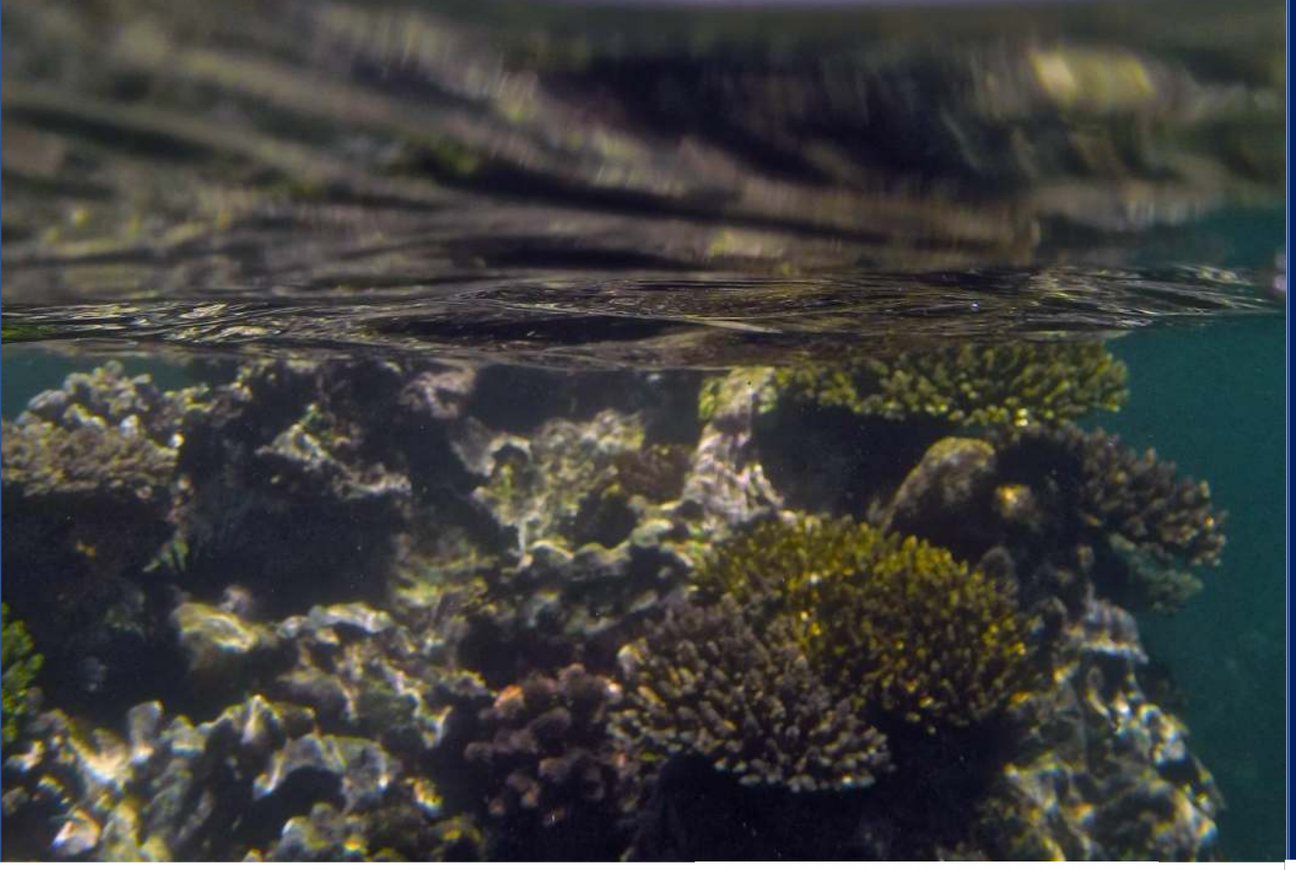
Coral Reefs and Climate Change in Watamu Marine National Park, Kenya



A ROCHA MARINE CONSERVATION PROGRAMME

KENYA WILDLIFE SERVICE

ACKNOWLEDGMENTS

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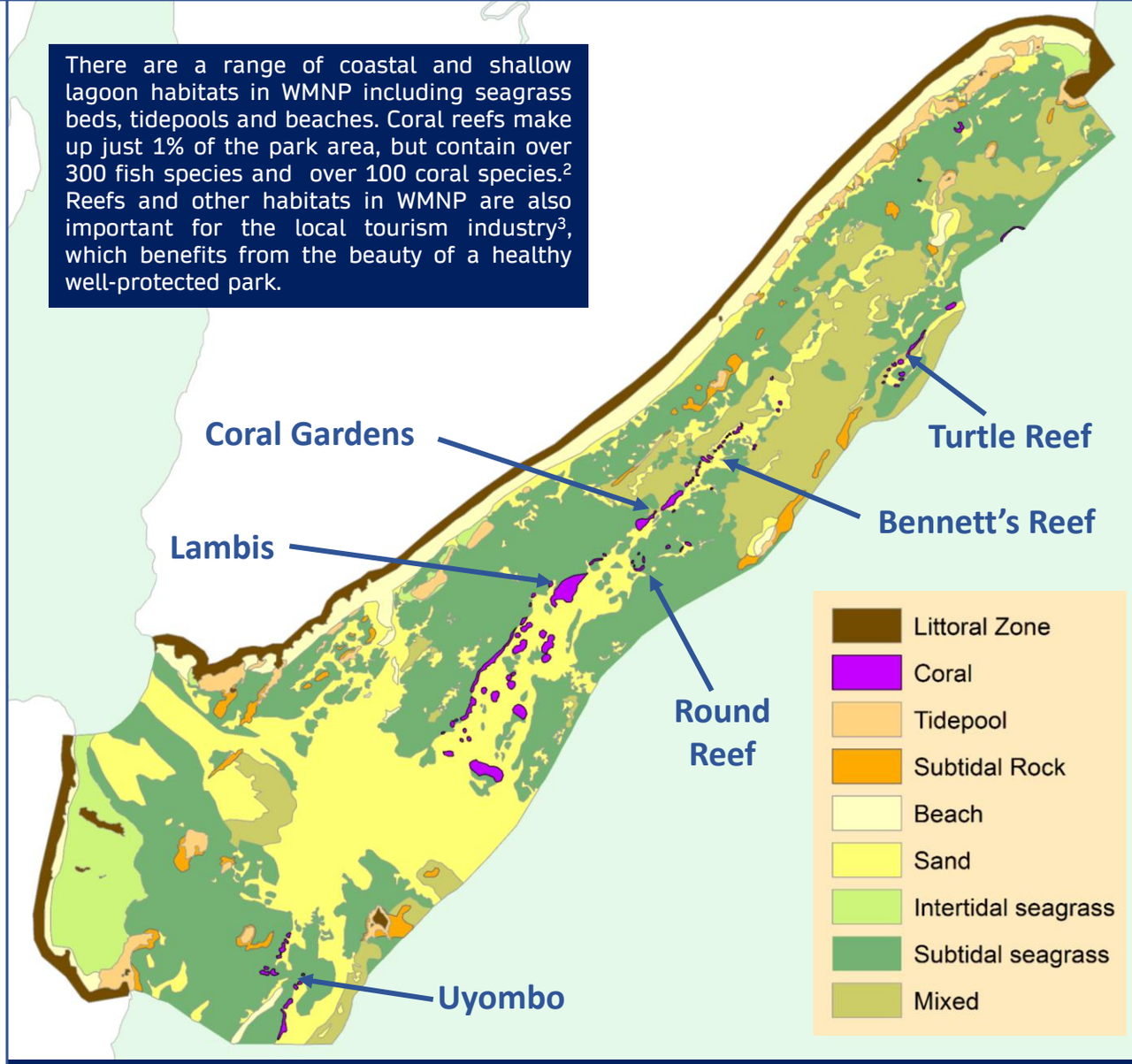
FOREWORD

Watamu Marine National Park **(WMNP)** is one of the **oldest** no-take Marine Protected Areas **(MPAs)** in the world, being established in **1968.** Since then the park has been **effectively protected**[1] against local human threats, such as **fishing** and **unsustainable coastal development.** However, the coral reefs in the park face the global threat of **increasing thermal stress** and **coral bleaching.** This 'report card' summarises the evidence available on;

- **Past changes** to WMNP's corals reefs from 1983 - 2020
- **Present resilience** of coral community, with signs of hope and ongoing issues
- **Future actions** to protect and even improve the park's coral community

There are a range of coastal and shallow lagoon habitats in WMNP including seagrass beds, tidepools and beaches. Coral reefs make up just 1% of the park area, but contain over 300 fish species and over 100 coral species.[2] Reefs and other habitats in WMNP are also important for the local tourism industry[3], which benefits from the beauty of a healthy well-protected park.

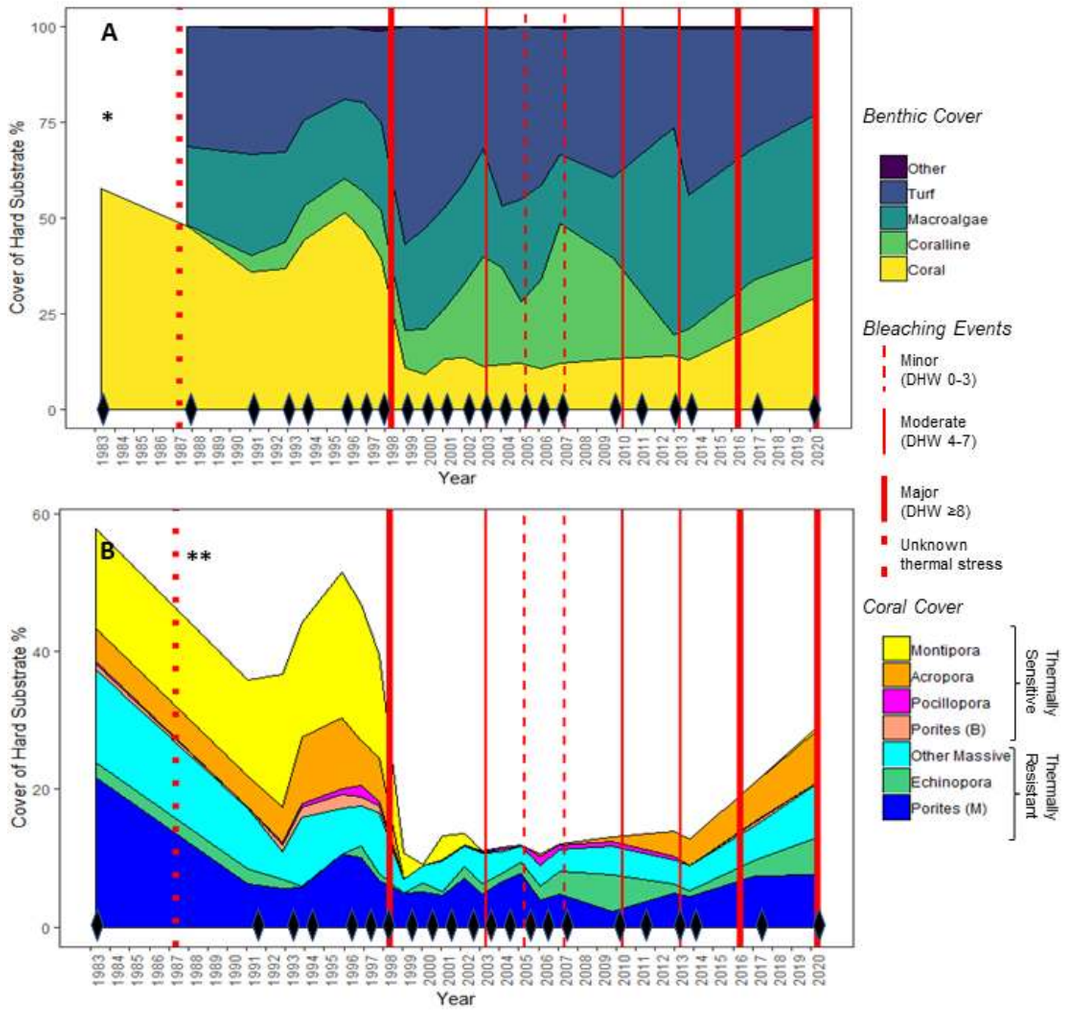


10km² Category 1 (No-Take) Marine Protected Area

One of four marine parks managed by Kenya Wildlife Service (KWS)

Around 30,000 marine park tickets sold annually

Timelines of A. Benthic cover as a % of available hard surface for coral growth and B. Coral cover by taxon from 1983 to 2020. Sampling periods are indicated on the x-axis with a black diamond. Known bleaching events are indicated with degrees of thermal stress experienced.



How does coral bleaching work?

- Corals are animals related to jellyfish and anemones
- They feed like plants using symbiotic algae in their cells to capture the sun's energy through photosynthesis
- When sea water temperatures go 1°C above average summer temperatures for a month or more, this symbiosis breaks down and corals lose their algae
- Without their algal pigments corals appears white and will eventually starve and die
- Coral reefs can recover from bleaching via new coral recruits and rapid regrowth of surviving colonies.
- Corals that survive bleaching often have higher resistance to thermal stress, meaning they can tolerate more thermal stress in the future.
- The long-term survival of a coral reef is dependent on thermal adaptation and regrowth outpacing the rate of warming sea temperatures

PAST CHANGES

Extensive historic research and monitoring has taken place on the coral community in WMNP, giving us a valuable timeline of coral cover and community composition over the past 37 years. During this time, nine bleaching events of varying severity were observed, resulting in significant changes in reef composition.

- **HEALTHY REEF 1983 – 1997:** The first quantitative data collection on WMNP's coral community was conducted in 1983. At that time coral cover was high (40-50%) with a dominance of thermally sensitive coral types such as *Acropora, Montipora* and *Pocillopora*. A bleaching event of unknown severity occurred in 1987, but the coral cover and community composition remained similar.
- **MASS BLEACHING AND MORTALITY 1998:** The global bleaching event in 1998 caused severe bleaching and mortality to the coral community in WMNP, with 74% of colonies turning completely white and a dramatic reduction in coral cover from 38% in 1997 to 10% in 1999.
- **DEGRADED REEF 1999 – 2013:** Coral cover was low (10%) and consisted of predominately thermally resistant colonies, such as *Porites* and *Echinopora*. Five minor and moderate bleaching stress events occurred during this period, but there was no further significant loss of coral cover. There was also no phase-shift to a macroalgal dominated space, with the majority of benthic space occupied by turf and coralline algae.
- **RECOVERING REEF 2013 – 2020:** Coral cover has begun to recover, reaching 25% in 2020 with more *Acropora* colonies. This is despite two major thermal stress events of a similar magnitude to 1998. Macroalgae cover also increases during this time.

THERMAL RESISTANCE VS. SENSITIVITY
Some coral types are better at coping with thermal stress than others. Branching forms, like *Acropora*, tend to bleach severely and die, whereas massive forms, like *Platygyra* tend to either resist bleaching or regain their colour when the thermal stress has passed[4].

PRESENT RESILIENCE

RESILIENCE describes the ability of a of a coral community to bounce back from thermal stress. The coral life processes of recruitment, growth and survival are essential for reef recovery and persistence.

RECRUITMENT of new baby corals to the reef is essential if many adults are killed by bleaching. Successful recruitment requires;

- **A SUPPLY OF LARVAE either from nearby adults or elsewhere**
- **SUITABLE SUBSTRATE free of competing macroalgae and sediment**

RECRUITMENT → GROWTH → SURVIVAL → RECRUITMENT

SURVIVAL of corals in WMNP is most threatened by coral bleaching, as many local human threats are effectively managed. Increased thermal tolerance and resistance to bleaching is essential

Rapid GROWTH of corals requires clear low nutrient water and lack of competition from macroalgae. Thermally sensitive branching corals grow faster than thermally tolerant massive forms.

SNAPSHOTS OF PRESENT-DAY WATAMU: Reef condition within WMNP is patchy with healthy reef and degraded reef being found within several hundred metres of each other.

HEALTHY REEF
High coral cover (>30%) with diverse coral types including abundant branching *Acropora* and *Pocillopora*.

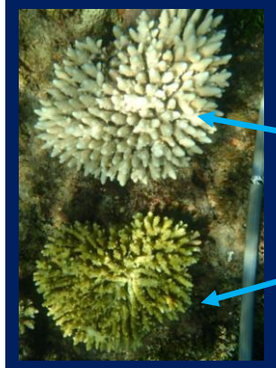
MODERATE CONDITION
Moderate coral cover (10 – 30%), with other substrate occupied by turf and coralline algae. Massive corals dominate.

DEGRADED REEF
Low coral cover (<10%), with high macroalgae cover. Only a few highly tolerant coral types (e.g. *Galaxea*) persist.

SIGNS OF HOPE: GROWTH AND SURVIVAL

The growth and survival rate of coral colonies surveyed in 2013 were similar to those on healthy reefs in 1993, prior to severe bleaching. This suggests that factors that reduce coral growth and survival, such as competition with macroalgae or turbid sediment-filled water, have not increased in this 20 year period. However, in 2013 there was moderate thermal stress, which should have resulted in a lower survival of corals than in 1993. Despite 70% of colonies bleaching, only 10% died. In 2020 the thermal stress was as severe as in 1998, but only 22% of coral colonies died. Corals that have experienced repeated thermal stress, have been shown to gain increased thermal resistance. It appears that corals in WMNP may be more tolerant of temperatures now than in 1998.

THERMALLY RESISTANT *ACROPORA?*



29.03.2020
30.0°C

This colony bleaches

This colony maintains most of its colour

19.08.2020
26.4°C

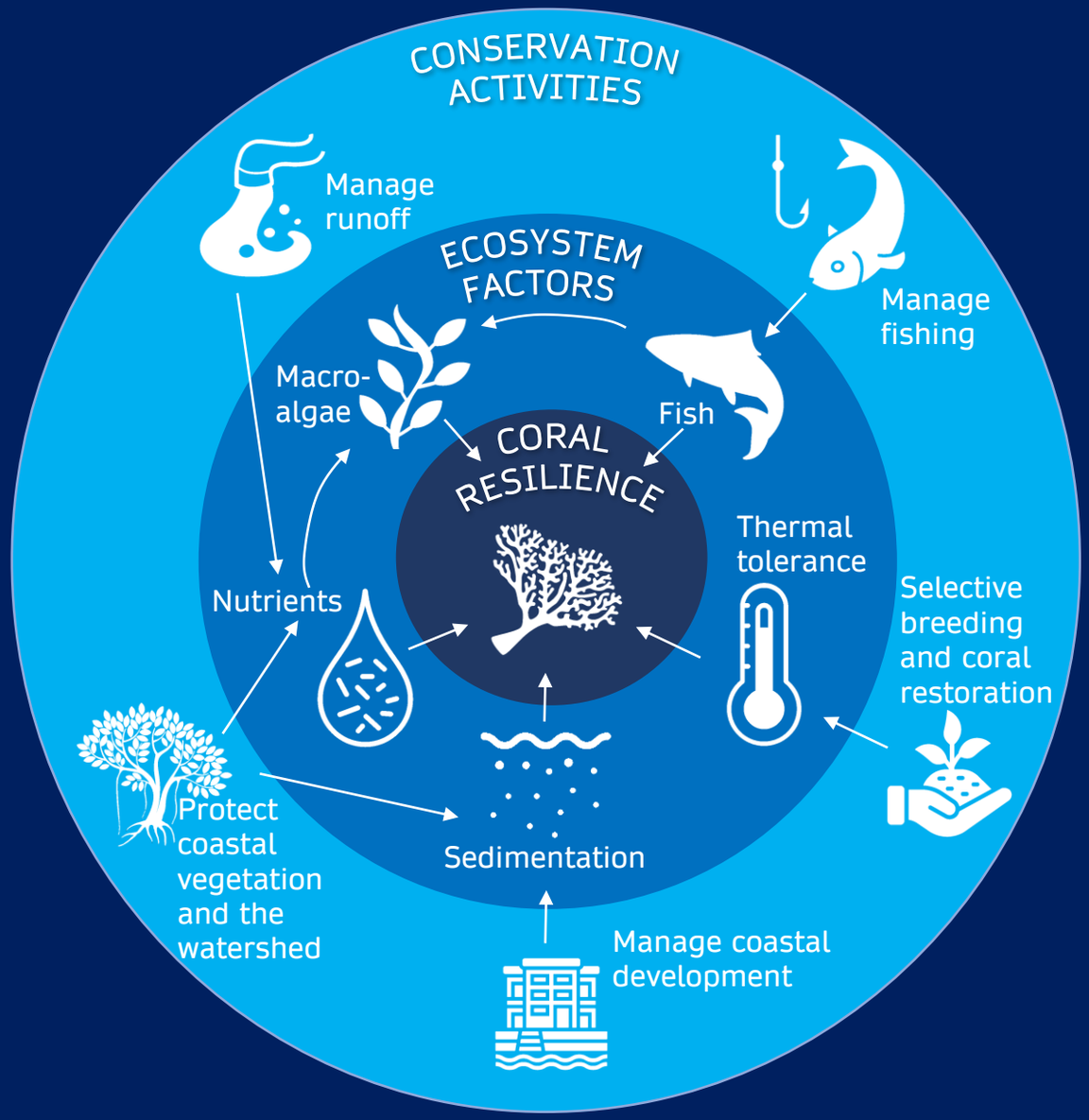
Both colonies survive – could these help repopulate the reef with thermally resistant corals?

ONGOING ISSUE: RECRUITMENT

The abundance of juvenile corals on the average Indian Ocean reef is 10 – 20 recruits per m^2. In Watamu recruit density was just 3.2 per m^2 in 1993, which declined significantly to 1.2 per m^2 in 2013. Hence recruitment in the park was low even in the past and has decreased further since then. Low recruitment may be one of two reasons;

- **Supply of Larvae:** The abundance of adult corals in Watamu is lower compared to pre-1998, meaning the local supply of larvae is also probably lower. Additionally reefs to the south, that are connected to Watamu, are probably also degraded and provide fewer larvae via currents.
- **Suitable Substrate:** Macroalgae competition and sedimentation do not appear to be affecting adults. However, recruiting corals are more vulnerable to mortality than adults hence, a small decrease in environmental suitability could reduce recruitment success

Without a regular recruitment of new juvenile corals, a reef will recover slowly from acute disturbances like coral bleaching. Low recruitment may partially explain the long period between 1999-2013 when coral cover remained ~10%.



FUTURE ACTIONS

Even with an extensive understanding of ecosystem state and processes, the complex nature of coral reefs makes it difficult to pinpoint which conservation activity is most likely to improve conditions. Macroalgae are the nemesis of corals, having numerous negative competitive interactions that can trigger 'phase-shift' from a coral dominated reef to an algae dominated one.[5] However, algal expansion could be caused by either loss of top-down control of parrotfish and other herbivores or from bottom-up nutrients driving algal growth rates. If nutrients are the issue, is the source from urban run-off and sewage or from agriculture using fertilisers and eroding soil kilometres away in the watershed of a local river? In this section, five commonly used conservation activities[6] used to combat local threats and promote reef resilience to coral bleaching are discussed in the context of Watamu.

MANAGE FISHING

In WMNP fishing activities have been effectively managed for many years by KWS[1]. The park's no-take status prevents any fishing or extractive use of the ecosystem and, as a result, the fish community in Watamu is healthy with high biomass and high biodiversity.[7] Herbivores, such as parrotfish, are important for controlling macroalgae growth, and a particular focus of resilience-based management activities. However, all reef species play a role in maintaining a healthy reef. For example predatory triggerfish eat urchins that, if they become too numerous graze, on coral recruits and cause bioerosion. The Triton's Trumpet (*Charonia tritonis*) is often targeted by curio-sellers for its beautiful shell, but it is also an important predator of the coral eating Crown-of-Thorns Starfish (*Acanthaster planci*). The continued prevention of all types of fishing in WMNP will help maintain these ecological links in the reef ecosystem and promote coral resilience.

Healthy fish populations in Watamu maintain a health ecosystem

PROTECT COASTAL VEGETATION AND THE WATERSHED

Clearing of coastal and watershed vegetation watershed can lead to a host of problems for a reef. Without leaves to intercept rain and roots to hold together the earth, soils erode and wash onto the reef causing increased sedimentation and turbidity. If the land has been cleared for agriculture, fertilisers will be washed onto the reef as well. In Malindi, 20km north of Watamu, the reef has been highly impacted by river born sediments from the Sabaki river,[8] eroded many kilometres away in the Kenyan highlands. Watamu is lucky that it has no major rivers flowing into the park, hence only local vegetation in a small watershed need to be considered. Inland from WMNP, Arabuko-Sokoke coastal forest reserve and Mida Creek mangrove reserve are being effectively protected by Kenya Forest Service. WMNP includes a 30m 'riparian zone' above the high-water mark of sand dunes, coastal scrub and limestone cliffs, which remains undeveloped and natural along much of WMNP's shoreline. This vegetation in the coastal zone and watershed of the park is essential for filtering freshwater entering the sea and helping to prevent erosion. Ultimately this maintains the clear low-nutrient water corals thrive in, and should continue to be protected in the future.

Sand dunes help prevent erosion and filter run-off from the land

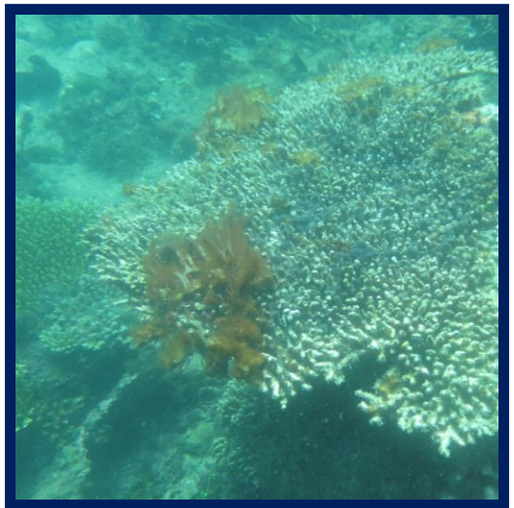
Sand bags used to control coastal erosion along the beach of WMNP

MANAGE COASTAL DEVELOPMENT

The beauty of coral reef areas makes them very attractive to developers of tourist resorts and luxury homes. Marinas, coastal defences and other infrastructure may be constructed in the coastal zone to support this development. However, clearing of coastal habitats and increased sedimentation in local waters can destroy the coral reefs and natural beauty that motivated development in the first place. In Watamu, construction within the park's boundary is prohibited and many of the adjacent coastal plots are low density privately owned homes. Some historical developments did not respect the riparian zone, clearing dune vegetation and constructing right up to the beach, which has resulted in recent erosion of their sea-wall. The erosion of sand and sand-bags used to combat this erosion led to increased sedimentation on reefs in Watamu in 2017, which may have harmed some corals in the nearby area. More recent developments have maintained coastal vegetation, which will minimise the impact of this new construction on reef health, as well as maintaining the beauty its visitors came to see in the first place.

MANAGE RUNOFF

The built-up area of Watamu has increased five fold since the 1960s, while population has increased nine fold.[1,9] Nutrients and chemical pollutants run off from human settlements and enter the sea via overland flow and seeping through sand and groundwater flow. On the reef in Watamu there has been a slight increase in macroalgal cover from 15% in 2013 to 25% in 2020 and during the summer of 2017 there was a bloom of cyanobacteria, indicative of a nutrient surplus in the water. In Watamu no water quality testing has taken place to date and it is not clear whether elevated nutrients and chemical pollutants are entering the park from the growing coastal town. It is highly recommended that future research assesses the potential impact of urban run-off on coral recruitment, growth and survival. Additionally local water management authorities should work with local property owners to ensure that drainage and sewage facilities are well managed.



Cyanobacteria overgrowing a coral colony in WMNP in 2017

Local people garden corals in Fiji. This work is supported by tourist donations and is a sustainable alternative livelihood to fishing.

SELECTIVE BREEDING AND REEF RESTORATION

Selective breeding of thermally resistant corals has been demonstrated to boost the natural process of thermal adaptation.[10] Growing and propagating colonies known to be resistant to bleaching, and then using coral gardening technique to restore the reef with these colonies, could be an effective way to repopulate degraded reefs. Post-1998 in Watamu, adult colonies grew and survived well, but a lack of new recruits hindered recovery. Many of the corals that were monitored during bleaching in 2020 survived, meaning we have identified thermally resistant colonies. Propagating and planting these colonies back onto the reef could help by-pass low recruitment and speed up the recovery of Watamu's reefs. Reef restoration is an expensive labour-intensive activity, but is often popular with visiting tourists and offers an alternative livelihood for local people.[11] Watamu has a thriving tourism industry, which could be used to support this activity through donations and voluntary work.

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