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MEETING THE CLIMATE CHALLENGE?

An Analysis of Coral Reef Conservation Systems in Kenya and Tanzania

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requirements for the MSc and/or the DIC

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DECLARATION OF OWN WORK

I declare that '*Meeting the Climate Challenge? An Analysis of Coral Reef Conservation Systems in Kenya and Tanzania*.' is entirely my own work and that where any material could be construed as the work of others, it is fully cited and referenced, and/or with appropriate acknowledgement given.

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‘Coral reefs… may be the single largest casualty of ‘business as usual’ greenhouse policies.’

- Ove Hoegh-Guldberg (1999)

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ABBREVIATIONS

BMU – Beach Management Unit
CA – Conservation Area (Tanzania)
CBD – Convention on Biological Diversity
CDA – Coastal Development Authority
CORDIO – Coral Reef Degradation in the Indian Ocean
COP – Conference of the Parties
DCCFF – the Department of Commercial Crops and, Fruits and Forestry (Tanzania)
DFMP – Department of Fisheries and Marine Products (Tanzania)
CRC – Coastal Resources Centre
EACC – East African Coastal Current
EIA – Environmental Impact Assessment
EMCA – Environmental Management and Coordination Act (Kenya)
EMSDA – Environmental Management for Sustainable Development Act (Tanzania)
ENSO – El Niño Southern Oscillation
FD – Forestry Department (Kenya)
FiD – Fisheries Department (Kenya)
GDP – Gross Domestic Product
ICAM – Integrated Coastal Area Management
ICZM – Integrated Coastal Zone Management
IUCN – The World Conservation Union
KICAMP – Kinondoni Integrated Coastal Areas Management Project
KWS – Kenya Wildlife Service
MACEMP – Marine and Coastal Environmental Management Project
MPA – Marine Protected Area
MNP – Maine National Park (Kenya)
MNR – Marine National Reserve (Kenya)
MP – Marine National Park (Tanzania)
MPRA – Marine Parks and Reserves Act (Tanzania)
MPRU – Marine Parks and Reserves Unit (Tanzania)
MR – Marine National Reserve (Tanzania)
NEMA – National Environmental Management Authority
NP – National Park
R&R – Resistance and Resilience
RUMAKI – Rufuji-Mafia-Kilwa (WWF)
SST – Sea Surface Temperatures

TCMP – Tanzania Coastal Management Partnership Management Partnership

UNEP – United Nations Environment Programme

UNFCCC – United Nations Framework Convention on Climate Change

UNEP – United Nations Environment Programme

USAID – United States Agency for International Development

WIOMSA – Western Indian Ocean Marine Science Association

WWF – World Wildlife Fund

WSSD – World Summit on Sustainable Development

ABSTRACT

Coral reefs are amongst the most diverse and valuable ecosystems on Earth, and are particularly important to developing countries – which are often highly reliant the goods and services they provide. However they are also highly threatened, not least due to the potentially devastating impacts of climate change and associated coral bleaching. Mitigating this global threat was, until recently, thought to be largely beyond the control of coral reef managers. However, the observed differences in the survival and recovery of coral reefs following bleaching events suggest that they can exhibit significant resistance and resilience to these impacts. Consequently, resilience (incorporating the concept of resistance) has become a key focus of management recommendations, in the belief that managers can play an active role in enhancing this property – specifically through appropriately planned and managed systems of Marine Protected Areas (MPAs).

Using principles offered by The Nature Conservancy's 'Resilience Model', this study assesses the protection against future climate change offered by the coastal management systems in Kenya and Tanzania – two developing countries whose reefs have already suffered significant damage from bleaching. The results suggest that both countries currently face significant gaps in their current protection. Given existing systems and their underlying policies and legislation, improving the effectiveness of current MPAs seems to be one of the few options available for Kenya to address these gaps. Although in some ways less well developed so far, Tanzania's systems seem to offer a much wider scope for satisfying the model's principles, including through the creation of new MPAs.

However, the analysis is found to be limited by problems in two key areas. Firstly, the data requirements, even for this simple model, are high and cannot be adequately met by the two countries, leading to assessments that are at best preliminary. Secondly, the resilience model itself is currently too early in its development to offer either a clear framework for assessment and planning, or to provide any more than a hypothetical route to protection against climate change. Nonetheless the model, and the concept of resilience that it embodies, can provide an early guide to policy makers wishing to address this threat, and further illustrate the potential importance of taking a carefully planned and strategic approach to conservation. The analysis also demonstrates the need for a significant improvement in research and monitoring to support these processes.

1. INTRODUCTION

Tropical coral reefs are now widely recognised as amongst the most diverse ecosystems on Earth. They provide habitat for around one quarter of all known marine fish species, despite occupying less than 0.1% of the of the ocean floor (Spalding et al, 2001). Including and beyond this biodiversity, coral reefs are undoubtedly of enormous value to humanity, providing vital coastal protection and tourist income, as well a major source of food to some 500 million people worldwide (Wilkinson, 2004). While quantifying their full economic value can be difficult, estimates suggest that the potential global net value of goods and services emanating from coral reefs could be as much as $30 billion per year – a figure that excludes the possibly substantial gains to be made from pharmaceutical research and development in reef areas (Cesar et al, 2003). The importance of these ecosystems is further magnified when it is considered that 75% of the world's coral reefs found in developing countries (Pauly et al, 2002) which may be highly reliant on the goods and services they provide. Unfortunately, while they represent a vital resource for development, '*reef-dependent poverty*' is noted as a key driver of reef degradation (Whittingham et al, 2003), as their riches attract ever-increasing coastal populations and rapid, unsustainable exploitation. As such, it is unsurprising that coral reefs are also thought to be one of the Earth's most highly threatened ecosystems.

The numerous anthropogenic threats to coral reefs at a regional or local level have been growing over the past 50 years, and are now well documented. Although spatially variable in their relative importance, these threats generally include pollution from land- and sea-based sources; destructive fishing and over-harvesting of fisheries and coral resources; sedimentation due to poor land-use practices; introduced species and disease outbreaks; and accidental damage due to shipping, boats and tourist activities (Buddemeier et al, 2004; Spalding et al, 2001). These alone pose significant problems, with Bryant et al (1998) estimating that 58% of the world's reefs are threatened to some extent by human activities, with 20% already effectively destroyed (Wilkinson, 2004). However, in the more recent past, a threat has emerged that may add to and synergise with existing problems – that of global climate change.

The increasing concentration of carbon dioxide in the Earth's atmosphere, and associated climate change, has various direct and indirect implications for our environment, but for coral reefs the effect that has perhaps received the greatest attention is temperature induced coral 'bleaching'. Bleaching can occur during periods of elevated sea surface temperatures as thermally stressed corals expel the symbiotic, photosynthetic algae (zooxanthellae) that live within their tissues and which supply much of the polyps' food. The loss of these vital, often colourful, zooxanthellae causes their coral hosts to 'bleach', becoming pale or even white. While they can, and often do, recover from such bleaching, severe or long-lasting stress can lead to widespread mortality of corals (Hughes et al, 2003). The devastating implications of this phenomenon was bought to the world's attention by a global scale bleaching episode in 1998, which devastated many of the world's coral reefs (Wilkinson, 2004).

While coral bleaching is certainly neither new nor unique to increasing oceanic temperatures, it appears that this type of temperature-induced, *mass* bleaching event is increasing in frequency as our climate changes. Over the last century, tropical sea surface temperatures have increased by around 1°C and are continuing on this trend – leading to predictions that episodes such as that experienced in 1998 may become a regular occurrence within the next 20 years (Hoegh-Guldberg, 1999). Such short time scales would offer limited scope for coral adaptation and thus, while the precise effects of such regular and severe events may be uncertain, it is clear that they are likely to have profound and dire consequences for coral reefs. Finding a way to mitigate their effects is thus vital, not only for conservation, but also to minimise the potential global economic losses associated with 'severe' bleaching, which could be as much as US$84 billion over the next 50 years (Cesar et al, 2003).

Tools such as Marine Protected Areas (MPAs) and Integrated Coastal Zone Management (ICZM) have been widely used to provide protection against the various threats to coral reefs, especially those that are anthropogenic in nature. However in climate change, managers and policy-makers are faced with a threat that is truly global in scale and which could quite reasonably be seen as beyond the reach of local level approaches to conservation. Fortunately, there is now an increasing recognition that, alongside wider efforts to reduce worldwide greenhouse emissions, important steps can be taken to 'buy time' for vulnerable ecosystems such as coral reefs, boosting the capacity of both ecosystems and the communities which rely upon them to adapt to the effects of climate change (Hansen et al, 2003). Specifically, it has been suggested by authors such as West and Salm (2003) that appropriately designed and managed systems of MPAs may be capable of capturing and enhancing both bleaching resistance – the capacity of corals to survive or avoid bleaching, and resilience – the capacity of corals to recover from bleaching, thus reducing mortality and speeding recovery after damaging events. Perhaps due to the vulnerability and value of coral reefs, hypotheses surrounding resistance and resilience have quickly gained favour, despite their early stage of investigation – not least in international agreements where they have added to more traditional approaches to the conservation of coral reefs. As such, there is now both some scientific and political support for the integration of these concepts into coastal management.

It is clear from the above that developments in the understanding of, and responses to, the effects of climate change and coral reefs have been extremely rapid. Accordingly, this study aims to provide a vital early insight into how recommendations for mitigating the effects of climate change on coral reefs can be applied to current and future management practice – particularly in vulnerable, developing countries. Given its relatively long history of coastal management and its experiences during the 1998 coral bleaching event, the study's primary focus will be Kenya. Tanzania also experienced significant bleaching and mortality in 1998 and, although less well covered in the literature, will provide a useful secondary case study and a valuable basis for comparing different systems within East Africa. Accordingly, the first part of the study examines the values of, and threats to the two countries' coral reefs, and investigates in greater detail the scientific and political recommendations which may be driving their conservation. The remainder of the study then attempts to answer the following, central question:

To what extent do current coastal management and policy/legislative systems in Kenya and Tanzania provide for the protection of coral reefs against future climate change?

This may be further separated into two sub-questions:

1. *To what extent do coastal management systems in Kenya and Tanzania reflect key recommendations for the protection of coral reefs against climate change?*

2. *Given the current state of these systems, and their underlying policies and legislation, how might any gaps identified in (1) be filled?*

Such analysis should provide a preliminary insight into the future of coral reefs in the two countries. With global climate change threatening the reefs of developing (and developed) countries throughout the world, lessons learned may be useful to scientists, managers and policy-makers in many other regions.

2. BACKGROUND

2.1. THE VALUE OF CORAL REEFS IN KENYA AND TANZANIA

The coastline of East Africa stretches over 4,000 km and is home to an estimated 11,000 species of plants and animals, of which 15% are endemic (UNEP, no date). Coral formations are dominated by fringing and patch reefs (Obura et al, 2000), which border 35% of the coast (Whittingham et al, 2003) and provide a significant source of this biodiversity. Amongst the five mainland countries which make this coastline (Kenya, Somalia, Tanzania, Mozambique and South Africa), Tanzania has the largest reef area and supports the greatest number of coral and reef fish species, recorded at over 370 and 679 respectively (see table 1.1). Kenyan reefs also have high biodiversity value – harbouring more than 300 coral species and almost 500 species of reef fish within a much smaller reef area. Of course the countries' coastal biodiversity is not limited to coral reefs, and both coastlines also feature other important flora and fauna, including mangroves and sea-grasses, as well as populations of marine mammals (whales, dolphins, dugongs), turtles and birds (WWF, 2005).

Table 1.1 – Selected coral reef and economic statistics for East Africa

Country	2003 GDP per capita† / US$	Coral Species*	Reef Fish Species‡	Reef Area* /km^2	Reefs at Risk* / %	Number of MPAs*
Somalia	n/a	308	559	710	95	0
Kenya	450	>300	490	630	91	9
Tanzania	287	>370	679	3580	99	11
Mozambique	230	>370	872	1860	76	5
South Africa	3,489	90	799	<50	n/a	2

Sources: *Reproduced from Obura et al (2004), † from UNDP (no date), ‡ from ReefBase (no date).

While the value of the world's coral reefs is beginning to be understood, the economic significance of those found in Kenya and Tanzania is less well studied. However, while no country-specific estimates currently exist as to their total economic value, multi-country studies give some indication of their value. One such study (Cesar et al, 2003) estimates a net present value of coral reefs in the Indian Ocean, calculated over a 50-year time frame, to be on excess of $111 billion. This figure includes biodiversity, fisheries, coastal protection and tourism, however, it's omission of other potential values (e.g. pharmaceutical) and the assumption of '*well managed and intact*' coral reefs serves to reduce its precision.

Sectoral data can provide a further idea as to the dependence of Kenya and Tanzania's coastal populations on reef resources. Accounting for some 25% of GDP (McClanahan et al, 2005b), tourism is a vitally important sector in the Kenyan economy. While there may not be a direct relationship between tourist numbers and presence of (healthy) coral reefs, it is worth noting that around 70% of Kenya's tourists are reported to spend at least some of their time on the coast (Obura, 1999), where much of the tourism is centred on coral reef areas. Of these, the protected areas along the southern coast are particularly important, with the MPAs at Kisite and Mpunguti alone generating annual net income in excess of US$1.6 million (Emerton and Tessema, 2001). Similarly, tourism in Tanzania generated 13% of GDP in 1999, with the coral reefs and beaches of Zanzibar, Mafia and Pemba providing particularly popular tourist attractions (TCMP, 2001).

In addition to tourism, both countries' reefs support valuable fisheries, with high levels of subsistence fishing found within poor coastal communities. While fisheries in Kenya are dominated by inland lakes, marine fisheries remain important. Small scale commercial and artisanal operations yield a total annual production of around 12,000 tonnes in support of 9,000 fishers and their dependents (Kenya Fisheries Department, 2004). In Tanzania, coral reef fisheries are overwhelmingly artisanal and provide around 30% of the total marine fish catch (Muhando, 1999), supporting some 43,000 fishers (Jiddawi and Öhman, 2002). Other extractive uses include coral mining, which represents a significant, though highly destructive, source of income in some areas of Tanzania (Darwall and Guard, 2000). Specific values for biodiversity, pharmaceutical and shoreline protection within the region are not well documented, but are likely to be significant.

2.2. ANTHROPOGENIC THREATS TO CORAL REEFS IN KENYA AND TANZANIA

Many of the world's reefs are increasingly under threat of destruction or degradation caused by human activities. East Africa is no exception with reefs, thought to have been largely pristine only 100 years ago, today being exploited by coastal populations growing at 5-6% per year (Obura et al, 2004). Such rapid population increases, even without the additional pressure of climate change, place significant pressures on coral reefs. Of these, perhaps the most significant is the threat posed by the extensive fisheries noted in the previous section, which are generally described as over-exploited in both Kenya and Tanzania (Darwall and Guard, 2000; Horrill et al, 2000; Obura et al, 2000). This over-fishing has been noted as having significant impacts on key predatory species and herbivores, with ensuing increases in sea urchin populations noted as having particularly detrimental effects on reef structure (Obura, 2001). In both countries, direct fishing impacts on reefs include degradation due to the continued use of destructive fishing gears such as seine nets (McClanahan et al, 2005a; Horrill et al, 2000) and dynamite fishing which, although declining, has been a long-standing problem in Tanzania (Suleiman et al, 2005).

Other notable threats include uncontrolled development and associated pollution (Spalding et al, 2001) – which are mainly focused around cities (e.g. Dar es Salaam and Mombasa) as well as major tourist centres (e.g. Zanzibar and Diani). Away from the coast, inland activities are also having an impact on corals. In particular, poor land-use practices are leading to high sediment loads in rivers such as the Ruvuma and Rufuji in Tanzania, and the Sabaki and Tana in Kenya, with their outflows causing siltation on some nearby reefs. The combination anthropogenic threats such as these has led to reefs throughout both countries being noted as extremely vulnerable, with 91% of refs in Kenya and 99% of reefs in Tanzania thought to be at risk of destruction (see table 1.1 above)

2.3. CLIMATE CHANGE AND THE THREAT OF CORAL BLEACHING IN KENYA AND TANZANIA

Climate change has presented new problems for coral reefs which threaten to add to and synergise with existing anthropogenic threats. Associated changes in seawater chemistry have the potential to decrease the rate at which corals can calcify and grow, and rapidly rising sea levels may 'drown' coral reefs (Grimsditch and Salm, 2005). However, while these may be considered as long-term threats, one impact of a changing climate has already begun to take its toll on coral reefs – coral bleaching. As noted in chapter 1, bleaching can have a devastating impact on coral reefs. This was vividly demonstrated in 1998, when a global scale bleaching event was responsible for the death of 16% of the world's coral reefs (Wilkinson, 2004) – placing it at the forefront of the coral conservation agenda.

Coral bleaching had already been observed for some years in East Africa, with significant events occurring in the region during both 1987 and 1994 (McClanahan et al, 2002). While these resulted in a degree of mortality, the 1998 bleaching event proved to be particularly devastating to the region's coral reefs. The event, in common with other major bleaching episodes, was associated with a disturbance to the El Niño Southern Oscillation (a global climate cycle) – which in 1998 was perhaps the strongest on record (Hoegh-Guldberg 1999). However in 1998, this effect is thought to have been further enhanced in East Africa due to the unusual coincidence of the El Niño with a warm phase of another climate cycle – the regional Indian Ocean dipole (Goreau et al, 2000), and specifically in Tanzania by a concurrent reduction in salinity (another cause of bleaching) resulting from heavy monsoon rain (Muhando, 1999).

Between from March and June 1998, sea surface temperatures along the Kenyan coast averaged 1.5ºC above those recorded during the same period in 1997 (Obura, 2001), and as much as 2ºC higher in Tanzania (Muhando, 1999). This high and persistent SST anomaly led to significant bleaching across much of the region, with subsequent mortality rates of 90% on both Kenyan reefs and Tanzanian Reefs (Obura, 2001; Wilkinson et al, 1999) – amongst the highest suffered anywhere in the world. This, inevitably, had significant effects on coral diversity. Particularly affected were fast growing species such as *Pocillopora, Stylophora* and *Acropora*, which suffered up to 100%

mortality on some sites (Obura, 1999; Muhando, 1999). In both countries, it was also noted that many of the reefs previously described as high diversity were those worst affected by the bleaching event (McClanahan et al, 2002; Muhando and Francis, no date), with many experiencing a shift towards dominance by algae (McClanahan et al, 2002).

Aside from the effects on reef biodiversity, the full socio-economic impact of coral bleaching and the subsequent degradation of East African reefs are so far largely uncertain. McClanahan et al (2002) found that the effects of the 1998 event on Kenyan fisheries were indistinguishable from those of general over-exploitation, and some *increases* in (particularly herbivorous) fish abundance were noted in Tanzania (Wagner, 2004). However, as pointed out by Westmacott et al (2000), catches in both countries could be expected to fall significantly as ongoing erosion of dead corals leads to a decline in the structural integrity of reefs. Aside from fisheries, Westmacott et al (2000) also investigated the losses in tourism values at Mombasa and Zanzibar in the months immediately following the bleaching event. They found that both economic and financial costs were substantial, at US$10.1-15.1 million and US$13.3-20.0 million respectively for Mombasa, and US$1.9-2.8 million and US$3.1-4.6 million for Zanzibar. While these estimates assumed the *permanent* disappearance of tourists and are hence perhaps unrealistic, they do highlight the magnitude of potential losses if long-term coral losses lead to a fall in coastal tourism. Projecting losses into the future, Cesar et al (2003) estimate the potential costs of 'severe' bleaching in the Indian Ocean region to be around US$13 billion over the next 50 years

Of course attempts to estimate the long term economic cost of bleaching rely on predictions of future events. Of these, perhaps the best known is that of Hoegh-Guldberg's (1999), who predicts massive, global coral losses in the next few decades due to bleaching. These predictions are supported at the regional level by Sheppard (2003), whose analysis for the Indian Ocean estimates that '*catastrophic*' temperature conditions such as those witnessed in 1998 will be a regular occurrence within the next 35 years (sooner at the most vulnerable latitudes between 10-15° South – e.g. southern Tanzania), leading to widespread destruction of the region's coral reefs. While the 1998 event was driven by an unusual coincidence of climatic events in the region, future ENSO fluctuations set against a general warming trend in the Earth's climate may see devastating temperature anomalies without the need for such coincidences (Goreau et al, 1999). Thus, despite the uncertainties surrounding this complex problem, it is widely suggested that coral bleaching is now the dominant threat to the East Africa's (and indeed the world's) coral reefs (West and Salm, 2003; Obura, 2001).

2.4. ESTABLISHED CONSERVATION APPROACHES FOR CORAL REEFS

Marine Protected Areas (MPAs) are the most long-established conservation tool used by policy-makers aiming to protect coral reefs. As such, reefs are found within MPAs in over 100 countries (Salm et al, 2000). MPAs in their widest sense may be defined as:

'Any area of inter-tidal or sub-tidal terrain, together with its overlying water and associated flora, fauna, historical and cultural features, which has been reserved by law or other effective means to protect part or all of the enclosed environment' (Kelleher, 1999).

Following from this broad definition, the precise nature of MPAs around the world can differ substantially. Such areas may encompass a variety of different goals including biodiversity/species conservation, fisheries protection or tourism promotion (Kelleher, 1999); and a varying degree of use restrictions – from strict closed areas through to multi-use, multi-zone MPAs; with each attempting to address any number of local threats. MPA management is also diverse, and may be undertaken by one or a combination of governments, non-governmental organisations, private owners or local communities. Accordingly, the selection, design and management and assessment of MPAs can involve a complex array of ecological and social considerations, which often need to balance conservation with sustainable use. Perhaps in part due to this complexity, success can be highly variable – ranging from highly effective MPAs to unmanaged 'paper parks'. One key development in attempting to increase general effectiveness has been to move towards inter-linked systems of MPAs. Amongst other things, this aims to replace previous selection processes, which have often been *ad hoc*, with a more strategic approach that takes into account goals and objectives that may not be considered when creating an individual MPA, such as representation and connectivity (Salm et al, 2000).

In a similar light, it has become clear that even the most carefully selected, designed and managed MPA or MPA system may be ineffective against some of the threats which lie outside their borders, such as pollution from agricultural run off or uncontrolled coastal development. As such, Integrated Coastal Zone Management (ICZM) has recently become established as a tool which can complement the use of MPAs, providing an effective means of placing these '*islands of protection*' within a wider ecological and socio-economic context (Salm et al, 2000). Through appropriate, integrated legislation and management, which accounts for the needs of a variety of stakeholders and a range of land- and sea-based activities, ICZM can address wider threats over which an individual MPA may lack specific jurisdiction, but which may be critical to the health of coral reefs.

Despite their successes, there has been some concern that these tools are best suited to addressing local or regional threats to coral reefs rather than global-scale issues such as climate change and that '*...the warming of the Earth... is largely ignored or beyond the control of local managers of coral reefs*' (McClanahan, 2000). In response to this perceived impotence, there has been a clamour to understand how locally-based policies might be adapted to face this ubiquitous threat. The result of such efforts has been to highlight the continuing role that well designed MPA *systems* (supported by ICZM) may yet play in buying time for these vulnerable ecosystems – maximising the chances of survival and adaptation through the removal of non-climate threats and the protection of resistant and resilient reefs (Hansen et al, 2003).

2.5. RESISTANCE, RESILIENCE AND THE CONSERVATION OF CORAL REEFS

Early authors such as Hoegh-Guldberg (1999), in predicting a bleak outlook for coral reefs, surmised that the process of adaptation amongst corals could not occur at a rate fast enough to provide protection against rapid climate change. However, as noted by Hughes et al (2003), this model assumes that all corals show identical responses to the same thermal stress event, which is a highly simplistic assumption. Indeed, it has been observed by various authors that, even following the most widespread and severe thermal stress, bleaching and mortality (and later recovery) responses can be highly variable within and between coral regions, reefs and species (Coles and Brown, 2003; West and Salm, 2003). In the years since the 1998 event, which proved to be no exception to this rule, the ecological concepts of resistance and resilience have increasingly been used to explain these differences (West and Salm, 2003).

2.5.1. Resistance

Ecological resistance, in general terms, may be defined as an organism's '*ability to maintain a relatively constant state in the face of disturbance or stress*' (Noss, 2001). This definition can be narrowed in this specific context to relate to coral's '*ability to withstand bleaching and mortality*' (Grimsditch and Salm, 2005). In exploring this concept, West and Salm (2003) identify high survival in corals that have experienced extreme temperature variation between seasons, emergence during low tides and previous ENSO events. They hypothesise that this kind of repeated thermal stress can lead to lead to intrinsic resistance – gained through the adaptation or acclimation of either the corals themselves, or their zooxanthellae. Corals at these sites are then liable to suffer lower levels of bleaching and/or mortality in response to later high temperature events. Importantly, it has also been suggested that, over time, these sites may provide an important source of recruits at other, damaged sites, resulting in the proliferation of resistant genotypes within coral reefs (Obura, 2005).

West and Salm (2003) also identify areas where strong survival has occurred alongside a diverse array of features such as the up-welling of cool water, cloud cover, strong oceanic currents and high wave energy. This leads them to suggest that these factors may play an important role in reducing temperature and/or light stress (which can act separately or synergistically to cause bleaching), or improving the flushing of the harmful toxins that result from bleaching – in each case increasing the likelihood of survival. Since they tend to reduce the *level* of stress experienced by specific colonies, reefs or regions during potential bleaching events, these extrinsic, non-physiological factors are also described as '*avoidance*' (Grimditch and Salm, 2005) or '*protection*' (Obura, 2005a).

2.5.2. Resilience

Resilience is another widely used ecological concept, and is generally defined by a system's ability to '*undergo change but to retain the same functions and general structure*' (Obura, 2005a). Such a definition, in this context, relates to the ability of a coral community to recover from the effects of a bleaching event to its former state (Grimsditch and Salm, 2005). It must also be seen as a time-dependent term, that requires recovery to take place within an appropriate time scale (ideally, in this case, before the next bleaching event). Such recovery may be brought about by the re-growth of corals within a reef that survive the (stress) event, or the successful recruitment of new corals from other areas (Obura, 2005a). Intrinsic factors governing these processes occur within the community/ ecosystem, and include a low abundance of corallivores and diseases, the ability of surviving corals to produce plentiful and healthy larvae, and those that promote the successful recruitment of larvae (West and Salm, 2003). Wider, spatial resilience results from processes that take place beyond the boundaries of a single ecosystem or community, including larval connectivity with distant source reefs due to oceanic currents. West and Salm (2003) further suggest effective management as another possible extrinsic factor which, through the removal of other threats, may enhance the rate at which reefs are able to recover from damaging events.

2.5.3. The 'Resilience' Model

These concepts are now increasingly well accepted as explaining many of the observed variations in bleaching responses. Accordingly, policies which can incorporate the concepts of resistance and resilience are seen as offering a means through which the effects of climate change may be addressed at a local and national (or regional) level. Management recommendations have thus centred around the identification of reef areas which display either resistance or resilience to climate change, and the subsequent design (or adaptation) and management of coastal management systems to enhance and promote these characteristics (Salm and West, 2003; Hansen et al, 2003). While such a process may require the consideration of a large number of underlying factors, The Nature Conservancy (TNC) – one of the organisations to have promoted these concepts most strongly – has outlined a 'Resilience Model' (incorporating resistance) which simplifies them into four key 'principles' (TNC, 2004).

- **Connectivity**. MPA networks should be designed to ensure that reefs damaged by coral bleaching are connected by currents to adequate of coral larvae – thus improving the chances of recovery.

- **Representation and Replication**. MPA systems should include, *inter alia*, all key habitats types. The replication of such habitats across multiple protected sites then reduces the risk that, following a damaging event, all examples of a habitat type and its species will be lost.

- **Refugia**. Key sites (such as bleaching resistant areas) should be protected within MPAs so as to provide sources of seed to damaged areas.

- **Effective Management**. Through minimising the effect of local threats, effectively managed MPAs should enhance the potential for recovery.

As noted above, concepts such as connectivity and representation and replication have previously been suggested as key criteria for the selection of new MPAs and the creation of networks (Salm et al, 2000). It is also reasonable to assume that effective management should be a goal of any protected area. Thus, with the possible exception of refugia (in the bleaching resistance sense at least), these principles should not require a radical departure from existing theory (see also section 2.7 below). However, while these concepts are widely used, they are more complex than they might appear and are to some extent poorly understood.

Perhaps unsurprisingly, the more recent idea of bleaching resistance (and hence the protection of refugia) appears to be one of the more controversial in its application to management. This is demonstrated in West and Salm (2003), which attempted to rank both resistance and resilience factors according to their '*reliability*' (whether they are persistent and predictable). Unfortunately, as shown in Table 2.1 below, many of the resistance factors they suggest are immediately noted as being of low reliability, especially those which are ephemeral in nature (cloud cover or wind-driven mixing of water). However, even those resistance factors described as highly reliable are noted as being subject to contradictions and requiring careful consideration. For instance, West and Salm (2003) suggest that protective up-welling can be disrupted during ENSO events – leaving usually protected reefs highly vulnerable, and that greater depth does not always correlate well with greater protection from bleaching. Following observations of a positive relationship between water flow and bleaching in Mauritius, McClanahan et al (2005) also question the reliability of flushing as a resistance factor. While such factors may remain important, it is likely that many of them are highly site specific and complex, and are difficult to separate from other confounding influences. Further uncertainty over factors such as up-welling and cool currents is added by the possible role of climate change in affecting future oceanic processes (Goreau et al, 2005; Soto, 2002).

Amongst the broader principles, the idea of connectivity is the subject of some controversy. Current speeds, the behaviour of different species and their larvae, and a host of other local factors which contribute to larval dispersal, can be highly variable. For example, there is some evidence that some coral larvae may be capable of surviving in the water column for many days, or even months (Wilson and Harrison, 1998), implying potentially vast dispersal distances. However, it has also been reported that due to various oceanographic processes larvae can often be retained close to natal reefs for long periods (Paris and Cowen, 2004) – implying that short distance dispersal may dominate. Consequently, the true scale at which connectivity operates is unclear, and design criteria may need to be very different according to species or location. Despite these uncertainties, recent literature on marine protected area networks has suggested that no-take areas should be separated by no more than a few tens of kilometres in order to maintain connectivity (Palumbi 2004; Shanks et al, 2003) – but such figures may be no more than a 'rule of thumb'. Even if such figures are accepted as reasonable, long-term planning for connectivity is again likely to be affected as key oceanic processes change with climate.

The principle of representation is also well discussed, but still there may be some uncertainty over what managers might choose to select for representation and at what scale. This is especially true for habitats, since even the small environmental variations can create differences in (micro-)habitat. To avoid excessive data requirements, Roberts et al (2003) suggest that MPA systems should be designed to represent bio-geographic regions and 'major' habitat types (such as coral reefs and mangroves) – and that doing so will maintain biodiversity and ecosystem function. However, it is unclear how appropriate these criteria might be when considering resilience to climate change. The idea of replication is perhaps less contentious, but recommendations are still largely theoretical and imprecise. Roberts et al (2001) suggest that systems of MPAs should aim to include between 20-50% of each habitat type, replicated across a number of different sites. Usefully, the upper limit is suggested for areas which suffer significant environmental fluctuation that result in mass mortalities of marine life (Roberts et al, 2006), and as such may be appropriate for areas prone to coral bleaching.

To some extent, such uncertainty and unreliability surrounding the principles (and their underlying factors) makes it difficult for managers and policy-makers to know what they are looking or aiming for. Indeed, as noted by Obura (2005a), factors should ideally be well understood and predictable if they are to be incorporated into management and policy interventions. Nonetheless, even without certainty over their precise impacts or nature, there is at least some degree of consensus over the *importance* of representation and replication and connectivity to general reef health, and as mentioned previously, effective management should always be a target for any conservation measure (otherwise why implement it at all?). Also, those aspects of resistance which are better understood may allow some sites to be identified as reliable and protected accordingly, even if others must wait until science progresses. A related point is made by Obura (2005a), who suggests that some of the concerns over focusing on resilience may be overcome if an adaptive approach can be taken to management. Following this suggestion would allow managers to work towards the implementation of some or all of the resilience principles (including the identification of resistant sites), using future bleaching events to test their effectiveness, and to adjust practices accordingly. Thus at this stage, especially given the current lack of alternative frameworks, following resilience-based recommendations in the creation or modification of MPA networks represents a pragmatic strategy for conservation.

While there is certainly no guarantee that even then ideal system of MPAs will provide protection against climate change, the *possibility* of success has been sufficient to encourage some changes in MPA systems around the world. One notable example has been the re-zoning of Great Barrier Reef Marine Park in 2004, which increased the area of no-take zones within the park from less than 5% to over 33%. Although not explicitly attempting to identify resistant sites, this rezoning did aim to build resilience to climate change, and incorporated principles such as representation and replication (GBRMPA, no date). The Great Barrier Reef Marine Park Authority chose to ensure that at least 20% of all '*bio-regions*' identified within the park were represented in (no take) protected areas, with 3-4 replicates in each case (Fernandes et al, 2005). Where data was available, connectivity was also considered during the design of the network (A. Green, personal communication). Such initiatives will be vital in the development of resilience theory as they offer a large scale experiment for the evaluation of various resilience hypotheses.

Table 2.1 – Environmental and human factors that are hypothesised to affect coral bleaching avoidance, resistance and resilience. Factors may influence one or a combination of (A)voidance, (R)esistance, resi(L)ience, or (M)anagement interactions.

	Influence	Reliability*		Influence	Reliability*
Physical factors that reduce temperature stress			*Ecological factors that aid recovery*		
Exchange (warm water replaced with cooler oceanic water)	A	High	Broad size and species distributions	L	High
Up-welling	A	High	Areas of considerable residual coral cover	L	High
Areas adjacent to deep water	A	High	Availability and abundance of local larvae	L	High
Wind-driven mixing	A	Low	Recruitment success	L	High
			Low abundance of bio-eroders, corallivores, diseases	L	High
Physical factors that enhance water movement / flush toxins			Diverse, well balanced community (e.g. herbivorous fishes)	L	High
Fast currents (eddies, tidal and oceanic current, gyres)	A,R	High			
Topography (peninsulas, points, narrow channels)	A	High	*Large scale factors that aid recovery*		
High Wave Energy	A,R	Low	Connectivity by currents (from larval source reefs)	L	Low
Tidal Range	A,R	Low	Strong and reliable source of larval supply	L	Low
Wind	A,R	Low			
			Human / management factors		High†
Physical factors that decrease light stress			Over-fishing	L,M	-
Shade (high island shadow, reef structural complexity)	A,R	High	Destructive fishing	L,M	-
Aspect relative to the sun	A,R	High	Pollution	R,L,M	-
Steep reef slope	A,R	High	Nutrients/sewage input	R,L,M	-
Turbidity	A,R	Low	Siltation/erosion	R,L,M	-
Absorption (e.g. by coloured, dissolved organic matter)	A,R	Low	Tourism	L,M	-
Cloud Cover	A,R	Low	Habitat destruction	L,M	-
			ICM management plan in use	R,L,M	-
Physical Factors that increase resistance			MPA management plan in use	R,L,M	-
Temperature variability	A,R	High	Fisheries management in operation	L,M	-
Emergence at low tide	A,R	High	Overall management effectiveness	R,L,M	High†
Population factors of adaptation / acclimation					
Genetic variation in bleaching traits	R,L	-			
Sexual reproduction (recombination)	R,L	-			
Acclimation history at local site	R,L	-			
Resistance to other stresses	R,L	-			

Table adapted from Obura (2005a) and West and Salm (2003). *West and Salm (2003) define reliability of a factor as *'whether the factor is predictable and persistent in its operation and thus of high value as a predictor of survivability'*. † West and Salm assign high reliability to management effectiveness as an extrinsic resilience factor without further differentiating the relative importance or reliability of individual actions. '-' indicates no specific reliability estimate assigned in West and Salm (2003)

2.6. CORAL REEFS, CLIMATE CHANGE AND WIDER CONSERVATION PLANNING

Many of the developments in conservation theory outlined above have been similarly applied to other ecosystem types – which may further support their application to coral reefs. Concepts such as representation, replication, refugia and connectivity are widely discussed in conservation literature (Rouget et al, 2003), and reflect a general movement towards landscape level management and the idea of creating protected area systems which allow for shifting ranges and protection against large-scale threats. ICZM can also be seen in a similar light. In fact, there is some suggestion that the incorporation of such principles into marine conservation has so far lagged behind progress in terrestrial environments (Soto, 2002). Indeed, given coral reefs' relatively high vulnerability to small and often local environmental variations, and the high mobility of their larvae, such delays in moving towards their large-scale conservation are perhaps surprising. The concept of resilience has also been discussed in relation to a variety of ecosystems and threats. Folke et al (2004) outline the critical role human impacts have played in reducing the resilience of a wide range of aquatic and terrestrial ecosystems (including coral reefs). They further highlight the general need to manage such ecosystems to maintain their resilience to disturbances – if their ability to meet the needs of social and economic development is to be sustained.

What is perhaps more recent and incomplete is the application of theses concepts to climate change. As noted by Hannah et al (2002), progress in integrating climate change into conservation strategies, including selection criteria for protected areas, has been slow. They also stress the importance of systematic, rather than *ad hoc*, approaches in addressing this shortfall in conservation planning. Such a systematic approach may include following four steps as outlined by Pressey and Cowling (2001):

1. Identification of conservations goals
2. Review of existing conservation areas in relation to these goals
3. Selection of additional conservation areas
4. Implementation of conservation actions

Importantly, as illustrated by Hansen et al (2003), resilience building has now become a central feature of efforts to plan for climate change, and it is apparent from their discussion that this type of approach may be applied to a range of ecosystem types. It can also be seen that setting resilience to climate change as the goal in step (1) may allow planning to be undertaken accordingly. Indeed, steps (2), (3) and (4) above may be partly addressed by this study and its recommendations. Given the fact that climate change-type effects are already so keenly felt by coral reefs, there is an opportunity for them to provide an early case study in (climate change-integrated) planning and the application of resilience concepts to ecosystem conservation.

2.7. CORAL REEFS IN MULTINATIONAL ENVIRONMENTAL AGREEMENTS RELEVANT TO KENYA AND TANZANIA

As highly valuable and vulnerable ecosystems, coral reefs have featured prominently within various international agreements. At a global level, perhaps the most well known of these has been the 1992 Convention on Biological Diversity (CBD). A significant impetus under the Convention came with the creation of the Jakarta Mandate on Marine and Coastal Biodiversity. It highlighted the implementation of Integrated Marine and Coastal Area Management, and the creation Marine and Coastal Protected Area networks as principal action areas for action (CBD, no date). However, more specific developments regarding coral reefs and climate change unsurprisingly began in 1998, where decision IV/5 first reported parties to be *'…deeply concerned at the recent extensive and severe coral bleaching, such as that reported by the African countries'* (CBD, no date).

Table 2.2 – Examples of activities and actions under the CBD's work plan on coral bleaching.

Activity	Examples of Highest Priority Actions
1. Management actions and strategies to support reef resilience, rehabilitation and recovery	• Identification of coral-reef areas that exhibit resistance and/or resilience to raised sea temperatures. • Establish programmes that provide information and resources to support understanding and application of resilience principles into the design [of MPA networks]
2. Information gathering	• Document instances of mass bleaching, and the impacts of coral-bleaching and coral-mortality events on social and economic systems • Build capacity and facilitate the development and implementation of coral-bleaching response plans
4. Policy development / implementation	• Use existing policy frameworks to… implement comprehensive local-to-national-scale integrated marine and coastal area management plans that supplement marine protected areas

Adapted from COP 7 decision VII/5, appendix 1 (CBD, no date).

Eventually this attention led to the development of a specific and comprehensive, although non-binding, work plan on coral bleaching under decision VII/5. The introductory text to this decision took the notable step of adopting the World Summit on Sustainable Development target of establishing a network of representative marine protected areas by 2012 (CBD, no date). The plan itself specified priority actions under five key headings: management actions and strategies to support reef resilience, rehabilitation and recovery; information gathering; capacity-building; policy development /implementation; and financing (see table 2.2). To some extent, the explicit inclusion of resistance and resilience (which later also made reference to the work of The Nature Conservancy) is perhaps surprising, given the uncertainties they embody. However this issue is recognised by the inclusion of a number of actions which encourage further research into the concepts in order to inform their use.

At a regional level, the Convention for the Protection, Management and Development of the Marine and Coastal Environment of the Eastern African Region (otherwise known as the Nairobi Convention) has mirrored much of the work of the CBD. Under the convention, marine protected areas have been promoted both under the original articles, and a later protocol (Protocol Concerning Protected Areas and Wild Fauna and Flora in the Eastern African Region). Its work programmes have also highlighted ICZM as a key tool for the protection of the region's marine resources. Importantly, coral reefs have been highlighted in these programmes as priority areas for protection, although so far they have not included specific actions related to resistance and resilience. Consequently, perhaps one of the most specific developments for coral reefs has been the establishment of a Coral Reef Task Force, mandated to act as a focal point for coral reef research and activities – including the development of a regional coral reef action strategy.

While the CBD and the Nairobi Convention include many similar aims and objectives, the importance of the regional agreement stems from its role in facilitating information sharing amongst the contracting parties, and translating the work of the CBD into actions more specific to their needs and capacities. However, neither convention so far provides much in the way of explicit targets for actions to be taken in order to protect coral reefs (perhaps with the exception of the '2012' target). Furthermore, as noted above, work plans and programmes are not strictly binding, and thus provide little more than frameworks which might be implemented according to national priorities and capacities. Nonetheless, the conventions do provide important political backing for the use of MPAs (systems) and ICZM. The CBD also aptly demonstrates the prominence of coral bleaching on the international conservation agenda, and confirms the role that resilience-building is expected to play in addressing this threat.

3. METHODS

With the concept of resilience forming a central focus in both conservation science and international discussions, it provides perhaps the most obvious basis for analysing coral conservation policy in relation to climate change. In this light, and given space and data restrictions, the four principles of the TNC Resilience Model offered a simple set of criteria against which current and future protection could be assessed. The nature of the Model is such that assessment is most appropriately focussed at the MPA *system* level, and as such this was the main approach taken in the study – with MPA specific examples used where available and appropriate. Much of the information needed to undertake such an assessment was available through the review of previously published regional and national literature related to coral reefs and coastal management. In the case of Kenya, limited GIS data (obtained through the United Nations Environment Programme) was a further a means of providing quantitative measures of connectivity and representation. The secondary part of the analysis – assessing the possibilities for future developments in protection – required additional research to gain a broad understanding of the existing frameworks. Again, this was achieved through the examination of existing, published literature, using original policy and legal documentation where available.

A visit to the offices of CORDIO (Coral Reef Degradation in the Indian Ocean) East Africa provided an additional opportunity to discuss issues related to both aspects of the study with staff members who were particularly familiar with the region, and the national context in Kenya. Further information was gathered through attendance at the '*The Western Indian Ocean Resilience Workshop*', jointly convened by the IUCN and The Nature Conservancy (in conjunction with other members of the 'Resilience Partnership' including the Kenya Wildlife Service, CORDIO East Africa, the Great Barrier Reef Marine Park Authority, NOAA, the Wildlife Conservation Society, and WWF) in Malindi, Kenya from 9th-12th May 2006. This facilitated the observation of the workshop attendees and their participation in various workshop activities. As the initial scope of the project did not include Tanzania, efforts at the workshop were focussed on the Kenyan representatives – both in terms of their contributions within the workshop and during some informal conversations which took place outside of the workshop timetable. Kenyan Wardens were also able to provide copies of some MPA management plans. Outside the specific remit of the project, the workshop provided a valuable opportunity to see at first hand the latest developments in the resilience model, and to gain an insight as to how such complex and novel concepts could be communicated to, and absorbed by, an audience of protected area practitioners.

During the workshop and a later visit to Nairobi, further discussions were held with Rod Salm, Director of The Nature Conservancy's 'Transforming Coral Reef Conservation' programme; Haji Machano, Monitoring Coordinator at the WWF/RUMAKI Seascape Programme, Tanzania; and Ulrika Gunnartz and Dixon Waruingue, both of the United Nations Environment Programme, Nairobi. These meetings primarily provided background information on the coral bleaching and the regional/global policy context.

4. RESULTS - KENYA

4.1. KENYA'S MARINE PROTECTED AREAS AND THE FOUR RESILIENCE PRINCPLES

Kenya's MPA system currently consists of nine sites, including five Marine National Reserves (MNRs) and four Marine National Parks (MNPs). The MNPs are small and are open to recreational uses (diving, glass bottom boat tours etc.), but are closed to extractive uses. All of the parks are found within (or adjacent to) larger buffer areas – the MNRs – which are open to 'traditional' fishing as well as recreational uses.

Table 4.1 – Marine protected areas in Kenya

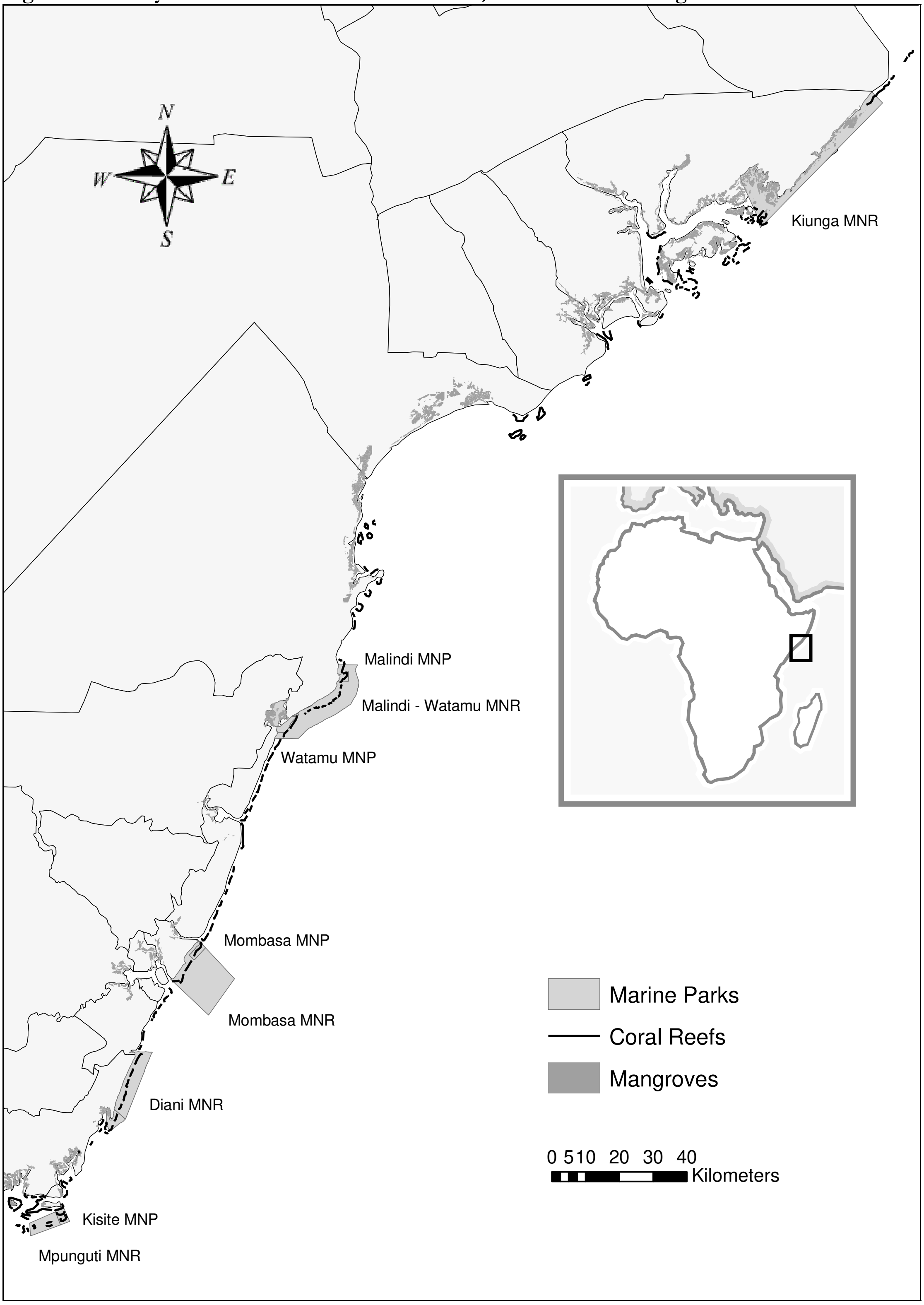
Marine Protected Area	Date Established	IUCN Category	Subtidal Area / km^2
Kiunga MNR	1979	VI	250.0
Malindi MNP	1968	II	6.3
Watamu MNP	1968	II	10.0
Malindi-Watamu MNR	1968	VI	245.0
Mombasa MNP	1986	II	10.0
Mombasa Marine MNR	1986	VI	200.0
Diani MNR	1995	VI	75.0
Kisite MNP	1978	II	28.0
Mpunguti MNR	1978	VI	11.0

Source: WWF, 2005

4.1.1. Connectivity

Connectivity may be assessed using the figures in section 2.5.3. However, given their general nature, it is perhaps also useful to calculate more specific figures for the larval dispersal distances which govern coral reef connectivity in Kenya. The main oceanic current affecting connectivity in the region is the North flowing East African Coastal Current (EACC), which travels up the coast from the Tanzanian border with Mozambique to the northern border of Kenya. The speed of this current varies throughout the year according to the monsoon winds, flowing at speeds of <0.25 - 0.75ms^{-1} in Kenya (Obura, 2001), and achieving a maximum during the South East Monsoon (Darwall and Guard, 2000). Using these figures alongside the 4-72 hours range of values given by Shanks et al (2003) for *Pocilloporid* and *Acroporid* larvae duration times, it seems that a lower distance range for dispersal, and hence effective connectivity, may be 4-65km, with an upper range of 11-194km (using upper and lower end of the current speed range respectively).

Figure 4.1 – Kenyan MPA locations and boundaries, coral reefs and mangroves



Source: GIS data supplied courtesy of the Division of Early Warning and Assessment (DEWA) United Nations Environment Programme, Nairobi. MNP – Marine National Park, MNR – Marine National Reserve.

Before using these figures, it is worth noting that a recent study focused on Mombasa (Mangubhai and Harrison, 2006) suggests that East African corals may largely spawn during the North East Monsoon, when currents are at their weakest. This would then imply that the lower distance range may be a more important gauge of connectivity. There is also some suggestion that, in the case of both Kenya and Tanzania, strong tidal currents (of up to $3.3ms^{-1}$) are likely to play at least as significant a role as the EACC in the dispersal of larvae (Horrill et al, 2000). Given these uncertainties, as well those outlined in chapter 2, even these local figures are likely to provide only an approximate guide to connectivity amongst Kenyan MPAs.

With this in mind, the GIS-estimates in table 4.2 show that the distances between Mpunguti-Diani (26km) and Diani-Mombasa (19km) could imply adequate connectivity – both falling within the lower range suggested above. However, this connectivity decreases further North, with a further 64 km between Mombasa and Malindi-Watamu MNR, and a yet greater 176 km between Malindi-Watamu MNR and Kiunga. The first of these figures is only just within the lower range, and may be of concern if periods of lower current speeds are more important. The latter figure is marginal even if we assume periods of high current speeds to be important. Connectivity problems for Kiunga may be further compounded by the outflow of the Tana River – which provides a year-round natural barrier to larval dispersal; and the effects of the North East Monsoon which can reverse flow of the EACC in North Kenya – periodically removing all connectivity with southern MPAs. These observations seem to be supported by field studies which have found larval recruitment in Kiunga to be generally been lower than in Southern sites (Obura, 2005b).

Table 4.2 – Separation distances between MPAs in Kenya

Gap	Distance* / km
Mpunguti MNR – Diani MNR	26
Diani MNR – Mombasa MNR	19
Mombasa MNR – Malindi-Watamu MNR	64
Malindi-Watamu MNR – Kiunga MNR	176
Kisite MNP – Mombasa MNP	85
Mombasa MNP – Watamu MNP	67
Watamu MNP – Malindi MNP	16

*** Straight line distances measured using GIS maps.**

A further consideration is that these distances represent the separation of the groups of MPAs (adjacent Marine National Reserves *and* Marine National Parks grouped together), when published literature tends to refer to distances between no-take areas only. If marine reserves are excluded, it can be seen that even the southern MPAs are outside the lower range (and indeed the 'few tens of kilometres' suggested in chapter 2), with Mombasa MNP separated from Kisite MNP by around 85km, with a further 67km to the next MNP at Watamu.

4.1.2. Representation and Replication

The application of representation and replication criteria to Kenya's protected area system is limited by available data. One relevant source is WWF (2005), which reveals that the Kenya's coastline features four '*priority seascapes*' (see table 4.3) – areas which include rare, pristine or a large numbers of habitats. Thus these seascapes combine a bio-geographic and habitat focus, and give some basis for assessment. Amongst these, the '*globally important*' Lamu Archipelago and Malindi Creek regions are partially covered within one MPA (4.1%) and three MPAs (16.7%) respectively. The '*eco-regionally important*' Msambweni-Tanga region is also covered (1.3%) in two MPAs, while the Tana River Delta (also eco-regionally important) is not covered in any MPAs. Comparing these figures to the standard set by the Great Barrier Reef shows that replication might be highly limited – especially if only MNPs were considered.

Table 4.3 – Protected area coverage of WWF 'priority seascapes' in Kenya

Country	**Priority Area**	**Importance**	**Area / km^2**	**Protected Area**	**% area protected**
Kenya	Lamu Archipelago	Global	6,064	Kiunga MNR	4.1 (0)
	Tana River Delta	Eco-regional	3,347	-	-
	Mida Creek-Malindi	Global	1,563	Malindi MNP	16.7 (1.0)
				Watamu MNP	
				Malindi-Watamu MNR	
Kenya	Msambweni – Tanga*	Eco-regional	2,990	Kisite MNP	1.3 (0.9)
				Mpunguti MNR	

Adapted from WWF (2005). Only includes protected areas with a subtidal component. * indicates trans-boundary areas which are also covered in other MPAs – thus the level of protection may be underestimated. Figures in brackets include only cover provided in marine national parks.

Coverage of major habitat types may also be compared to the 20-50% suggested by Roberts et al (2006). Coral reefs are found within all nine MPAs, and simple GIS estimates suggest that they cover 22% of all Kenya's coral reefs. However, this figure falls to only 3.1% if reserves are excluded. According to Taylor et al (2003), mangroves are found within 8 of Kenya's protected areas (not exclusively MPAs), and similar GIS estimates suggest that coverage within MPAs is around 12%. However, none of this coverage is within marine parks, and it is obvious from figure 4.1 that some very significant areas of mangrove remain outside the Kenyan MPA system - most notably in the areas around Lamu, the Tana and Sabaki River estuaries, and around the Kenya-Tanzania border (WWF, 2005). There is little if any information published on the coverage of sea-grasses in Kenya, although it is likely that they are found within all MPAs.

4.1.3. Refugia: The Protection Status of Areas Displaying Resistance and Resilience

Resilience model, it is suggested that areas are chosen for protection should be those which display one or both of resistance and resilience. However, since much of the research and monitoring effort is understandably focused on established MPAs, assessment here is largely limited to examination of possible resistance and resilience (as measured by changes in mean coral cover) within the areas *already* under protection. Mean figures also fail to indicate individual reefs' survival and recovery, leading to analysis that is necessarily coarse. However, it may give some initial indication of the resistance and resilience within the existing MPA system, and thus the need for continued or increased protection at a broad scale.

Within Kenya's MPAs, resistance to the 1998 bleaching event appears to have been universally low. Mean figures for the relative loss of coral cover in the parks at Kisite, Mombasa, Watamu and Malindi Marine Parks were all above 50% (McClanahan et al, in review), with no specific data available for the reserves. Amongst these, Watamu and Malindi were reported as having the highest loss of relative cover, reported as 76% and 75% respectively, with the highest absolute losses in Malindi. Kisite and Mombasa both suffered a 55% loss in relative cover, although absolute losses were higher at Mombasa. Published data on recovery is aggregated across MPAs, with McClanahan et al (2006a) reporting that the live (hard) coral cover across five sites within the marine parks at Malindi, Watamu and Mombasa had, by 2004, recovered to mean of around half of pre-bleaching levels (around 22%). The same paper does, however, report recovery at sites in Kisite as very positive, with mean coral cover across three sites exceeding pre-bleaching (1996) levels by over 50% in 2004. In Kiunga, there are once again some differences noted across sites. Obura (2002) reports that coral cover within 'good' sites had recovered to 80% of pre-bleaching levels by 2002, but that some 'bad' sites had continued to decline even up to 2002. For Kiunga, it was reported that recovery is generally better in shallow channels and outer reef sites, and poorer at deeper sites where up-welling of cool, nutrient rich water may be inhibiting recruitment and promoting algal growth (Obura, 2005b).

Table 4.4 – 'Resistance and resilience' in Kenyan MPAs

Marine Protected Area	Resistance	Resilience	Comments
Kiunga MNR	--	+/-	Recovery generally poor at deeper sites, possibly due to the influence of cool up-welling. Recovery has largely been better in shallow channels and outer reef sites. Sources: Obura (2005b), Obura (2002)
Malindi MNP	--	+	At over 70% in both cases, mortality was highest at Malindi and Watamu (MPs) compared to other Southern sites. Malindi, Watamu and Mombasa (aggregated) have recovered to around 50% of pre-bleaching (1996) coral cover. No specific figures available for reserves areas. Sources: McClanahan et al (2006a; in review), Obura (1999), Obura 2005b.
Watamu MNP	--	+	
Malindi Watamu MNR	n/a	n/a	
Mombasa MNP	--	+	
Mombasa Marine MNR	n/a	n/a	
Diani MNR	--	n/a	Source: McClanahan et al (in review)
Kisite MNP	--	+	Cover before the bleaching event was already quite low (22%) but has now recovered to around 30% No separate data available for Mpunguti Sources: McClanahan et al (2006a; in review),
Mpunguti MNR	n/a	n/a	

Resistance: (-) moderately affected by 1998 bleaching event – relative live coral cover decreased by 50% or less; (--) severely affected by 1998 bleaching event – relative live coral cover decreased by greater than 50%; (+) Little or no negative effects from 1998 bleaching event. Resilience: (-) recovery since 1998 described as poor; (+) recovery since 1998 described as good. n/a indicates no data available.

As noted above, data outside the protected areas are limited, but studies do show some interesting results. McClanahan (in review) reports that at (southern) unprotected areas in Diani (unmanaged), Ras Iwatine and Vipingo, relative losses in coral cover were similar to those found in the protected areas, at 60-70%, although initial cover was lower in (≈20%) in all cases. This suggests that resistance is also low in areas outside current management. One notable exception has been at Kanamai, which although showing low initial cover, lost only 2% of its cover after the 1998 bleaching event. It is suggested that a history of high temperature variation may have, in this case, provided some resistance to bleaching (McClanahan and Maina, 2003). Data on recovery in unprotected sites is again aggregated, with Obura (2002) reporting that recovery of coral cover in southern (unprotected) sites had reached 70% of pre-bleaching levels by 2001 (although absolute cover remained relatively low at around 14%).

4.1.4. Management Effectiveness

Building capacity for the effective management and assessment of MPAs has received increasing attention in recent years, both globally and in East Africa – the latter being highlighted by the proliferation of tools and programmes to help countries make improvements in these areas (e.g. Mangubhai and Wells, 2004; IUCN 2004a). However, despite these efforts, the assessment of management effectiveness in Kenya remains at an early stage. In terms of biodiversity protection, there is some indication that Kenya's marine protected areas have been effective. This is especially true in the parks where both coral and fish communities are reported to have benefited from the high level of protection (Obura, 2001). However, coral communities within the MPAs have suffered recently due to the coral bleaching, masking some of the beneficial effects. Otherwise, the most extensive review of management effectiveness so far undertaken in Kenya, (IUCN, 2004b) concluded that assessment of its MPAs against most management targets is hampered by '*insufficient or inappropriately designed monitoring*' (which in itself is likely be a significant barrier to effective management). With this in mind, an alternative approach is to examine some of the factors which may contribute to or limit the effectiveness of management. Francis et al (2002), in a general appraisal of MPA success in East Africa, identify some key factors in this respect, many of which are covered elsewhere in this study (e.g. MPA design and legislation). Of those which are not, analysis here is limited by space to those factors for which information is most readily available: management plans, finance and capacity, and collaborative management.

Management Plans

Adequate planning is an important feature of effective management. Recognising this, the KWS are now required to produce management plans for all MPAs. Consequently plans were written in 1999 for sites throughout Kenya (with the exception of Diani), as part of an initiative sponsored by the KWS/Netherlands Wetlands Conservation and Training Programme. They were created to cover the period 1999/2000-2004/2005, using a common template. This includes sections on the MPAs' backgrounds, management issues and actions, and day-to-day processes.

Table 4.5 – Example activities from Kenyan MPA management plans.

Management Action Category	**Example Actions**
Additional legislation required for management	Secure improved regulations for activities in the park and reserves
Stakeholder relations	Formalise relationships with key stakeholders and resolve conflicts between marine resource users
Land Tenure	Acquire title deeds for park/reserve areas
Zoning plans and regulations	Establish 'no use zones' to aid the regeneration of reef resources and establish monitoring and evaluation in such areas
Management of marine and land-based activities	Reduce impacts from upstream land use activities and promote better waste disposal practices
Licensing procedures	Improve co-ordination between KWS and various licensing committees and ensure compatibility of licensing with MPA objectives
Infrastructure and equipment needs	Review and improve infrastructure and equipment
Human resources and training needs	Provide additional staff and training to improve management capability
Public awareness, education and interpretation	Develop education and awareness programmes to improve appreciation and support for conservation and MPA
Research and monitoring (policy and priorities)	Develop a research and monitoring policy to support and inform MPA management
Enforcement of regulations	Enforce MPA regulations effectively including involving collaboration with other stakeholder
Information management	Improve information management systems to allow effective decision-making with other stakeholders
EIA requirements for all activities which might impact on the MPA	Advocate mandatory EIAs for all developments which may impact on the MPA

Source: categories taken from Weru et al, 2001a/b. Example action adapted from the same, in some cases combining two or more activities specified within management plans.

Given the absence of such management plans at the time of the 1998 bleaching event, this process may well be regarded as an improvement. However, given the close proximity of the plans' writing to the event itself, there are no specific actions included to address bleaching, and indeed the Malindi-Watamu plan states that '*such events are beyond the control of MPA management*' (Weru et al, 2001b). Even so, while specific actions in this respect are absent, the plans are sufficiently comprehensive to include a number of others which may be particularly important for building reef resilience - such as improved zoning and better enforcement of regulations. However, comments made during the workshop indicated that zoning had not so far taken place in any of the Kenyan MPAs, despite its place in the plans.

More generally, it is not entirely clear whether these plans are actually being fully implemented on the ground. Some indication of this is given in IUCN (2004b), where it is reported that 30% of management actions (as specified in the plans) had been completed at Watamu, 20% at Malindi and 60% were ongoing at Mombasa. These figures appear low, however it must be noted that in some cases, actions prescribed within the plans are not directly within the (sole) power of Wardens to implement – such as changes in regulations and EIA requirements. In all cases, the current wardens were too new at the time of the study to comment as to whether they felt that day-to-day management effectiveness had improved since the development of the plans. Since they are currently due for review (having reached the end of the period they cover), there should soon be some opportunity to assess their success more fully. However, during the workshop, the Wardens revealed that few steps had so far been taken to begin this process (with the exception of Kiunga, where some effort had been made to plan the first meeting of stakeholders). When they do take place, data deficiencies may also continue to inhibit assessment. Even before this process, one key criticism has been of the management plans' failure to clearly differentiate between the parks and the reserves (and between Malindi and Watamu, which currently share the same management plan), despite obvious differences in their management needs (IUCN, 2004b).

Finance and Capacity

Insufficient and/or unsustainable funding can inevitably provide a significant barrier to the effective management of MPAs (Emerton and Tessema, 2001). Indeed, management plans are worth little if there is insufficient funding or capacity to undertake the measures they recommend. Likewise, the possibilities for responding and adapting to new management demands associated with climate change are likely to be limited by low levels of funding, especially in the longer-term. This area has previously been noted as a key problem in East Africa, with funding '*inadequate in all countries throughout the region*' (Francis et al, 2002).

In Kenya, the finance structure of MPAs is fairly consistent. All of the MPAs receive funding from the KWS, who pay staff salaries and redistribute income gathered from all of the protected areas (both terrestrial and marine) to support management activities. While this may be of benefit to areas which generate little of their own income (such as Kiunga), other, more successful MPAs lose out, receiving significantly less in funding than they generate. This arrangement leaves little incentive for Wardens to try to increase visitor numbers through improved management efforts. According to IUCN (2004b), Malindi National Park (and Reserve) received around 50% of the money required to undertake management activities, with KWS support falling between 2000 and 2003 despite revenues increasing over the same period. This finding was reinforced by the comments of the Wardens during the workshops, with those from Malindi admitting that resources were insufficient to patrol the reserves more than 'occasionally', and that consequently they were not able fully control illegal (fishing) activities in these areas.

Table 4.6 – Capacity indicators at Kenyan MPAs

Marine Protected Area	Subtidal Area / km^2	No. of staff	No. of Boats	Warden's Length of Service in Current Post / months	Previous Experience of Warden in MPAs?
Kiunga MNR	250	11	1	12	Yes (extensive experience within a number of MPAs)
Malindi MNP*	6.3	36	2	1 (deputy also 1 month)	No
Watamu MNP*	10	28	2	1	No
Mombasa MNP/MNR	210.0	30	3	10	Yes (some previous experience gained at Kisite)
Kisite MNP/Mpunguti MNR	39.0	30	4 (although not in good working order)	2	No

Source: Staff/boat/Warden data obtained during conversations with wardens during the workshop. * Malindi and Watamu figures also jointly cover Malindi-Watamu MNR which has an area of 245km^2.

One notable attempt so far to find an alternative funding model at the MPA level was the Beach Management Programme at Mombasa. This collaboration between hotels, boat operators and the KWS saw hotels make direct payments to the KWS for their management services. Unfortunately, despite some initial success, the programme quickly failed due to a lack of legislative support for collecting payments, and is yet to show any signs of being revived (Muthiga, 2003a). Furthermore, there is some concern that the long-term financial sustainability of the KWS itself may questionable – especially given its high reliance on donor contributions (WWF, 2004) – putting the future management of Kenya's MPAs, and indeed their very survival, at some risk (McClanahan et al, 2005b).

In terms of staff numbers, capacity within the Kenyan MPAs is quite high (see table 4.6). The exception is Kiunga, which despite being the single largest MPA has only 11 staff compared to ~30 in all other cases. However, despite the generally high number of staff, rapid turnover remains a key barrier to effective management. In an effort to reduce corruption, staff are moved between individual (marine and terrestrial) protected areas regularly, often with no special attention paid to previous experience. Consequently, of the 6 MPA wardens (1 deputy) at the workshop, all had been in their current post for one year or less (in 4 cases less than 3 months), and only two had previous experience in MPAs. While three of the wardens had received some marine training from KWS/WIOMSA, a general lack of experience was apparent during the workshops, where some of the wardens were not confident discussing marine issues and showed a lack of enthusiasm for swimming or biodiversity identification exercises during field trips.

While there was consensus amongst the wardens that the retention of staff had improved in this respect for rangers (who were staying in their posts longer), and that efforts were being made by the Director of KWS Coast to achieve a similar result for wardens, it was felt that management capacity (such as the knowledge gained at the workshop) is currently being lost through the staff rotation policy. One recent and positive development in capacity is the creation of a KWS scientific team based in Mombasa that is now undertaking some limited monitoring which, over time, may reduce KWS reliance on external organisations such as the WCS, CORDIO and WWF.

Collaborative Management

Collaboration with local communities and other stakeholders is increasingly seen as a key driver of effective MPA management. Indeed, in the absence of strong (and expensive) enforcement efforts, it unlikely that stakeholder compliance with regulations will be high unless they are involved in the design and ongoing management of MPAs. However in Kenya, the creation of MPAs has not traditionally been undertaken in consultation with local communities (or other stakeholders), and has instead tended to reflect a more 'command and control' type approach. The problems associated with this approach are illustrated by events at Diani MNR, where efforts to involve local communities before designation were insufficient to overcome strong local opposition. This led to the effective abandonment of the site by the KWS, and efforts are still ongoing to try and find alternative methods of protection of the site (such as ICZM), with an understandably high emphasis on community participation (McClanahan et al, 2005c).

Nonetheless, there have been some recent improvements in the involvement of local stakeholders in the running of the protected areas. At a national level, the KWS has created a community wildlife department, which aims to strengthen the involvement of local communities. This process has been further supported under the Environmental Management and Coordination Act (see section 4.2), which provides for the inclusion of a variety of local stakeholders in environmental management through provincial and district environment committees (Government of Kenya, 1999). However, according to WWF (2005), mechanisms are yet to be put in place to allow this to be enacted on the ground. Within individual MPAs, local stakeholders (including both businesses and community members) were consulted during the formulation of management plans and accordingly they suggest the formation of advisory bodies to ensure their continued involvement (Muthiga, 2003a). In line with this development, Wardens revealed during the workshop that there are now ongoing meetings with local stakeholder groups at all sites, varying from monthly meetings at Malindi to every three or four months in Watamu and Mombasa (the frequency of meetings at Kisite and Kiunga were not apparent).

Such developments are a positive step, and are thought to have increased compliance within MPAs (Muthiga, 2003a). In the case of Mpunguti improved relations have led to local communities themselves recommending an increase in the size of the reserve (IUCN, 2004b). However, the degree to which ongoing meetings at the individual MPAs represent collaboration rather than simply consultation is unclear – for instance none of the MPAs are directly managed by local communities or private sector intuitions. Thus management of MPAs, although variable across sites, does remain largely central-government led, contributing to the persistent management problems within some of the MPAs (McClanahan et al, 2005b; D. Obura, personal communication).

4.2. LEGISLATION AND POLICIES FOR COASTAL MANAGEMENT AND THE CONSERVATION OF CORAL REEFS IN KENYA

Underlying MPA systems, and their present and future fulfilment of the four principles, are the legislation and policies that support them. In Kenya, the main instrument for the creation of MPAs has been the Wildlife (Conservation and Management) Act - the 1989 amendment to which also established the Kenya Wildlife Service as the competent (national) authority for their management. In addition to the Wildlife Act, there is also some scope for the creation of closed areas under the Fisheries Act (Weru, 2005). This should soon be augmented by proposed Beach Management Unit (BMU) regulations (also related to fisheries). It is suggested that these will offer communities the opportunity to create their own protected areas, as a means of managing their local fisheries resources (Cinner and McClanahan, 2006).

Currently, all of the MPAs discussed above are designated under the Wildlife Act and are managed by the KWS. Thus they may, in a limited institutional and legislative sense at least, be regarded as part of a centralised and unified system. However, it has been noted that the Wildlife Act and its regulations are more appropriate for terrestrial rather than marine protected areas (Muthiga, 2003; McClanahan et al, 2005b), thus diminishing their usefulness. Similarly, as noted by Obura (2001), Kenyan fisheries legislation was drafted with regard to inland (freshwater) fisheries, and makes no direct reference to marine issues. As such, there is also some ambiguity in fishing and MPA regulations related to activities within the reserves, where 'traditional' fishing methods are allowed but remain largely undefined. Such imprecise focus and legislative omissions can only serve to weaken current MPA effectiveness. Many of the regulations are yet further undermined by the low level of fines administered to transgressors, making their enforcement an '*inefficient and expensive process*' (Muthiga et al, 2003a).

Barriers to the effective management of coastal resources have arisen due to the overlapping mandates between various government bodies and associated legislation. According to Obura (2001), environmental legislation was, until recently, spread among 77 separate statutes, with at least 21 policy instruments infringing on the management of MPAs alone (Muthiga et al, 2003b). Of particular importance in this respect have been overlaps between the mandates of the KWS and the Fisheries Department (FiD) within the marine reserves; between KWS and the Forestry Department (FD) in Mangrove areas; and between KWS and the Tourism department regarding the licensing of tourist activities in and around protected areas (Muthiga et al, 2003a). This situation has improved to some extent with the signing of various Memoranda of Understanding (MOUs), including those between the KWS and both the FD and the FiD.

A recent step forward in legislation for coastal protection has been the passing of the Environmental Management and Coordination Act (ECMA) (Government of Kenya, 1999). As the name suggests, this framework act provides for a much greater degree of co-ordination on general environmental issues and led to the establishment of the National Environmental Management Authority (NEMA) in 2002. The Authority is charged with a variety of tasks, including formulating national strategies, policies and the transposing of relevant international agreements into national law. Vitally, the Act makes specific reference to the conservation of coastal zones, highlighting coral reef and mangrove ecosystems as high risk areas which may require protective measures. In this respect, EMCA provides another possible route for the creation of marine protected areas. A vital feature of EMCA in wider policy terms is the requirement for the periodic creation of an integrated management plan for the coastal zone (including an undertaking to survey the state of coral reefs), with review of the plan at least every two years. However, according to the recent NEMA strategic plan (NEMA, 2005), the first of these plans will not be prepared until end of 2006.

NEMA also has some responsibility for helping to take forward ICZM. In particular, its strategic plan (NEMA, 2005) specifies the creation of a national ICZM policy as an objective for the period 2005-2010. Previously the Coast Development Authority (CDA) has been the primary national body focused on the planning for ICZM, and has taken the step of forming a Secretariat made up of the various key stakeholders in the process (including the Fisheries Department, KWS etc). However, despite the efforts of the CDA to coordinate ICZM in Kenya, practical progress has so far been limited to the development of two pilot sites, at Nyali-Bamburi-Shanzu (Mombasa) and Diani-Chale – the latter aiming to provide some management of coastal resources where the MPA has so far failed (see section 4.1). Although these pilots have so far achieved some localised successes in terms of learning and awareness-raising, further developments in the implementation of ICZM have so far been hindered by inadequate funding and capacity (McClanahan et al, 2005b).

5. RESULTS - TANZANIA

5.1. TANZANIA'S MARINE PROTECTED AREAS AND THE FOUR RESILIENCE PRINCPLES

The MPA system in Tanzania is rather more complex than in Kenya, largely due to the administrative separation of the mainland from Zanzibar (see section 5.2). In total, there are eleven MPAs of varying descriptions. On the mainland there are two Marine Reserves (MRs) (with Dar es Salaam in fact comprising four areas which are managed as one unit), and two Marine Parks (MPs). These are termed differently to Kenya, with Reserves as the smaller, non-extractive use areas, and the larger Parks zoned to allow multiple uses. The mainland is also home to a collection of collaborative fisheries areas around Tanga, which include (closed) MPA components. Zanzibar's MPAs are more varied, encompassing a number of different management approaches including both private and community-based areas (see later sections).

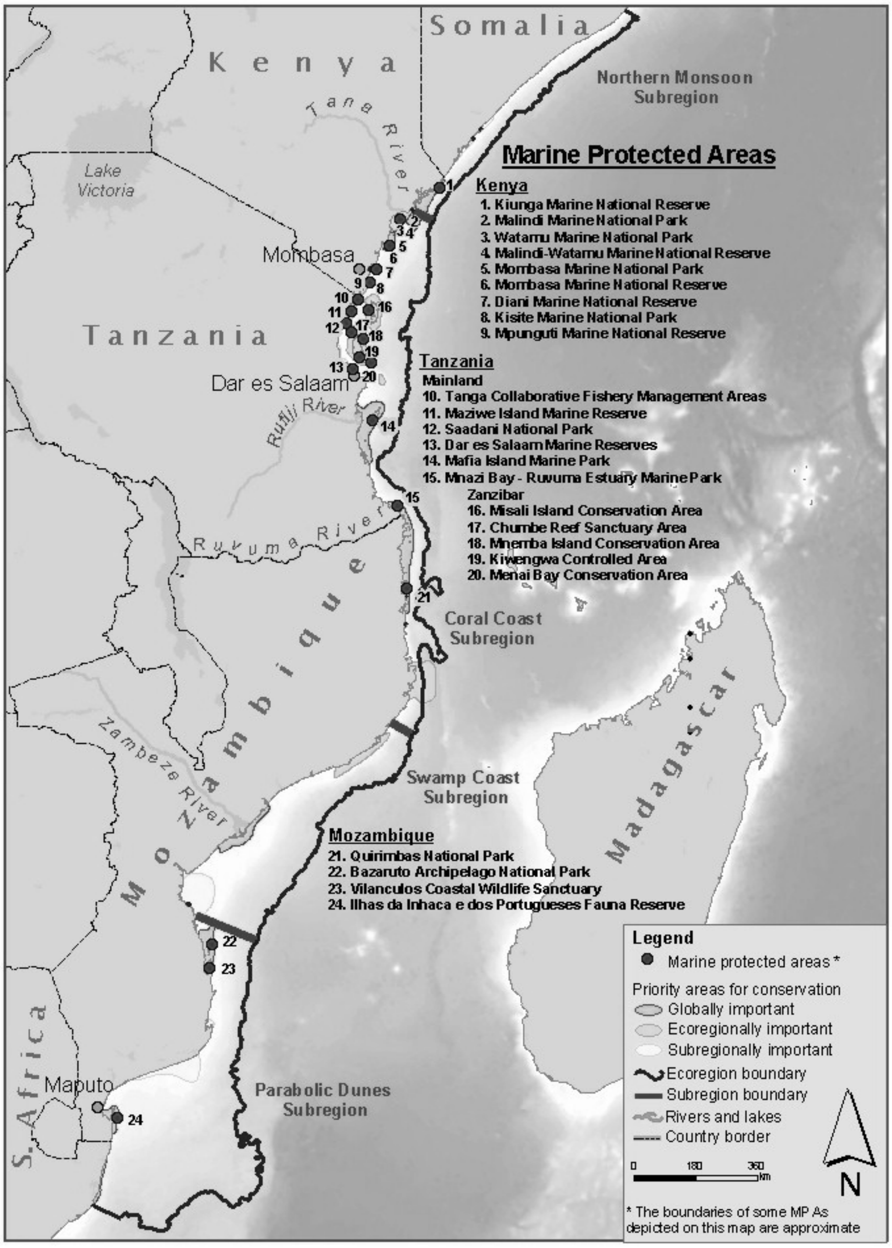
Table 5.1 – Marine protected areas in Tanzania

Marine Protected Area	Date Established	IUCN Category	Subtidal Area / km^2
Tanga Collaboravtive Fisheries Areas	1996-2000	- (includes small no-take zones)	25.4 (no-take areas)
Maziwe Island MR	1981	II	2.6
Dar es Salaam MRs (including Bongoyo Island, Fungu Yasini, Mbudya Island and Pangavini Island)	1975	II	26.0
Mafia Island MP	1995	VI	615.0
Mnazi Bay - Ruvuma Estuary MP	2000	VI	200.0
Menai Bay CA	1997	VI	470.0
Chumbe Reef Sanctuary	1994	II	0.3
Misali Island CA	1998	VI	21.6
Mnemba Island CA	2002	VI	0.15
Kiwengwa Controlled Area	2000	-	17.5
Jozani - Chwaka Bay NP	2004	-	25.0

Source: WWF, 2005

5.1.1. Connectivity

Figure 5.1 – Marine protected areas in East Africa



Source: supplied courtesy of WWF Eastern African Marine Eco-region Programme.

Current speeds for Tanzania are somewhat faster than those found for Kenya, reported at around 1.1 - 3ms^{-1} in Tanzania (Darwall and Guard, 2000). Using the same methodology and dispersal times used for Kenya, this gives a lower range for dispersal of 16-285km, and an upper range of 43-778 km. Similar analysis of the Tanzanian system is precluded by the lack of appropriate GIS data. However, coarse measurements taken from the large scale map in figure 5.1 can be used to illustrate some of the key points. It seems likely that connectivity in the North of the country (including Zanzibar) may be quite reasonable, with 9 MPAs areas concentrated within a short (~200km North-South) stretch of the coast – giving a mean separation (~22km) which is well within the lower range above. Further South, MPAs are more widely dispersed, with Mafia Island MP separated from its closest Southern neighbour at Mnazi Bay- Ruvuma Estuary MP (MBREMP) by over 200km, and Mafia separated from Dar es Salaam by around ~150km. These distances are significant and, while high current speeds mean that they lie within the calculated ranges, they are clearly far beyond the 'few tens of kilometres' suggested in chapter 2. Consideration of no-take areas alone may affect conclusions less clearly than in Kenya, since the majority of marine protected areas are either fully protected, or include no-take zones. However, since many of these areas are small, their contribution as sources of larvae may be limited.

5.1.2. Representation and Replication

Table 5.2 – Protected area coverage of WWF 'priority seascapes' in Tanzania

Country	Priority Area	Importance	Area / km^2	Protected Area	% area protected
Tanzania	Msambweni – Tanga*	Eco-regional	2,990	Tanga Collaborative Fisheries Management Areas	0.9†
				Miziwe MR	
Tanzania	Pemba Island	Eco-regional	4,193	Misali Island Conservation Area	
	Unguja Island	Eco-regional	5,557	Menai Bay Conservation Area	9.2
				Mnemba Island Conservation Area	
				Chumbe Reef Sanctuary	
				Kiwengwa Controlled Area	
				Jozani-Chwaka Bay NP	
	Latham Island	Eco-regional	409	-	-
	Bagamoyo	Sub-regional	806	Saadani NP	8.2
	Rufuji – Mafia Complex	Global	9,490	Mafia Island MP	6.5
	Mtwara – Quirimbas*	Global	9,371	Mnazi Bay – Rufuma Estuary MP	2.3

Source: Adapted from WWF (2005). Only includes protected areas with a subtidal component. * indicates trans-boundary areas which are also covered in other MPAs. † For Tanga, only includes closed areas within the Collaborative Fisheries Management Areas.

Similarly to Kenya, estimates for bio-geographical representation and replication can be found in WWF (2005). According to the report, the overall proportion of Tanzania's continental shelf covered by MPAs is estimated to be 7.9%. Of their priority areas, the '*eco-regionally important*' Msambweni-Tanga, Pemba Island, Unguja Island and Latham Island are covered by two (0.9%), one (0.5%), five (9.2%) and zero MPAs respectively.

The '*sub-regionally important*' Bagamoyo area is covered in one MPA (8.2%) and the '*globally important*' Rufuji-Mafia Complex and the Mtwara-Quirimbas areas are covered in one MPA each at 7.0% and 2.0% respectively. In all cases, coverage is less than half that recommended by comparison with the Great Barrier Reef. In terms of specific habitat representation, appropriate GIS data was unavailable. However, coral cover within no-take MPAs is reported by WWF (2005) as 1.9%. All mangroves on both the mainland and Zanzibar are designated as forest reserves under forestry legislation, rather than (exclusively) finding protection within MPAs. According to Taylor et al (2003) they are protected in seven different sites, but many of these areas are zoned for different levels of use, and it unclear what proportion receives full (or a high level) of protection. There is no data on the total area or proportion of sea-grasses under protection, but it is thought that they are found within all of Tanzania's MPAs (WWF, 2005).

5.1.3. Refugia: The Protection Status of Areas Displaying Resistance and Resilience

The data for Tanzania are also largely focused on MPAs, but is a little less aggregated than that found for Kenya, and shows considerable variation in both initial losses and recovery within and between sites. Although Mafia Island Marine Park was generally badly affected by the 1998 bleaching, some reefs within Chole Bay (specified use) showed greater resistance than the fully protected site at Tutia (Kitutia) and the specified use site at Mange (Mohammed et al, 2000). In Zanzibar, Chumbe also showed some resistance to bleaching, losing less than 20% of its coral cover (McClanahan et al, in review). Within the Dar es Salaam Marine Reserves, Bongoyo, Mbudya and Pangavini suffered low mortality (10-20%), while Fungu Yasini was badly damaged (Mohammed et al, 2000). In terms of resilience, Bongoyo and Mbudya also showed increases in coral cover between 1997 and 2000 (Muhando and Francis, no date). More generally, resilience is reported to have been weakest at the reefs which suffered the worst effects in 1998 such as Misali Island CA and at Mafia's Tutia reef – although in the latter, recent increases in coral recruitment may indicate that recovery is improving (Suleiman et al, 2005). General recovery in areas around Zanzibar, and Mtwara (including MBREMP) has been reported as good (Suleiman et al, 2005) but is aggregated and un-quantified.

Table 5.3 – 'Resistance and resilience' in Tanzanian MPAs

Marine Protected Area	Resistance	Resilience	Comments
Tanga Collaborative Fisheries Areas	--	+	Mean coral cover at four sites found to be higher in 2004 than 1996. Sources: Muhando and Mohammed (2002), McClanahan et al (2006)
Maziwe Island MR	n/a	n/a	n/a
Dar es Salaam MRs	+/-	+	Coral cover increased in Mbudya and Bongoyo between 1997 and 1999. Mortality in Fungu Yasini was severe. Good recovery in most sites, although recently affected by a crown of thorns starfish outbreak. Sources: Mohammed et al (2000), Suleiman et al (2005)
Mafia Island MP	- -	-	Worst affected reefs were those adjacent to deep water (e.g Tutia), and especially reef flats. Recovery at Tutia has so far been inhibited by competition with algae (which is increasing due to nutrient inputs and over-fishing) although recruitment is improving. Msumbiji and Utumbi Reefs showed better initial survival. Sources: Mohammed et al (2000), Suleiman et al (2005)
Mnazi Bay - Ruvuma Estuary MP	-	+	Corals at Kati were less badly affected than those at Matenga. Recovery slow although reefs have not so far shown signs of overgrowth by algae. Sources: Muhando and Francis (no date, Muhando and Mohammed (2002), Suleiman et al (2005)
Menai Bay CA	n/a	n/a	n/a
Chumbe Reef Sanctuary	-	+	Recovery at Chumbe has been good compared to a similar but unmanaged site at Kwale Sources: McClanahan et al (in review), Mohammed et al (2002), Wagner (2004)
Misali Island CA	- -	-	Initial losses were high (~80%) at all sites. Recovery has been better on deeper sites Sources: McClanahan et al (in review), Suleiman et al (2005)
Mnemba Island CA	n/a	n/a	n/a
Kiwengwa Controlled Area	n/a	n/a	n/a
Jozani - Chwaka Bay NP	n/a	n/a	n/a

Resistance: (-) moderately affected by 1998 bleaching event – relative live coral cover decreased by 50% or less; (--) severely affected by 1998 bleaching event – relative live coral cover decreased by greater than 50%; (+) Little or no negative effects from 1998 bleaching event. Resilience: (-) recovery since 1998 described as poor; (+) recovery since 1998 described as good. n/a indicates no data available.

Outside Tanzania's protected areas, there are a number of sites which have seemingly displayed a reasonable level of resistance and/or resilience, and which may merit future protection. Reefs around Zanzibar town, including Chapwani, Bawe, and Changuu, were noted to have shown some resistance to bleaching event. All lost less than 50% of their cover, with Bawe losing only 15% (McClanahan et al, in review; Mohammed et al, 2002). However Changuu and Chapwani have since recovered relatively slowly, while Bawe – although showing an increase in coral cover between 1997 and 1999, saw a slight decrease 1999-2002 (Mohammed et al, 2002). Another example of a possible resistant area in Tanzania is the Songo Songo archipelago. This area has been reported as one less impacted by the bleaching event of 1998, maintaining high coral cover and diversity (Obura, 2005a). Corresponding with one of the factors in section 2.5, it has been hypothesised that this may have been due to protection from light stress offered by the turbid waters from the Rufuji River that bathe the Archipelago.

5.1.4. Management Effectiveness

In Tanzania progress in monitoring management effectiveness has also been limited. According to one available report (IUCN, 2004b), management targets for biodiversity were beginning to be met at Mafia but, like Kenya, data required for the assessment of measurement of other outcomes was unavailable. Possibly due to its early stage of development and the absence (at that time) of a management plan, the report reached few conclusions regarding progress in Mnazi Bay's management. Elsewhere, the variety within Tanzania's MPA system makes general conclusions extremely difficult to reach. Management is considered to be effective at the privately run MPA in Chumbe, while at the opposite end of the scale, Maziwe and Dar es Salaam Reserves are have been described as ineffective, with little or no management in place (Suleiman et al, 2005). Thus it is also useful in the case of Tanzania to look at some of the factors which may underlie MPA management.

Management Plans

Under the Marine Parks and Reserves Act (MPRA, see section 5.2), Marine Parks and Reserves are required to have general management plans in place to guide activities. So far, this has led to the creation of management plans for both Mafia Island MP (currently due for review), and more recently, Mnazi Bay-Ruvuma Estuary MP, with a management plan for Dar es Salaam MR still under development. The management plans for Mnazi Bay and Mafia follow a relatively similar structure (United Republic of Tanzania 2000; 2005). In common with Kenya's plans, neither make substantial direct references to coral bleaching, however actions such as those outlined in table 5.4 could easily be applied to coral reefs – such as the protection of critical habitats (e.g. coral reefs) during key periods (perhaps including periods of elevated SSTs). The plans also make some provisions for the involvement of local stakeholders, and for the ongoing review of management effectiveness, but do not specify day-to-day management activities.

Table 5.4 – Selected actions from the Mnazi Bay – Ruvuma Estuary Marine Park management plan potentially relevant to coral reefs and bleaching

Strategy	**Actions**
Conserve biodiversity and ecosystem processes	Focus compliance efforts in critical and threatened areas, through patrolling and self-enforcement
Sustainable Use of Marine Living Resources and Rehabilitation of Damaged Resources	Develop a zoning plan to protect critical habitats (e.g. breeding grounds, spawning aggregation sites), limit fishing activities during key periods
Research and Monitoring of Resource Condition and Use	Prioritise research and monitoring of resource condition around critical and threatened habitats and threatened / endangered species

Source: United Republic of Tanzania, 2005.

On Zanzibar, legislation also requires the creation of management plans. However, while a plan has long been in place at Chumbe (currently due for review), progress has been slower elsewhere, with plans either in preparation or draft form at Menai Bay, Misali, Mnemba and Kiwengwa as recently as 2005 (WWF, 2005). As with Kenya, it is generally unclear to what extent actions under the plans have been implemented on the ground. Perhaps the one exception to this is Mafia which, according to IUCN (2004b), claimed to have implemented or completed 63% of planned management actions in 2002.

Finance and Capacity

Again, the diverse nature of Tanzania's MPAs makes it more difficult to draw general conclusions as to the adequacy of financing and capacity. However, one common issue has been raised as of considerable importance – the reliance on external funding. Few are self financing, and although (unlike Kenya) Tanzanian MPAs are able to retain income they may receive, mechanisms for revenue generation and collection are, in general, not well developed (Ruitenbeek et al, 2005). As such MPAs in Tanzania are faced with a situation where as much of 90% of their income comes from external donors, thus leaving long-term effectiveness and adaptability vulnerable to changes in their support. One obvious exception to this is the privately managed and self-financing Chumbe Reef Sanctuary, where the day-to-day costs are paid from revenue received from tourists visiting the park. However, even this relatively successful finance model is highly reliant on a single source of income, and may be vulnerable to variations in Tanzania's tourist market (Lindhjem et al, 2003).

Capacity within the system is consequently equally varied. IUCN (2004b) recorded 25 staff at Mafia, compared to 12 at MBREMP (although the former is almost 3 times larger). Even so, while Mafia is one of the more effective MPAs in Tanzania, it is still reported to have too few staff to undertake enforcement activities effectively (Rubens and Kazimoto, 2003). Similarly on Zanzibar, it has been noted that the large MPA at Menai Bay has insufficient resources to undertake '*optimal*' patrolling of the area (Lindhjem, 2003). Another interesting observation regarding the mainland is that, despite their theoretically higher protection status, Marine Reserves have no permanent staff and rely on 'honorary' wardens to fulfil some management duties, whereas Parks have a range of staff, paid by the government (WWF, 2005). Such arrangements undoubtedly contribute to the ineffective management in these areas noted by Suleiman et al (2005).

Collaborative Management

Unlike in Kenya, there is a relatively strong basis for collaborative management in Tanzania, perhaps driven by the fact that many of its MPAs include an inhabited terrestrial component. The MPRA requires the involvement of local communities both in the initial creation of MPAs and in their ongoing management (through advisory committees) – including the preparation of plans and any changes to the nature of regulations related to the MPA. The MPRA also provides for benefit sharing with local communities. Such provisions are reflected in management plans (United Republic of Tanzania, 2000; 2005) and should help to boost support for MPAs amongst stakeholders. However, it has been noted that, in some instances, these committees do not exist on the ground (Shauri, 2003), and that formal sharing of revenues has yet to take place (Hurd et al, 2003). In this respect, an assessment of management effectiveness at Mafia also revealed that there is some level of dissatisfaction with the actual level of community involvement in the management of the park (Rubens and Kazimoto, 2003).

Elsewhere, there are a number of clear examples of successful collaboration within MPAs. Perhaps the most obvious of these is in Tanga, where the creation of collaborative management areas has been driven from the outset by the desire of local communities to address resource degradation. The result has been a significant level of joint decision-making and implementation between government and resource users – including the establishment of small, temporary closed areas. Consequently, peer pressure has led to relatively effective enforcement of fisheries regulations – to the benefit of coral health, and there is now even some enthusiasm for the permanent closure of the temporary site at Mtang'ata (McClanahan, 2006a; Wagner, 2004). On Zanzibar, such co-operation has perhaps been an even more central feature of MPA approaches. Both Misali Island and Menai Bay are directly co-managed with local community groups, while even the privately managed sites at Mnemba and Chumbe actively include the local communities as staff and within their advisory committees (WWF, 2005).

5.2. LEGISLATION AND POLICIES FOR COASTAL MANAGEMENT AND THE CONSERVATION OF CORAL REEFS IN TANZANIA

The administrative separation of mainland Tanzania from Zanzibar leads to two different regimes for coastal management. In contrast to Kenya, the mainland has a dedicated instrument for the designation of MPAs in the form of the Marine Parks and Reserves Act. Importantly, the Act also established a specialised body – the Marine Parks and Reserves Unit (MPRU) – as responsible for MPA establishment, management, enforcement and monitoring. The Act also includes a requirement for EIAs to be undertaken for certain activities which may affect MPAs, and as previously mentioned, provides for the creation of management plans and community collaboration. As illustrated by the case of Tanga, mainland fisheries legislation provides an additional instrument for creating MPAs, including as a means of protecting critical habitats (Shauri, 2003; Ruitenbeek et al, 2005). In a similar vein, fisheries legislation now also provides for the establishment of BMUs – fishing community groups who may create their own MPAs to help in the management of their local resources (Shauri, 2003).

In Zanzibar, MPAs may also be established under a number of different instruments. Like on the mainland, fisheries legislation provides a possible avenue for their designation and management. Also important is the 1996 Environmental Management for Sustainable Development Act (EMSDA), which is a framework Act that provides for the establishment of MPAs, as well as the wider planning of coastal conservation. Importantly, the EMSDA explicitly introduces the need to establish a protected areas *system* according to criteria such as biodiversity richness and representation (Ruitenbeek et al, 2005), with the specific body (the Zanzibar Nature Conservation Areas Management Unit) due to be established to oversee its management. However, MPAs so far remain under the control of two different authorities within the Ministry of Agriculture, Natural Resources, Environment and Cooperatives: the Department of Commercial Crops and, Fruits and Forestry (DCCFF – responsible for Menai Bay, Kiwengwa and Mnemba) and the Department of Fisheries and Marine Products (DFMP – responsible for Misali).

Thus it can be seen that the legal basis for MPA is at once comprehensive and complex. This complexity, both in terms of the separation of the two regimes, and the various instruments within them, has led to the suggestion that MPA legislation in Tanzania is '*far-fetched and uncoordinated*' (Shauri, 2003). Like in Kenya, legislation is also undermined to some extent by problems with enforcement of regulations, which is also '*inadequate in most areas along the coastline*' (Ruitenbeek et al, 2005). Amongst other things, this is due to problems with the prosecution process, which separates the police prosecutors from fisheries officers who make the arrests and gather evidence (Ruitenbeek et al, 2005).

Beyond the boundaries of single MPAs, Tanzania has achieved some important progress in implementing ICZM. There are a number of projects on the mainland – with recent examples such as Kinondoni Integrated Coastal Areas Management Project (KICAMP) and the Bagamoyo Integrated Coastal Management Programme already showing some success (Wagner, 2004). On Zanzibar, the EMSDA also provides for ICZM, requiring the preparation of integrated coastal area management plans, with one demonstration site at Chwaka Bay so far providing a model to be applied elsewhere on the island (Mbarouk et al, 2003). Actively involved in this progress has been Tanzania Coastal Management Partnership (TCMP) – a joint undertaking between the National Environmental Management Council, the United States Agency for International Development (USAID) and the Coastal Resources Center (CRC) of the University of Rhode Island. Importantly, this partnership has built upon local experiences to develop a National Integrated Coastal Zone Management Strategy, which was adopted in by the Tanzanian government in 2002.

The document includes seven strategies to be implemented by 2025. Amongst these, strategy four is perhaps of most interest in the context of coral reefs and climate change, promising to '*establish an integrated planning and management mechanism for coastal areas of high economic interest and/or with substantial environmental vulnerability to natural hazards.*', through the production of Special Area Management Plans (United Republic of Tanzania, 2003). The strategy also highlights the role that a *system* of MPAs will play in future implementation of ICZM (United Republic of Tanzania, 2003). At a system level, one other key development has been the Tanzanian government's pledge to expand the coverage of MPAs, which it made at the World Parks Congress (WPC) in Durban in 2003. This pledge saw the government commit to increasing MPA coverage to 10% of its seas by 2012, and to 20% by 2025.

6. DISCUSSION

6.1. ACHIEVEMENT OF THE FOUR RESILIENCE PRINCIPLES

Connectivity

In terms of connectivity, it is clear that conclusive analysis is limited by a lack of relevant data. This includes information on the region's oceanographic processes, and how they might be affected by climate change, and dispersal distances for key species (especially those coral species vulnerable bleaching). This need is illustrated by the extent to which recommended separation distances changed in the preceding chapters according to the larval duration times and current speeds used. Even so, it was possible to draw simple conclusions. As shown, connectivity in the South of Kenya appears to be reasonable, although it is dependent on the choice of range and whether reserves are included. To remove this uncertainty, it may be useful to provide some protection in between Mombasa and Watamu, and to try and implement some form of protection at Diani since, in its current unmanaged state, it may not contribute greatly to connectivity. Further North, evidence suggests that Kiunga MNR is isolated from southern MPAs whichever range is chosen, but it is unclear how this might be overcome given the natural barriers to larval recruitment formed by the Tana River and the periodic reversal of the EACC. The only possibility may be to focus on local connectivity through enlarging Kiunga or adding another MPA North of the Tana River.

In Tanzania, it seems that MPAs may need to be less close together due to the high current speeds. Accordingly, MPAs in the North of the country appear to be easily close enough in a geographical sense, but further study will be required to establish whether they are genuinely connected. Of more obvious concern may be the distances separating MPAs in the South, which are substantial – especially between Mafia and Mnazi Bay. Even though they fall within both of the calculated ranges, precaution, especially in the light of the general figures in the literature, may suggest the need for some new MPAs to reduce the size of these gaps. One further issue for both countries is that 'worst case' connectivity could assume that all areas outside current no-take zones are lost due to climate change (or other threats), or at least will not provide significant 'sources of seed'. Thus although we may hypothesise that recent recovery in the two systems may have been facilitated by present connectivity, it is not known what role non-closed areas played in this process, and how it would be affected if they were lost in the future. Furthermore, the reappearance in Kenya's southern MPAs of coral species which suffered 100% mortality in 1998 (D. Obura, personal communication) suggests that connectivity *between* the two countries is important, and should be considered in future assessment and planning of MPAs.

Representation and Replication

Assessment of representation and replication again relies on 'rules of thumb' and limited data. However if the results above are at all indicative, there are some significant shortfalls in the two systems. It does not seem that these criteria have so far been a significant aspect of MPA selection and accordingly, while both countries' MPAs fortunately include (represent) major habitat types and most bio-regions, replication is lacking. Only Kenya's Mida Creek-Malindi seascape and coral reefs are close to coverage level suggested in the literature or by efforts in the Great Barrier Reef. Even these positive examples are weakened if only no-take areas are included, or if the 50% coverage suggested by Roberts et al (2006) for vulnerable cases is a better benchmark for analysis. In Tanzania, MPA coverage is below 10% for all of the WWF seascapes, and only 1.9% of coral reefs are estimated to receive full protection. Under this principle then, there seems to be a need to significantly expand both MPA systems. However, once again there are some substantial data requirements to be met before precise recommendations can be made, since the use of the broad habitat types and WWF priority areas may neglect some important features which may require representation and replication (such different reefs zones or key resistant coral species).

Refugia: The Protection Status of Areas Displaying Resistance and Resilience

Under this principle, few conclusions as to future protection needs are possible for Kenya. The data is generally focused in Parks which are already (theoretically) fully protected, and even within these there was little evidence for resistance to bleaching. Although recovery in these MPAs has been described as good, it has also been slow, suggesting that their resilience is relatively low, although aggregated data hides finer-scale differences within and between MPAs. The exception to this Kisite, where strong recovery suggests that local resilience may be high, and that there may be some need to expand the park to enhance this feature. A lack of data regarding the southern reserves is a significant issue, since it precludes suggestions on whether zoning in these MPAs might is needed to protect key sites within their boundaries. This importance of this omission is demonstrated by Kiunga, where potentially useful data on recovery at 'good' sites was identified by more detailed study. Another limitation is the lack of data covering areas outside current MPAs, and so far, only the resistant site at Kanamai has emerged as a serious candidate for protection. However data showing relatively rapid recovery at unprotected sites in the south (albeit to a low level of cover) suggest that these sites may warrant further study.

In Tanzania, many MPAs have no data, but for those where it was available, there is large variation in resistance and/or resilience. Resistant sites at Chumbe and Dar es Salaam are already no-take areas, but the latter is widely suggested to lack management, and so its protection could be increased. Variable resistance shown at sites in Mnazi Bay and Mafia suggest that there might also be some scope for rezoning these multiple-use Parks to ensure that the strongest sites are better protected, and that protection is effective (since over-fishing is suggested to be inhibiting recovery at Tutia). Outside MPAs monitoring is again limited. However, notable resistance has been observed at reefs around Zanzibar town and in the large and diverse Songo-Songo Archipelago, suggesting that these may be candidates for future protection. In the former case, protection may also help to improve their (previously slow) rate of recovery from bleaching events.

The immediate implications of the above are twofold. Firstly that a greater number of sites, both within and outside MPAs, need to be studied; and secondly that some changes in protection might eventually be needed. However it is clear that research is also needed to confirm *why* these variations in coral responses have occurred, since in many cases explanations so far are still no more than hypotheses (e.g. turbidity at Song-Songo). Thus, until these are confirmed, there may be some risk associated with expanding MPAs or zoning purely on the basis of inferences made from coral cover data. Clear explanations may be especially important if it is suggested that any current MPAs may be abandoned in favour of other sites that show stronger resistance or resilience. It is interesting to note that the data also illustrate the potential pitfalls of using the various factors as an *a priori* basis for protection, with sites at Tutia and Misali suffering high mortality despite proximity to deep water (a 'reliable' factor).

Management Effectiveness

The importance of effective management is highlighted by the fact that any 'paper parks' will also impact on the achievement of other principles (e.g. should perhaps not count as contributing to connectivity, representation or replication). This is especially true for Kenya and Tanzania, where local-scale threats are significant. Unfortunately, despite recent programmes and tools that will surely aid future progress in this area, management effectiveness generally remains difficult to quantify, and is poorly recorded in the two countries. What data is available suggests that effective management may be restricted to Kenya's parks, and Chumbe (and possibly Mafia) in Tanzania, and that even these MPAs may share (albeit to a lesser extent) the problems identified as affecting the other sites.

However, the proxies used in chapters 4 and 5 do indicate some areas which may be affecting current management. In Kenya, problems include a lack of capacity and resources, overly centralised management and inappropriate regulations. Since the 1998 event, the introduction of management plans and the increasing KWS focus on community engagement are likely to have enhanced effectiveness, but these developments are at an early stage and may be yet to attain their intended goals. In Tanzania, such system-wide conclusions are not possible given the wide range of management arrangements in place. The most notable successes are perhaps in the progress of collaborative management, while the most obvious weakness appears to be in financing – which undoubtedly inhibits many other management processes. With such variation, perhaps the clearest conclusion is that MPAs in Tanzania should make an effort to share experiences allowing mistakes to be avoided and successes to be repeated.

6.2. FUTURE OPTIONS FOR INCREASING ACHIEVEMENT OF THE FOUR PRINCIPLES

It seems that in order to better satisfy the four principles, some adjustments are required in the two countries' coastal management systems. This seems to be supported by observations that although recovery has taken place in both countries, it has often been slow – indicating that overall resilience is currently low. It is clear that data limitations prevent many specific suggestions (and indeed demonstrate that one important policy will be to increase research and monitoring). However, it is possible to propose some of the key areas which may most feasibly be addressed, and in some cases they might be addressed – given current systems, policies and legislation.

Kenya has been suggested as having '*probably has the most extensive network of MPAs in the region and does not have the capacity for establishing further MPAs*' (IUCN, 2001). This view is supported by the apparent lack of any policy pledges to expand the current MPA system – for climate change reasons or otherwise. It can be said that EMCA's mention of coral reefs as being in need of protection may *eventually* lead to the creation of new MPAs, and its requirements for national level strategies may also lead to a more systematic approach to their selection. However, for the moment there seems to be few options for addressing the shortcomings of representation, replication and connectivity identified above. Increasing protection of resistant areas could be achieved through zoning (or focused enforcement efforts) within existing reserves, and is provided for under current management plans, but would require research to be expanded to more areas outside current Parks and careful consultation with relevant stakeholders. A possible intermediate step may be to simply focus enforcement on notably resistant or resilient sites until zoning can be more officially introduced.

With limited scope for new MPAs, it seems that the focus should be on improving management within current MPAs. The upcoming review of management plans will provide a route through which current management issues can be more accurately identified and addressed, and site-level steps to combat bleaching (such as bleaching response plans) may be introduced. However, steps may be limited by the ongoing problems with finance, capacity (revenue sharing and staff turnover in particular), insufficient local involvement, and inappropriate and unenforceable regulations. It is unclear whether any of these are likely to be fully rectified without new legislation (in addition to the non-specific EMCA) that replaces or at least revises the Wildlife Act. In this respect, WWF (2005) suggest that efforts are underway to revise its regulations, but progress in this respect is unclear. That said, allowing some revenue retention and only rotating staff *within* MPAs may not require new legislation, and increased collaborative management is already supported under EMCA and developments at KWS. Thus these approaches may offer simple ways of increasing effectiveness. Since new MPAs may not be possible, the role of EMCA (and NEMA) in taking forward ICZM could also be vital. Improved efforts in this respect would not only increase the effectiveness of current MPAs (through reducing external threats), but would also provide some degree of protection to new areas where MPAs are not possible (as is happening in Diani).

As noted by WWF (2004), the coastal management frameworks in Tanzania are comparatively '*modern in outlook*', and may be better able to respond to the threat of climate change. Vitally, Tanzania's pledge to expand its MPA coverage provides an immediate opportunity to address some of the gaps identified above, and doing so should theoretically be supported by reasonably comprehensive and specific legislation. Importantly the National ICZM strategy, in making provision for areas of high value and natural vulnerability, should focus attention on coral reefs (and climate change). Given the significant gaps under the second principle, the EMSDAs inclusion of representation (although unfortunately not replication) as a criterion for future protected area selection will also be useful. In terms of protecting refugia, it is also important that zoning is well established (although perhaps limited by insufficient data).

A key feature of the Kenyan system is its diversity, which ensures that there is also a wide range of management models and experiences for decision-makers to draw upon when choosing the means of any expansion. This knowledge will be further augmented by two externally funded coastal management programmes – the WWF's Rufuji-Mafia-Kilwa (RUMAKI) seascape programme, and the World Bank's Marine and Coastal Environmental Management Project (MACEMP). In particular, the first of these programmes may add to any government efforts to increase protection of the (resistant) reefs of the Songo-Songo Archipelago, which has also recently been designated as a Ramsar site.

However, development of a true system of MPAs may be limited by the complexity of current legislation, and any new additions may be undermined by the problems with management effectiveness. With management inhibited in particular by limited resources, there is no guarantee that new MPAs will truly help to address the gaps identified – especially if external financial support declines in the long-term. Thus there may be some advantages to focusing available resources on existing MPAs – ensuring that current legislation is implemented (including the creation of adequate management plans, and ensuring legitimate community involvement). These options should all be possible within existing frameworks, as should increasing protection at the resistant reefs at Dar es Salaam reserves and any re-zoning within Mafia or Mnazi Bay MPs. Of course it is also possible that the implementation of the national ICZM strategy will help to address many of the management problems faced in current MPAs, and it should give some priority to coral reefs under its special areas management plans. Perhaps then, the biggest challenge to Tanzania will be to choose between the options available, and to ensure that resilience is at least considered when choices for new or improved MPAs are made.

More generally, one of the most feasible avenues for addressing gaps identified above for both countries appears to be taking a community-based approach. Focusing on this area may help to overcome finance problems and community opposition, as well as coinciding better with wider sustainable development priorities. New possibilities in this respect may be opened up by the emergence of Beach Management Unit legislation (still at the planning stage in Kenya). Already the experiences in Tanga have shown that community-based management can include closed areas, and that these areas can be popular and effective. There has also been some early progress in implementing a collaborative approach at Kuruwitu in Kenya – an area close to Kanamai which has also shown some signs of resistance to bleaching (T. McClanahan, personal communication), and which falls in the 'gap' between Mombasa and Watamu. These early successes could be consolidated and used as a model to be repeated in locations that help the countries improve connectivity, representation and replication – and efforts could even be focused on notable resistant sites. Furthermore, while such initiatives are not likely to lead to the establishment of large, closed areas, they may have the advantage of being better enforced. Like ICZM, this approach could also better provide for the flexible MPA boundaries which may be required under conditions of climate change (Soto, 2002), and could lead to the later establishment of larger MPAs (McClanahan et al, 2006a).

6.3. THE RESILIENCE MODEL AND PROTECTION AGAINST CLIMATE CHANGE

At this preliminary level of investigation, it seems that the two systems currently fall short of fully meeting any of the four principles of the resilience model. Some routes can also be identified through which some gaps may be addressed. This may be seen as answering two of the questions set by this study. However, it can be seen that the answer to the central question – whether either system can currently be expected to provide protection against future climate change – does not necessarily follow. Firstly, analysis here is highly simplified, and to accurately assess the needs of these two countries would require a level of study that would currently be inhibited by inadequate data. Secondly and perhaps more critically, while analysis suggests that *fully* meeting the four principles may be difficult in both countries, especially in Kenya, it is not clear whether this means their reefs will or will not survive future climate change. This is because, at this stage, fulfilment of the principles only really provides a hypothetical route to long-term protection, which science is yet to adequately prove or disprove. If the hypothesis that meeting the principles will protect against climate change is false, then perhaps no country, for climate change reasons at least, has an incentive to try and meet the four principles. Such a failure could be the result of various factors. It could be that it is impossible to build sufficient resilience, or build it fast enough, to allow recovery in between ever more frequent and severe bleaching events. Alternatively, it could be that building resilience to bleaching is misplaced if other threats (such as destructive fishing, or other climate change related impacts such as ocean acidification) emerge to be more important.

If the hypothesis is true, then perhaps many countries will need to take steps to ensure the principles are satisfied by their MPA systems. However, the principles are individually subject to their own controversies and targets are vague. Thus it is unclear precisely what countries should actually be aiming for. Also, when choosing amongst policy options, which principle(s) should take priority? Do all of the principles need to be (completely) fulfilled to protect against climate change? At first it seems that countries may be ill-advised to expand MPAs when those already in place are not effectively managed, and struggle to address even local scale threats (as is the case in Kenya and Tanzania). However it may be that a larger number of semi-effective MPAs may give more protection against climate change and bleaching. In this respect, Hannah et al (2002) suggest that when implementing a climate change integrated conservation strategy, it is unlikely that managers will be able to fully adopt all of its aspects at once. Clearly then, a priority must be to identify those aspects of the framework that may have the most impact in addressing this threat.

Thus, in a number of respects, the resilience model is clearly not yet the perfect basis for analysing the degree of protection an MPA system may provide against climate change. Analysis is hindered both by uncertainties related to its principles, and information requirements that would be high for any country. These factors also limit its use under the four steps of effective planning outlined in section 2.6 – not least because its goal (in terms of *how resilient* reefs will need to be) is unclear, further inhibiting assessment of relevant progress. Such problems may be particularly pertinent in the case of developing countries who can ill afford to implement strategies which cannot guarantee success, especially in the presence of other, possibly opposing, priorities (related to climate change or otherwise). However, while it is yet to provide a proven policy framework, the resilience model is an important attempt outline what the key considerations might be if policy makers wish to mitigate the effects of climate change on their coral reefs. With management effectiveness as a central principle, it seems to incorporate an important, in-built 'self assessment mechanism', which may help to encourage the kind of adaptive management that could be essential to climate change planning. Importantly, it also reinforces the need to consider conservation of coral reefs at the system level. Thinking in this way may be particularly important given the scales at which bleaching events can occur, and the interconnected nature of reef ecosystems (as demonstrated by Kenya and Tanzania).

One other key observation from this study is that although neither Kenya nor Tanzania has so far made explicit attempts to build bleaching resilience principles into their policies, both have made some progress towards their fulfilment. This progress is therefore in some senses 'accidental' – the result of largely *ad hoc* selection of MPAs according to other criteria. It should perhaps be seen as fortunate that past and future efforts focused on individual MPAs, may (if effective) address local threats and needs while *contributing* towards building overall system resilience. However if attempts to mitigate the effects of climate change do require MPA systems to be as resilient as *possible*, a failure to systematically plan for appropriate connectivity, representation and replication may leave coral reefs overly vulnerable. Of course, these principles may be incorporated into MPA systems without the need to explicitly consider climate change. Unfortunately, a focus on threats other than climate change is likely to pay inadequate attention to protecting sites resistant to coral bleaching – a feature that, although imperfectly understood, could be vital to the future adaptation of coral reefs, irrespective of other aspects of resilience.

7. CONCLUSIONS AND RECOMMENDATIONS

Despite having reefs that are both highly valuable and highly vulnerable to climate change, neither Kenya nor Tanzania has yet taken significant steps to build consideration of this threat into their conservation strategy. This may simply reflect the fact that they have other threats and priorities in mind. However, given the experiences in this study, it could equally have resulted from the lack of a clear means for policy makers, both in East Africa and beyond, to assess and address climate change-related gaps in their current systems. Thus, developing such tools has become an urgent priority – as reflected by the rapid proliferation of resilience concepts into management recommendations. However, the resilience model used here illustrates the difficulty of incorporating under-developed and untested ideas into conservation strategies – as well as the high data requirements if such climate change-integrated approaches are to be evaluated and applied. However, such problems do not necessarily imply that these early models and concepts are not valuable. Even at this early stage, using the resilience model has yielded some initial observations regarding two protected area systems and how they might be feasibly be changed to build resilience. It has also enabled some key areas of study to be identified that will help to inform both the development of the model itself, and its possible implementation in the future.

Recommendations for Future Study

- As recommended by Obura (2005a), a priority must be to translate early resistance and resilience hypotheses into reliable and implementable management interventions. In particular, studies to identify reliable resistance factors will be vital - given their possible role the future adaptation of reefs. It may also be important to identify which factors/principles may contribute most strongly to building resilience, so that these may be prioritised by policy makers.

- More research is needed to provide guidelines on MPA connectivity that are *specific* to different countries and regions. This will need to include detailed information on relevant oceanographic processes and their effect on the dispersal of key species.

- Similarly, studies may be required to identify how representation and replication specifically relates to climate change and bleaching. Specifically, what should be represented and what level of coverage is required to insure against climate change.

- Detailed coral reefs studies are required both within and beyond the boundaries of all current MPAs, including coral size/class data and the presence of any of the resistance and resilience factors. This will be essential if resistant and resilient sites are to be reliably identified, protected and tested by managers. Such studies could also form a component in studies of representation and replication.

- Assessment of management effectiveness needs to be supported by studies that record appropriate data. It may be important to develop measures of management effectiveness that can specifically be used to assess progress in building resilience - e.g. the recovery rates of any reef areas that suffer negative impacts (including, but perhaps not limited to, bleaching and mortality). As suggested by West and Salm (2003), such studies will form an essential part in the adaptive management of resilience-based management strategies.

- Regional level climate modelling will be needed to ensure that policy planning is robust to uncertainty. At a global scale, such modelling may also identify vulnerable countries where resilience-promoting policies could be tested.

- Finally, analyses such as that presented here may well be undertaken elsewhere to provide coarse but rapid assessments of MPA systems, with the level of detail dictated by available data. An alternative early approach could involve assessing progress against the CBD's work plan on coral bleaching. These studies should then be repeated further in the future as any data deficiencies identified are overcome, and the current resilience model is refined or replaced.

The overall recommendation must be that a great deal of further research and monitoring is needed to inform coral conservation, and that any data generated needs to be more widely disseminated to managers, policy makers and other interested stakeholders. Given the scale at which climate change acts, and the inter-connected nature of coral reefs, much of this research may be best carried out at regional level. This would obviously require a high degree of co-operation and co-ordination, and thus established regional fora (such as the Nairobi Convention) will play an important role. As noted in section 2.7, a significant part of their task will be to assess how recommendations might be modified to account for regional capacities and priorities. Another role for international bodies will be in financing these studies and the implementation of related policies. In the context of developing countries reliant on coral reefs, adaptation funding (such as the Special Climate Change Fund and the Least Developed Countries Fund) may come to be important.

Returning to Kenya and Tanzania, conclusions regarding the future of the two countries' reefs are clearly hard to reach. There has been some suggestion that Tanzania's reefs may generally be more resistant (and resilient) to bleaching than their Kenyan counterparts (McClanahan et al, in review), and the analysis above suggests that its system, although relatively new, may more able to respond to future conservation needs. Despite its long history of coastal management, opportunities for increasing protection and enhancing the current (low) resilience in Kenya appear to be more limited. However, the predictions of Sheppard (2003) imply that Kenya's reefs (and indeed its policies) could have more time to adapt; and importantly its coral communities may, over time, benefit from recruitment of larvae from resistant reefs in Tanzania. It is interesting to note that more recent bleaching events in East Africa in 2001 and 2003 have been relatively minor, and that in some cases species that suffered badly in 1998 were the least affected (Obura, 2001; Obura et al, 2004). Future studies may confirm whether was at least in part due to reefs' adaptation or improved protection since 1998. More generally, it seems that it is currently impossible to predict the long-term future of the world's coral reefs, especially given the unknown (relative) importance of other threats. What is clear is that options are available to MPA managers and policy makers that may build their resilience. Of course building resilience cannot guarantee that reefs will survive climate change in the long term, but given the value of reefs, taking a gamble may be appealing.

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