Wildlife Conservation Society

A SUMMARY OF WCS KNOWLEDGE ON THE STATE OF CORAL REEFS IN MOZAMBIQUE

Birrell, C. L., Sola, E., Bennett, R. H., van Beuningen, D., Costa, H. M., Sitoe, J. J., Sidat, N., Fernando, S., Darling, E. S., Muthiga, N. A. and McClanahan T. R.

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Cover photograph: Corals (*Porites sp., Pocillopora sp.*) and coral dwelling reef fish in province of Cabo Delgado ©Hugo Costa

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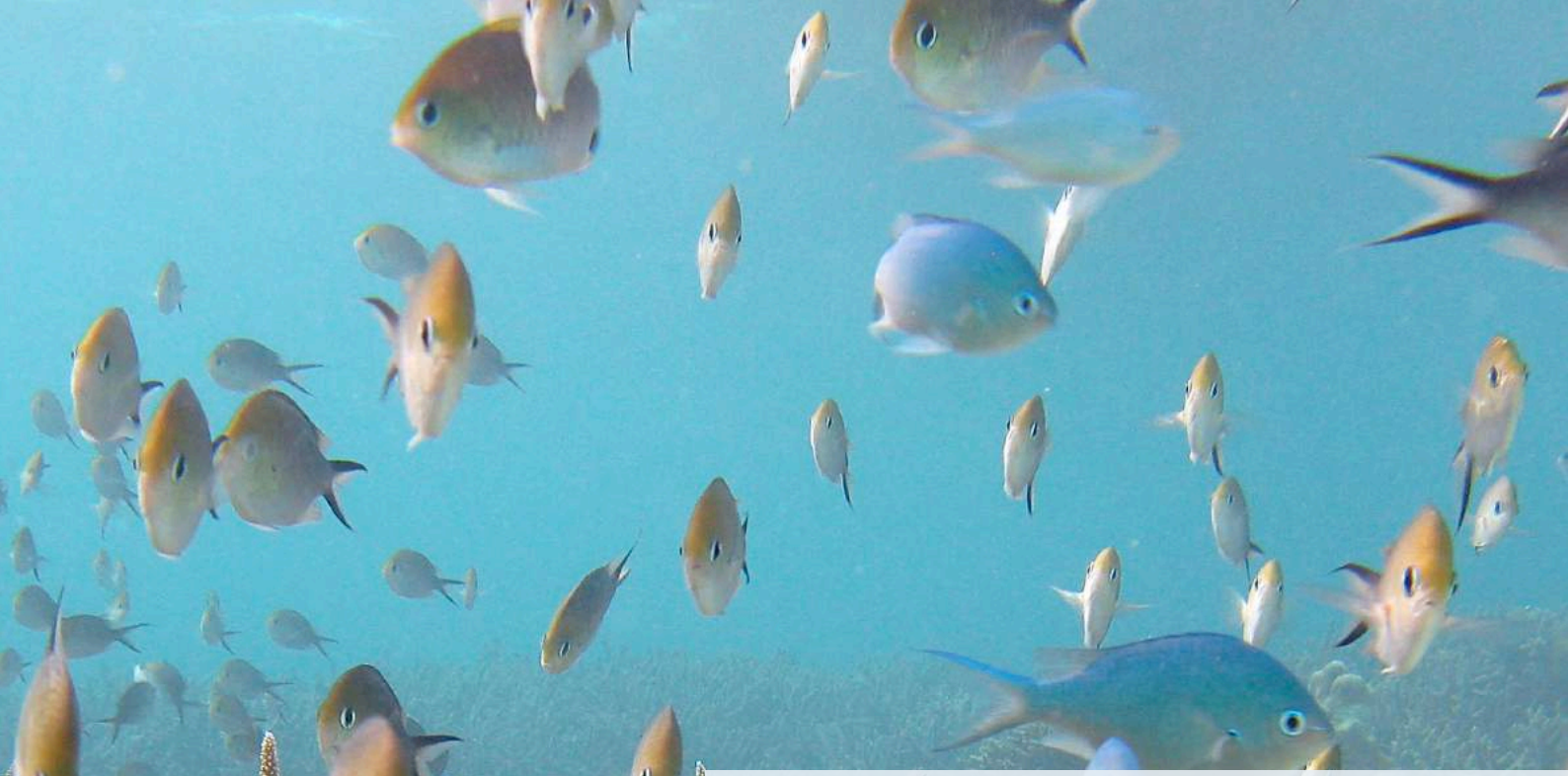

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OBJECTIVO DESTE RELATÓRIO

Este relatório tem como objectivo resumir os dados de monitoria de recifes de coral colectados pela Wildlife Conservation Society (WCS) e que estão disponíveis na plataforma de dados Mermaid e em publicações efectuadas por cientistas da WCS relativas a recifes de coral em Moçambique, de modo a contribuir para o desenvolvimento de uma Estratégia Nacional e Plano de Acção para os Recifes de Corais (ENPA-RC).

SUMÁRIO

Este relatório apresenta e resume os dados e conhecimentos sobre recifes de coral resultantes do trabalho realizado por cientistas da WCS em Moçambique até 2020. A WCS Moçambique iniciou um programa marinho em 2018, no entanto, desde 2008 que vários cientistas da WCS trabalharam sob diferentes iniciativas regionais ou nacionais, contribuindo para o conhecimento dos recifes de coral no País. O objectivo deste relatório consiste em fornecer informação para apoiar o governo de Moçambique e seus parceiros de conservação no desenvolvimento de uma Estratégia Nacional e Plano de Acção para os Recifes de Coral.

Este relatório apresenta os dados ecológicos recolhidos por cientistas da WCS para corais duros, corais moles e macroalgas em 60 locais e dados para peixes de recife colectados em 70 locais nas províncias de Cabo Delgado, Nampula, Inhambane e Maputo. Adicionalmente, já no âmbito do programa marinho da WCS para Moçambique, juntamente com o IIP, a Faculdade de Ciências da Universidade do Lúrio e outros parceiros, a WCS reuniu dados ecológicos de presença de tubarões e raias em 364 locais nas províncias de Cabo Delgado, Inhambane e Maputo com recurso a vídeo subaquático remoto em estéreo com isca (BRUVS). Investigadores da WCS também realizaram avaliações socioeconómicas de pesca e da gestão de pesca na província de Nampula e, em colaboração com o IIP e outros parceiros, foram realizados inquéritos sobre a captura de tubarões e raias nas províncias de Cabo Delgado, Nampula, Zambézia, Inhambane e Maputo. Os métodos de colecta de dados da WCS são padronizados em todo o mundo e permitem a comparação com dados de outras nações.

Os registos da cobertura de coral duro variaram entre 4,5 % e 70,3 %, e os registos da cobertura de coral mole variaram entre 0% e 38,2 %. No entanto, os efeitos da actividade de gestão na cobertura de corais duros e moles não são evidentes nos dados da WCS. Os registos de cobertura de macroalgas variaram entre 0 % e 39,1 % e a cobertura de macroalgas foi mais baixa em áreas onde a pesca era proibida, mas a cobertura média de macroalgas nos recifes de Moçambique (15 %) encontra-se acima da cobertura média para o Oceano Índico Ocidental (5 %). Três recifes (4,7 % dos recifes amostrados) tinham menos do que 10 % de cobertura de corais duros o que é considerado abaixo de um nível sustentável. Um número adicional de 14 recifes (21,9 % dos recifes amostrados) possuíam cobertura de corais duros abaixo de 30 %, percentagem que a WCS considera a desejável para sustentar a biodiversidade e actividade da pesca. Um total de 49 recifes (76,6 % dos recifes amostrados), tinha cobertura de corais duros abaixo de 50 %, valor que é considerado o necessário para acompanhar o aumento do nível do mar associado a patamares de concentração representativos (RCP) de RCP4.5 e apenas 3 (4,7 % dos recifes) tinham uma cobertura de corais duros de 70 % ou mais, percentagem que é considerada a necessária para acompanhar o aumento do nível do mar em 0,5m, que se prevê até 2100 segundo o cenário RCP8.5.

Os dados colectados pela WCS exploram os resultados dos regimes de gestão de pesca com vedas, pesca restrita e áreas sem restrições de pesca. Os registos de biomassa de peixes de recifes variam entre 107,1 kg/ha e 3038,5 kg/ha e tendem a ser mais altos em recifes em que a gestão é a de pesca proibida. Das 81 amostragens detalhadas neste relatório, pelo menos metade (50,6 %, ou 41 amostragens) tinha a biomassa de peixes abaixo do recomendado para permitir uma pesca sustentável (biomassa de peixe ≥ 450 kg/ha) e, neste grupo, estavam incluídas todas as amostragens em recifes sem restrições de pesca (18 amostragens), junto com metade das amostragens em recifes com restrições de artes de pesca (11 amostragens). A maioria das 16,1

% de amostragens em recifes com uma biomassa de peixes recomendada para reter a diversidade de peixes (13 amostragens com biomassa de peixes ≥ 600 kg/ha) foram em recifes geridos com vedas em que a pesca era proibida (10 amostragens) e um pequeno número permitia a pesca com restrições (3 amostragens). Quase todas as 16,1 % das amostragens em recifes que satisfizeram as metas de conservação propostas (13 amostragens com biomassa de peixe ≥ 1150 kg/ha) foram realizadas em recifes geridos com proibição de pesca (12 amostragens) e um tinha restrições ao nível da sua gestão. A gestão através de vedas, com proibição de pesca, evidencia resultados de conservação positivos para os recifes de coral em Moçambique.

As amostragens com BRUVS registaram a ocorrência de 3 espécies de raias e nenhum tubarão na província de Cabo Delgado, 7 espécies de tubarões e 9 espécies de raias na província de Inhambane e 8 espécies de tubarões e 7 espécies de raias na província de Maputo. Os inquéritos realizados nos locais de desembarque de pesca registaram 5 espécies de raias na província de Cabo Delgado, mas nenhuma de tubarão, 8 espécies de tubarões e 14 espécies de raias na província de Nampula, 7 espécies de tubarões e 7 espécies de raias na província da Zambézia, nenhum tubarão e 3 espécies de raias na província de Inhambane e 6 espécies de tubarões e 7 espécies de raias na província de Maputo. Existe uma proporção relativamente alta de juvenis nos tubarões e raias capturadas, variando de 11 % a 100 % nos inquéritos sobre capturas, o que inclui espécies criticamente ameaçadas, como o tubarão martelo comum, *Sphyrna lewini*, e os peixes cunha *Rhynchobatus australiae* e *Rhynchobatus djiddensis*, e peixe guitarra *Rhina ancylostomus*.

A conservação dos recifes de coral em Moçambique irá beneficiar de acções de gestão que favorecem o aumento da cobertura de coral, reduzem a cobertura de macroalgas e aumentam a biomassa de peixes nos recifes. Uma rede de áreas de veda permanente e áreas de pesca restrita associadas a habitats de recifes de coral é uma abordagem eficaz para alcançar estes objectivos. A conservação de tubarões e raias em Moçambique irá beneficiar de acções de gestão, tais como áreas de veda permanente que se estendam para além dos recifes de coral e restrições à pesca para evitar a captura de juvenis e espécies ameaçadas.

AIM OF THIS REPORT

This report aims to summarize Wildlife Conservation Society (WCS) coral reef monitoring data available in the Mermaid data platform and publications by WCS scientists for coral reefs in Mozambique to support the development of a National Strategy and Action Plan for Coral Reefs.

SUMMARY

This report introduces and summarises the survey data and knowledge on coral reefs resulting from the work undertaken by WCS scientists in Mozambique up to 2020. WCS Mozambique started a marine program in 2018, however since 2008 several WCS scientists working under different regional or national initiatives have contributed to knowledge of coral reefs in the country. The objective of this report is to support the government of Mozambique, and its conservation partners, to develop a National Strategy and Action Plan for Coral Reefs.

This report refers to ecological data collected by WCS scientists for corals, soft corals and macroalgae from 60 sites, and reef fish data from 70 sites in the provinces of Cabo Delgado, Nampula, Inhambane and Maputo. Together with the Instituto Nacional de Investigação Pesqueira (IIP, National Institute for Fisheries Research) and other partners, WCS surveyed sharks and rays at 364 sites in the provinces of Cabo Delgado, Inhambane and Maputo, using baited remote underwater video in stereo (BRUVS) surveys. WCS' scientists also collaborated in socio-economic assessments of fisheries and fisheries management in the province of Nampula, and together with IIP and other partners has undertaken shark and ray catch surveys in Cabo Delgado, Nampula, Zambézia, Inhambane and Maputo. The WCS data collection methods are

standardised worldwide and allow for comparison with data from other nations.

Records of hard coral cover range between 4.5 % and 70.3 %, and records of soft coral cover range between 0% and 38.2 %, however effects of management on the cover of hard and soft corals are not clearly identified. Records of macroalgae cover range between 0 % and 39.1 % and macroalgae cover is lower in no-take areas, however the average macroalgae cover on reefs in Mozambique (15 %) is above the average for the Western Indian Ocean (5 %). Three reefs (4.7 % of surveys) had hard coral cover below 10 %, which is considered to be below sustainable. An additional 14 reefs (21.9 % of surveys) had hard coral cover below 30 %, which WCS considers desirable to sustain biodiversity and fisheries. A total of 49 reefs (76.6 % of surveys), had hard coral cover below 50 % which is considered necessary to keep up with sea level rise associated with representative concentration pathway (RCP) of RCP4.5, and only 3 reefs (4.7 % of surveys) had hard coral cover of 70 % or more, which is considered necessary to keep up with sea level rise of 0.5 m foreseen by 2100 under RCP8.5.

Data collected by WCS explores the impacts of management regimes of no-take, restricted fishing gears and open access fishing areas. Records of fish biomass range between 107.1 kg/ha and 3038.5 kg/ha and tend to be higher in no-take areas. From 81 reef surveys, fish biomass of at least half of the surveys (50.6 % or 41 reefs) was below thresholds for sustainable fishing (fish biomass ≥ 450 kg/ha), and this includes all of the reefs with open-access management (18 surveys), and half of the reefs with restricted fishing management (11 surveys). Most of the 16.1 % of surveys recording sufficient biomass to retain fish diversity (13 reef surveys with fish biomass > 600 kg/ha) were under no-take management (10) with a small number under restricted management (3 surveys). Almost all of the 16.1 % of surveys that satisfied proposed conservation targets (13 surveys with fish biomass > 1150 kg/ha) were on reefs under no-take management (12 surveys) with one reef under restricted management. No-take management provides clear benefits for the conservation of coral reefs in Mozambique.

BRUVS surveys recorded 3 species of rays and no sharks in Cabo Delgado province, 7 species of sharks and 9 species of rays in Inhambane province and 8 species of sharks and 7 species of rays in Maputo province. Fisheries landing site surveys recorded 5 species of rays but no sharks in Cabo Delgado province, 8 species of sharks and 14 species of rays in Nampula Province, 7 species of sharks and 7 species of rays in Zambézia province, no sharks and 3 species of rays in Inhambane province and 6 species of sharks and 7 species of rays in Maputo province. The proportion of juvenile sharks and rays caught is relatively high, ranging from 11 % to 100 % in the catch surveys. These include critically endangered species such as the scalloped hammerhead shark (*Sphyrna lewini*), bottlenose and whitespotted wedgefishes (*Rhynchobatus australiae* and *R. djiddensis*) and bowmouth guitarfish (*Rhina ancylostomus*).

The conservation of coral reefs in Mozambique will benefit from management actions that favour an increase in coral cover, reduction in macroalgae cover and increase fish biomass on reefs. A network of no-take areas and restricted fishing areas associated with coral reef habitats is an effective approach to achieve this. The conservation of sharks and rays in Mozambique will benefit from management actions, such as no take areas that extend beyond coral reefs and fishing restrictions to avoid the capture of juveniles and threatened species.

INTRODUCTION

The Wildlife Conservation Society (WCS) was established in 1895 and its mission is to save wildlife and wild places worldwide through science, conservation action, education, and inspiring people to value nature. WCS works in more than 60 nations and has supported governments and communities worldwide to create or expand 268 marine and terrestrial protected areas. Mozambique is in one of the 14 regions where WCS focuses on coral reefs and associated organisms together with Eastern Africa, Madagascar, and the Western Indian Ocean. WCS established a country program in Mozambique in 2012.

The WCS Global Marine Program is investing in ocean protection, sustainable fisheries, and marine species conservation in waters of 23 countries from all five oceans. The Mozambique marine program started its activities at the end of 2018, and prioritises climate resilience and protection of key marine species and key marine habitats. These include corals and fish in coral reef habitats; sharks, rays and their habitats; and marine mammals and their breeding and migration sites. WCS efforts will help to ensure that local communities have continuous access to the natural resources and ecosystems services on which they depend for their livelihoods. WCS Mozambique is providing technical and scientific advice to the "Instituto Nacional de Investigação Pesqueira" (IIP, National Institute for Fisheries Research) for the development of a National Strategy and Action Plan for Coral Reef conservation and management in collaboration with several other stakeholders, gathered in a national coral reef working group.

The diversity of marine habitats and biodiversity in Mozambique result from latitudinal and temperature gradients, coastal islands, oceanic current eddies in the lee of Madagascar, and deep water in the Mozambique Channel amongst other factors. The coral reefs in northern Mozambique are among the centres of the highest coral diversity in the Western Indian Ocean (Ateweberhan and Mcclanahan 2016). The southern margin of this coral diversity hotspot is unclear as a result of limited data south of Pemba and Nacala (Obura 2012; McClanahan and Muthiga 2017). The coral diversity in Northern Mozambique includes approximately 300 species (Obura 2012). Extensive coral reef development is observed north of Quelimane, with noted coral reef environments in the Quirimbas, Primeiras and Segundas, Pemba, and Nacala. It is suggested that natural barriers associated with the Zambeze River limit connectivity of marine communities, contributing to lower coral diversity and reef community diversity in southern regions of Mozambique, where reefs are mostly coral communities established on submerged rock surfaces (McClanahan and Muthiga 2017). In southern regions of Mozambique, relatively high attention has been given to isolated reefs in and near the Bazaruto Archipelago as well as coastal areas near Xai-Xai, where coral diversity is reported to include approximately 100 species (Schleyer and Celliers 2005). In the most southern regions of Mozambique corals become less diverse and more isolated, in transient communities or limited to isolated reefs as the marine environment becomes progressively subtropical, as seen at Inhaca Island (Schleyer and Pereira 2014).

The coral reefs of Mozambique have repeatedly been subjected to widespread environmental stresses in recent decades. Bleaching events have impacted the corals of Mozambique and were described to variable extents in 1998, 2004, 2005, 2010, and 2016-7 (Wilkinson 2004; McClanahan, Maina, and Muthiga 2011; Obura et al. 2017; Gudka et al. 2018). It was also declared likely that coral bleaching would re-occur in 2020 in the CORDIO bleaching alert newsletter of 16 March 2020, but surveys and reporting have been hindered by restrictions associated with the Covid-19 pandemic. Cyclones have impacted the coast of Mozambique and there is concern these may be increasingly frequent in association with La Niña warm sea surface anomalies (Vitart, Anderson, and Stockdale 2003; Fitchett and Grab 2014).

There are scattered reports of crown-of-thorns starfish (COTS), *Acanthaster sp.*, affecting reefs in Mozambique (Wilkinson 2004; Haszprunar, Vogler, and Wörheide 2017). COTS outbreaks were reported for reefs in the Bazaruto Archipelago and nearby coastal reefs in 1995-1996, impacting approximately 90% of corals on affected reefs (Schleyer and Celliers

2005). More recently COTS were reported from reefs in southern Mozambique (Celliers and Schleyer 2007). Hill et al. (2010) also report COTS in the Quirimbas Archipelago of northern Mozambique and COTS outbreaks have concerned reef managers to the north of the Mozambique border with Tanzania (Wagner 2007).

Human activities have contributed to reef degradation in Mozambique during recent decades. Population migrations in Mozambique driven by armed conflict between 1976 and 1992, extreme weather events generating floods and droughts, and environmental degradation, have all frequently increased coastal populations and pressure on coral reef environments (Raimundo 2009; Stal 2011; Blythe, Murray, and Flaherty 2013; Menezes, Eide, and Raakjær 2011). Artisanal fishing has frequently applied destructive fishing gears, exacerbated by migrant fishermen, on reefs and other marine environments along the coast, typically including beach seines, gillnets, and mosquito nets, frequently damaging habitats, exploiting juvenile fish populations and impacting corals (Wilkinson 2008; 2004; Menezes, Eide, and Raakjær 2011). The human population and the number of fishers and collectors has also increased steadily in Mozambique since 1965, increasing the pressure on marine environments (Jacquet et al. 2010). Industrial developments, including port expansions, mining and oil and gas extraction, create localised impacts on marine and coastal environments in locations such as Inhambane, Moma, Nacala, Pemba, and Palma (Quirimbas Archipelago), with more developments proposed (Perreira et al. 2014). A concern is that there is a lack of baseline knowledge that can be used to assess human impacts on many of the marine environments of Mozambique (Pereira et al. 2014). A further concern is the limited release of environmental studies undertaken by private industry.

There is a need to re-establish coral reef monitoring and management at a national level in Mozambique. A coordinated effort for monitoring of coral reefs in Mozambique was undertaken from 1998 to 2003 by the Mozambique Coral Reef Monitoring Programme (MCRMP), which continued intermittently until 2009 (Pereira et al. 2000; Motta et al. 2002; Pereira et al. 2003; Obura et al. 2017). This combined expertise of the government's Coastal Management Unit (Unidade de Gestão Costeira, UGC), IIP and the former Ministry for the Co-ordination of Environmental Affairs (Ministério de Coordenação Ambiental, MICOA), currently known as the Ministry of Land and Environment (Ministério da Terra e Ambiente, MTA), as well as the University of Eduardo Mondlane (Universidade Eduardo Mondlane, UEM) and the Swedish International Development Cooperation Agency (Sida). Subsequent efforts have been undertaken for specific locations and associated with specific marine protected areas by non-governmental organisations (NGO) or individual studies (Pereira et al. 2014). In the current climate of regional threats to coral reefs associated with climate change and human exploitation a coordinated effort for conservation and management of the reefs of Mozambique is desirable.

This report aims to support the development of a National Strategy and Action Plan for coral reef conservation, which will involve multiple stakeholders to address the current needs in Mozambique. The first objective is to introduce and summarise the data WCS regional scientists gathered between 2008 and 2015 (before WCS Mozambique started a Marine Program) from coral reef surveys in Mozambique under regional or national projects led by other conservation partners to show the geographical coverage of the data and provide insight to the state of coral reefs in Mozambique. Data for sharks and rays collected by IIP and WCS since 2018 have also been included. The second objective is to highlight the conclusions from studies and publications that WCS regional scientists have produced under regional initiatives, to support coral reef conservation and management in Mozambique. However, the original references cited herein should be consulted for a detailed understanding of those studies and their conclusions.

PROCEDURE FOR THE **PREPARATION** OF THIS REPORT

Prior to WCS establishing a formal marine program in Mozambique in 2018, WCS scientists have collaborated with other stakeholders in Mozambique (e.g. WWF) to provide scientific advice and expertise for surveys of the marine environment. The WCS Global Marine Program benefits from a worldwide team of marine scientists and has contributed to ecological surveys and developed conservation guidelines for the Western Indian Ocean for several decades. The information in this report is based on a review of available information, and highlights conclusions from scientific "peer-reviewed" publications that WCS marine scientists have produced. The data presented in this report have been compiled using the MERMAID web application for coral reef data collection, which is a joint WCS and WWF global venture that aims to increasingly make field data from various sources reliable, available and standardised (www.datamermaid.org). We have identified the metrics available for data that provide comparable quantitative information regarding the state of key coral reef organisms. The results are shown with a focus on understanding the amount of data available that can provide baseline knowledge for coral reefs of Mozambique. We provide an overview of the geographic coverage of the data for each administrative coastal province in Mozambique where WCS scientists have conducted coral reef surveys (Table 1, Table 2, Figure 2 to Figure 9). A similar overview is presented for surveys of sharks and rays in reef waters and catch surveys of sharks and rays (Table 3). Key knowledge and data relevant to coral reefs in Mozambique for corals, macroalgae, coral reef fish, coral reef urchins, coral reef fisheries and coral reef sharks and rays is subsequently presented in individual sections of the report.

WCS KNOWLEDGE OF **CORAL REEFS** IN MOZAMBIQUE

Sites surveyed in Mozambique by WCS

WCS scientists have collaborated with local organisations and marine protected area (MPA) representatives to share expertise and participate in a variety of surveys in Mozambique since 2008. The habitats that WCS has surveyed (Figure 1 to Figure 9) are predominantly coral reef sites, characteristically associated with hard substrates, either calcium carbonate past reef structures or sandstone (e.g. Bazaruto Archipelago). These coral reef sites are both on windward and leeward sides of local reefs or islands and mainland landmasses. The depths of sites surveyed range from 1.5 m to 20 m, recorded as the low tide equivalent, and tidal range is generally of 3 m to 4 m (McClanahan and Muthiga 2016). WCS scientists have undertaken a greater number of surveys of benthic coral reef organisms and reef fish in the province of Cabo Delgado relative to the provinces of Nampula, Inhambane and Maputo, and have not surveyed coral reefs of other provinces in Mozambique (Table 1).

Data from WCS surveys are likely to be biased towards reporting higher fish biomass and diversity, as well as higher coral cover and diversity, because the coral reefs where data were collected are mostly in MPAs and proposed MPAs. Sampling efforts are thus non-random in distribution, and focus on areas with management, such as no-take areas and restricted fishing sites. Locations of restrictive management are unevenly distributed and cover a relatively low sea surface area in East Africa (Jones et al. 2018).

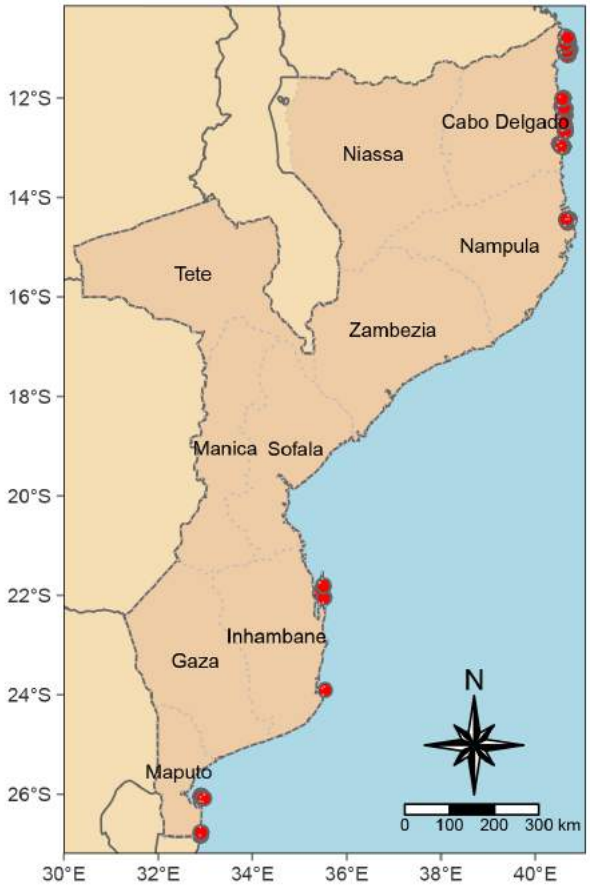


Figure 1. Locations marked in red of the 60 benthic quadrat survey sites and 70 fish belt transect survey sites used by WCS scientists in Mozambique from 2008 to 2015. Some of the sites were surveyed in multiple years. Geographic data for map reproduction was sourced from Natural Earth.

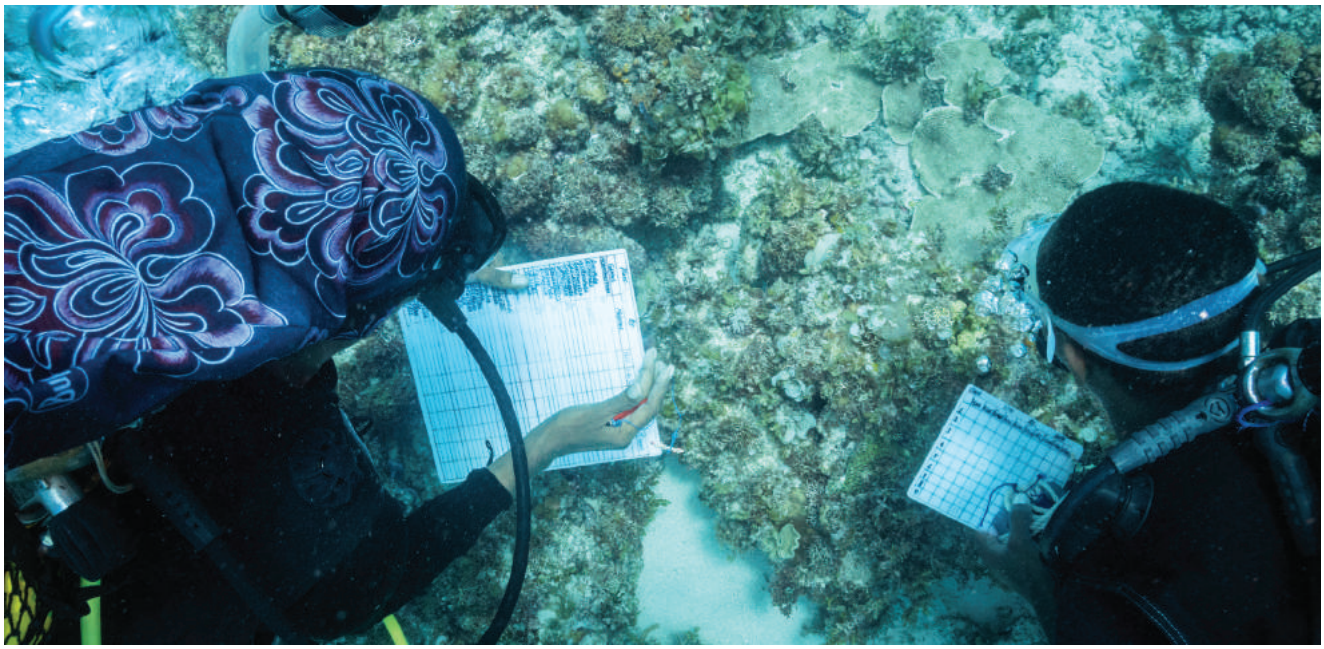
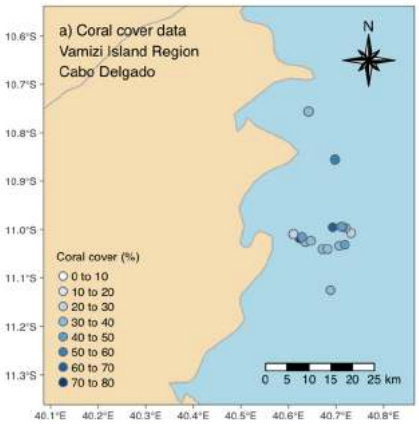
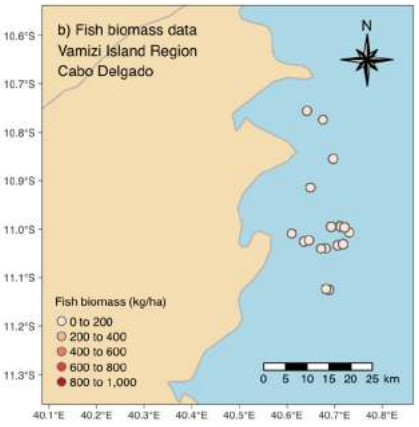


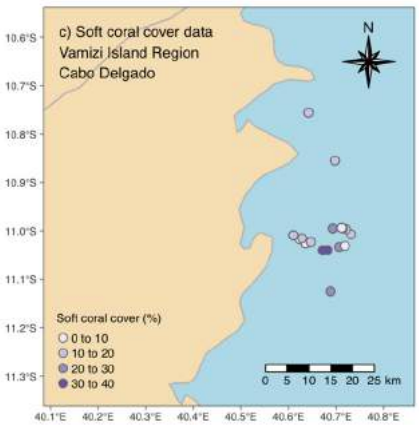
Table 1. Distribution of WCS survey efforts for reef fish and benthic organisms in Mozambique

Province	Number of surveys	Years	Data collected	Method used
Cabo Delgado	Benthic (50) Fish (63)	2008 2010* 2011 2012 2013 2014 2015**	Coral, macroalgae and soft coral cover (%) Coral diversity Coral bleaching Fish abundance (n/ha) Fish biomass (kg/ha) Fish size class (10 cm bins) Fish diversity Urchin abundance (n/ha)	Belt transect (fish) Benthic quadrat
Nampula	Benthic (5) Fish (5)	2014	Coral, macroalgae and soft coral cover (%) Coral diversity Coral bleaching Fish abundance (n/ha) Fish biomass (kg/ha) Fish size class (10 cm bins) Fish diversity Urchin abundance (n/ha), Fish catch per unit effort	Belt transect (fish) Benthic quadrat Fisher questionnaires
Zambézia	0	--	--	--
Sofala	0	--	--	--
Inhambane	Benthic (8) Fish (7)	2010 2013*	Coral, macroalgae and soft coral cover (%) Coral diversity Coral bleaching Fish abundance (n/ha) Fish biomass (kg/ha) Fish size class (10 cm bins) Fish diversity Urchin abundance (n/ha)	Belt transect (fish) Benthic quadrat
Gaza	0	--	--	--
Maputo	Benthic (1) Fish (6)	2009	Coral, macroalgae and soft coral cover (%) Coral diversity Coral bleaching Fish abundance (n/ha) Fish biomass (kg/ha) Fish size class (10 cm bins) Fish diversity Urchin abundance (n/ha)	Belt transect (fish) Benthic quadrat

Note: * Benthic data only, ** Reef fish data only







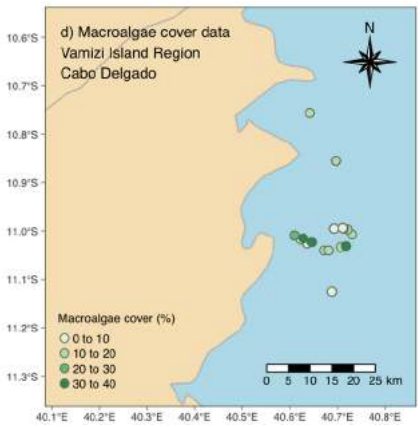
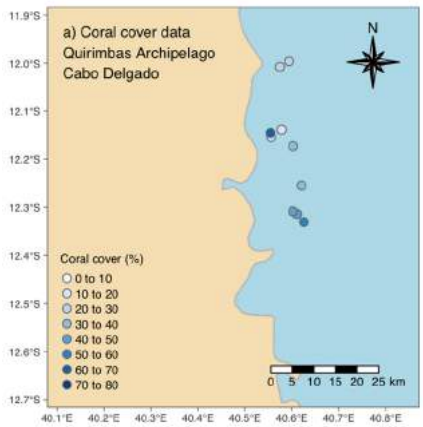
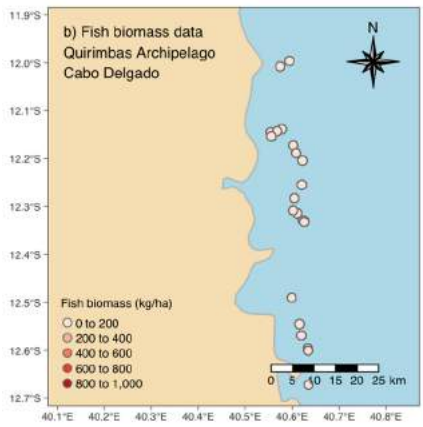
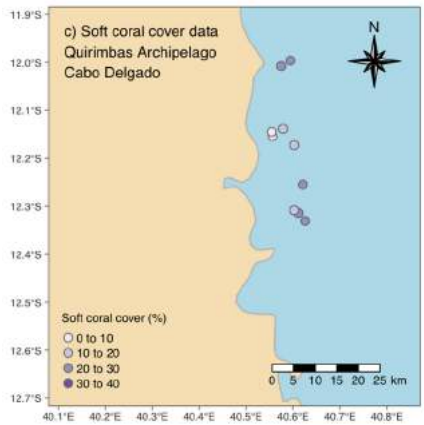


Figure 2. Sites in the region of Vamizi Island, province of Cabo Delgado, that have been surveyed by WCS scientists for a) coral cover, b) fish biomass, c) soft coral cover and d) macroalgae cover.







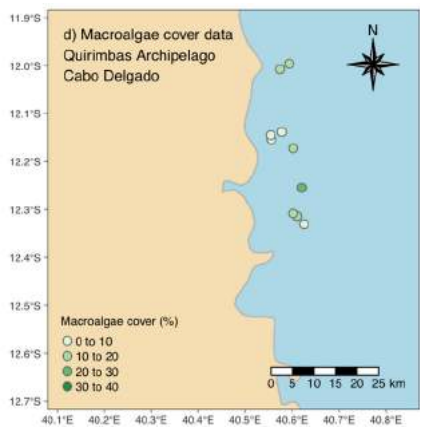
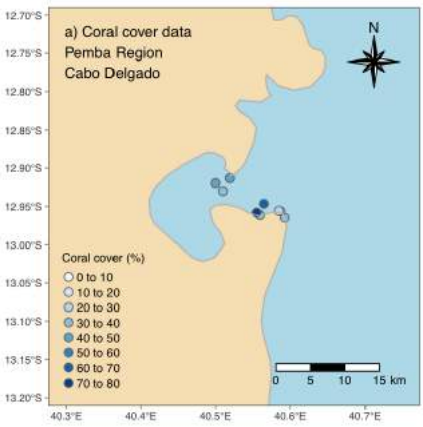
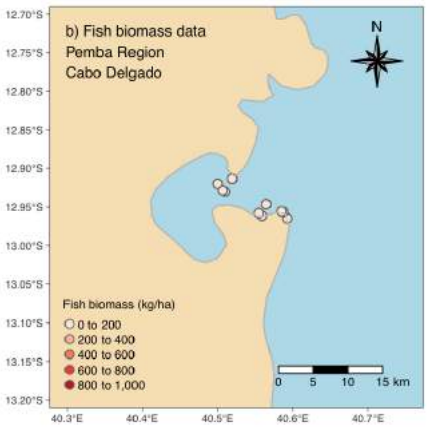
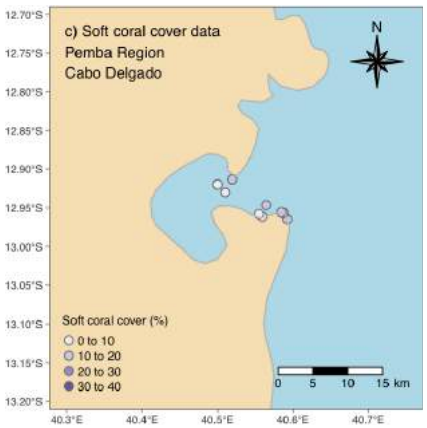


Figure 3. Sites in the Quirimbas Archipelago, province of Cabo Delgado, that have been surveyed by WCS scientists for a) coral cover, b) fish biomass, c) soft coral cover and d) macroalgae cover.







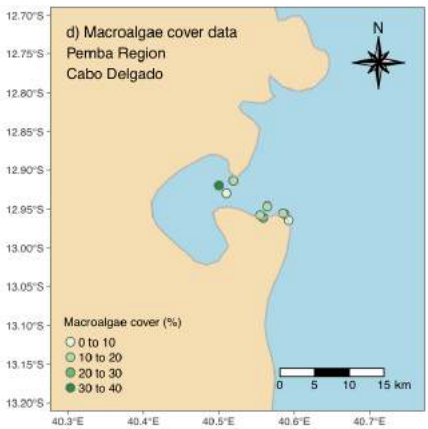


Figure 4. Sites in the region of Pemba, province of Cabo Delgado, that have been surveyed by WCS scientists for a) coral cover, b) fish biomass, c) soft coral cover and d) macroalgae cover.

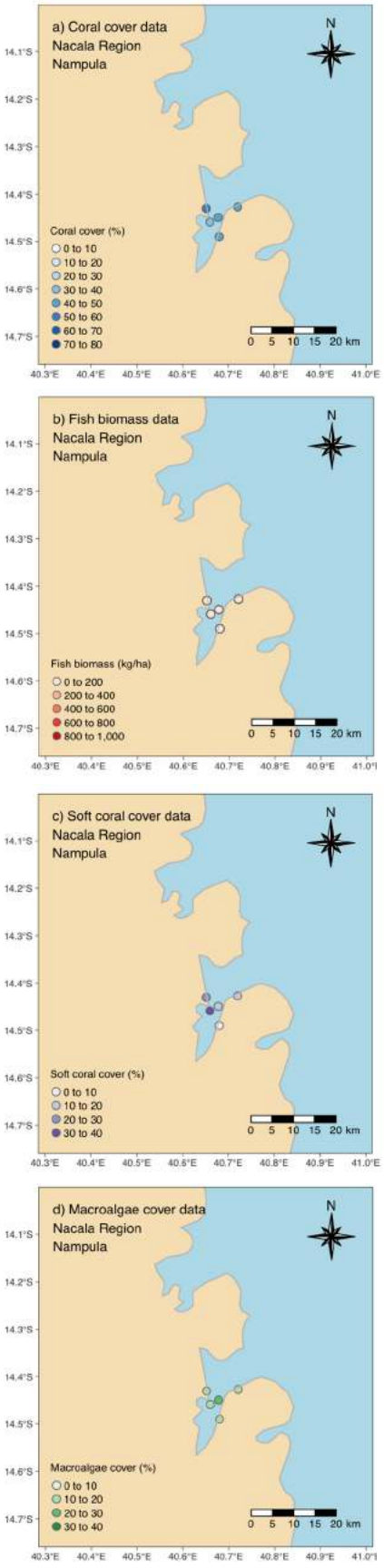


Figure 5. Sites in the region of Nacala, province of Nampula, that have been surveyed by WCS scientists for a) coral cover, b) fish biomass, c) soft coral cover and d) macroalgae cover.

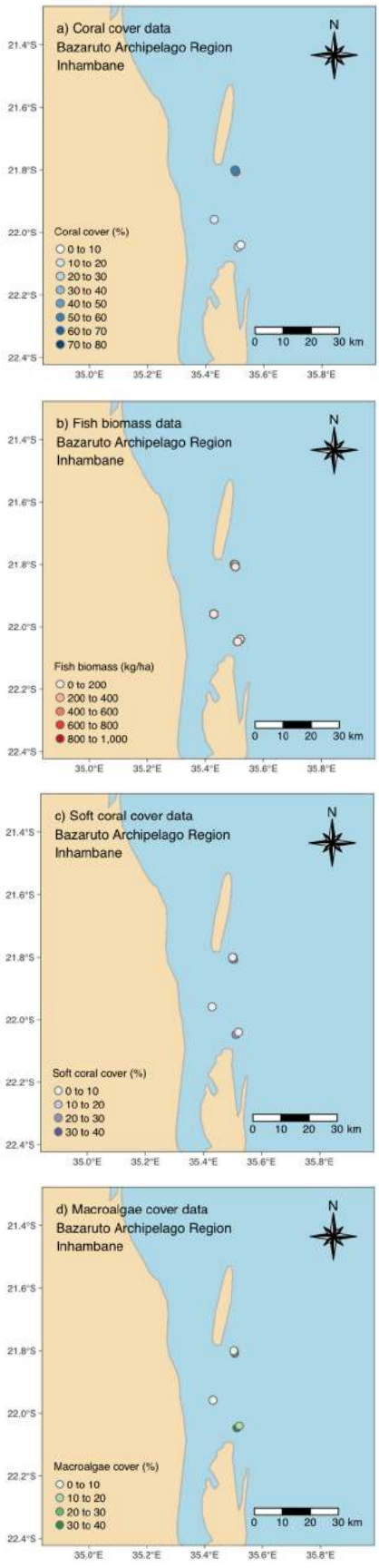


Figure 6. Sites in the region of Bazaruto Archipelago, province of Inhambane, that have been surveyed by WCS scientists for a) coral cover, b) fish biomass, c) soft coral cover and d) macroalgae cover.

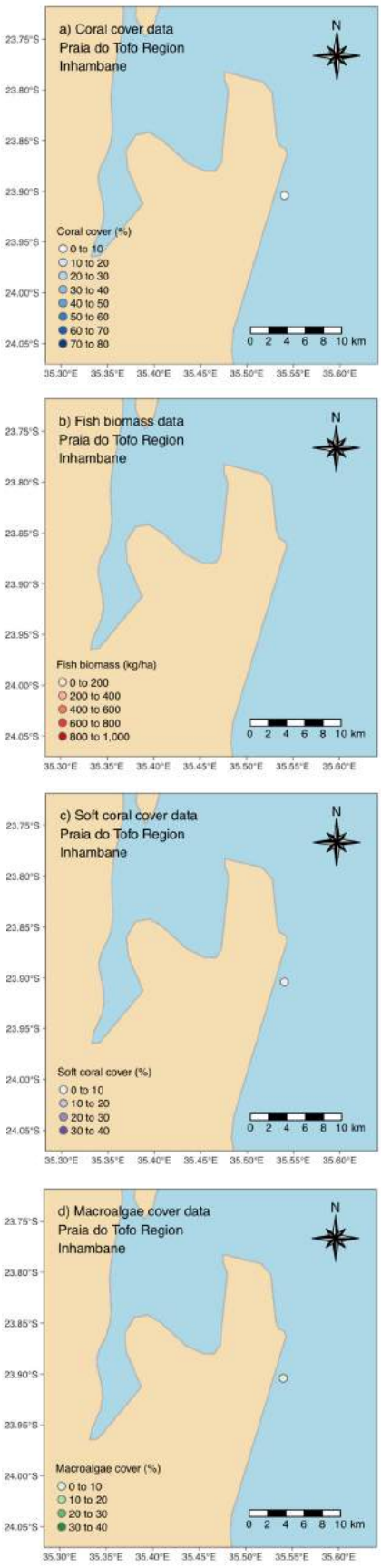
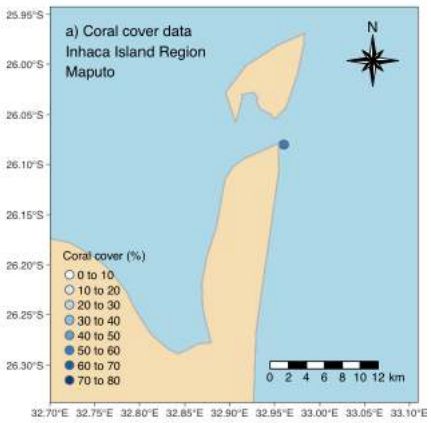
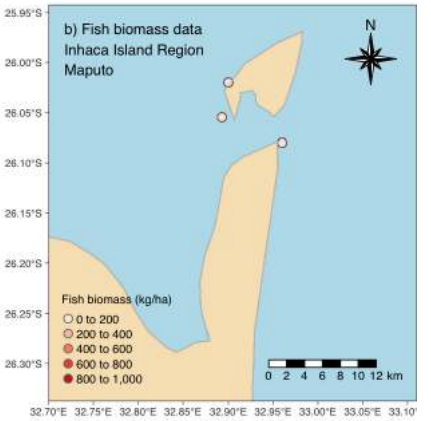
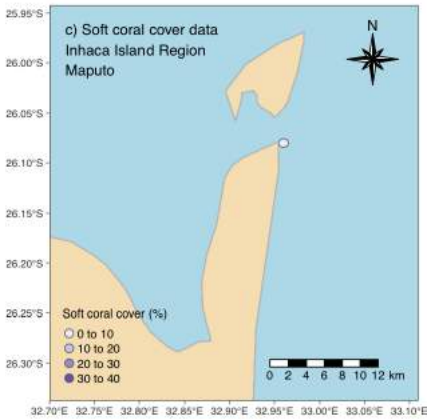


Figure 7. Sites in the region of Praia do Tofo, province of Inhambane, that have been surveyed by WCS scientists for a) coral cover, b) fish biomass (no surveys), c) soft coral cover and d) macroalgae cover.







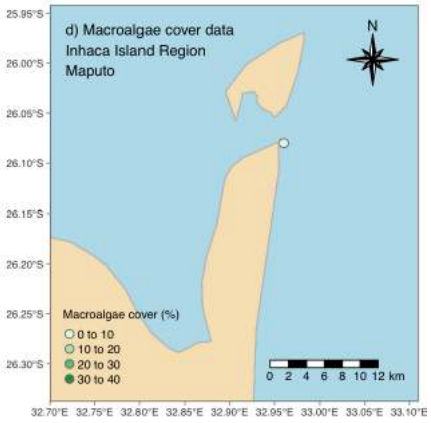
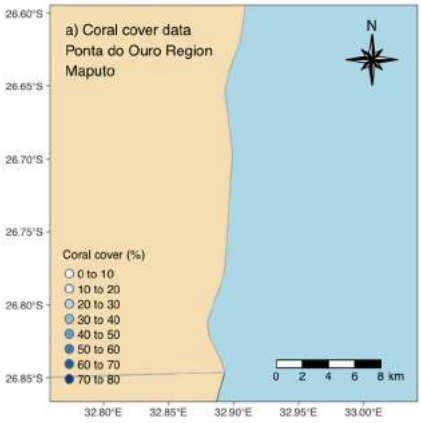
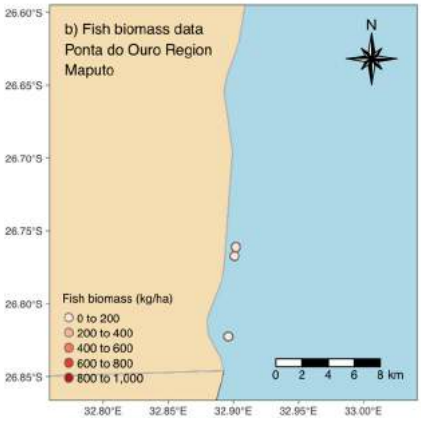
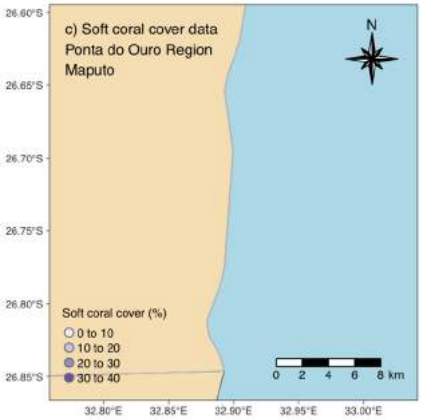


Figure 8. Sites in the region of Inhaca Island, province of Maputo, that have been surveyed by WCS scientists for a) coral cover, b) fish biomass, c) soft coral cover and d) macroalgae cover.







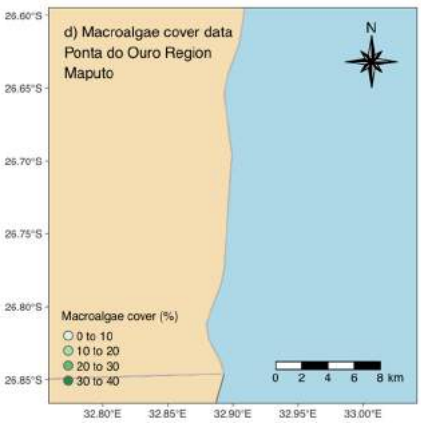


Figure 9. Sites in the region of Ponta do Ouro, province of Maputo, that have been surveyed by WCS scientists for a) coral cover (no surveys) b) fish biomass, c) soft coral (no surveys), and d) macroalgae (no surveys).

WCS KNOWLEDGE OF **CORALS** IN MOZAMBIQUE

A brief description of the survey method for corals and other benthic organisms

WCS scientists collected data for coral cover in Mozambique from visual surveys of 15 to 20 haphazardly placed quadrats of approximately 2 m^2 at each site. Coral surveys were usually undertaken at sites where fish were surveyed simultaneously in belt transects. In the quadrats all corals larger than 5 cm in diameter were counted and identified to the level of genera. The health of each coral was described based on the visible intensity of pigmentation and corals were allocated to one of seven categories (Normal, Pale, 0-20 % bleached, 20-50 % bleach, 50-80 % bleached, 80-100 % bleached, Dead). In each quadrat the overall percent cover of corals, as well as upright macroalgae (not turf algae), and soft corals, was described in increments of 5 %. A majority of the surveys were undertaken in reef slope environments. A small number of sites were surveyed more than once, and in total 64 surveys were undertaken at 60 sites (Figure 1, Table 1). WCS undertakes more detailed surveys of corals and other benthic organisms throughout the WIO region using point intercept transects and line intercept transects, however only a small number (7 surveys) have been undertaken in Mozambique and these data are omitted here.

The data available for corals

Surveys undertaken by WCS researchers have provided data for the site level percentage cover of corals, the number of coral genera per site, and the site level dominance or diversity of coral genera (modified Simpson's Index). The data can also allow for an assessment of the impacts of coral bleaching on a coral community from the relative proportion of corals with different levels of pigmentation and calculation of a coral community bleaching susceptibility index if undertaken during a bleaching event (see McClanahan 2007a).

Summary of results and key findings for corals

The average coral cover ranges from 4.5 % to 70.3 % in surveys. Human influences have not been significantly associated with variation in coral cover or coral diversity in northern Mozambique (McClanahan and Muthiga 2017) and it is unclear if there is an influence of management regimes on the patterns of coral cover in the data presented here (Figure 10). Coral cover tends to be higher in Northern Mozambique (Figure 11), and this agrees with reported regional patterns of coral biogeography (Obura 2012; Ateweberhan and McClanahan 2016; McClanahan and Muthiga 2017). Coral cover is generally higher in back reef environments compared to reef crests and reef slope environments within the no-take management regimes (McClanahan and Muthiga 2017). There are few reports of coral bleaching in WCS data for Mozambique, however this is most likely because the majority of surveys were undertaken outside of the months of February to April when coral bleaching is most likely to occur. Coral diversity is greater in northern Mozambique compared to southern Mozambique (Ateweberhan and McClanahan 2016) and provinces such as Nampula and Cabo Delgado in the north of Mozambique should be conservation priorities because reefs there are less prone to stress from temperature anomalies that drive coral bleaching events (McClanahan et al. 2015; McClanahan and Muthiga 2017).

A relatively high proportion of surveys, 73.4 %, recorded hard coral cover that WCS scientists consider desirable to maintain biodiversity and fisheries on coral reefs, however few reefs are likely to keep up with sea level rise predicted by 2100. The percentage cover of hard corals was below 10 % on three reefs or 4.7 % of the reefs surveyed, which is considered the threshold for reefs to accrete at a faster rate than the rate at which they erode (Perry et al. 2013) (Figure 11, Figure 12). An additional 14 surveys, or 21.9 % of the surveys, had hard coral cover below 30 %, which is the conservation threshold that WCS scientists consider desirable to sustain biodiversity and fisheries on coral reefs (Wildlife Conservation Society 2020). A total of 49 reefs, 76.6 % of those surveyed, had hard coral cover below 50 % which is considered necessary to keep up with sea level rise associated with Representative Concentration Pathway (RCP) of RCP4.5 (Perry et al. 2018, IPCC 2013). Only 3 surveys or 4.7 % of the surveys had hard coral cover of 70 % or more, which is considered necessary to keep up with average sea level rises of 0.5 m predicted for the Western Indian Ocean by 2100 under RCP8.5 (IPCC 2013, Perry et al. 2018).

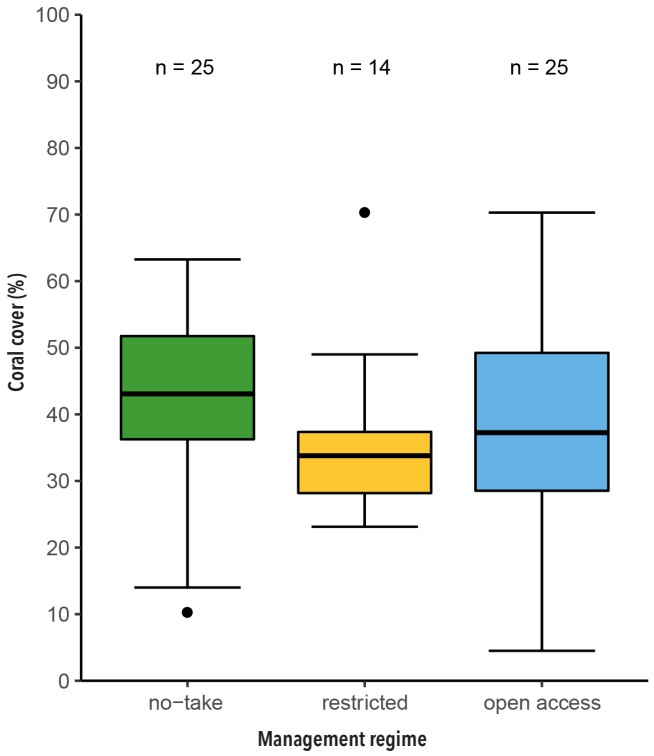


Figure 10 (left). Boxplot of coral cover in Mozambique separated by reef management regime. Management regimes of sites are no-take, restricted (restrictions on fishing gear use) and open access. The number of surveys for each management regime is indicated by "n". Individual points represent potential outliers.

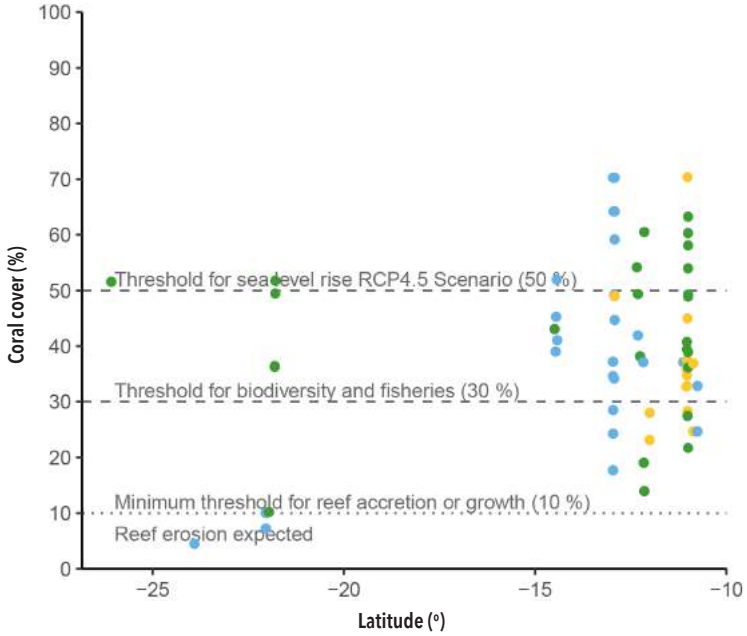


Figure 11 (below). The average coral cover from reef surveys in Mozambique. Management regimes of sites are no-take, restricted (restrictions on fishing gear use) and open access. The latitude of the most southern site is 26.08° S and the most northern site is 10.756° S. Thresholds of 10 % coral cover are the minimum suggested for coral reefs to persist (Perry et al. 2013), of 30 % coral cover are suggested as necessary to maintain coral reef biodiversity and sustainable reef fisheries, and of 50 % coral for reefs to persist under the predicted sea level rise by 2100 associated with representative concentration pathway RCP4.5 (IPCC, 2013, Perry et al. 2018).

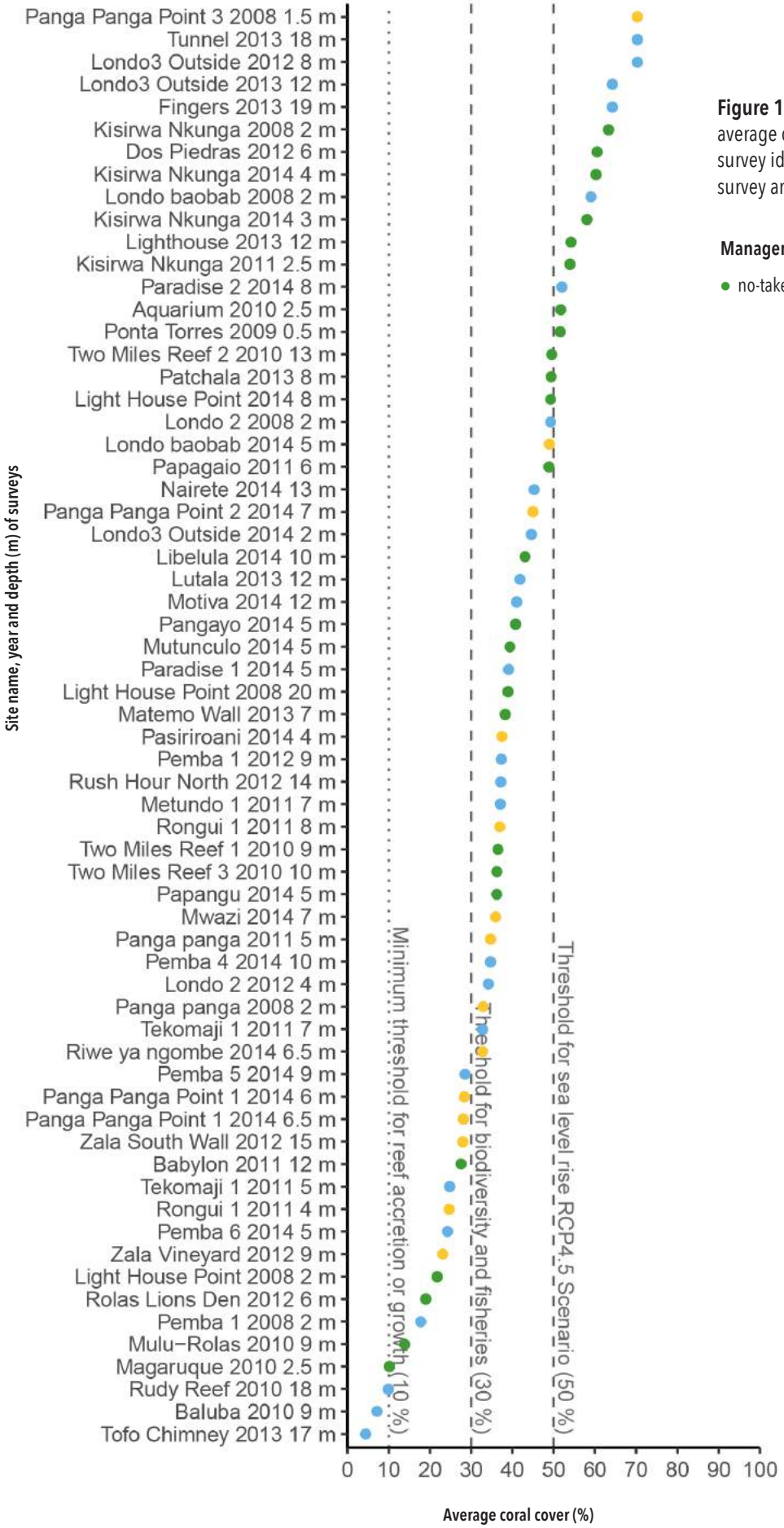


Figure 12. Cumulative frequency plot of the average coral cover recorded during each survey identified by the site name, year of survey and depth surveyed at the site.

WCS KNOWLEDGE OF **SOFT CORALS** IN MOZAMBIQUE

A brief description of the soft coral survey method

Similar to the coral surveys above the percentage cover of soft corals is visually estimated in increments of 5 %. Surveys were undertaken haphazardly with observations in quadrats of approximately 2 m^2.

The data available for soft corals

Surveys collected data for the percentage cover of soft corals. Soft corals were not identified to taxa.

Summary of results and key findings for soft corals

The average cover of soft corals ranged from 0 to 38.2 % at the sites surveyed. Soft coral cover was similar across all management regimes (Figure 15). It is unclear if there is a pattern in soft coral cover driven by latitude from the current level of replication in the data (Figure 14).

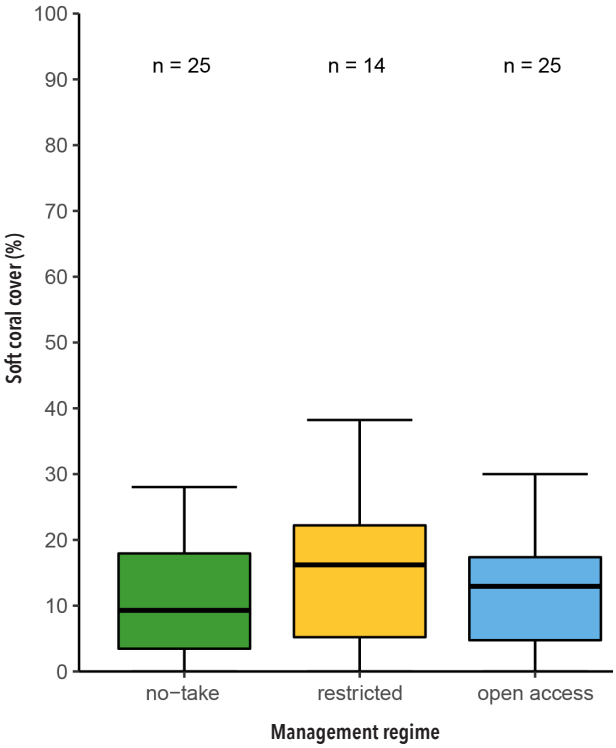


Figure 13. Boxplot of soft coral cover recorded in surveys in Mozambique. Surveys are grouped by site management regime. Management regimes of sites are no-take, restricted (restrictions on fishing gear use) and open access. The number of surveys for each management regime is indicated by "n".

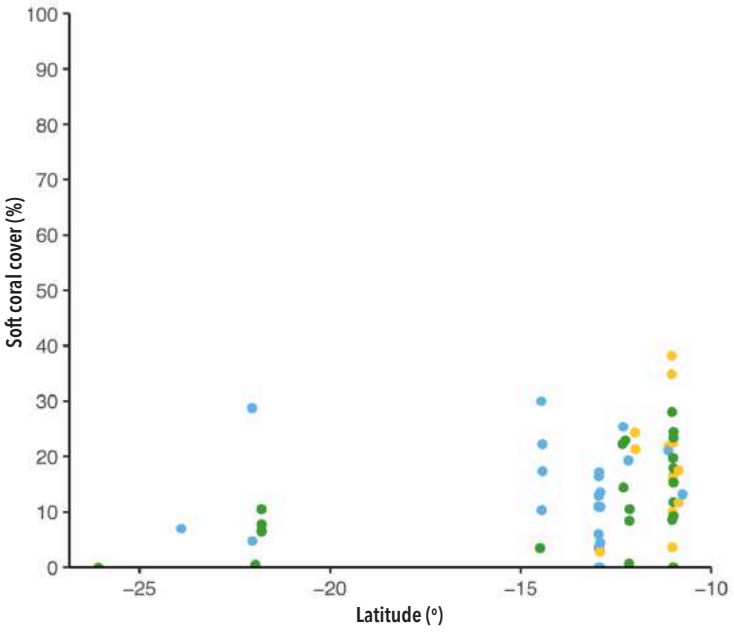


Figure 14. The average soft coral cover recorded in surveys in Mozambique. Management regimes of the sites surveyed are no-take, restricted (restrictions on fishing gear use) and open access. The latitude of most southern site is 26.08° S, and the most northern site is 10.756° S.

Management

● no-take ● restricted ● open access

WCS KNOWLEDGE OF **MACROALGAE** IN MOZAMBIQUE

A brief description of the macroalgae survey method

Similar to the coral and soft coral surveys described above the percentage cover of upright macroalgae was visually estimated in increments of 5 % from haphazardly placed quadrats of approximately 2 m^2.

The data available for macroalgae

Surveys conducted by WCS scientists collected data for the percentage cover of macroalgae. Macroalgae were not identified to taxa and did not include turf algae.

Summary of results and key findings for macroalgae

The average cover of macroalgae ranges from 0 to 39.1 % in the surveys. Macroalgae cover is lowest under no-take management regimes (Figure 15). It is unclear if there is a pattern in macroalgae cover driven by latitude from the current level of replication in the data (Figure 16). The average cover of macroalgae is 15 %, and is higher than the Western Indian Ocean average of 5 % (McClanahan and Muthiga 2017).

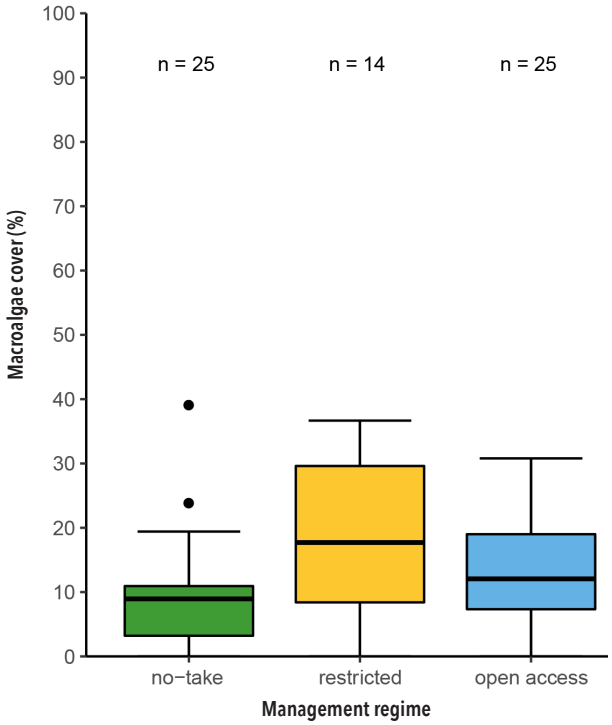


Figure 15. Boxplot of macroalgae cover in Mozambique grouped by management regime. Management regimes of sites are no-take, restricted (restrictions on fishing gear use) and open access. The number of surveys for each management regime is indicated by "n". Individual points represent potential outliers.

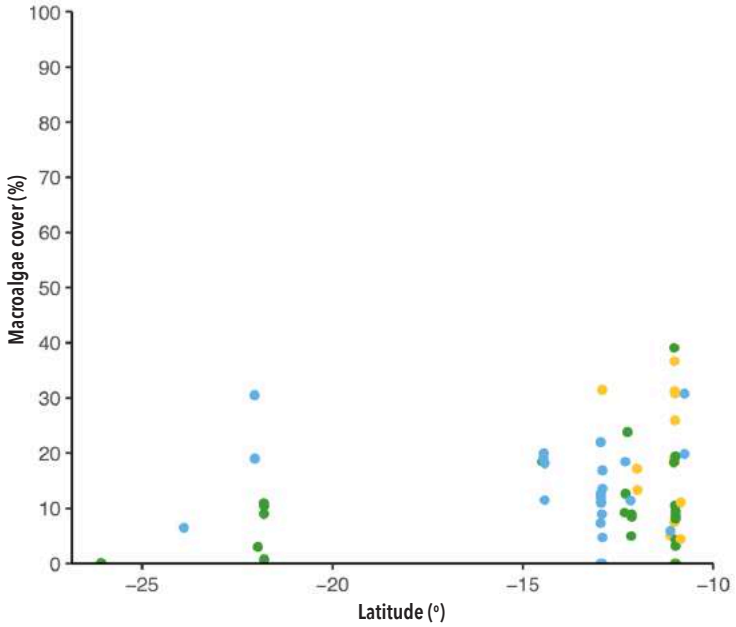


Figure 16. The average cover of macroalgae recorded in surveys in Mozambique. Management regimes of sites are no-take, restricted (restrictions on fishing gear use) and open access. The latitude of most southern site is 26.08° S and the most northern site is 10.756° S.

Management

● no-take ● restricted ● open access

WCS KNOWLEDGE OF **CORAL REEF FISH** IN MOZAMBIQUE

A brief description of the reef fish survey method

WCS scientists surveyed coral reef fish in belt transects of 5m ×100 m (500 m^2 or 0.05 ha). An experienced observer identified the fish of the following 23 families: Acanthuridae*, Aulostomidae, Balistidae*, Caesionidae, Carangidae, Chaetodontidae*, Diodontidae*, Fistularidae, Haemulidae, Holocentridae, Labridae*, Lethrinidae, Lutjanidae, Muraenidae, Mullidae, Pempheridae, Pinguipedidae, Pomacanthidae*, Pomacentridae*, Scaridae*, Serranidae, Scorpaenidae, Siganidae, and Sphyraenidae. All remaining fish were grouped as "other". A smaller group of pre-selected families (identified with *) were counted and identified to species level. Only fish larger than 3 cm in length were counted and fish size was visually estimated in size class intervals of 10 cm (McClanahan and Muthiga 2017).

The data available for reef fish

WCS scientists collected data for the abundance (n = number of fish), density (n/ha), diversity of fish families (and at species level for certain families), and fish size classes. These data allow for the calculation of biomass per hectare and demographic interpretations such as the relative proportion of reproductive fish. Fish biomass was calculated in the Mermaid application (www.datamermaid.org) using length weight relationships and coefficients a, b and c reported in the scientific literature and compiled in FishBase (Froese and Pauly 2020). In total 81 surveys were undertaken at 70 sites (Figure 1, Table 1).

Summary of results and key findings for reef fish

Benchmarks for fish biomass at reef sites of the East African coast, including Mozambique, are proposed as 1150 kg/ha for desirable conservation outcomes, 600 kg/ha to maintain diversity in fish communities, and 450 kg/ha to allow for artisanal fishing to be sustainable (McClanahan 2019). Higher fish biomass on reefs in Mozambique was associated with no-take areas and fishing restrictions (Figure 17, McClanahan and Muthiga 2017). Whilst, larger fish size and twice the total fish biomass on many reefs were associated with fishing gear restrictions (McClanahan and Muthiga 2017). The total fish biomass ranged from 107.1 to 3038.5 kg/ha in the surveys reported here (Figure 17). Of the total 81 surveys, 13 or 16.1 % met the desired conservation benchmark of total fish biomass above 1150 kg/ha, and of these 12 received no-take management and one was managed with restrictions on fishing gear (Figure 18). Another 13 surveys, 16.1 %, exceeded the 600 kg/ha benchmark below which loss of fish diversity is expected, and of these 10 surveys were on reefs under no-take management and 3 surveys were on reefs with restricted management.

Fish biomass was below the benchmark for minimum sustainable yields at all of the 18 surveys in open access sites reported here (Figure 18, Figure 19). Fish biomasses for a further 12 surveys in no-take sites and 11 surveys in restricted fishing sites were also below the benchmark for minimum sustainable yields. Altogether 41 surveys, or 50.6 % of surveys, were below the 450 kg/ha benchmark for minimum sustainable yields. Of the remaining 14 surveys, 17.2 % of those reported, fish biomass was between the 450 kg/ha benchmark for minimum sustainable yields and the 600 kg/ha benchmark, below which a loss of fish diversity is expected. Half of these (7 surveys) were at sites with no-take management and half (7 surveys) were at sites under restricted management (Figure 18, Figure 19).

The fish biomasses for surveys reported here are relatively high for the perceived state of reefs in Mozambique. Predications for Mozambique are that 0.23 % of reefs have the desired conservation biomass of 1150 kg/ha, and that biomass exceeds the 450k g/ha benchmark for minimum sustainable yields on only 2.19 % of reefs (McClanahan et al. 2016). In contrast predictions for the WIO Region are that 38.59 % of reefs have a desired conservation biomass of 1150 kg/ha and that 58 % of reefs have biomass that exceeds the 450 kg/ha benchmark for minimum sustainable yields (Table 2).

Table 2. The percentage of reefs within each fish biomass range from surveys detailed in this report compared to predicted values for Mozambique and predicted values for the WIO Region (McClanahan et al. 2016).

Country	Fish biomass (kg/ha) <300	300–450	450–600	600–1150	>1150
Mozambique (81 reported surveys)	28.38 %	22.22 %	17.2 %	16.1 %	16.1 %
Mozambique (predicted)	80.73 %	17.07 %	0.18 %	1.78 %	0.23 %
WIO Region (predicted)	27.22 %	14.77 %	6.13 %	13.28 %	38.59 %

The data summarised here also provide an indication that the biomass of reef fish communities is more variable in higher latitude reef environments (Figure 18). Four fish families dominate the biomass and determine community composition, two of which are herbivores (Acanthuridae and Scaridae) and two piscivores (Labridae and Lutjanidae) (McClanahan 2019). The biomass of these families, together with the families Haemulidae, Holocentriade, Serranidae, and Balistidae are among the most impacted by human activities. Although the biomass of the Labridae is less impacted by human activity. Fish biomass is also lower in sheltered areas presumably because these are more accessible to fishers than exposed sites (McClanahan 2019).

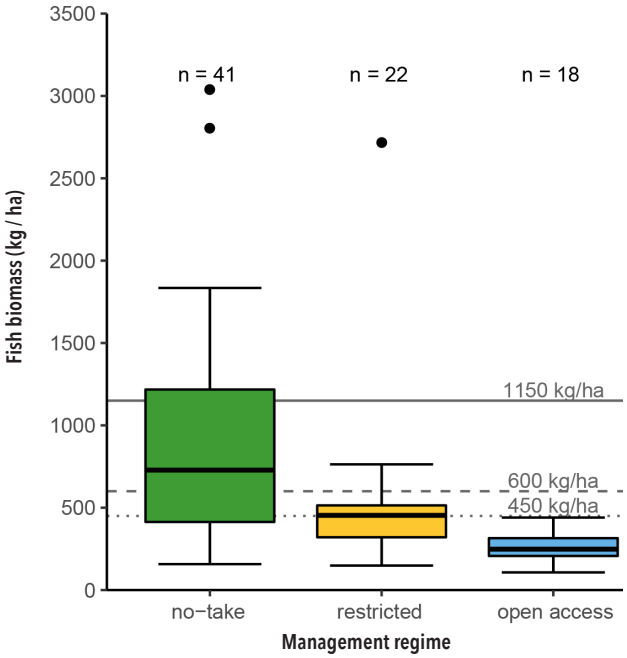


Figure 17 (above). Boxplot of fish biomass in Mozambique separated for management regime. The number of surveys for each management regime is indicated by "n". Biomass thresholds are indicated by a solid line for the conservation benchmark of 1150 kg/ha, fish diversity benchmark of 600 kg/ha and minimum sustainable yield biomass of 450 kg/ha. Individual points represent potential outliers.

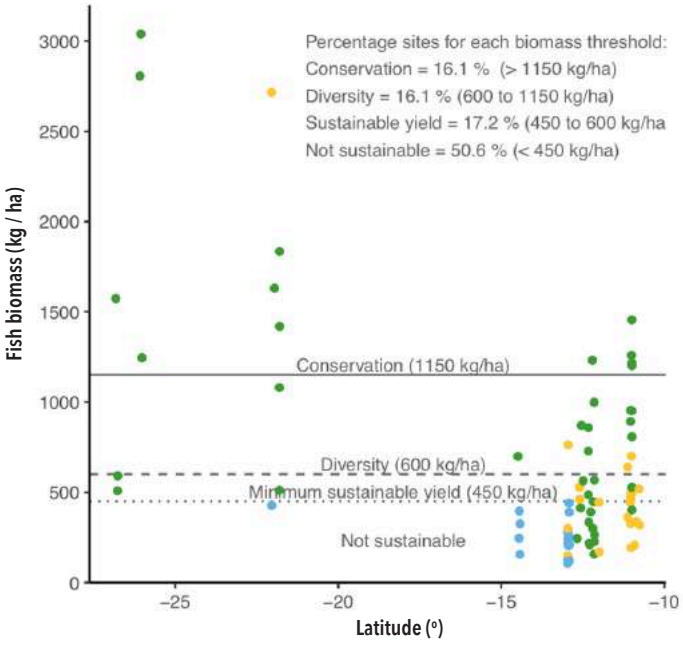


Figure 18 (left). The total fish biomass recorded in surveys in Mozambique. The latitude of most southern site is 26.823° S and the most northern site is 10.756° S. Fishing is unsustainable at 50.6 % of sites because the total fish biomass was below the minimum sustainable yield threshold of 450 kg/ha.

Management

● no-take ● restricted ● open access

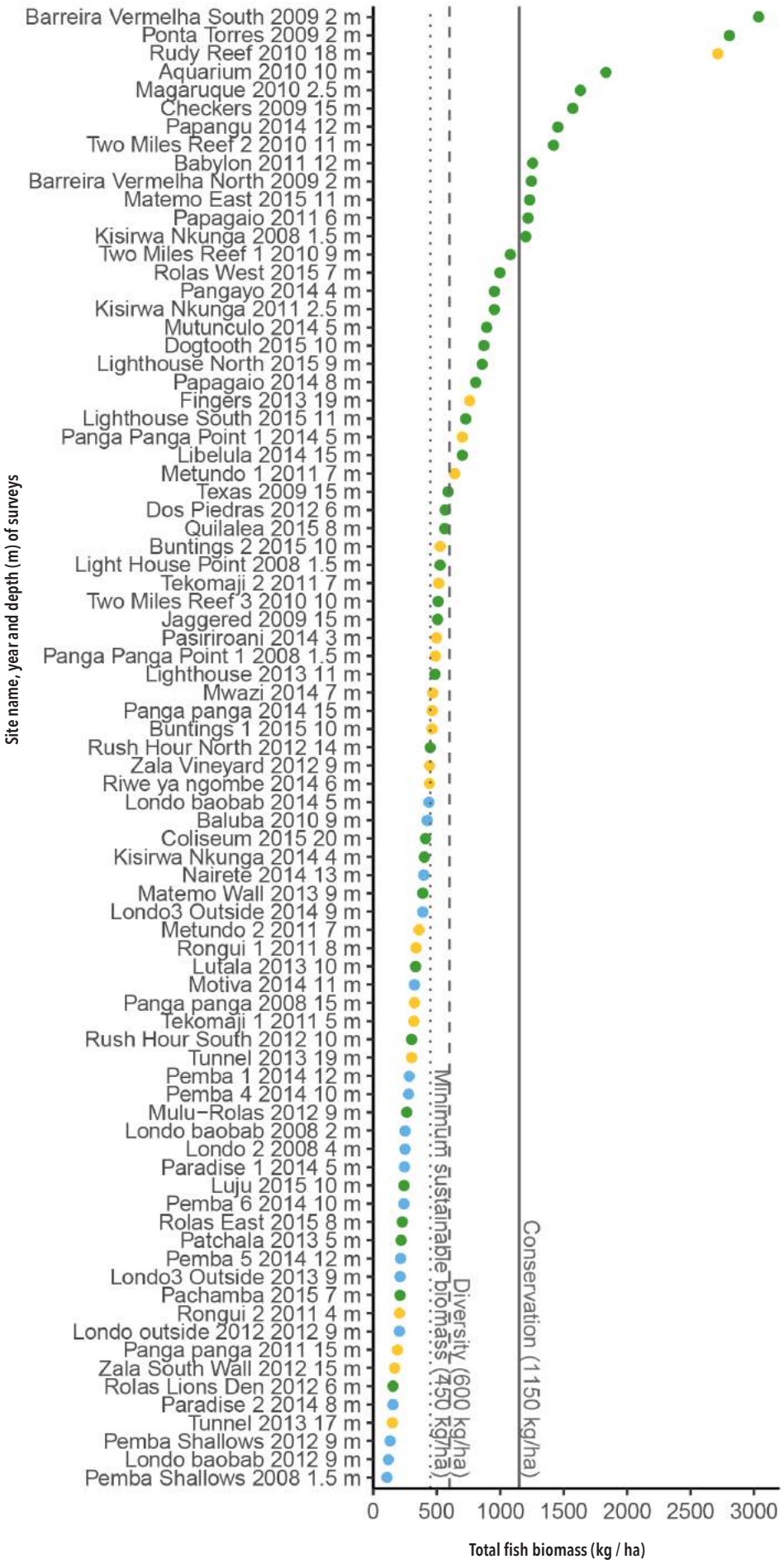


Figure 19. Cumulative frequency plot of total fish biomass recorded in each survey identified by the site name, year and depth of the survey.

Management

● no-take ● restricted ● open access

WCS KNOWLEDGE OF **SEA URCHINS** IN MOZAMBIQUE

A brief description of the sea urchin survey method

WCS scientists surveyed the abundance and the diversity of sea urchins at many of the sites where coral reef fish and corals were surveyed since 2008 as described above. Sea urchins were surveyed in haphazardly distributed circular patches with an area of 10 m^2. The circular patches were defined by haphazard placement of a weighted marked rope, the length of which equals the radius of circle with a 10 m^2 area (r = 1.784 m). Individual sea urchins were counted and identified to species.

WCS data available for sea urchins

Surveys of sea urchins conducted by WCS scientists allow for the estimation of species-specific abundance and density. The biomass of sea urchins was also calculated by multiplying species-specific density by previously estimated mean body weights for each species (McClanahan 1998).

Summary of results and key findings for sea urchins

Sea urchin density on reefs in Mozambique is below the regional average values (McClanahan and Muthiga 2017). The average density of sea urchins in Mozambique is 1600 kg/ha whilst the average densities on reefs in the Western Indian Ocean are generally above 2300 kg/ha.

WHAT IS KNOWN OF **MANAGEMENT REGIMES** AND **ENVIRONMENTAL PARAMETERS**?

A brief description of the socio-economic survey method

WCS researchers have used questionnaires and community member interviews to gather socio-economic data, and have also compiled environmental data for complementary factors that included management regime, depth, habitat type, habitat complexity, distance from shore and nearest market, surrounding population density, and environmental variables from satellite data such as sea surface temperature. For details of how socio-economic metrics were collected and interpreted please refer to Hicks and McClanahan (2012), and McClanahan, Cinner, and Abunge (2013). Descriptions of how environmental metrics have been gathered can be found in McClanahan and Muthiga (2017). This knowledge, combined with knowledge from coral reefs in other countries, and the data collected in Mozambique allows for the interpretation of how these factors impact the state of corals, macroalgae, reef fish, sharks and rays amongst other organisms.

Summary of results and key findings

No-take areas and fishing restrictions are associated with higher fish biomass on reefs in Mozambique (Figure 6, McClanahan and Muthiga 2017). In particular, fishing gear restrictions are associated with larger fish size and double the total fish biomass on many reefs (McClanahan and Muthiga 2017).

The biomass of reef fish in Mozambique is largely driven by 4 dominant families, 2 herbivore groups (Acanthuridae and Scaridae) and 2 carnivores (Labridae and Lutjanidae), that were distinguished by their biomass and depth associations (McClanahan and Muthiga 2017). It is highly recommended to maintain total fish biomass above 600 kg/ha to maintain fish diversity on coral reefs in Mozambique (McClanahan 2019). It is also important to note that it is unlikely that any of the coral reefs of Mozambique represent environments that have not been historically impacted by fishing and land use. Many reefs in Mozambique continue to be fished, even though total fish biomass is below the recommended levels for fishing to be sustainable (McClanahan, Cinner, and Abunge 2013; McClanahan and Muthiga 2017). High fishing pressure has particularly impacted the dominant families, such as Scaridae and Lutjanidae, and subdominant families, such as the Haemulidae, Holocentridae, Serranidae, and Balistidae (McClanahan 2019).

A meta-analysis of how environmental parameters, such as depth and exposure, impact the biomass of reef fish found that fish biomass was higher in shallow areas (shallower than 50 m within 10 km of human settlements), and also found that fish biomass was lower in sheltered reef sites compared to exposed reef sites (McClanahan 2019). These differences most likely resulted in part from the challenges to access more exposed fishing grounds caused by seasonal exposure to waves and currents during the winter southeast monsoons (McClanahan 2019).

WHAT IS KNOWN OF CORAL REEF **FISHERIES**?

WCS socio-economic surveys have evaluated stakeholder preferences for management and institutional design elements for community fishing councils or "Conselhos Comunitários de Pesca" (CCP) of Pemba in the province of Nampula. Interviews were conducted with fishers, community leaders and government fisheries officers. Questionnaires gathered information on: (1) perceptions of fishing restrictions, (2) socio-economic conditions, and (3) the institutional design and rules of the CCP (McClanahan, Cinner, and Abunge 2013).

Key findings

Most fishers were permanent residents of their village and have less than 4 years of school education. Fisher households range from 9 to 12 people and the fortnightly expenses of fishers were on average USD$100 (McClanahan, Cinner, and Abunge 2013). Fishers generally did not favour restrictions on fishing effort, however perceptions across fishers supported a range of fisheries regulations, particularly gear and minimum size restrictions. Fishers suggested the minimum catch size for fish should be approximately 20cm, and suggested on average that the size of no-take areas should be 8.4 km^2 (SD ± 2.0) (McClanahan, Cinner, and Abunge 2013).

Fishers associated with community or conservation groups are more supportive, with positive views of no-take areas and other restrictions on fishing gear or activity. A number of the key design principles for sustainable fisheries management are already implemented by such fishers or groups (McClanahan, Cinner, and Abunge 2013). Graduated fishing sanctions are a recommended addition to current practices. WCS also suggests there is a need for strengthening groups, forums, leadership training in finance, and means to implement transparency and graduated sanctions (McClanahan, Cinner, and Abunge 2013).

WHAT IS KNOWN OF CORAL REEF **SHARKS AND RAYS**?

The WCS Mozambique Marine Program has started its shark and ray conservation activities by undertaking landing site surveys, with a focus on coastal (artisanal) fisheries to assess shark and ray fisheries in Mozambique. Surveys were started in November 2018 and repeated weekly until February 2020, and have been interrupted in precautionary response to the Covid-19 pandemic. The surveys are undertaken in landing site locations in each of the 5 provinces of Cabo Delgado, Nampula, Zambézia, Inhambane and Maputo (Figure 20). In Cabo Delgado, sampling was done in Pemba (Nanhimbe and Paquitequete) and Mecúfi Beach in a total of 3 landing sites. In Nampula sampling was done in the districts of Angoche (including the local market), Larde and Moma, totaling 3 landing sites. In the province of Zambézia sampling was done in the landing sites of Pebane and Zalala, totaling 2 landing sites (Praia de Zalala and Malawa). In the southern region of the country, in Inhambane province the sampling was done in 4 landing sites located in Tofo Beach, Coconuts Bay and Inhambane Bay. In Maputo, sampling was done in 2 sites, in the Bairro dos Pescadores and their respective market, and in Macaneta Beach. Interviews are administered by local partners in particular the Institute for Fisheries Research (IIP) in Zambézia and Inhambane, UniLúrio in Pemba and Mecúfi, World Wide Fund for Nature - Mozambique Country Office (WWF-MCO) in Nampula and Zambézia and WCS Mozambique in Maputo. Information is collected on fishing effort (fishing gear used, fishing locations, and temporal data such as time spent fishing and seasonal effort), and on catches (shark and ray numbers, lengths, weights and species identification).

These surveys have focused on describing the:

i) Species captured and instances when species caught are listed on Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) or Convention on the Conservation of Migratory Species of Wild Animals (CMS) appendices, or as threatened under the International Union for the conservation of Nature (IUCN) Red List,
ii) Importance of fishing locations for sharks and rays,
iii) Population demographics of species captured to identify potential mating, pupping, nursery or aggregation sites, and,
iv) Seasonality trends of shark and ray presence and catches.

Marine Protected Areas of Mozambique

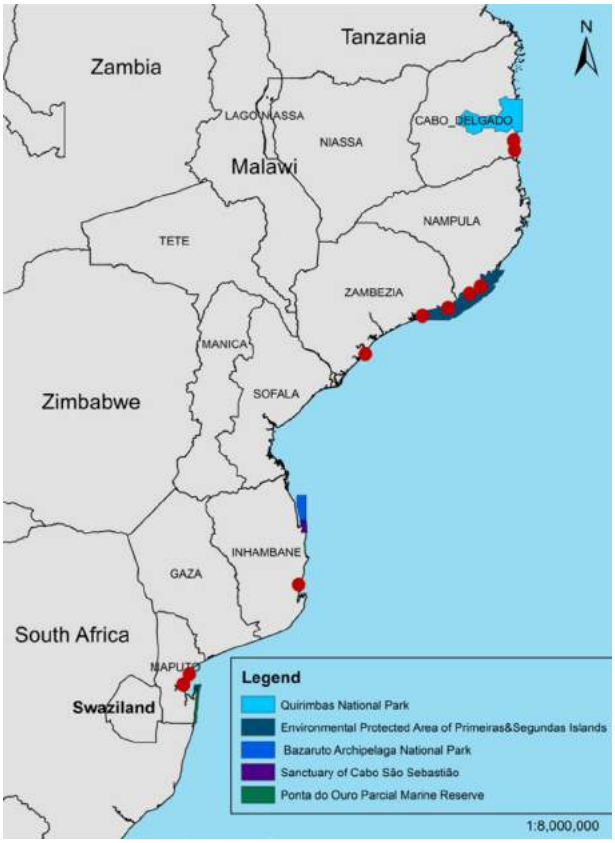


Figure 20. Locations of landing sites where WCS Mozambique and partners have surveyed catches of sharks and rays between 2018 and 2020 to learn of the species caught and of the sizes of the individuals caught.

WCS Mozambique has also partnered with IIP to survey sharks and rays with stereo baited remote underwater video (BRUVS) surveys as part of a regional assessment that includes South Africa, Tanzania, Kenya and Madagascar. These surveys have been undertaken in the province of Cabo Delgado between the Lúrio river mouth and Matemo island in Quirimbas National Park, in the province of Inhambane, between Guinjata Bay and Praia da Barra, and in the province of Maputo, between Ponta do Ouro and Inhaca island, in the Ponta do Ouro Partial Marine Reserve.

WCS data available for sharks and rays

The landing site surveys conducted by WCS, IIP and conservation partners provide insight to the fishing pressure on sharks and rays, and basic estimates of the catch biomass and sizes of individuals caught. IIP and WCS shark and ray BRUVS surveys provide information on the diversity, numbers of individuals, and their relative abundance in geographic areas surveyed. Data for the size of live sharks and rays is calculated from stereo imagery providing size class structures and demography data such as numbers of juveniles and reproductive adults in each study region. WCS deployed BRUVS using globally standardised methods to sample reef areas for 1 hour, using 1kg of bait, and with samples separated by at least 300 m to avoid pseudoreplication (https://globalfinprint.org/about/_assets/global-finprint-basic-bruvs-protocol.pdf).

Summary of results and key findings

The BRUVS surveys have recorded a total of 120 sharks and rays from 364 videos of 1-hour duration. Three species of rays and no sharks were observed in Cabo Delgado province, 7 species of sharks and 9 species of rays were observed in Inhambane province and 8 species of sharks and 7 species of rays were observed in Maputo province.

The data from surveys at fisheries landing sites in 5 provinces of Mozambique collected from November 2018 to February 2020 have revealed catches of at least 11 species of sharks and 16 species of rays. Nampula produced the greatest number of species, with 8 species of sharks and 14 species of rays, followed by Zambézia with 7 species of sharks and 7 species of rays, and Maputo Province with 6 species of sharks and 7 species of rays. Of the 11 shark species recorded in the catches, three species, *Sphyrna lewini, Stegostoma tigrinum*, and *Hemipristis elongata* are considered to be threatened with extinction (Table 3). Whilst eleven rays, *Rhynchobatus australiae, Rhynchobatus djiddensis, Rhina ancylostomus, Acroteriobatus leucospilus, Aetobatus ocellatus, Himantura uarnak, Himantura leoparda, Mobula kuhlii, Pateobatis jenkinsii, Pateobatis fai* and *Taeniurops meyeni* are considered to be threatened with extinction (Table 3).

Catches of sharks are relatively high in the provinces of Zambézia and Maputo and juveniles contribute considerably to catches in all provinces for which there are data (Table 4). In Zambézia, 94 % of the sharks caught were juveniles. More rays were recorded in catches in Nampula, where 14 species are reported. The proportion of juvenile rays in catches is also considerable ranging from 12 to 100 % depending on the province.

Table 3. Sharks and rays (by number) recorded in landing site and BRUVS surveys from 2018 to 2020. The provinces where each landing site or BRUVS survey took place are denoted by CD (Cabo Delgado), N (Nampula), Z (Zambezia), I (Inhambane) and M (Maputo). The International Union for the Conservation of Nature (IUCN) Red List Categories define the extinction risk of species assessed (see note below table). Arabic numerals indicate the relevant appendices of Convention on the Conservation of Migratory Species of Wild Animals (CMS) and Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES). We indicate the relevant resolution when fishing a species is prohibited by the Indian Ocean Tuna Commission (IOTC).

	Species	Landing survey					BRUV			IUCN	CMS	CITES	IOTC
		CD	N	Z	I	M	CD	I	M				
Sharks (≥ 16 species)	*Pseudoginglymostoma brevicaudatum*							X		CR			
	Sphyrna lewini		14	320		5		X		CR		II	
	Stegostoma (tigrinum) fasciatum		1						X	EN			
	Carcharhinus albimarginatus								X	VU			
	Hemipristis elongata		1							VU			
	Carcharhinus amblyrhynchos							X	X	NT			
	Carcharhinus brevipinna					29				NT			
	Carcharhinus leucas		1					X	X	NT			
	Carcharhinus limbatus			2		3		X	X	NT			
	Carcharhinus sorrah		8	7						NT			
	Galeocerdo cuvier			1					X	NT			
	Triaenodon obesus							X	X	NT			
	Loxodon macrorhinus		4	3		3				LC			
	Rhizoprionodon acutus		4	17		57				LC			
	Carcharhinus humani		1	4		5			X	DD			
	Paragaleus leucolomatus							X		DD			
	Carcharhinus spp			1		5				n/a			
	Carcharhinidae		2	69						n/a			
	Sphyrnidae			171						n/a			
	Unidentified shark			75		9				n/a			
Rays (≥ 16 species)	*Rhina ancylostomus*	1								CR		II	
	Rhynchobatus australiae	1	3	1						CR		II	
	Rhynchobatus djiddensis					1		X	X	CR		II	
	Acroteriobatus leucospilus		5			7		X		EN			
	Mobula kuhlii		6					X	X	EN	I, II	II	Res. 19/03
	Aetobatus ocellatus		2	1				X		VU			
	Himantura leoparda		2	3	1					VU			
	Himantura uarnak		18	3	3	10		X	X	VU			
	Mobula birostris							X		VU	I, II	II	Res. 19/03
	Pateobatis fai		2		3	2			X	VU			
	Pateobatis jenkinsii		10						X	VU			
	Taeniurops meyeni		1						X	VU			
	Maculabatis ambigua	1	53	10		27				NT			
	Taeniura lymma	16	3				X	X	X	NT			
	Neotrygon caeruleopunctata	15	1				X	X		NE			
	Rhinoptera jayakari		5	9		2				NE			
	Pastinachus ater		2	2		3	X			LC			
	Megatrygon microps							X		DD			
	Dasyatidae		3	3						n/a			
	Himantura spp		1	1						n/a			
	Unidentified batoid			21		4				n/a			
	Number of samples						10	36	74				
	Total animals	**34**	**153**	**724**	**7**	**172**	**100**	**135**	**129**				

Note. The IUCN Red List Categories define the extinction risk of species assessed. The categories are Not Evaluated (NE), Data Deficient (DD), Least Concern (LC), Near Threatened (NT), Vulnerable (VU), Endangered (EN), Critically Endangered (CR), Extinct in the Wild (EW) and Extinct (EX). Critically Endangered, Endangered and Vulnerable species are considered to be threatened with extinction (IUCN 2012). CMS Appendix I lists species which must be protected at a national level. CITES Appendix II lists species that are not necessarily threatened with extinction now, but that may become so unless trade is closely controlled. IOTC Resolution 19/03 is specifically intended to prevent the fishing of mobulid rays (mobula and manta rays), and applies to all fishing vessels on the IOTC Record of Authorised Vessels, but **not fishing vessels carrying out subsistence fishing** that, anyhow, shall not be selling or offering for sale any part of, or whole, carcass of mobulid rays.

1 A subsistence fishery is a fishery where the fish caught are consumed directly by the families of the fishers rather than being bought by middle- (wo)men and sold at the next larger market, per the FAO Guidelines for the routine collection of capture fishery data. FAO Fisheries Technical Paper. No. 382. Rome, FAO. 1999. 113p.

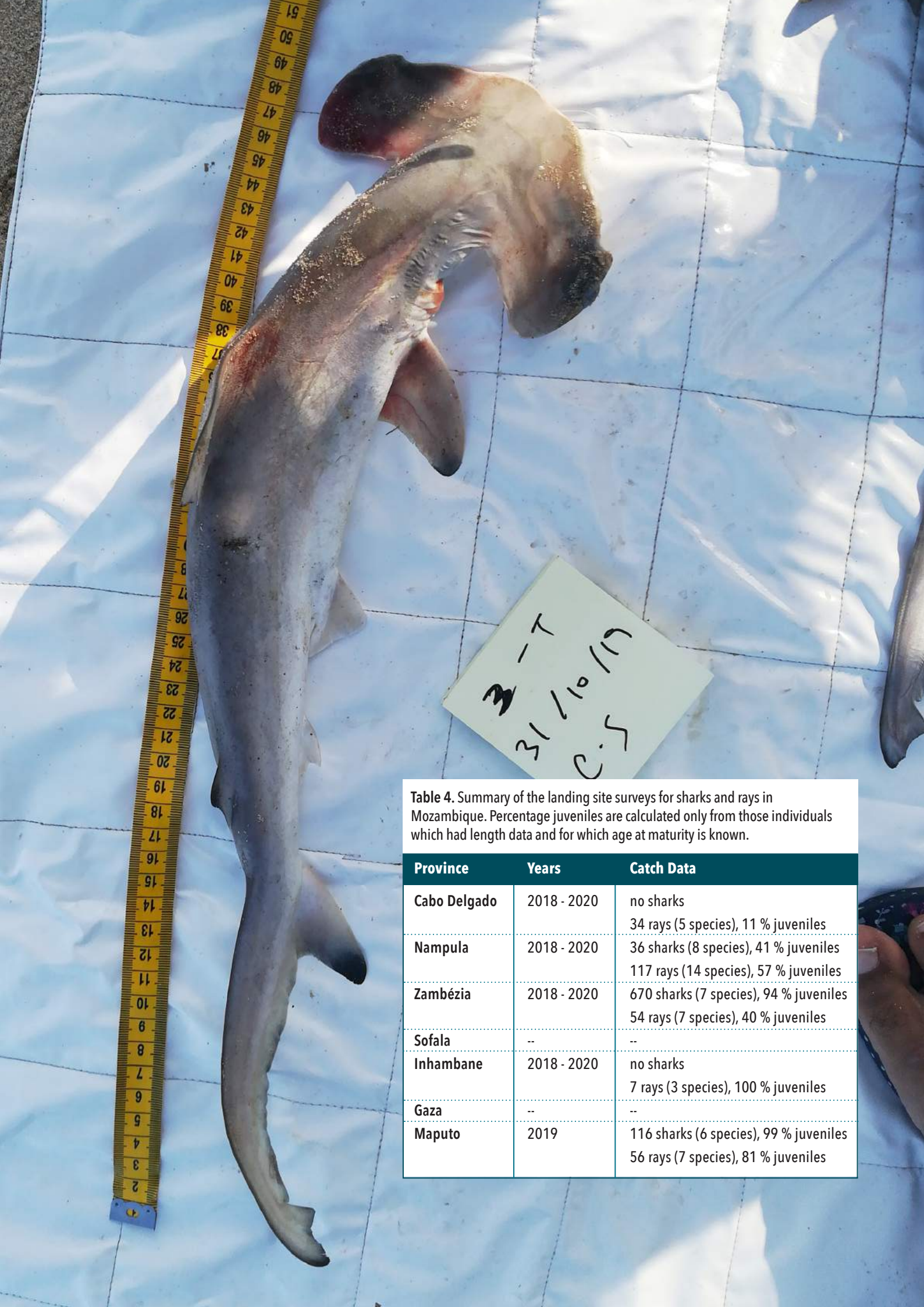


Table 4. Summary of the landing site surveys for sharks and rays in Mozambique. Percentage juveniles are calculated only from those individuals which had length data and for which age at maturity is known.

Province	Years	Catch Data
Cabo Delgado	2018 - 2020	no sharks 34 rays (5 species), 11 % juveniles
Nampula	2018 - 2020	36 sharks (8 species), 41 % juveniles 117 rays (14 species), 57 % juveniles
Zambézia	2018 - 2020	670 sharks (7 species), 94 % juveniles 54 rays (7 species), 40 % juveniles
Sofala	--	--
Inhambane	2018 - 2020	no sharks 7 rays (3 species), 100 % juveniles
Gaza	--	--
Maputo	2019	116 sharks (6 species), 99 % juveniles 56 rays (7 species), 81 % juveniles

OVERALL APPRAISAL OF THE **CAPACITY** FOR WCS MOZAMBIQUE TO SUPPORT CORAL REEF CONSERVATION IN MOZAMBIQUE

Studies conducted by WCS scientists in Mozambique and in the WIO region have resulted in management and conservation recommendations that may benefit the development of a National Plan of Action for Coral Reef Conservation in Mozambique. Work undertaken by WCS scientists has provided information relative to corals, fish, macroalgae, soft corals and urchins from 81 coral reef surveys, from various habitats under no-take, restricted and open access management regimes, surveyed between 2008 and 2015 in the provinces of Cabo Delgado, Nampula, Inhambane and Maputo (McClanahan et al. 1996; McClanahan and Muthiga 2017). Complementary socio-economic research has been undertaken to understand coral reef fisheries and fishers' perceptions in Pemba in the province of Nampula (McClanahan, Cinner, and Abunge 2013). This information has so far contributed to at least 20 "peer-reviewed" scientific publications. The recently started WCS Mozambique Marine Program has also been contributing to the development of a National and WIO region roadmap for shark and ray conservation and together with IIP and several conservation partners is gathering knowledge of coral reef shark and ray fisheries, diversity and abundance in the provinces of Cabo Delgado, Nampula, Zambézia, Inhambane and Maputo. WCS Mozambique can support coral reef conservation in Mozambique with the knowledge and baseline data summarised in this report, with data management using the Mermaid platform, and with access to the personnel and expertise of the WCS Global Marine Program.

WCS understanding of reef fish ecology and fisheries management can be applied to support the development of policy, monitoring and conservation plans, and legislation that can promote coral reef resilience. Human populations, management regimes and reef habitats have all been reported to impact the biomass and diversity of reef fish in Mozambique, whilst it is less clear if there are impacts for hard corals (McClanahan and Muthiga 2017). Based upon fieldwork throughout the WIO and other tropical regions WCS scientists have proposed regional biomass thresholds for coral reef fish of at least 450 kg/ha to allow for fishing to be sustainable, 600 kg/ha to maintain diversity for fish communities, and 1150 kg/ha to achieve conservation goals (McClanahan 2019). These benchmarks can be combined with guidance specific to habitat and management regimes, to promote the resilience of a coral reef community (McClanahan et al. 2011; McClanahan 2016; 2018). Based on WCS surveys in Mozambique, the reefs that meet the conservation benchmarks were almost exclusively under no-take management, and all of the reefs under open access management were below the minimum sustainable biomass for fishing. Half of the restricted management sites were also below the minimum sustainable biomass threshold. This knowledge can be applied to define the state of reefs and to decide when to implement management measures that promote the recovery of coral reef fish communities and fisheries (Worm et al. 2009; Macneil et al. 2015). WCS socio-economic studies have demonstrated the ability to gather community information on fisheries and to identify fishing gear and management priorities in Pemba and in the Nampula province (McClanahan, Cinner, and Abunge 2013; McClanahan and Abunge 2016), which can be compared to similar WCS studies in Tanzania, Kenya and Madagascar as well as other regions to benefit conservation and management decisions in Mozambique (Mcclanahan and Hicks 2011; Hicks and McClanahan 2012; Maina et al. 2015)

The knowledge gathered can benefit the design and management of marine protected areas to promote coral reef resilience. Surveys have indicated coral cover is below recommended levels of 50 %, believed necessary for reefs to withstand predicted sea level rise by 2100 under the relatively favourable scenario of RCP4.5, and only three sites met recommendations to withstand scenario RCP8.5 (Perry et al. 2018). WCS surveys in Mozambique have reported low biomass of herbivorous parrot fishes (Scarridae) as well as regionally low densities and biomass of sea urchins, which are also key herbivores on coral reefs (McClanahan and Muthiga 2017). The lower presence of these herbivores is frequently associated with management regimes that allow fishing and reefs that have higher macroalgae cover (Mumby et al. 2006; Hughes et al. 2007), as observed in Mozambique at sites with restricted and open-access management regimes (Figure 15). Management regimes, such as no-take areas, that maintain higher herbivore biomass, lower macroalgae cover, and are likely to promote higher coral cover are

likely to promote more resilient coral reefs that recover more quickly from disturbances such as cyclones and coral bleaching events.

WCS researchers have guided responses to climate change and coral bleaching events globally and specifically in the WIO with research to determine the taxon-specific susceptibility of corals to bleaching and the adaptation of corals to thermal anomalies (McClanahan 2004; McClanahan et al. 2007; Graham et al. 2015; McClanahan 2017). Greater diversity of corals has been described on reefs in northern Mozambique (Ateweberhan and Mcclanahan 2016) and the variation in coral communities has been described in response to local habitat features (McClanahan and Muthiga 2017). This understanding has also been used to the identify regions in northern Mozambique that are less prone to temperature stress and thus recommended as priority areas for coral reef conservation (McClanahan, Maina, and Muthiga 2011; McClanahan and Muthiga 2017). Overall this knowledge provides guidelines for the design of marine reserves that are more resilient to climate change (MacNeil et al. 2010; Graham et al. 2008; McClanahan, Maina, and Muthiga 2011; Maina et al. 2015).

In the WIO, WCS has been a key participant in the development of a roadmap for the conservation and management of shark and rays. Within Mozambique, WCS currently collaborates with the IIP and plans to assess socio-economic drivers of fisheries and the current fishing pressures on sharks and rays. WCS is also monitoring shark and ray communities in coral reef environments of the WIO, namely in Mozambique, Tanzania, Kenya and Madagascar, where numerous threatened species of sharks and rays are caught. The conservation of sharks and rays is one of the WCS global priorities, which enables WCS Mozambique to also draw on a global resource of scientific knowledge and expertise.

To support the Government of Mozambique in the development of a National Plan of Action for Coral Reef Conservation, WCS Mozambique can draw on the expertise of the WCS Global Marine Program and the East Africa, Madagascar and Western Indian Ocean regional programs. WCS can also contribute to building local capacity to identify and monitor key indicators of coral reef resilience. These indicators can be used to successfully guide conservation decisions (Mcleod et al. 2019). This enables WCS Mozambique to resort to a global set of skills and knowledge to provide support and guidance that will strengthen collaborations with stakeholders and increase the likelihood of successful and lasting coral reef conservation efforts in Mozambique.

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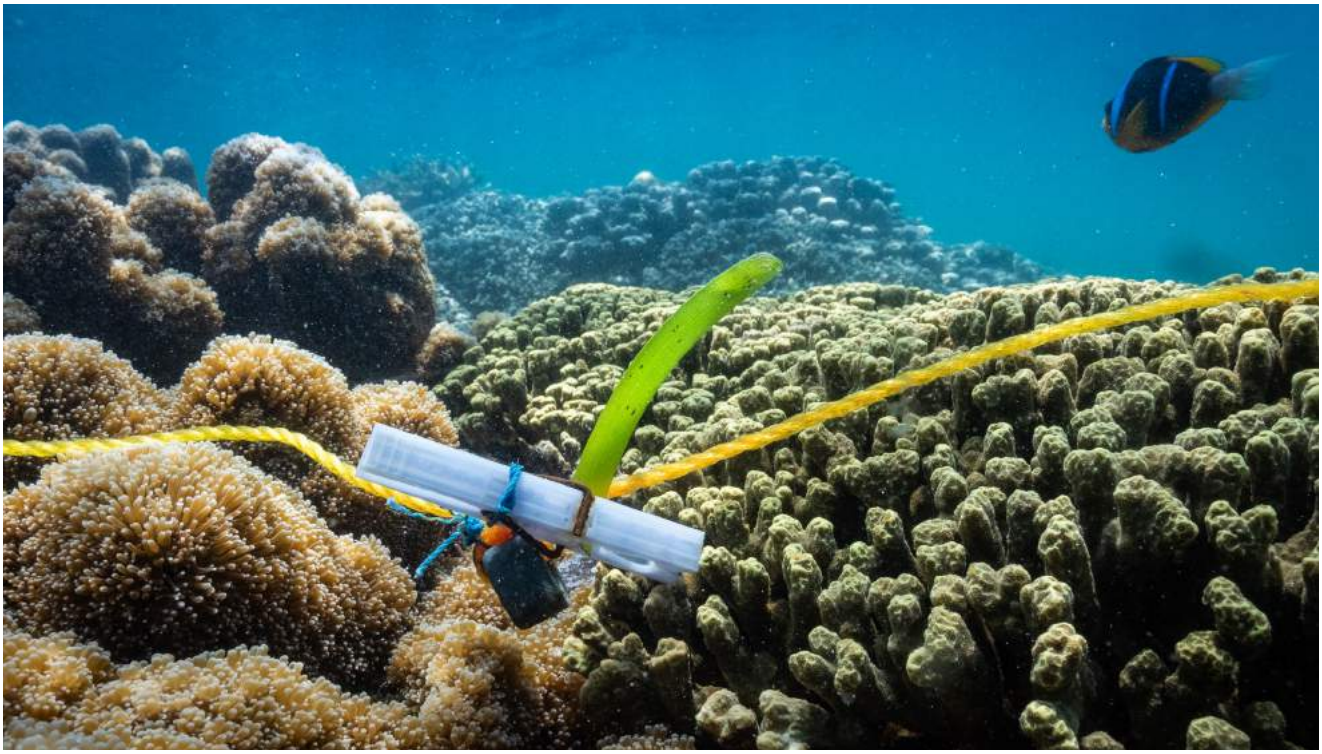

LIST OF ABBREVIATIONS

	Portuguese	English
BRUVS	Vídeo subaquático autónomo em estéreo com atração com isco	Baited remote underwater video in stereo
CCP	Conselho Comunitário de Pesca	Community Fishing Council
CITES	Convenção internacional para o comercio de espécies ameaçadas	Convention for the International Trade of Endangered Species
CMS	Convenção sobre a Conservação das Espécies Migratórias de Animais Selvagens	Convention on the Conservation of Migratory Species of Wild Animals
CORDIO	Investigação dos Oceanos Costeiros e Desenvolvimento no Oceano Indiano	Coastal Oceans Research and Development in the Indian Ocean
CORDIO (Sida)	Degradação de recifes de Coral no Oceano Indiano	Coral Reef Degradation in the Indian Ocean project
COTS	Estrela do mar *Acanthaster sp.*	crown-of-thorns starfish
ha	hectare	hectare
IIP	Instituto Nacional de Investigação Pesqueira	National Institute for Fisheries Research
IOTC	Comissão de Atum do Oceano Indiano	Indian Ocean Tuna Commission
IPCC	Painel intergovernamental sobre alterações climáticas	Intergovernmental Panel on Climate Change
IUCN	União Internacional para Conservação da Natureza	International Union for the Conservation of Nature
kg	Quilograma	Kilogram
km	Quilómetro	Kilometre
MCRMP	Programa de Maneio de Recifes de Coral de Moçambique	Mozambique Coral Reef Management Programme
MICOA	Ministério de Coordenação Ambiental	Ministry for the Co-ordination of Environmental Affairs
MPA	Área Marinha Protegida	Marine Protected Area
MTA	Ministério da Terra e Ambiente	Ministry of Land and Environment
n/a	Não aplicável	Not applicable
NGO	Organisação Não Governamental	Non Governmental Organisation
RCP	Patamares de Concentração Representativos	Representative Concentration Pathways
Sida	Agencia Sueca Internacional de Desenvolvimento e Cooperação	Swedish International Development Cooperation Agency
UEM	Universidade de Eduardo Mondlane	University of Eduardo Mondlane
UGC	Unidade de Gestão Costeira	Department of Coastal Management
WCS	Sociedade da Conservação da Natureza	The Wildlife Conservation Society
WIO	Oceano Indiano Ocidental	Western Indian Ocean
WWF	Fundo Mundial para a Natureza	World Wildlife Fund for Nature

WCS Mozambique

A Wildlife Conservation Society Program

Saving wildlife and wild places

By discovering how to save nature, we can inspire everyone to work with us to protect wildlife in the last wild places on Earth.