that there was likely to be substantial export to adjacent exploited areas.

EXPORT OF PRE-RECRUITS

The purpose of the Tortugas Sanctuary in the Gulf of Mexico was to optimize the yield of pink shrimp *Penaeus duorarum* by protecting small shrimp until they reach harvestable size (Klima *et al.* 1986a, b). This protective legislation was based on the understanding that small pink shrimp move through the sanctuary and recruit in adjacent waters. The legislation was intended to prevent unnecessary discarding of undersized shrimps, and to allow maximum recruitment to the fishery in the adjacent area. A lack of evidence for improvement in catches during the first two years of the sanctuary was attributed to poor compliance to sanctuary regulations by the fishery (Klima *et al.* 1986b).

EXPORT OF ADULTS

Attwood and Bennett (1994) analysed the movements of 1 103 tagged galjoen *Dichistius capensis* in the centre of the 50 km De Hoop Marine Reserve in South Africa. In all, 17% of the recoveries were outside the reserve boundaries, some as far as 1 000 km away, but the remainder were recovered at the site of release. The export loss to the reserve population was equivalent to a fishing mortality rate of $0.18 \cdot \text{year}^{-1}$. In relation to the natural mortality rate of $0.3 \cdot \text{year}^{-1}$, it suggested that the reserve contributes to the adjacent fishery by providing a continuous source of fish.

Davis (1989) tagged adult spiny lobsters *Panulirus argus* in Florida Bay, U.S.A., to study their movements. They found that the bay was a lobster nursery area. Juvenile lobster settle there and remain for approximately 3 years before dispersing to the Gulf of Mexico and the Atlantic coast. Based on the known movements of lobsters, it was hypothesized that a lobster sanctuary in Florida Bay would increase the availability of lobsters to adjacent fisheries.

EVIDENCE FOR IMPROVED CATCHES

The study by Alcala and Russ (1990) is frequently quoted as the only example of evidence of enhanced catches as a result of a MPA. While the Sumilon Island Reserve was operational, the catch-per-unit-effort (*cpue*) of fishing boats was recorded for one year. The reserve management broke down after 10 years, and $1\frac{1}{2}$ years after that, despite little change in total fishing effort, the *cpue* declined by about 50%. It was inferred that the reserve had been supporting catches, and that its removal was to the detriment of the fishery. At nearby Apo Island, a small reserve of <1 km, there were in increases in fish abundance and species richness at distances between 200 and 500 m from the reserve boundary (Russ and Alcala 1996). Fishermen were unanimous that their catches had improved since the inception of the reserve. No other hard evidence could be found which suggests that yields have increased as a result of no-take reserves, although anecdotal reports from fishermen are frequently reported – Rowley (1994) lists a few examples. A large part of the problem of detecting improved catches associated with the creation of MPAs is the absence of adequate fishery data-capture programmes.

MPAs are a recent form of fishery management, and conclusive results on their effectiveness are likely to be forthcoming in the near future. At this stage the weight of the arguments and the circumstantial evidence suggest that no-take reserves of appropriate size do have positive effects on fisheries, and unquestionably benefit the stocks inside well-managed reserves.

DESIGN OF MARINE PROTECTED AREAS

With the incorporation of MPAs into management procedures for biodiversity and fisheries, design is an important issue. To fulfil certain functions, the size, shape and location of individual MPAs will require careful consideration, as will the total extent of protection in a given management area, species range or biogeographic zone. MPAs should contain a certain proportion of habitat, or of a population, to ensure success, and should include grounds which are known to be used by species for crucial stages of their life cycle. Fishery objectives will usually require optimizations involving protection and yield. To prevent pollution or to enhance recruitment, the location of MPAs relative to currents may also be important.

Large v. small

There are advantages to keeping a MPA small (Beuttler 1994):

(i) Small MPAs enjoy local public support. The community can develop a sense of stewardship towards the MPA and may indirectly assist in its management. This is unlikely to happen with a MPA which covers thousands of square kilometres.

(ii) Small MPAs are easy to establish, manage and enforce. A small, clearly defined MPA will not encroach on as many industries and users as a large MPA. Furthermore, industries are threatened by large MPAs which appear to be designed to force them out of business (Rigney 1990).

(iii) Opportunities for comparative studies of the effect of exploitation should also be greater, with a number of small adjacent zones, and with the possibility of each experiencing varying levels of protection.

On the contrary, certain objectives are attained exclusively with the use of large MPAs.

(i) Large MPAs have a good buffering capacity, which will dampen the influence of natural and man-induced events, (e.g. red-tide, pollutant spills, poaching).

(ii) Large MPAs may be needed to hold viable populations of threatened species.

(iii) Some ecosystems (e.g. coral reefs) need protection in their entirety.

(iv) To accommodate a variety of uses and various levels of protection, a large MPA can be zoned (Kelleher and Kenchington 1992).

(v) Large reserves are more likely to include a high diversity of habitats.

(vi) A single large reserve will be easier to manage than several small reserves of equivalent total size.

A combination of large and small MPAs could provide for the optimum level of protection and resource use, if the advantages of each are combined into an integrated management system. Small marine reserves with specific objectives (e.g. enhance fishery, protect local stock) can be embedded within large MPAs which provide more complete environmental protection. The larger, umbrella MPAs should not be promoted as a restriction on users, but rather as an environmental watchdog, drawing attention to the value of the area, and with the power to stop habitat-threatening developments. This is essentially the Biosphere Reserve concept (Battise 1993), examples of which are the Great Barrier Reef Marine Park, Florida Keys National Marine Sanctuary and St Lucia/Maputaland Marine Reserve. Hockey and Branch (1994) suggested a separate, two-tier system of marine protection. The first tier consists of large representative MPAs for the conservation of biological diversity. A second tier of "fishery reserves", established primarily for more focused fishery objectives, can be separate from the larger MPAs.

How much should be protected?

The question of how much to protect is quite separate from the size of an individual MPA. The World Conservation Union (IUCN) has proposed a goal of conserving 20% of the world's coastline by the turn of the century (IUCN 1992), but it is unclear what that value is based on and what level of protection is implied. Ballantine (1991, 1995) claims widespread political support in New Zealand for setting aside 10% of their territorial waters for "no-take" MPAs by the year 2000. The Plan Development Team (1990) suggest that 20% of the total range of a population should be protected. This value is based on the result of fishery modelling which shows that the risk of fishery collapse (for a variety of population's dynamics), increases dramatically if the spawner biomass falls below 25% of its unexploited value (Punt 1993). The Plan Development Team (1990) suggests further that, where fishery management in exploited areas is poor, a value of 30% of the range is a more appropriate target. Both these estimates were concerned with no-take reserves.

A network of "no-take" MPAs has emergent properties which gives it greater value than any one of its components (Ballantine 1997). An MPA on its own is not able to sustain marine communities in the face of natural and anthropogenic disturbances. However, a network can provide a basis for self-sustaining resilience in protected communities, with the capacity to seed exploited areas. Knowledge of marine ecological processes is often too limited to design individual MPAs to cater for protection and stock enhancement of all important species. Ballantine (1997) argues that no detailed knowledge of the transport of propagules and population dynamics is needed to set up an effective network, provided that the principles of representativity, replication and size are observed. The recommendation is 10% of the area protected for direct effects (protection of biodiversity) and 20–30% for indirect effects (resilience and seeding).

Ballantine's (1997) advice to concentrate on design principles for a network rather than individual MPAs has considerable merit when it is considered that, in practice, sophisticated concepts on the design of an individual MPA are rarely implementable. Those MPAs most likely to achieve acceptance are those which are conceived by the public. It is common for citizens who are concerned about the state of the local marine environment to request or establish a MPA, which may later gain statutory proclamation. Such MPAs arise out of circumstance and are usually not designed with the aid of biological, sociological and fishery information. Even where MPAs are initiated by conservancies or fishery authorities, the possibilities for a variety of designs are usually very limiting. Design is dictated by acceptability to the public and the fishing industry (McCay 1988).

Single Large or Several Small (SLOSS)

The SLOSS debate has its roots in terrestrial conservation (Simberloff 1988), but it is as applicable to the design of MPAs, although the processes under consideration may differ. The debate concerns species diversity, edge-effects and the transfer of biota (and pollutants) across reserve boundaries. Numerous small reserves have a greater combined edge than fewer but larger reserves of the same total area. McNeill and Fairweather (1993) studied *Zostera* and *Posidonia* seagrass beds in temperate Australian estuaries to test the theory that a single large MPA will preserve the same diversity of species as several small ones of the same total area. They compared the density and diversity of fish and invertebrates in beds of different sizes and showed that two small seagrass beds included more species than one of the same total size. One possible explanation is that the greater perimeter of two allows for a greater chance of interception by propagules. If this is the case, the orientation and shape of the bed relative to the current would have significance too. They went on to manipulate the size of some artificial seagrass beds and repeated the observations. The artificial experiments did not show any difference between the diversity in two small versus one large bed. McNeill and Fairweather (1993) concluded that the contradictory results of the natural comparison and the artificial experiment typify the SLOSS debate. Some unconsidered factors may have had strong bearings on the result, including distances and connections between beds, patchiness within beds, and dispersal characteristics of the species. The authors recommended a design which conserved discrete beds within a larger area or network, not unlike the Great Barrier Reef Marine Park.

Some fishery models have incorporated fishing pressure and fish mobility to estimate the optimal size and spacing of fishery reserves. DeMartini (1993) developed a model of three typical coral reef fisheries and found a strong interplay between reserve size, harvesting rate and dispersal rate. The author stated that "The overall contribution of multiple, small closures will be, however, less than that of one closure of equal total size, in inverse proportion to the increase in total perimeter of (hence dispersal from) the multiple closures" (DeMartini 1993, p. 425). Attwood and Bennett (1995) used estimates of dispersal from tag and recovery studies to model reserve size. Relationships between yield and reserve size and spacing were established for three species, although the model simulated a symmetrical reserve field only, i.e. one in which all reserves had equal size and were equally spaced. These are promising techniques. However, the reliability of the results depend critically on the exploitation and dispersal rates, which were poorly estimated.

Selecting the location of MPAs

The conventional means of selecting the location of a MPA is by comparison of potential sites in terms of a broad set of criteria. The evaluation of a candidate site is compared with those of alternatives or to a

Table II: Criteria for the establishment of MPAs (based on Salm and Price 1995)

Social criteria	Economic criteria	Ecological criteria	Pragmatic criteria
Social acceptance	Fishery yield	Diversity	Urgency
Public health	Tourism	Naturalness	Size
Recreation		Representativity	Degree of threat
Culture		Uniqueness	Effectiveness
Aesthetics		Integrity	Uniqueness
User conflicts		Productivity	Integrity
Education		Vulnerability	
		Research opportunity	

predetermined minimum rating. Various sets of criteria are in use throughout the world, but essentially they all contain similar elements (Table II). Ecological criteria are not the only considerations. In the context of coastal zone management, MPAs need to be considered in terms of the impact of social and economic structure of the region. Also of crucial importance is the practicality of the candidate site as a MPA in terms of management.

Hockey and Branch (1997) have developed a list of objectives that MPAs can be expected to fulfill, and criteria by which the degree to which a given area meets these objectives can be assessed. The evaluation in terms of criteria can vary from a qualitative to a quantitative process. For example, in New Zealand it is necessary to demonstrate that the site meets certain criteria as specified in the Marine Reserves Act (Department of Conservation 1994). A more rigorous evaluation in terms of social, pragmatic and economic criteria is difficult to achieve, but in terms of ecological criteria more quantitative scoring and weighting systems have been devised. The Canadian system assigns a "representation" rank to each site, which is the sum of presence/absence scores of habitats, species and historical and cultural features (Kelleher and Kenchington 1992). The ranking system may be weighted if greater importance is attached to particular species or features. Odendaal *et al.* (1995) presented a more elaborate ranking system which included the condition or status of the species and habitat, the extent of human use, adequacy of government infrastructure, proximity to important sites, and tourism potential. A number of alternative weightings for criteria are used to correspond to various MPA objectives. For example, some criteria will count more heavily if the objective is conservation, as opposed to tourism, and *vice versa.*

Criteria for conservation should not be on biological diversity alone, but should consider representativity. Hockey and Branch (1994) suggested a middle/edge system of MPA siting, whereby MPAs situated in the centres of major biogeographic zones would cover aspects of representativity (middle) and diversity (edge). By placing MPAs in the centre, conservation is hedging its bets as to which way climate change might force species distributions. It is also argued that organisms reproduce more successfully in the centre of their range than on the edge. Emanuel *et al.* (1992) state that a well chosen site should be representative of a biogeographic type which is in need of conservation, should be representative of a variety of community types within the area, and should be representative of the physiographic heterogeneity of the region. This latter consideration can be quite important, as Davidson and Chadderton (1994) showed for rocky shore communities in New Zealand. The type of rocky substratum has a major bearing on the community composition. Studies which elucidate this type of effect should be a precursor to any site-selection process, if the aim is to achieve a representative set of MPAs.

Where the objective of the MPA is to protect a population or to improve the fishery for a species, the site-selection process will require a detailed knowledge of the life history of the species and of the local oceanography. MPA location and orientation should take cognizance of breeding, recruitment and nursery grounds, current patterns, the proximity of the fishery, the stability of the populations and communities, the frequency of natural disturbances and the permeability of biota and pollutants across the boundaries (Dugan and Davis 1993, Rowley 1994). Carr and Reed (1993) discussed the effect of a number of fish life-history models in relation to reserve design. Populations may be downstream of spawning grounds, fish may spawn throughout their range, or spawning may be localized, with larval transport in all directions. In each case a different design of MPA will be necessary. Larval and adult fish movement studies are therefore crucial for reserve design, but these studies may take many years to complete (tag and release methods), or may involve expensive oceanographic studies (larval tracking and current measurements). The shape and orientation of the reserve relative to the current may well have an impact on the stability of the population within the MPA. Rowley (1994) discussed the effects of various

MPA orientations to currents on the permeability of fish across the boundaries. For example, a large reserve perimeter perpendicular to the current will allow for greater permeability than if it were parallel to the current.

ESTABLISHMENT AND MANAGEMENT OF MARINE PROTECTED AREAS

The processes of establishing and managing MPAs will depend on the social, geographical and political characteristics of the country. Nonetheless, lessons can be learnt from countries that have successfully implemented MPAs, and from others where MPAs could not be established, or having been established, did not attain the stated objectives. It is common for an officially designated MPA, without sufficient community or industry support, to degenerate into a "paper park", one which exists in legislation, but which is ineffective in protecting resources (White 1986, Causey 1995). The process of establishment is now widely recognized as making the difference between success and failure. As MPAs are at the heart of integrated coastal and marine management, there is often uncertainty about the domain to which the management belongs, sometimes resulting in a duplication of MPA authorities. The management process itself has a major role to play in bringing the functions of the MPA to fruition. As a conservation means, it requires as much management as a terrestrial reserve, and more than any other form of fishery control.

How are MPAs established?

The common elements in MPA establishment processes are:

(i) perception of a local or national need for a MPA;
(ii) identification of an area suitable for MPA status;
(iii) application for statutory MPA status;
(iv) drafting of management plans and legislation;
(v) public and government agency review;
(vi) designation of the MPA.

The responsibility for each task and the order in which they are accomplished vary from one country to the next. Some well-described MPA-designation procedures from the western world provide interesting contrasts among countries that are socio-economically similar. However, these do not necessarily address the problems faced by "third world" nations, from which there is little documented experience of designation procedures.

LOCAL INITIATIVE

Prompted by a perceived need to protect the local environment, concerned citizens may initiate the idea of establishing a MPA. This is common in many western countries, and in France and New Zealand it is an important means by which MPAs have been established (Beuttler 1994, Department of Conservation 1994). In both countries, MPA applications from the public sector proceed in a prescribed manner. At an early stage, the applicants are encouraged to rally support and to refine the objectives of the proposed MPA. An official in the conservation authority presents the format for a formal application, and may assist in drafting it. The formal application is submitted to the Minister or relevant authority, who then undertakes an obligatory review processes. The public sector, affected industries and government agencies are invited to comment on the proposal. Serious objections can block the proposal. The entire process may take up to 10 years, depending on the opposition.

France and New Zealand have 21 and 14 MPAs respectively. As a consequence of the local initiative process, the MPAs are small and carry strong community support. From a management perspective, these are positive attributes. Large MPAs are unlikely to be established by this process, because local applicants seldom take a broad perspective beyond their immediate surroundings, and the possibility of termination or delay in the application processes increases with the size of the proposed area. The bottom-up approach has a further failing in that the resulting network is unplanned. MPAs in New Zealand, for example, are very clumped in their distribution, with six MPAs in the Hairaki Gulf on the east coast of North Island, and virtually none on the entire West Coast. No systematic protection is afforded to biogeographic zones or fishery resources. In New Zealand, the fishing industry opposes MPAs. This may be a consequence of the motivation coming from the public and recreational sectors, while the benefits of MPAs to fisheries are not adequately communicated.

GOVERNMENT INITIATIVE

Alternatively, a government authority may plan and designate MPAs. The procedures used in the U.S.A. and Canada involve considerable public, industry and government agency review. The marine sanctuary authority selects a site from a list of candidates, after an evaluation process. An environmental impact assessment is conducted. A proposal with a draft management plan is then reviewed and undergoes public hearings, after which a final environmental report and management plan are submitted for presidential approval. The site designation process is therefore under complete government control, although in the case of Monterey Bay National Marine Sanctuary, political pressure forced the government to initiate the MPA. In the U.S.A., the National Marine Sanctuaries Program (NMSP) was established for the designation and management of marine sanctuaries (Pritchard 1993).

In all MPAs in the U.S.A., controlled human activities are allowed if they are not in conflict with the objective of the MPA. In practice, this has been a negotiated settlement after extensive public participation. Ehler and Basta (1993) and Barley (1993) describe the process which led to the drafting of a management plan for the massive Florida Keys National Marine Sanctuary. An "advisory council" provided the critical link to local citizens and user groups and was an important part of the planning process. Working partnerships were established between the NMSP and other government agencies. "Focus meetings" with various user groups and environmentalists were responsible for resolving heated debates.

It is noteworthy, however, that the U.S.A. has no significant no-take reserves, because of the extensive public participatory processes. With the original designs of no-take reserves severely compromised by negotiation, MPAs in the U.S.A. are aimed at preserving habitat, water quality and avoidance of user conflict, but they have not prevented the overexploitation of fish on the East or West Coast (J. Bohnsack, University of California, and M. Carr, National Marine Fisheries Service, pers. comm.). There is little or no MPA protection for exploited species.

The Canadian National Marine Park Policy is also a recent development, but one which is upheld as an exemplary procedure of MPA designation (Kelleher and Kenchington 1992). The MPA establishment process is controlled and initiated by a government agency, starting with an evaluation of suitable areas, similar to the procedure used by the NMSP in the U.S.A. In the Canadian case, this is based on a presence/absence or more sophisticated scoring system to rank areas for representativity. The advantage of this system is that the MPAs will eventually form part of a planned network.

VOLUNTARY APPROACHES

Not all MPAs are designated in legislation. It has been customary practice for hundreds of years for communities to establish and police MPAs in South-East Asia and Polynesia (Johannes 1982, White 1988). In those countries, communities have traditional rights of ownership over areas of the sea, and community-managed MPAs have successful fishery management measures. The structure of these community-based management systems has been regarded as a model of successful fishery management in the tropics. In western countries, the sea is almost always regarded as a commonage, but this has not deterred the development of voluntary MPAs.

The statutory approach to MPA designation in the U.K. has been criticized for being too slow and producing weak legislation (Gubbay 1993). Since the Wildlife and Countryside Act provided for Marine Nature Reserves in 1981, the Nature Conservancy Council has been able to proclaim only two statutory MPAs. An alternative approach which has developed in the U.K. is Voluntary Marine Conservation Areas, driven by concern, enthusiasm and organization of local coastal communities. An important objective of these voluntary reserves was to draw attention to the biological importance of the areas and to promote responsible use of the area while preventing deterioration of the environment. The U.K. has nine Voluntary Marine Conservation Areas, each protected by agreements and codes of conduct. Some enlist the services of a warden and others receive assistance from sympathetic landowners.

However, the lesson from the U.K. lies not in the success of the voluntary approach, but rather the failure of the statutory approach. Gibson and Warren (1995) maintain that the legislation fails to put MPAs at the top of a pyramid of devices for habitat protection, and hence it is not possible to control all activities within a MPA. Extensive consultation is required between government and local authorities, even before official application can be made, with the result that the MPA proposal is compromised before receiving official consideration. Gubbay (1993) describes the progress of MPA designation in the U.K. as disappointing.

The dangers of voluntary MPAs are their vulnerability to changes in social and industrial circumstances. Their protection is likely to break down when it is needed most. For example, the community-based no-take reserve at Sumilon Island in the Philippines was established by agreement between the community and the university, but the management of the reserve broke down after 10 years (Alcala 1988). Codes of conduct are agreed to by local residents and tourists, but not by industry or developers.

RESTRICTING ACCESS AND REMOVING RIGHTS

It is now widely recognized that an essential part of the MPA establishment process is the involvement of the local community (White 1986, Asava 1994, Wells and White 1995). This becomes particularly problematic when rights to an area are being removed as part of a strategic conservation or fishery plan. For example, the creation of the Florida Keys National Marine Park and the Great Barrier Reef Marine Park avoided the complete removal of rights by zoning the various activities. Considering that most users in those two parks are highly mobile, a negotiated settlement based on zonation was possible. In poorer communities, where local people depend on local resources, the complete removal of fishing rights will require an innovative approach, most likely involving an alternative source of livelihood.

Odendaal *et al.* (1995) recognized that the Masoala Peninsula of Madagascar required the protection of a zoned MPA, including some core no-take areas for the protection of fish stocks, coral and turtles. In advocating the establishment of the MPA, those authors were forced to confront the issue of local people's rights to the sea, which was seen as a commonage. They maintained that, because fishermen realize that their catch rates have diminished, they are receptive to the concept of a MPA which is established to protect their own livelihood. Even in communities where fishermen are generally well aware of fishery matters, and agree to the need for MPAs, there is an attitude towards MPAs of "rather in someone else's backyard than mine" (Ballantine 1991). Clearly, a large part of establishing no-take marine reserves will be addressing the issues of removal of rights. A possible solution here is the participation of local communities in MPA management. There is a trend worldwide to increase the participation of users in MPA management to ensure a better marriage of the conflicting needs of conservation and local subsistence (Beaumont 1997).

WHAT CHARACTERIZES A SUCCESSFUL MPA ESTABLISHMENT PROCEDURE?

Both local and government-initiated approaches have sufficient merits to compliment each other in addressing the full potential of MPAs. The former are important for developing an ethic of conservation and for promoting non-consumptive industries. The latter, however, can provide better protection for biodiversity and fisheries. It is important that a government structure should be appointed to proceed with proposals from both sources in a predetermined manner. All proposals will need a thorough review process. However, any MPA policy and legislation should be strong enough not to compromise essential MPA objectives by a lack of full consensus. A set of criteria which takes into account the distribution and function of MPAs should be applied to ensure a well balanced and managed network of MPAs.

Management of MPAs

MPA management is usually the responsibility of nature conservancies, or, less commonly, fishery management agencies. This is perhaps a result of the function of MPAs traditionally being regarded as one of nature conservation, similar to the role of nature reserves in the terrestrial environment. The role of MPAs in fisheries is a more recent development, which will necessitate closer ties between nature conservancies and fishery authorities. Some successful MPA networks are managed by national MPA programmes (e.g. Canada and the U.S.A.). MPAs affect resources and rights which are under the control of several different government agencies, and a national programme is perhaps the most appropriate means of ensuring a working partnership between them.

It is also common to find that MPAs within a country are established under different sets of legislation and managed by different authorities. In California, this situation has resulted in a plethora of small MPAs under state management, requested by organizations outside the state authority, which have been created independently and without guidelines to set standard terminology or standards regarding restrictions on use (Smith *et al*. 1989). The process has been described as reactive and unplanned.

MPAs typically have managers and enforcement staff, but they may enlist representatives of local interest groups in an advisory capacity. Some MPAs in France have an advisory council comprising representatives of government agencies, fishing industries, tourist industries and recreational users (Beuttler 1994). The advisory committee and manager meet once or twice per year to resolve issues of concern. Revisions to management plans, financial statements and research proposals are discussed by the advisory council. Some National Marine Sanctuaries in the U.S.A. have Sanctuary Advisory Councils (SAC) which have been successful as communication channels between the sanctuary authority and user groups (NOAA 1996b). Members of the SAC are selected by the sanctuary authority and participate on a voluntary basis. Committees of local users commonly manage MPAs in South-East Asia, even in cases where the MPA has clear statutory designation. The committee can become involved in activities such as drafting or amending management plans, enforcement and setting up user facilities (Wells and White 1995). Advisory councils guide management, resolve conflicts and give local communities a stake in the MPA.

A vital component of MPA management is the drafting of a management plan. MPAs require active management to attain their full objectives. Monitoring, enforcement, education and restoration are the important managerial tasks. The management plan specifies how these activities are to be accomplished to serve as a guide for management and as a public document to inform the interested parties about the management and purpose of the MPA. According to Kenchington and Kelleher (1995), common elements in a management plan include:

(i) resource inventory;
(ii) regulation of activities (including zoning);
(iii) enforcement;
(iv) environmental and fishery education;
(v) monitoring of user activity;
(vi) monitoring of resources;
(vii) habitat restoration.

Enforcement of the MPA regulations provides the link between the regulations and environmental and biotic protection. The failure of reserves to conserve valuable fish populations is frequently blamed on poor enforcement or uncontrollable poaching (e.g. Klima *et al.* 1986b, Tegner 1993). The nature of the policing activities will depend on, among other factors, the legal system and the regulations applicable in the MPA. Much of the advocacy for community involvement in MPA management is compliance with regulations and informal policing by people who have a sense of ownership of the resource. Where territorial rights are allocated, law-breakers are deterred by peer pressure and local aggression (Johannes 1982). In countries where territorial rights are not upheld, enforcement can be an expensive exercise.

Causey (1995) describes the successful approach used in some U.S. National Marine Sanctuaries. The lessons learnt there are likely to hold for most MPAs. Fines will always be necessary to act as a deterrent to law-breaking, particularly serious offences such as poaching and pollution. However, an alternative form of "interpretative enforcement" can rapidly and efficiently reduce transgressions, especially of minor offences committed through ignorance or apathy. "Interpretative enforcement" is the process whereby the offenders are educated on the reason for the regulation, rather than being penalized, and hence being further alienated from the cause of marine protection. The philosophy of "preventative enforcement" requires enforcement officers to make frequent contact with users, issuing educational literature and on-site discussions. Enforcement therefore will require a reasonable field presence of officers. The mere presence of a law enforcement officer is a considerable deterrent against law-breaking.

How are MPAs financed?

Typically, MPA management is funded by the state or local government. These funds are usually insufficient to accomplish the necessary tasks to full effect, even in affluent nations (Pritchard 1993). Despite the fact that some MPAs result in large tourist industries, Dixon *et al.* (1993) found that very little of the resulting revenue found its way back to the management of the MPA. Some of the tourism and fishing benefits which are attributable to MPAs could be channelled to the MPA through the sale of permits to visitors, tour guides, fishermen, recreational craft, etc. In some U.S.A. National Parks, financial deficits and staff shortages have been alleviated by donations and volunteer staff (O'Neill 1993). The use of money recovered from fines can be used to restore the damage caused by the offence, or to improve the management of the MPA where active restoration is not possible (Causey 1995). An innovative concept recently started by the U.S. National Marine Sanctuaries Program (NMSP) is the marketing of a logo, designed to represent sanctuaries. Corporate sponsorships are invited in exchange for the right to display the logo on the certain products.

INTERNATIONAL CONVENTIONS ON MARINE PROTECTED AREAS

As a shared resource, the ocean requires international planning and cooperation for its conservation and wise utilization. The Law of the Sea imposes a basic obligation on states to protect and preserve the marine environment, to prevent, reduce and control pollution, and to protect rare and fragile ecosystems and species. However, it makes no direct reference to MPAs, nor does it dictate specific technical measures (Gibson and Warren 1995). While nations are not bound to create MPAs under international law, there are numerous international policies and conventions on MPAs. These have been the result of work by specialist organizations which have arisen out of a need for global environmental protection. They include the World Conservation Union (IUCN), the United Nations Educational, Scientific and Cultural Organisation (UNESCO), the United Nations Environment Program (UNEP), and the International Maritime Organization (IMO). Important international conventions include the International Convention for the Prevention of

Pollution from Ships (MARPOL), the Ramsar Convention, FAO's Code of Conduct for responsible fishing, UNESCO's Convention on Biological Diversity, the Bonn Convention, the Antarctic Treaty, and the Convention for the Conservation of Antarctic Marine Living Resources (CCAMLR).

World Conservation Union (IUCN)

By the early 1960s, it was recognized that the scale of man's activities and technological advancements posed an escalating threat to the physical structure and ecological balance of the oceans, particularly its coastal waters (Björklund 1974). At a number of international symposia on environmental matters in the 1960s and 1970s, the need for MPAs was emphasized, and the first International Congress on Marine Parks and Reserves was sponsored by the IUCN in Tokyo 1975. The congress recognized the increasing pressure on the marine environment and called for a well monitored system of MPAs, representing all marine systems. A paper delivered by Ray (1976) mentioned critical marine habitats, the threats of pollution, overfishing and uncontrolled coastal development, with possible solutions in the form of MPAs. The current paper is a major treatise covering every aspect of MPAs, and shows that, in the last two decades, the issues surrounding MPA management have not altered substantially, except perhaps in the field of fishery management and in the need for community involvement.

The IUCN launched its Marine and Coastal Areas Programme in 1985. The objective of this programme was to conserve marine and coastal species and ecosystems to demonstrate how conservation and development can reinforce each other in marine and coastal environments, to enhance awareness of marine conservation issues, and to mobilize the global conservation community to work for marine and coastal conservation. It was recognized that an integrated approach to the management of the global marine ecosystem was urgently required. A policy framework for marine conservation was established at the 4th World Wilderness Congress, in September 1987, and the identical resolution was adopted by the 17th General Assembly of IUCN, in February 1988.

Kelleher and Kenchington (1992) elaborate on this statement in a comprehensive set of guidelines for MPAs, including policy, objectives, criteria for selection, legal aspects and planning. The document aims to foster initiatives in marine and estuarine protection, conservation and management at government and agency levels. An important goal of the IUCN initiative is the development and implementation of a global, representative system of MPAs, recognizing that such a system will be part of a broader framework of integrated marine ecosystem management.

UNESCO Biosphere Reserves

UNESCO's Man and the Biosphere Programme launched the Biosphere Reserve concept in response to the need to manage environments in an integrated way, to accommodate man's conflicting requirements for development, recreation and health (Batisse 1993). Therefore, Biosphere Reserves are said to be characterized by playing three roles, i.e. conservation, logistics (science) and development. The Biosphere Reserve consists of a central core area (or areas), in which the requirements for nature preservation are strictly enforced, a buffer zone where certain low-consumptive activities are practiced, and an outer transition zone where full, sustainable use is made of the resources. As with most conservation efforts, Biosphere Reserves have been applied most frequently to terrestrial systems: only 10 out of 271 recognized Biosphere Reserves incorporate the marine environment (Elder 1993).

Protected areas can be nominated for Biosphere Reserve status. South Africa is presently developing nominations for two Biosphere Reserves which may include the marine environment, namely the West Coast, including the West Coast National Park as a core area, and the Koggelberg, with the H. F. Verwoerd MPA as a possible core area.

UNEP – Convention on Biological Diversity

An *ad hoc* working group of experts on biological diversity explored the need for an international legal instrument for the conservation and sustainable use of biological diversity, taking into account the need to share costs and benefits between developed and developing nations. The Convention on Biological Diversity was completed in May 1992, and was opened for signatures at the United Nations Conference on Environment and Development (the Rio Earth Summit) in June 1992. It represents a dramatic step forward in the conservation of biological diversity, the sustainable use of its components, and the fair and equitable sharing of benefits arising from the use of genetic resources.

Contracting nations agree that (among others) "*the fundamental requirement for the conservation of biological diversity is the in situ conservation of ecosystems and natural habitats and the maintenance and recovery of viable populations of species in their* *natural surroundings"*. The convention also takes cognisance of the necessity to respect the dependence of local communities and indigenous people on biological resources.

South Africa ratified the convention in June 1993 and the development of a policy to implement the convention is at an advanced stage (Van Jaarsveld and Chown 1996).

UNEP – Regional Seas Programme

The Regional Seas Programme was initiated by UNEP in 1974. Since then, its Governing Council has repeatedly endorsed a regional approach to the control of marine pollution and the management of marine and coastal resources and has requested the development of Regional Action Plans. UNEP's Regional Seas Programme currently includes 12 regions, with more than 120 participating coastal states (Verlaan 1995). Each region has an Action Plan, formulated according to its needs as determined by the governments concerned. Among the requirements of the Action Plan is the establishment of MPAs.

An Eastern African Plan was produced during the period 1980–1985, and was later formally adopted as the Nairobi Convention by several East African countries, but not South Africa (Anon. 1985).

International Convention for the Prevention of Pollution from Ships

This convention has prescribed industry standards for shipping practices throughout the seas to reduce the incidence of marine pollution. Additional controls are applied to sensitive (or poorly flushed) areas which warrant special protection, and therefore qualify as MPAs in the broadest sense. MARPOL "special areas" include the Mediterranean, Black Sea, Baltic Sea, North Sea and the Antarctic.

Antarctic Treaty and CCAMLR

The Antarctic Treaty represents a system of agreements, regulations and conventions specifically directed at protecting the Antarctic environment south of 60°S (Miller 1991). By virtue of compliance to regulations calling for demilitarization, non-nuclear proliferation, and freedom to conduct scientific research, and by the adoption of "Agreed Measures for the Conservation of Antarctic Fauna and Flora", the area can be considered the world's largest MPA.

CCAMLR is an attempt by consultative parties to protect Antarctic marine living resources. It was instituted in 1980 in response to concerns that the global interest in krill exploitation may place the entire Antarctic ecosystem in jeopardy. CCAMLR boundaries extend farther north than those of the Antarctic Treaty, and include sub-Antarctic islands. Contracting states are required to abide by the provisions of the Convention and with certain principals of conservation and resource management. The mechanisms for dealing with compliance and enforcement of the regulations are provided by the Convention, but the position of non-contracting parties in this regard is unclear (Miller 1991). The intensive international fishing for recently discovered Patagonian toothfish stocks around islands of the southern Indian Ocean raises some doubt over the ability of the treaty to protect valuable resources.

South Africa is a member of both the Antarctic Treaty and CCAMLR.

The Antarctic Treaty and CCAMLR have been used as models of international cooperation in conservation which could be applied to other areas which experience problems relating to habitat conservation, overexploitation and sovereign disputes (McManus 1994).

Ramsar Convention

The primary aim of this convention is the conservation of waterfowl and shorebirds through the protection of wetland habitat (Gibson and Warren 1995). It requires participating states to designate at least one site within its territory for inclusion in a list of internationally recognized wetlands. These wetlands include islands and tidal waters with a depth not exceeding 6 m at low tide. The convention has been a driving force behind the protection of a global network of stop-over wetlands along the flyways of migratory birds. Ramsar has recognized a wider, more integrated approach to wetland management and has called for member states to include coral reefs in Ramsar sites, to involve local communities and to take steps to perpetuate the survival of fish. While Ramsar advocates the establishment of wetland conservation areas, the effectiveness of these depends entirely on the application of national legislation.

Protected areas can be nominated for Ramsar status. South Africa has 22 Ramsar sites, five of which include marine habitat. These are the Orange River Delta, West Coast National Park, the Wilderness National Park, the St Lucia Marine Reserve and the Maputaland Marine Reserve.

International Maritime Organization

This organization has set aside "areas to be avoided" by ships, because of their vulnerability to pollution. In all, 26 sites have been declared (mostly northern hemisphere), and a set of criteria has been developed by which additional areas can qualify for the status of "particularly sensitive sea areas". However, no specific legal protection is offered, and states are bound only by convention. These designations are recognized by the various environment organizations of the United Nations as areas where ship-based pollution should be monitored, and measures implemented to reduce environmental damage.

RELEVANCE FOR SOUTH AFRICA

While the state of coastal biodiversity has steadily become more critical, it is the widespread collapse of fisheries that has prompted the sudden interest in marine protection. The turning point in fishery yield has passed, and global catches have begun to decline. However, MPAs are not finding easy acceptance. There is resistance from a number of sources. Fishermen, industrialists and recreationalists have been fierce opponents when their rights are affected, irrespective of favourable long-term prognoses. Bureaucracies and legislation are often not geared-up for the challenge. Even among fishery managers there is a certain amount of apprehension – current management strategies, models and monitoring techniques are not suited to management with MPAs.

MPAs are not new in South Africa, but the reasons that they are topical now are as new here as elsewhere. The review of MPAs in South Africa (Attwood *et al.* 1997) has shown that there is a need for some of the concepts which are being applied elsewhere.

Hockey and Buxton (1989) noted that the conservation status of South Africa's coastline was potentially good, although not all biogeographic zones were adequately protected and existing MPAs were beset with legislative, administrative and socio-economic problems. Little has been achieved in South Africa in terms of the protection of the physical marine environment. Large, zoned MPAs could be more widely applied in South Africa, in view of the success that has been achieved elsewhere with respect to habitat protection, combating of pollution and multiple use. As an example of a candidate for a large MPA zoned for multiple use, the Agulhas Bank is an important fishery ground and a centre of endemism for a large assemblage of fish species. The Agulhas Bank is threatened by oil and gas exploration and the transport of toxic cargo, and trawlers sweep part of it continuously. Tourism is developing into an important industry in South Africa, and the potential includes whale-watching, cage-diving among sharks, recreational angling and birdwatching.

South Africa's large no-take MPAs have served to demonstrate the positive effects of total protection on heavily exploited fish species, yet the idea of harvest refugia has yet to find a formal place in operational management procedures for South African fisheries. Cognizance ought to be taken of the important paradigm shift toward ecosystem management advocated by fishery scientists in northern hemisphere countries, where some important stocks have collapsed. The benefits of MPAs can be officially recognized in management policies. South Africa is well positioned to play an important role in research on the development of principles of MPA design, particularly for fisheries.

It is in respect of establishment and management procedures where the largest improvement can be made to South Africa's marine protection. The main points to emerge from this review are as follows:

- MPA establishment could be top-down or bottom-up, but should follow a prescribed format which incorporates a public consultation process.
- MPAs should be managed by a national programme to consolidate a network of MPAs, although individual MPAs may be managed by different national and provincial authorities and under different sets of legislation.
- MPA policy and legislation should be strong enough to provide protection where it is needed, and should not allow short-sighted arguments to block effective protection. On the other hand, the essential needs of local communities should be considered in the design of protected areas.
- Advisory groups can provide a communication link to local communities.
- Education, enforcement and monitoring programmes should be detailed in management plans.

South Africa is party to a number of conventions which call for the designation of MPAs. It is therefore right that a revised policy on MPAs for South Africa should take these commitments into account and integrate them with local needs.

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