World Heritage papers 32

Assessing Marine World Heritage from an Ecosystem Perspective

The Western Indian Ocean

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Assessing Marine World Heritage from an Ecosystem Perspective

The Western Indian Ocean

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Preface

This year is the 40th anniversary of the *World Heritage Convention*. The World Heritage Committee, the statutory body in charge of the protection of the 936 properties on the World Heritage List, has recognized that the List does not yet fully represent all types of cultural and natural heritage which are of Outstanding Universal Value.

In 1994, the World Heritage Committee launched a Global Strategy for a representative, balanced and credible World Heritage List. The Strategy suggests avoiding an over-representation of a small number of regions or categories and ensuring that the World Heritage List reflects the broad diversity of the world's cultural and natural areas of OUV. An important contribution to the Global Strategy is the effort to encourage nomination of properties from categories and regions currently not or underrepresented on the World Heritage List.

One hundred and eighty-nine nations are now "States Parties" to the *World Heritage Convention* and therefore eligible to submit nominations for sites, including marine areas, to be considered for World Heritage listing to the World Heritage Committee. First, each country makes an inventory of sites located within its boundaries for inclusion on the Tentative List of sites that a State Party may decide to submit for inscription in the next 5–10 years. The World Heritage Committee cannot consider a nomination for inscription on the World Heritage List unless the property has already been included on the State Party's Tentative List.

Contrary to the traditional country-by-country approach, marine World Heritage requires reflection of marine features at larger scales meaningful from an ecosystem perspective. Marine ecosystems almost always transcend national boundaries. In anticipation of increased interest globally in designating new marine World Heritage sites, this project was established to test a more scientific and robust approach to identify marine sites of potential OUV. The project initiated a new approach in the Western Indian Ocean, an area largely under the jurisdiction of African countries and with unique and age-old geological processes currently under-represented on the World Heritage List.

The recent expert workshop and this report examined potential areas of OUV in the Western Indian Ocean. The results will enable the States Parties, the World Heritage Committee, and the World Heritage Centre, to take actions to address the need for enhanced protection and sustainable management of marine ecosystems in the Western Indian Ocean.

Kishore Rao
Director
UNESCO World Heritage Centre

Introduction

Since about 70% of the world's surface area is ocean, marine areas are generally under-represented in the World Heritage List. In 2005 the World Heritage Marine Programme was established in part with the aim of ensuring that marine sites with Outstanding Universal Value are inscribed on the World Heritage List and protected so future generations can continue to enjoy them. Following the 1994 Global Strategy, a major focus of the Marine Programme is to support States Parties with the identification of sites in all major marine regions and marine ecosystem types in a balanced, credible and representative manner.

Marine ecosystems support much of the world's goods and services and provide invaluable economic benefits, yet less than five percent of sites on the World Heritage List are nominated for marine heritage values at this time. Recent reports on the state of marine ecosystems and their resources provide alarming indications on their condition. For example, coral reefs and associated mangrove forests and sea grass beds are severely threatened from a combination of human activities and natural influences, e.g. climate change. Urgent action is needed to revert the decline of these globally significant diverse and productive marine ecosystems.

Forty-five marine sites have now been inscribed on the World Heritage List, covering about 1.5 million km^2 of the ocean surface – an area about the size of the Gulf of Mexico. Each of these 45 sites represents exceptional features in the ocean that are recognized by the international community for their outstanding natural beauty, extraordinary biodiversity, or unique ecological, biological and geological processes. However, on a planet where more than 95% of all living space is located in the ocean, a huge amount of our heritage is still left undiscovered.

The *World Heritage Convention* is an important tool to bring attention and protection for these unique marine ecosystems as they are a compelling illustration of major types of natural heritage not sufficiently represented on the World Heritage List.

This report builds on previous efforts to navigate a long-term future for the World Heritage Marine Programme and to facilitate the process of replicating regional assessments in other marine ecoregions.

To access this report visit this webiste: http://www.vliz.be/projects/marineworldheritage/.

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Acknowledgements

This report builds on prior work under the World Heritage Marine programme, and parts of the text in the first part of this report have been derived directly from those reports, including the 1994 Global Strategy for a Representative, Balanced and Credible World Heritage List, the 2011 report Navigating the Future of Marine World Heritage, and the newly developed brochure on using Marine Ecoregions of the World as a basis for identifying marine gaps on the World Heritage List, as well as from the World Heritage website and other official documents. We would like to acknowledge our use of unpublished datasets generously provided by the Indian Ocean Commission on behalf of the member countries of the Commission. We would like to thank Fanny Douvere and the staff at the World Heritage Centre, Diana Dumeril, Agne Bartkute, Rachida Kameche, for guidance and support in conducting this work. We would also like to thank the workshop hosts in la Reunion, Mrs Fabienne Couapel Sauret, Vice-Présidente of la Region Reunion, and Soudjata Radjassegarane, Laurence Provot and Anne Nicolas. The comments and feedback from the World Heritage Focal Points from countries of the Western Indian Ocean was helpful in scoping the document, and we thank Fareed Chuttan, Laure Dexcidieux, Solange Laura Macamo, Chumani Mangcu, E. Eliwasa Maro, G. James Njogu. Finally, for the experts who contributed their time in the workshop, and/or in providing or reviewing technical content of the report, we acknowledge Ameer Adbulla, Tim Andrews, Lionel Bigot, Philippe Bouchet, Jerome Bourjea, Salvatore Cerchio, Pascale Chabanet, Vic Cockroft, Gerard Collin, Bertrand Denis, Frauke Fleischer-Dogley, Hans Fricke, Nicole Gravier-Bonnet, Francisco (Tjess) Hernandez, Nigel Hussey, Jeremy Kiszka, Erwan Lagabrielle, Catherine Latreille, Mathieu Le Corre, Adriano Macia, Eric Marguerite, Carole Martinez, Jan Mees, Jeanne A. Mortimer, Mika Odido, Karine Pothin, Jean-Pascal Quod, Jerome Raimbault, Harifidy Ralison, Andriamia Ranjato, Sonia Ribes, Matt Richmond, Melita Samoilys, Francis Staub, Gisele Tarnus, Jean-François Ternon, Gwenaelle Thiery, Ross Wanless and Andrew Zaloumis.

Abbreviations

ABNJ	Areas Beyond National Jurisdiction
CBD	Convention on Biological Diversity
CCAMLR	Commission for the Conservation of Fauna and Flora of Antarctic Marine Living Resources
CNPPA	Commission on National Parks and Protected Areas
COI	Commission de l'Océan Indien (in English – Indian Ocean Commission, IOC)
DWFN	Distant-water fishing nations
EACC	East African Coastal Current
EBSA	Ecologically and Biologically Significant Area
EEZ	Exclusive Economic Zone
GSP	Global Seabird Programme (BirdLife International)
IBA	Important Bird Areas
ICZM	Integrated Coastal Zone Management
IOS	Indian Ocean Sanctuary
IP	Indo-Pacific
IUCN	International Union for the Conservation of Nature
K-T	Cretaceous-Tertiary boundary
KBA	Key Biodiversity Areas
KMNR	Kiunga Marine National Reserve
LIP	Large Igneous Province
MAB	Man and the Biosphere
MBREMP	Mnazi Bay-Ruvuma Estuary Marine Park
MC	Mozambique Current
MEOW	Marine Ecoregions of the World
MPA	Marine Protected Areas
mya	millions of years ago
OUV	Outstanding Universal Value
RAMP – COI	Réseau des Aires Marines Protégées, project of the Indian Ocean Commission
ROV	Remotely Operated Vehicles
SC	Somali Current
SEC	South Equatorial Current
SWIO	South West Indian Ocean
TAAF	French Southern and Antarctic Lands (Terres australes et antarctiques françaises)
UNEP	United Nations Environment Program
UNESCO	United Nations Education, Science and Cultural Organization
WCPA	World Commission on Protected Areas
WHC	World Heritage Convention
WIO	Western Indian Ocean
WIOMER	Western Indian Ocean Marine Ecoregion
WIPR	West Indo-Pacific Realm
WPC	World Parks Congress
WWF	World Wildlife Fund (World Wide Fund for Nature in some countries)
ya	years ago

Table of Contents

Executive summary and conclusions

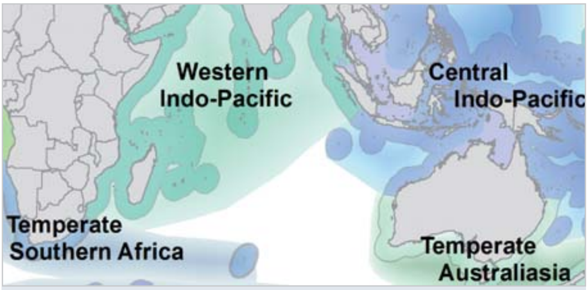
The 1972 *World Heritage Convention* conserves and protects cultural and natural heritage of Outstanding Universal Value (OUV). Today, the World Heritage List contains 936 terrestrial and marine sites, in 153 countries. World Heritage natural sites protect almost 2.5 million km^2 of the planet's lands and waters. Because of the recent addition of large marine sites to the World Heritage List, some 57 per cent of the total area is marine, though in only 45 sites (5% of the number of World Heritage sites).

In anticipation of increased interest globally in designating new marine World Heritage sites, this project was established to pilot a more scientific and robust approach to identify marine sites of potential OUV. Contrary to the traditional country-by-country approach, marine World Heritage requires reflection of its features at larger scales meaningful from an ecosystem perspective. This project initiated a new approach in the Western Indian Ocean, an area largely under jurisdiction of African countries and with unique and age-old geological processes currently under-represented on the World Heritage List.

This report has four main parts – the first provides basic guidance on World Heritage for the region and in relation to marine systems, the second outlines the methodology applied and that can be undertaken in future regional assessments elsewhere, and the third and fourth identify the features and sites in the Western Indian Ocean that this study determined to be of potential OUV. For a more interactive view of the contents of the report, and further developments in marine World Heritage, visit the website http://www.vliz.be/ projects/marineworldheritage/.

The methodology followed three main steps, using data and information already available as peer-review scientific publications, grey literature reports, and expert knowledge, and with particular attention to historical biogeographic and biodiversity analyses. These steps were: 1) identification of the appropriate bio-regional scale at which to apply the assessment; 2) identification of the key physical and biological features that distinguish the region compared to others globally; and 3) identification of the sites in the region that exemplify these features, and that are of sufficient integrity and scale to meet the criteria of OUV. This exercise was undertaken first by the project team, and the results validated and reviewed through a carefully composed regional expert conference and individual consultations.

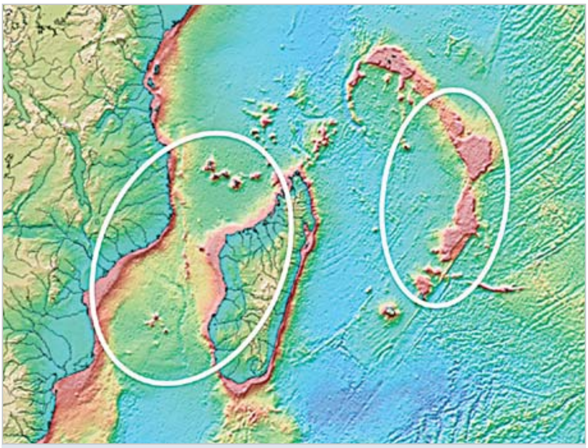
Two principal features stand out as globally unique in the Western Indian Ocean – the Mozambique Channel and the Mascarene Plateau. They are both distinct elements of the geological history of the Indian Ocean basin, going back >150 million years for the Mozambique Channel, and 40 million years for the Mascarene Plateau. They fundamentally affect the currents that drive all marine ecosystems and species, on evolutionary and ecological scales. Due to the location of Madagascar and the Mascarene Plateau in the path of the South Equatorial Current, and of the Asian monsoon system with its opposing trade winds, the Western Indian Ocean experiences a highly energetic and seasonally variable western boundary current system found nowhere else on the planet. Because of the geographic size of both of these areas, they could be considered as serial trans-boundary sites containing multiple smaller-scale sites that are essential components of the whole.



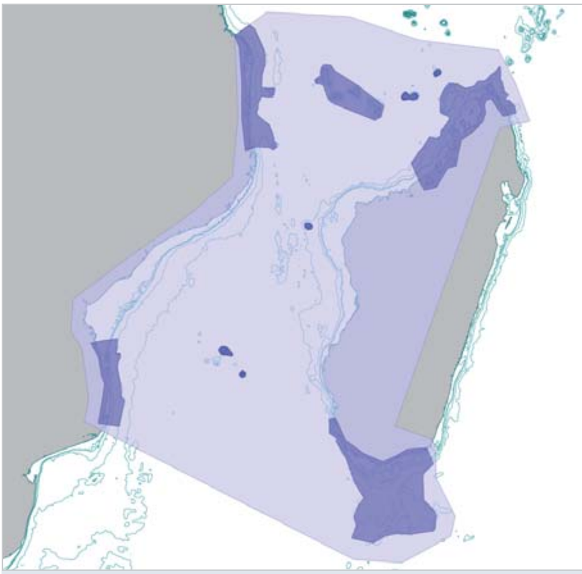
The Western Indo-Pacific Realm (WIPR) encloses the Western Indian Ocean (WIO). Proximity to the Central Indo-Pacific to the east, and to Temperate Southern Africa to the south affect the biogeography of the WIPR and the WIO. ©Spalding et al. 2007

The Mozambique Channel experiences a highly energetic and variable regime of meso-scale circular currents (eddies, approx. 100-300 km across) that cause water to flow in all directions – north, south, east and west – and fundamentally affect the diversity and productivity of marine ecosystems within the channel. The coral reefs in the northern channel are the most diverse in the Indian Ocean (save for those parts bordering Indonesia), and represent a second hotspot of tropical marine biodiversity globally. The open-water food webs in the channel are highly productive and dynamic, resulting in concentrations of fish, turtles, marine mammals and seabirds that are critical for the species themselves and are spectacular natural phenomena. They also support the coastal and national economic activities of the bordering countries, through sectors such as fisheries and tourism. The Mozambique Channel and East African coast are the prime habitat of the coelacanth, a 'living fossil' that illustrates the long term stability of this region.

Sites within the Mozambique Channel are presented in the report as examples that express some aspect of the geological and/or oceanographic features that make the channel unique globally, combined with biological features best represented at the individual sites. States Parties with jurisdiction over these sites (Mozambique, Madagascar, Comoros, Tanzania and France) may follow a traditional approach of single-state nominations to the World Heritage



The Mozambique Channel and the Mascarene Plateau are the two principal features of the WIO that are unique on a global scale. ©topex; http://topex.ucsd.edu/marine_topo/



Map showing sites within the Mozambique Channel. © David Obura

List, or develop an innovative inter-governmental approach that could establish a multi-country serial site in the Mozambique Channel.

The Mascarene Plateau, being more remote than the Mozambique Channel, and with emergent land and small islands only at its southern extreme, is less well-known, but with indications of unique oceanographic features and habitats, including the largest seagrass beds in the world, species endemism and significant aggregations of marine mammals and seabirds. Mauritius and the Seychelles have individual or joint jurisdiction over the waters and entire seabed of the plateau, though the waters over the Saya de Malha Bank are beyond national jurisdiction and in the High Seas.

Additional unique features and areas mentioned in the report (Kiunga-Lamu archipelago, Kenya; Antongil Bay, Madagascar; the Kwazulu-Natal Sardine Run, South Africa; and the Kerguelen-Crozet archipelagos) are more consistent with traditional approaches to World Heritage site designation, as they fall within national jurisdictions. In addition, three of them are in transition zones to neighbouring biogeographic zones, and may be considered in other regional assessments. Other sites within the region could potentially qualify to meet the *World Heritage Convention* criteria of OUV but may not have been identified in this report because they are likely less unique when compared to other regions in the world.

Importantly for the region, and potentially foretelling the future of marine World Heritage, the two primary areas identified – the Mozambique Channel and Mascarene Plateau – show the opportunity for inter-governmental cooperation and set a precedent toward a more comprehensive approach when identifying potential new marine sites. An ecosystem approach – as opposed to the more traditional country-by-country approach – can considerably enhance future conservation of exceptional marine features on the World Heritage List because this approach is more meaningful from an environmental perspective. For both areas, the Nairobi Convention (for the Protection, Management and Development of the Marine and Coastal Environment of the Eastern African Region) is the prime vehicle for intergovernmental cooperation in marine affairs, and all countries in the region are party to both the World Heritage and Nairobi Conventions. For the Saya de Malha bank, in addition to the Nairobi Convention, initiatives under the Convention on Biological Diversity and the United Nations Law of the Sea offer avenues for multi-country cooperation and new approaches to High Seas governance. Through this report we aim to enhance knowledge and understanding among the States Parties in the Western Indian Ocean of the potential for marine World Heritage sites that lie within their jurisdiction. Next steps will focus on working with the respective States Parties to explore with them potential inscription of the respective sites which are identified as likely of OUV through this science-based approach.

POTENTIAL AREAS IDENTIFIED IN THIS REPORT

The Mozambique Channel
- Quirimbas – Mtwara
- Northern Madagascar
- The Comoros – Glorieuses crescent
- The Iles Éparses (Scattered Islands)
- Tofo – Bazaruto
- Madagascar Plateau

Mascarene Plateau
- Saya de Malha bank

Other sites
- Kiunga – Lamu archipelago
- The KwaZulu – Natal sardine run
- Antongil Bay
- French Southern Territories (Crozet, Kerguelen, Saint Paul and Amsterdam)

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Understanding Marine World Heritage

© Keith Ellenbogen

Marine World Heritage

Background

The 1972 *World Heritage Convention* aims at the conservation and protection of cultural and natural heritage of Outstanding Universal Value (OUV). Today, the World Heritage List contains 936 terrestrial and marine sites including 725 cultural, 183 natural, and 28 'mixed' properties, recognized for their universal cultural and/or natural values, in 153 countries. The World Heritage natural sites protect over 2,420,000 km^2 of the planet's land and marine waters. Of this total 643,000 km^2 are inland lands (27 per cent), 385,000 km^2 are coastal and island lands (16 per cent) and 1,380,000 km^2 are located in marine waters (57 per cent). The first marine World Heritage site was Australia's Great Barrier Reef, inscribed in 1981. Now there are 45 World Heritage sites listed specifically for their marine values, including many of the largest and most pristine marine protected areas on the planet (Map 1).

Purpose of this project

The objective of this project is the development of a regional comparative assessment for potential marine World Heritage sites in the Western Indian Ocean, in support of the 1994 Global Strategy toward a balanced, credible and representative World Heritage List. Traditionally, identification and prioritization of sites for World Heritage listing is done at national scales, but recent trends in identification of marine phenomena and sites for conservation underline the need for supra-national, or regional scales for site identification and eventually for management and governance. This regional comparative assessment focuses on the identification and description of features of unique value in the Western Indian Ocean, a distinct biogeographic region. The aim was to apply a science-based approach to the assessment of an entire marine province or biome, and to develop a framework that will later be applicable to other marine regions that are also under-represented on the World Heritage List. Based on the regional scale assessment, specific sites with potential OUV, that represent the most superlative expression of these values were identified, whether they lie within national boundaries (Exclusive Economic Zones, EEZs) or beyond them in high seas areas.

The assessment incorporated results from a regional expert conference, that had two objectives; 1) to provide a general introduction to the *World Heritage Convention* and aspects relevant to marine inscription, for government officials, World Heritage focal points and experts of the region (primarily from African countries), and 2) to receive scientific expert assessment of marine sites in the Indian Ocean to identify which could be of OUV.

The Western Indian Ocean (WIO) is defined biogeographically in later sections, and includes the following countries, all States Parties to the *World Heritage Convention* (year of ratification/accession in brackets): Comores (2000), France (La Réunion, Mayotte and Isles Eparses) (1975), Kenya (1991), Madagascar (1983), Mauritius (1995), Mozambique (1982), Seychelles (1980), South Africa (1997) and Tanzania (1977). This region is also consistent with the area identified by the UNEP Regional Seas programme, which has been formalized by the countries through their ratification of the Nairobi Convention (Protection, Management and Development of the Marine and Coastal Environment of the Eastern African Region).

The World Heritage Marine Programme

In 1994, the World Heritage Committee launched the Global Strategy for a representative, balanced and credible World Heritage List. The Strategy aims at avoiding an over-representation of a small selection of regions or categories and ensuring that the World Heritage List reflects the broad diversity of the world's cultural and natural areas of OUV. Crucial to the Global Strategy are efforts to encourage nomination of properties from categories and regions currently not or underrepresented on the World Heritage List.

Considering that the world exists for 70% out of ocean, marine systems are generally under-represented in the World Heritage List. In 2005 the World Heritage Marine Programme was established in part with the aim of ensuring that marine sites with OUV are inscribed on the World Heritage List and well protected so future generations can continue to enjoy them. Following the Global Strategy, a major focus of the Marine Programme is to support States Parties with the identification of sites in all major marine regions and marine ecosystem types in a balanced, credible and representative manner.

The following meetings and documents have set out a path for the growing Marine Programme, on which this report builds:

1. The "World Heritage marine biodiversity workshop: Filling critical gaps and promoting multi-site approaches to new nominations of tropical coastal, marine and small island ecosystems" held in Hanoi, Viet Nam, in 2002;

2. The "Bahrain Action Plan for Marine World Heritage – Identifying priorities and enhancing the role of the *World*

Heritage Convention in the IUCN-WCPA Marine Global Plan of Action for MPAs in our Oceans and Seas" held in the Kingdom of Bahrain, February 2009;

3. An IUCN thematic study on Marine World Heritage – meeting organized by IUCN and the WHC in Vilm (Germany) on scaling up Marine World Heritage, 30 June-4 July 2010;

4. A strategy for the future from the meeting, "Navigating the Future of Marine World Heritage. Results from the first World Heritage Marine Site Managers Meeting" in Honolulu, Hawaii, 1-3 December 2010;

5. A preliminary analysis on marine representation as a basis for building up a representative and credible portfolio of marine World Heritage sites using the widely recognized Marine Ecoregions of the World (MEOW) classification, Spalding 2007.

This report has been prepared to be consistent with these, and to facilitate the process of replicating regional assessments in other marine ecoregions in the future.

The High Seas

The *World Heritage Convention* applies to waters within EEZ's, but does not apply to the seas beyond national jurisdiction. About 60 per cent of the ocean (221 million km^2) lies in the High Seas, and cannot be claimed by any nation. While it belongs to all, its effective protection has yet to be achieved, and nations have not yet agreed on how this may best be done. No existing mechanism has the legal power to protect effectively this enormous expanse with its rich biodiversity. At present, efforts are underway to establish governance mechanisms for the high seas, including for conservation.

The High Seas are home to the great whales, sea turtles, seabirds, tuna and deep-dwelling fishes and other animals that lead long, slow-motion lives in the eternal dark. Muddy plains, coral-capped seamounts and vents all give rise to unique marine life found nowhere else on the planet. It is said that less is known about the High Seas species and ecosystems than about the moon, so there is an urgent need to protect this poorly known common heritage, and fill the large gaps of areas as yet unexplored and unmapped. The World Heritage Marine Programme, in cooperation with IUCN is currently undertaking first steps toward the application of the concept of OUV to areas beyond national jurisdiction – a first comprehensive response to the 2011 External Audit's recommendations of the Global Strategy.

The *World Heritage Convention* and its operations

Roles and responsibilities

The **Convention concerning the Protection of the World's Cultural and Natural Heritage**, adopted in 1972 and commonly known as the *World Heritage Convention* was founded on the premise that certain places on Earth are of OUV and as such should form part of the common heritage of humanity. As of March 2012, the convention has been ratified by 189 countries, the States Parties to the Convention. Operationally, the following groups play a role in managing and conserving World Heritage sites:

The States Parties – In ratifying the Convention, countries take on obligations to identify and protect sites nominated to the World Heritage List, and to protect their national heritage, both natural and cultural. The States Parties are also encouraged to integrate the sites into the day-to-day life of the public, and support scientific and technical conservation research. Countries must also report regularly to the World Heritage Committee on the state of conservation of their World Heritage properties. These reports are crucial in assessing the condition of the sites, provide support to the site managers and resolve recurrent problems. Each country has a formal World Heritage representative, the **National Focal Point**, mandated with implementing Convention activities within the country, and being the channel for information between the Secretariat, countries and other stakeholders.

The **World Heritage Committee** is the decision making body for all World Heritage matters and consists of representatives from 21 of the States Parties to the Convention elected by the General Assembly of the Convention. The Committee meets once a year, and the Bureau of the World Heritage Committee is made up of 7 of the States Parties elected by the Committee, and coordinates the work of the Committee. The **General Assembly of States Parties to the Convention** meets during the sessions of the General Conference of UNESCO, the primary mechanism drawing the countries together for decision making and approving the work programmes of the operational elements implementing the Convention.

The **World Heritage Fund** is established under the Convention, from compulsory and voluntary contributions from the States Parties, as well as from private donations. Annually, about US$4 million is made available to assist States Parties in identifying, preserving and promoting World Heritage sites. Emergency assistance may also be made available for urgent action to repair damage caused by human-made or natural disasters. The World Heritage Committee allocates funds according to the urgency of requests, priority being given to the most threatened sites.

The **World Heritage Centre**, established in Paris in 1992, is the focal point and coordinator within UNESCO for all matters related to World Heritage. Ensuring the day-to-day management of the Convention, the Centre organizes the annual sessions of the World Heritage Committee, provides advice to States Parties in the preparation of site nominations, organizes international assistance from the World Heritage Fund upon request, and coordinates both the reporting on the condition of sites and the emergency action undertaken when a site is threatened. The Centre also organizes technical seminars and workshops, updates the World Heritage List and database, develops teaching materials to raise awareness among young people of the need for heritage preservation, and keeps the public informed of World Heritage issues. The World Heritage Marine Programme is located within the World Heritage Centre and is one of the Centre's six thematic programmes.

Advisory bodies: In addition to the above, three international non-governmental or intergovernmental organizations are appointed to advise the Committee in its deliberations. These bodies provide technical evaluations of nominations submitted to the World Heritage List, as well as ongoing assessments and advice on existing sites and the issues they face. The bodies are:

- The **International Union for the Conservation of Nature (IUCN)** – is an international, non-governmental organization that provides the World Heritage Committee with technical evaluations of natural heritage properties (including all marine World Heritage) and, through its worldwide network of specialists, reports on the state of conservation of listed properties. With more than 1000 members, IUCN was established in 1948 and is located in Gland, Switzerland.

- The **International Council on Monuments and Sites (ICOMOS)** – provides the World Heritage Committee with evaluations of cultural and mixed properties proposed for inscription on the World Heritage List. It is an international, non-governmental organization founded in 1965, with an international secretariat in Paris.

- The **International Centre for the Study of the Preservation and Restoration of Cultural Property (ICCROM)** – is an intergovernmental body which provides expert advice on how to conserve listed properties, as well as training in restoration techniques. ICCROM was set up in 1956 and is located in Rome.

Types of World Heritage sites

Several types of World Heritage site are possible, becoming increasingly complex and inclusive as the selection process for sites has evolved over the years. The principal options are:

Natural, cultural and **mixed** – the latest operational guidelines of the Convention identify six cultural and four natural criteria for assessing OUV of the sites. Sites may be inscribed for any one of these criteria, to be 'natural' or 'cultural' World Heritage sites, or a combination of natural and cultural criteria, as 'mixed' World Heritage sites. In this context, significant interactions between people and the natural environment are recognized as 'cultural landscapes'.

Particularly in relation to the marine environment and the natural connections caused by ocean currents linking sites with one another often across national boundaries, further terminology has been identified for inscription of sites:

Serial sites (the word "cluster" has also been used synonymously for this, so from this point, only 'serial' is used in this document) consist of two or more areas that don't share a direct boundary, but which are related for example because they belong to the same geological, geomorphological formation, the same biogeographic province, the same ecosystem type, or are biophysically linked by ocean currents. The whole series of sites should be of OUV, not only its individual components. Serial nominations are inscribed as a single property on the World Heritage List. The locations, size and boundaries of each component must be explicit, as well as the linkages between them.

Transboundary sites may occur where the features of a site span international boundaries. Transboundary nominations are inscribed as a single property on the World Heritage List, and require joint nomination by the States Parties involved.

The above types of sites may be combined, such as a transboundary serial natural site.

Outstanding Universal Value (OUV)

Nomination of a site for consideration of its listing as World Heritage is decided by a determination of its Outstanding Universal Value (OUV), which is the central construct of the *World Heritage Convention*. What do these words mean?

Outstanding Universal Value (OUV)		
Outstanding – the site should be *exceptional*. The *World Heritage Convention* sets out to define the geography of the superlative – the most outstanding natural and cultural places on Earth.	**Universal** - The scope of the Convention is *global* in relation to the significance of the properties to be protected as well as its importance to all people of the world. Sites cannot be considered for OUV from only a national or regional perspective.	**Value** – implies clearly defining the *worth* of a property, ranking its importance based on clear and consistent standards, including the recognition and assessment of its integrity.

Inscription criteria

Under the *World Heritage Convention*, six inscription criteria relate to **cultural** heritage (i–vi) and four relate to **natural** heritage (vii–x). World Heritage marine sites need to comply with at least one of the natural criteria.

Inscription criteria			
vii. Contain superlative **natural phenomena** or areas of **exceptional natural beauty** and aesthetic importance;	**viii.** Be outstanding examples representing **major stages of Earth's history**, including the record of life, significant ongoing **geological processes** in the development of landforms, or significant geomorphic or physiographic features;	**ix.** Be outstanding examples representing significant ongoing **ecological and biological processes** in the **evolution and development** of terrestrial, fresh water, coastal a nd marine ecosystems and communities of plants and animals;	**x.** Contain the most important and significant **natural habitats** for in situ **conservation of biological diversity**, including those containing threatened species of OUV from the point of view of science or conservation.

The criteria for marine

The primary documents for World Heritage listing omit specific reference to physical marine or ocean processes. Inspection of the criteria for natural heritage, vii – x, suggests two options for their inclusion: Criterion vii refers to 'natural phenomena' which could include ocean processes. However this is stated alongside 'natural beauty', and the criterion is generally considered insufficient for listing of natural World Heritage sites due to the subjective nature of 'beauty'. Criterion viii refers to earth history, geological processes, landforms, geomorphic and physiographic features, clearly targeting physical and geological features of the planet. Physical oceanographic features – water masses, currents and other physical processes – may be most directly related to these terms. Given the caveats noted above on criterion vii, we have identified criterion viii as the most appropriate one for physical ocean processes, with criterion vii having application consistent with its current use on land, for additional values where sites already meet at least one of criteria viii, ix or x. This lack of text in the criteria specifically mentioning ocean processes in contrast to geological processes may pose a significant barrier for expanding the coverage of World Heritage sites in the marine realm.

With respect to biological oceanographic processes, marine species and evolutionary processes, and habitat and ecosystem dynamics are equivalent to those of terrestrial features, so criteria ix and x are appropriate for marine features. Further, criterion ix explicitly mentions the words "coastal" and "marine".

Meeting the criteria

Nominating a site for inscription of the World Heritage List requires a rigorous process of identifying the features of potential OUV at a site, and making a case for inscription. First, this implies that the features of the proposed site are outstanding globally, and to do this effectively requires a global comparative analysis, rating the features of the site up against other sites on a global scale. Secondly, a screening of existing properties on the World Heritage List must be undertaken, to ensure that the site in question is not a redundant addition to the list, and includes some features that are lacking from the existing portfolio of World Heritage sites. Both of these processes require significant investment in conducting the appropriate level of data collection – in situ and from the literature – both on the site in question, and its comparison against sites around the world.

Integrity of World Heritage Sites

It is not enough for a site to meet the World Heritage criteria only. A site must also meet the conditions of 'integrity' and/or 'authenticity' (for cultural sites) and must have an adequate protection and management system to ensure its safe-guarding. The condition of integrity is a measure of the wholeness and intactness of the heritage of the site and its attributes that are established when an adequate and long-term protection and management system is in place to ensure its safe-guarding. Thus, the conditions of integrity and/or authenticity are an integral element when considering the concept and application of OUV and without both having been met a site should not be listed. This question is even more when important when looking at sites that straddle different jurisdictions, in international waters and potentially High Seas.

Management of World Heritage sites

The commitment of a State Party to maintain the OUV of a World Heritage site is equivalent in importance as the values themselves, so potential World Heritage sites go through a rigorous evaluation that includes assessment of the ability to manage and maintain the values for which the site is proposed for inscription.

World Heritage marine sites have many similar characteristics, but their management goals and objectives often differ greatly. IUCN has defined a series of six protected area management categories based on the primary objective of the site (Table 4), and any of these may be compatible with World Heritage designation, so long as the management objectives preserve the feature of OUV at the site. Out of 40 World Heritage marine sites, four categories of management have been specified, the numbers for each being shown in the table below have been specified as either Strict Nature Preserves, managed mainly for science (19 of 40 sites), or National Parks, for ecosystem protection and recreation (20 of 41 sites). Nine of 40 sites are managed as a Habitat/Species Management Area, mainly for conservation, and seven as either a Protected Seascape, for seascape conservation and recreation, or Managed Resource Protected Area, for sustainable use.

Reporting & Monitoring

Inscribing a site on the World Heritage List is not the end of the story. Site managers and local authorities continuously work towards managing, monitoring and preserving the World Heritage properties. States Parties have an obligation to regularly prepare reports about the state of conservation and the various protection measures put in place at their sites. These reports allow the World Heritage Committee to assess the conditions at the sites and, eventually, to decide on the necessity of adopting specific measures to resolve recurrent problems. One of such measures is the inscription

<table>
<tr><th colspan="4">IUCN protected area management categories and definitions</th></tr>
<tr><th colspan="2">Category</th><th>Definition</th><th>Site</th></tr>
<tr><td>1a</td><td>Strict Nature Preserve: protected area managed mainly for science</td><td>Area of land and/or sea possessing some outstanding or representative ecosystems, geological or physiological features and/or species, available primarily for scientific research and/or environmental monitoring.</td><td>19</td></tr>
<tr><td>1b</td><td>Wilderness Area: protected area managed mainly for wilderness protection</td><td>Large area of unmodified or slightly modified land, and/or sea, retaining its natural character and influence, without permanent or significant habitation, which is protected and managed so as to preserve its natural condition.</td><td>0</td></tr>
<tr><td>2</td><td>National Park: protected area managed mainly for ecosystem protection and recreation</td><td>Natural area of land and/or sea, designated to: (a) protect the ecological integrity of one or more ecosystems for present and future generations; (b) exclude exploitation or occupation inimical to the purposes of designation of the area; and (c) provide a foundation for spiritual, scientific, educational, recreational and visitor opportunities, all of which must be environmentally and culturally compatible.</td><td>20</td></tr>
<tr><td>3</td><td>Natural Monument: protected area managed mainly for conservation of specific natural features</td><td>Area containing one, or more, specific natural or natural/cultural feature that is of outstanding or unique value because of its inherent rarity, representative or aesthetic qualities or cultural significance.</td><td>0</td></tr>
<tr><td>4</td><td>Habitat/Species Management Area: protected area managed mainly for conservation through management intervention</td><td>Area of land and/or sea subject to active intervention for management purposes so as to ensure the maintenance of habitats and/or to meet the requirements of specific species.</td><td>9</td></tr>
<tr><td>5</td><td>Protected Landscape/Seascape: protected area managed mainly for landscape/seascape conservation and recreation</td><td>Area of land, with coast and sea as appropriate, where the interaction of people and nature over time has produced an area of distinct character with significant aesthetic, ecological and/or cultural value, and often with high biological diversity. Safeguarding the integrity of this traditional interaction is vital to the protection, maintenance and evolution of such an area.</td><td rowspan="2">7</td></tr>
<tr><td>6</td><td>Managed Resource Protected Area: protected area managed mainly for the sustainable use of natural ecosystems</td><td>Area containing predominantly unmodified natural systems, managed to ensure long-term protection and maintenance of biological diversity, while providing at the same time a sustainable flow of natural products and services to meet community needs.</td></tr>
</table>

Fishing boats, East Africa. Traditional wooden dhows are the primary vessels used throughout the East African and Madagascar coasts. ©Sue Wells

of a property on the List of World Heritage in Danger. In situations where the site deteriorates to a point where the OUV is lost, the World Heritage Committee may decide to remove it from the World Heritage List.

The highest international standard of marine conservation

The *World Heritage Convention* is the leading international legal instrument in natural heritage and biological diversity conservation due to its focus on OUV, the role of World Heritage sites as 'flagship' sites, a tried and proven intergovernmental legal framework, a rigorous deliberative process, and systematic evaluations against established criteria and high standards.

Benefits of World Heritage listing

Once a site is inscribed on the World Heritage List, it joins an international community that values and appreciates outstanding examples of natural wealth. Today the World Heritage concept is so well understood that sites on the list are a magnet for international cooperation and receive financial assistance for conservation projects from a variety of sources. Finally, inscription of a site on the World Heritage List brings an increase in public awareness of the site and its OUV and can lead to increased tourist activities at the site. When tourism is well planned and organized around sustainable tourism principles, it can bring important funds to the site and the local economy. The prestige that comes from having sites inscribed on the World Heritage List often serves as a catalyst to raising awareness for conserving marine natural heritage for future generations.

Becoming a World Heritage site

World Heritage sites are identified through a rigorous, multi-year nomination, evaluation and inscription process that is based on a set of specific criteria. General steps in this process include:

- Local and national level consultations arriving at a decision to pursue World Heritage Listing, including a scientific basis for establishing the values of a site;
- The State Party submits the name of the site, as well as other potential future sites, to the Tentative List;
- The State Party and management agency, local authorities and stakeholders invest in preparation of a nomination dossier that includes all relevant supporting information on the values, integrity and condition of the site, as well as on management structures, capacity and sustainability;
- The site nomination dossier is submitted by the State Party to the World Heritage Centre;
- Evaluation of the nomination, is completed by the IUCN for natural criteria and ICOMOS/ICCROM for cultural criteria (if relevant);
- Recommendations of the evaluation are made to the World Heritage Committee;
- Nominations recommended highly enough are passed by the Committee to the annual meeting of the Council/General Assembly where States Parties vote for acceptance, referral or rejection of a nomination; and
- If accepted, the site is listed on the World Heritage List, and takes on obligations for maintaining the OUV and integrity of the site, with periodic reporting to the World Heritage Centre on the state of the site.

World Heritage in the Western Indian Ocean

This section summarizes the current status of marine sites in the Western Indian Ocean that are already inscribed on the World Heritage List – Aldabara Atoll, Seychelles and iSimangaliso, South Africa – and ongoing tentative listing and nominations. The text on Aldabra and iSimangaliso are presented to show the formal preparation of a statement of OUV, and could be used as a standard to be set in future nominations of sites in the region.

Aldabra Atoll, Seychelles

Aldabra Atoll, in the Seychelles, was inscribed on the World Heritage List in 1982. The site is an outstanding example of biological evolution, containing superlative natural phenomena and the only habitat where a number of animals of OUV can survive. The updated statement of OUV is reproduced below, and further information is available at: http://whc.unesco.org/en/list/185.

The Outstanding Universal Value of Aldabra Atoll, Seychelles	
Criterion (vii) Superlative natural phenomena or natural beauty	Aldabra Atoll encompasses a large expanse of relatively untouched natural beauty where a range of important flora and fauna species thrive, among remarkable land formations and ecological processes, providing a magnificent spectacle of natural phenomena. The lagoon contains many smaller islands and the entire atoll is surrounded by an outer fringing reef. Geomorphologic processes have produced an extraordinarily rugged topography, which supports a variety of habitats with a relatively rich biota for an oceanic island and a high degree of endemism. The richness and diversity of the sea and landscapes in colour and formation gives it an amazing aesthetic appeal.
Criterion (ix) Ongoing biological and ecological processes	The atoll is a superlative example of an oceanic island ecosystem in which evolutionary processes are active within a rich biota. Most of the land surface comprises ancient coral reef (~125,000 years old) which, for the sixth time, has been raised above sea level and colonised by giant tortoises. The size and morphological diversity of the atoll has permitted the development of a variety of discrete insular communities with a high incidence of endemicity among the constituent species. The ecological processes occur with virtually no human interference and can be clearly observed in their full complexity.
Criterion (x) Biological Diversity and threatened species	Aldabra provides a natural laboratory and is a platform for key scientific research and discovery. The atoll constitutes a refuge for viable populations of many rare species, many of which are endemic to the atoll, and consequently has been identified as part of a global Biodiversity Hotspot and an Important Bird Area. Aldabra is inhabited by over 400 endemic species and subspecies (including vertebrates, invertebrates and plants) These include the largest giant tortoise population in the world, the last remaining flightless bird of the Western Indian Ocean the white-throated rail, globally important breeding populations of endangered green turtles and critically endangered hawksbill turtles, vast waterbird colonies including the second largest frigatebird colonies in the world and one of the world's only two oceanic flamingo populations. The giant tortoise population is entirely self-sustaining and all the elements of its intricate interrelationship with the natural environment are evident. The pristine fringing reef system and coral habitat are in excellent health and their intactness and the sheer abundance and size of species contained within them are rarely paralleled in similar ecosystems.

Aldabra Atoll is a prime example of a raised coral atoll that occupies a total area of 346 km^2 and is arguably the largest raised coral atoll in the world. The atoll is home to the largest giant tortoise population in the world, about 10 times larger than that of the Galapagos. Due to its remoteness and inaccessibility, the atoll has remained largely untouched by humans for the majority of its existence. This makes it an extraordinary laboratory in which to study evolutionary and ecological processes. Furthermore, the richness and diversity of the ocean and landscapes result in brilliant colours and formations that give the atoll astonishing appeal and exceptional beauty.

Integrity – the property includes the four main islands that form the atoll plus numerous islets and the surrounding marine area. It is sufficiently large to support all ongoing biological and ecological processes essential for ensuring continued evolution in the atoll. Aldabra displays an almost intact ecosystem and there is a naturally viable population of the species at the top of the terrestrial food chain, a trophic level which, unusually, is occupied by a herbivore; the giant tortoise, which adds to Aldabra's global interest and appeal. The remoteness and inaccessibility of the atoll limit extensive human interference that would jeopardize ongoing processes.

Protection and management – the property is legally protected under the Law of Seychelles Chapter 159, the National Parks and Nature Conservancy Act. In addition a public trust, the Seychelles Islands Foundation, was established by Presidential Decree Chapter 217 in 1979 to manage and conserve the natural life of Aldabra and to initiate and promote scientific research on the atoll. A Management Plan was developed (1998) which guides daily operations. However, there are tremendous logistical challenges related to the remoteness of the property. The most imminent threats are invasive alien species, climate change and oil spills, particularly the latter if oil exploration increases in the region.

iSimangaliso, South Africa

iSimangaliso Wetland Park, in South Africa was inscribed on the World Heritage List in 1999 (then the Greater St Lucia Wetlands Park). The site consists of 13 contiguous protected areas comprising the largest estuarine system in Africa and the southernmost extension of the coral reefs on the continent. It contains a combination of on-going fluvial, marine and aeolian processes that have resulted in a variety of landforms and ecosystems. Features include wide submarine canyons, sandy beaches, a forested dune cordon and a mosaic of wetlands, grasslands, forests, lakes and savanna. Natural phenomena include shifts from low to hyper-saline states in the Park's lakes; large numbers of nesting turtles on the beaches; the migration of whales, dolphins, and whale-sharks offshore, ceolocanths off-shore and huge numbers of waterfowl including large breeding colonies of pelicans, storks, herons, and terns. The Park's location between subtropical and tropical Africa as well as its coastal setting has resulted in exceptional biodiversity, including some 521 bird species.

Brief synopsis

The iSimangaliso Wetland Park, South Africa, covers an area of approximately 3,585 km^2 that encompasses five major ecosystems and has a number of notable and diverse land forms. Over geological time, changing sea levels and depositions have moulded spectacular and diverse landscapes and triggered the intricate processes of the contemporary iSimangaliso wetland system. The Lubombo Mountains, in the west and the spectacular dune systems along an extended and largely unspoilt coastline in the east, enclose the lake systems, consisting of two estuarine-linked lakes (St Lucia and Kosi) and four large freshwater lakes (Sibaya, Ngobezeleni, Bhangazi North and Bhangazi South). The uMkhuze and uMfolozi swamps contain swamp forest, extensive reed and papyrus wetlands, which contrast with the inland western shores, formed from ancient shoreline terraces and consisting of dry savannah woodland. It is this set of exceptional natural assets that were consolidated to form the iSimangaliso Wetland Park ("iSimangaliso"), which is considered a natural asset of global significance that must be conserved for the people of the region, the country and the world. It is also a natural resource that is helping drive the economic revival of a region that was systematically underdeveloped during the apartheid era. Although iSimangaliso was not listed for any cultural criteria, these aspects are important for the site. iSimangaliso has a large repository of Stone Age and Iron Age sites which provide significant evidence of the presence of people for thousands of years in the area, and important insights into how they lived in southeast Africa over time. Many of the communities living in and around iSimangaliso today continue to have a rich relationship with the land and natural environment. Cultural traditions, land use management practices and indigenous knowledge systems continue to shape the current environment. Less tangible but equally important are resources such as significant sacred spaces, oral traditions and rituals.

The Outstanding Universal Value of iSimangaliso, South Africa	
Criterion (vii) Superlative natural phenomena or natural beauty	iSimangaliso is geographically diverse and contains superlative scenic vistas along its 220 km coast, including natural phenomena and areas of exceptional natural beauty and aesthetic importance. From the clear waters of the Indian Ocean, wide undeveloped sandy beaches, a forested dune cordon and a mosaic of wetlands, grasslands, forests, lakes and savannah, the iSimangaliso contains exceptional aesthetic qualities. Three natural phenomena are judged outstanding (i) the shifting salinity states within Lake St. Lucia, which are linked to wet and dry climatic cycles, with the lake responding accordingly with shifts from low to hyper-saline states, (ii) the spectacle of large numbers of nesting turtles on the beaches, and the abundance of dolphins and migration of whales and whale sharks offshore, and (iii) the large numbers of waterfowl and large breeding colonies of pelicans, storks, herons and terns.
Criterion (ix) Ongoing biological and ecological processes	iSimangaliso is an outstanding example representing significant ongoing ecological and biological processes in the evolution and development of terrestrial, fresh water, coastal and marine ecosystems, and communities of plants and animals. The combination of fluvial, marine and aeolian processes initiated in the early Pleistocene in iSimangaliso has resulted in a variety of landforms and continues to the present day. The transitional geographic location between sub-tropical and tropical Africa as well as the coastal setting have resulted in exceptional species diversity. Past speciation events in the Maputaland Centre of Endemism are also ongoing and contribute another element to the diversity and interplay of evolutionary processes at work in iSimangaliso. In its marine component, the sediments being transported by the Agulhas current are trapped by submarine canyons on the continental shelf allowing for remarkably clear waters for the development of coral reefs. Major events such as droughts, floods and coastal storms, are regularly experienced in iSimangaliso, further complicate the interplay of this environmental heterogeneity. The site is also of sufficient size and retains most of the key elements that are essential for long-term functioning of the ecosystems. The ecological linkages between the five ecosystems found in the iSimangaliso Wetland Park have been a major attraction for research on the geomorphological and biological processes occurring there.
Criterion (x) Biological Diversity and threatened species	The five interlinked ecosystems found in iSimangaliso provide habitat for a significant diversity of African biota, including a large number of rare, threatened and/or endemic species. iSimangaliso contains some of the most important and significant natural habitats for the in-situ conservation of biological diversity, including those containing threatened species of OUV from the point of view of science or conservation. The five ecosystems are (i) the marine ecosystem, characterised by a warm sea, the southernmost extension of coral reefs in Africa, submarine canyons and long sandy beaches (ii) the coastal dune system, consisting of linear dunes up to 180 m in height, sub-tropical forests, grassy plains and wetlands (iii) lake systems, consisting of two estuarine-linked lakes (St Lucia and Kosi) and four large freshwater lakes (Sibaya, Ngobozeleni, Bhangazi North and Bhangazi South) (iv) the uMkhuze and uMfolozi swamps, with swamp forest, extensive reed and papyrus wetlands, and (v) the inland western shores, with ancient shoreline terraces and dry savannah woodlands, thickets and sand forests that occur on the higher lying ground between the coastal plain and the Lubombo Mountains. As iSimangaliso is situated on the southernmost extremity of the Mozambique coastal plain, it hosts numerous species reaching the southernmost limit of their range which are, thus, not found elsewhere in South Africa. This adds to the value and importance of this unique area from a South African species conservation perspective. The presence of some of these species north of our borders cannot detract from the importance of conserving the South African populations, as little information is generally available on their conservation status and distribution in other parts of southern and central Africa. iSimangaliso is clearly a critical habitat for a range of species from Africa's marine, wetland and savannah environments. The species lists for iSimangaliso are the lengthiest in the region and population sizes for most of them are viable. Of the over 6,500 plant and animal species known to occur in the Park, populations of species of conservation importance include 11 species that are endemic to the Park, and 108 species endemic to South Africa, while 467 are listed as threatened in South Africa. In addition, iSimangaliso contains four Ramsar sites that recognise the ecological functions of wetlands as well as their importance as resources of economic, cultural, scientific and recreational value (i) St. Lucia Lake System (Ramsar Site # 345) (ii) Turtle Beaches/Coral Reefs of Tongaland (Ramsar Site # 344) (iii) Kosi Bay Lake System (Ramsar Site #527), and (iv) Lake Sibaya (Ramsar Site # 528). The remarkable ecological diversity and significance of iSimangaliso is, therefore, unique, not only on the African continent, but also in a global perspective, adding to its importance.

Sites including marine features in the region on the World Heritage Tentative List				
Site name	**Ref. #**	**Site type**	**Criteria**	**Date submitted**
Marine Ecosystems for the Comoros Archipelago	5107	natural marine	(ix) (x)	31 January 2007
Ponto de Ouro Protected Marine Area	5382	natural marine	(vii) (x)	20 May 2008
Quirimbas Archipelago	n/a	mixed natural and cultural	(ii) (iv) (x)	20 August 2008

Integrity – Many of the issues and challenges identified by the World Heritage Committee at the time of the inscription of iSimangaliso as a World Heritage site have been resolved. Previously comprising fragmented parcels of land, iSimangaliso has been consolidated into one proclaimed protected area under South African legislation, the *World Heritage Convention* Act. Importantly this act adopts the Convention and writes the protection of the World Heritage sites into South African law, whilst also recognising the need to deliver economic and social benefits to neighbouring communities, without which the long term integrity of the Property could be compromised. Added to this, a zone of influence (buffer zone) has been delineated along iSimangaliso's boundary, where development controls afford the Park an additional layer of protection. The necessary conservation and visitor infrastructure that is required for effective conservation and interpretation of the Park's universal values has largely been put in place including, fencing most of the Park. Conservation programmes include the reintroduction of native species and removal of alien commercial plantation species from iSimangaliso, with on-going and rigorous alien plant control programmes being applied. Additional terrestrial and marine areas of ecological significance to the iSimangaliso has also been incorporated into the Park. Nine of the 14 land claims have been settled under a National Government policy framework which ensures that iSimangaliso will be managed by the state in perpetuity as a conservation area.

Protection and management – South Africa has solid legislation that affords iSimangaliso the necessary legal protection. Furthermore, the Park is managed by a dedicated agency founded in South African law, the iSimangaliso Wetland Park Authority. The iSimangaliso Authority has made significant progress in the past 10 years. Policies and plans have been formulated and systematically implemented, monitored for effectiveness, reviewed and adapted. A range of challenges that require management and intervention remain; two critical issues being the diminished hydrological functioning of the Umfolozi River and the delivery of meaningful benefits to communities. To meet the many and varied challenges the iSimangaliso Authority has developed and consulted its Integrated Management Plan. This updated five year plan will guide the on-going protection and development of iSimangaliso, ensuring its integrity and the values for which it was originally inscribed on the World Heritage List. Dedicated programmes aimed at enhancing the hydrological functioning of the Umfolozi River and implementing the iSimangaliso People and Parks' programme have been put in place. In addition, WH listing helped prevent further proposals to mine Titanium in the sand dunes and other industrial activities which would have negatively impacted the area.

National tentative lists

Some States Parties in the Western Indian Ocean have already named sites to the Tentative World Heritage List, which are listed above. The contents of the Tentative Lists were not consulted in preparation for this study in order not to influence the overview of unique features of the WIO, and the findings of this report may be used in strengthening existing nomination processes where possible.

There are currently three sites including marine features in the region on the World Heritage Tentative List.

2

Methodology

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Methodology

The overall aim of this assessment was the identification of marine areas in the Western Indian Ocean (WIO) that could be of Outstanding Universal Value (OUV), through a generic approach that can be applied to other regions. The method uses an approach that is more suitable to the dynamics of the marine environment and at scales more meaningful from an ecosystem perspective. This approach can greatly enhance comprehensive support to States Parties when identifying new potential marine World Heritage sites, and ultimately facilitate conservation of the site once inscribed on the World Heritage List. In parallel with this document, IUCN is developing general guidance for the identification of natural marine sites of OUV for inclusion on the World Heritage List (Abdulla et al., in prep). It has a global overview in contrast to this regional one, with a focus on the gaps in the existing WH List in terms of biogeography, habitat, and region.

The methodology followed three main steps, using data and information already available as peer-review scientific publications, grey literature reports, and expert knowledge, and with particular attention to historical biogeographic and biodiversity analyses. These steps were: 1) identification of the appropriate bio-regional scale at which to apply the assessment; 2) identification of the key physical and biological features that distinguish the region compared to others globally; and 3) identification of the sites in the region that exemplify these features, and that also are of sufficient integrity and scale to meet the criteria of OUV.

The global significance of the Western Indian Ocean

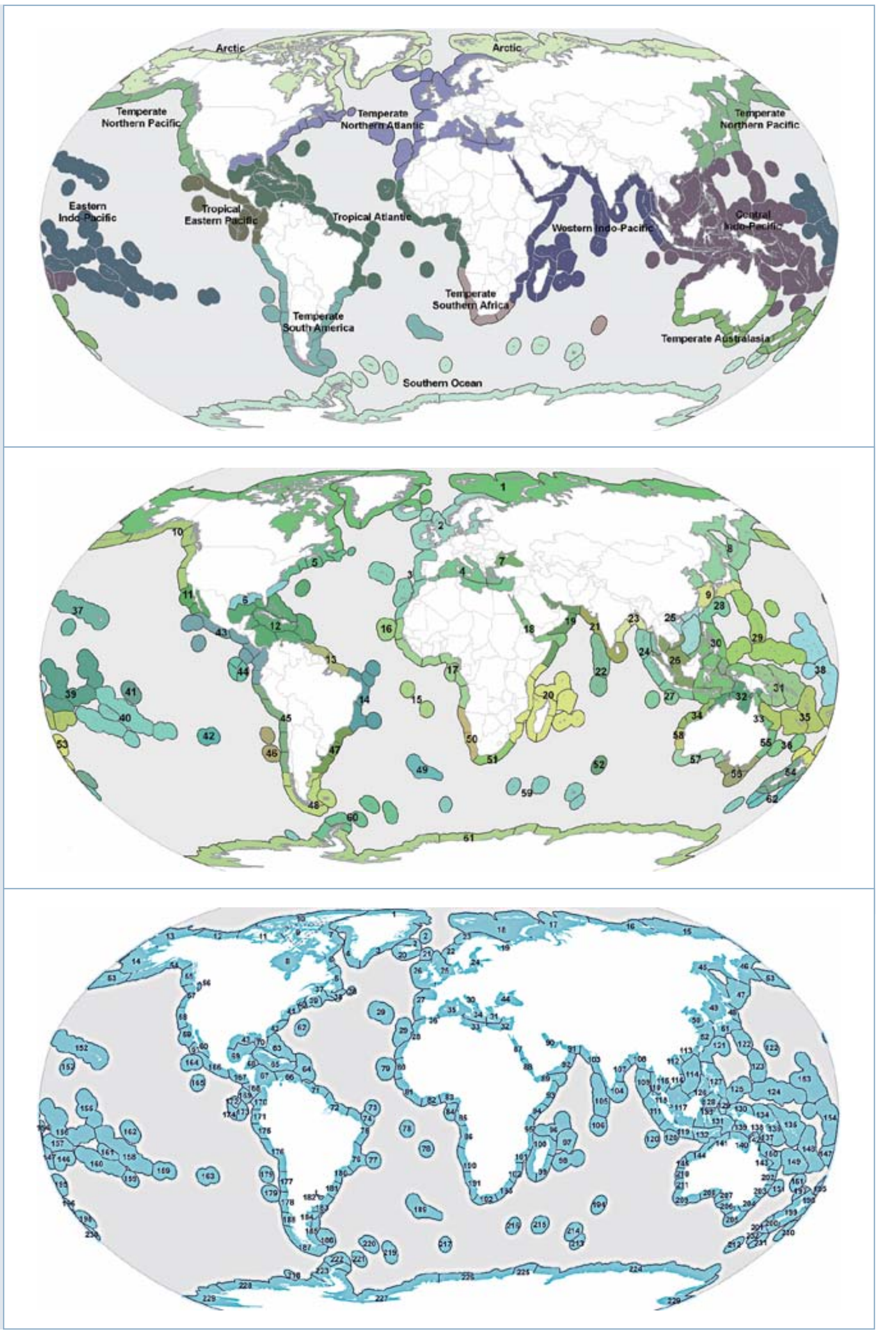
The Indo-Pacific is the largest marine biome on the planet distinguished primarily by the continuity of tropical marine ecosystems and species carried by equatorial currents along an east-west axis. For the tropical fauna of relevance in this study, this biome is entirely separated from the tropical Atlantic, though they share common origins from the Tethys Sea, which allowed circumglobal tropical currents up to the Miocene or about 20 million years ago (mya). Now the Indo-Pacific, by virtue of its size and complexity, contains by far the highest diversity of tropical marine species, as well as the bulk of tropical and subtropical marine habitats from shallow coastal seas to the deep ocean.

The central part of the Indo-Pacific, in the Southeast Asian region now coined the 'Coral Triangle', hosts a far greater abundance of species per unit area within tropical marine ecosystems than any other place on earth, reflecting the confluence of multiple speciation and diversity maintaining processes over periods of tens of millions of years (Roberts et al. 2002). This diversity spills out to the east and west, and at present the diversity of species at the margins of the Indo-Pacific is dominated by this Central Pacific center of high diversity. Nevertheless, peripheral regions have a distinct history, and the western part of the Indian Ocean is distinguished by its closer geographic and evolutionary history with the ancient Tethys Sea, and processes of isolation and vicariance that result in endemism and restricted species ranges unique to the region.

Subdividing the Indo-Pacific has always created a challenge for biogeographers. Spalding et al. (2007) note that very few species occur across the entire region. Of the 4000 shore fishes found in the region only 12 are found in common between the Red Sea, Easter Island and Hawaii; and moving in from these extreme limits, only 492 species are shared between the Western Indian Ocean and French Polynesia (Randall, 1998). The Marine Ecoregions of the World (MEOW) classification scheme has drawn a primary boundary at the level of Realms, of which there are four in the Indo-Pacific: the West, Central, and East Indo-Pacific Realms and the East Pacific Realm. A level below these are the provinces, of which the WIO is one of seven in the West Indo-Pacific Realm, and below these are ecoregions, of which there are nine in the WIO Province.

Prior to the MEOW classification, the distinctness of the WIO has been recognized within the broader Indian Ocean and Indo-Pacific biome by a variety of historical studies (Briggs 1974, Kelleher et al. 1995), reflecting the consistency of biogeographic patterns, and its distinctness from the other marine regions of the planet. This distinctness of the WIO is the foundation of Part 3 of this report, but can be summarized as the following (Obura, in review, a):

- Dominance of the South Equatorial Current (SEC) as a conveyor belt of species from east to west;
- Northern connections with Red Sea and Arabian Gulfs subregions, where extreme environments and isolation resulting in distinct ecosystems and high endemism of species;
- Gyres in the northern (seasonal) and southern parts of the western Indian Ocean, reaching as far east as Sri Lanka/western India, and the Mascarene islands (respectively) creating distinct subregions isolated from the eastern Indian Ocean and West Pacific; and
- These features are layered on top of a geological history that features the opening of the Indian Ocean first as the Mozambique channel opened, then India and Australia moved away from the African coast at the same time as northward movement of Africa and India closed off the Tethys Sea from 45-15 mya (Obura, 2012).



Marine Ecoregions of the World (MEOW), showing realms (top), provinces (middle) and ecoregions (bottom). This study focuses on the Western Indian Ocean Province and its 9 ecoregions, in a framework designed to identify unique and superlative features and sites of global significance and Outstanding Universal Value.

© Spalding et al. 2007

Taken together, these factors result in a biologically distinct region with unique features at the level of the Indo-Pacific as well as globally. The methodology and analysis in this report represent an effort to standardise a process for identifying and assessing the global significance of sites, to evaluate their OUV for designation as World Heritage Sites. In addition to serving as a pilot toward a more ecologically sound approach for identifying marine gaps on the World Heritage List, the results of this work also aim to enhance knowledge and understanding among the States Parties in the region, primarily African countries, of the potential for marine World Heritage sites that lie within their jurisdiction. Next steps will focus on working with the respective States Parties to explore with them potential inscription of the respective sites which are identified as likely of OUV through this scientifically based project.

Ecoregions within the Western Indian Ocean Province (#20)

- 94 North Monsoon Current
- 95 East African Coral Coast
- 96 Seychelles
- 97 Cargados/Tromelin
- 98 Mascarene
- 99 Southeast Madagascar
- 100 West & North Madagascar
- 101 Sofala
- 102 Delagoa

Unique regional features

The Marine Ecoregions of the World (MEOW) establishes a hierarchical classification that defines Realms, Provinces and Ecoregions (Spalding et al, 2007). The distinctive features relevant to the WIO are described in a companion document to this one (Spalding 2012). Within the WIO, the MEOW scheme identifies nine Ecoregions, with additional support for these in Obura (in review) based on a detailed study of scleractinian corals. Obura (in review) extends the biogeographic analysis of Spalding et al. (2007) to include geological and oceanographic features that drive the region's uniqueness on a global scale. Together, these provide a framework for describing those features of the WIO that make individual sites and zones globally unique.

We identified features in the WIO relevant to criteria viii, ix and x of the World Heritage List that make it unique, and on the basis of which OUV can be assessed. The main features were grouped into:

The physical processes that define and drive the region:

- Geology – the plate tectonics and hotspot activity of the Indian Ocean; and
- Oceanography – major currents and productivity processes that define biological linkages across the Ocean, and its sub-regional structure;

On the basis of these, the biological characteristics and processes present in the region:

- Biogeography – the overall distribution of species across the WIO and how this reflects the historical and present-day processes that have led to the suite of species and habitats present today;
- Habitats – the major and unique habitats and ecosystems in the WIO; and
- Species – species of special concern, and that are unique, or show unique patterns and behaviours on a global scale.

The first part of the results describes each of these in detail, with a focus on how they are evident in the WIO.

Potential sites of Outstanding Universal Value

The final step was to identify a shortlist of sites that illustrate how the unique features of the WIO are expressed to the highest level at these locations. In practice the geological and oceanographic features that were unique for the WIO identified large geographic zones. Within these, sites with particular instances of these two classes of features, and different cases of biological features, were identified. Thus, we present these broader geographic zones of geological and oceanographic OUV, followed by smaller sites with specific instances of these values plus the biological features of the individual sites. This approach emphasizes the fact that while many of the features are spread across the region, only a few sites express them to a sufficient level to meet the OUV criteria of the *World Heritage Convention*. At the same time, it is not only the sites mentioned here that might meet the criteria, and States Parties may consider other sites with sufficient value as alternatives.

In the description of each site, the following aspects are presented:

- Site name and location, with approximate geographic coordinates, and a description of the sites.
- Presentation of potential OUV – based on criteria viii–x of the Convention, how one or more of the features within the site are outstanding for the WIO and globally;
- Geographic scale, integrity and site type are strongly dependent on one another – designation of a site may vary from small to large depending on many factors, and options for this with respect to exclusion/inclusion of multiple other features including human populations and threat sources are discussed. A key issue of concern is the integrity of the site necessary to maintain its OUV, and how geographic scale may influence this. Scale also influences whether a single, cluster or transboundary designation might be appropriate, and the pros and cons of each in the context of the features for which the site is selected.
- Threats and Management – a basic summary of existing or potential threats and management approaches necessary to maintain the OUV of the site are presented. A full understanding of threats and management challenges would require in-depth socio-economic and contextual studies on a site by site basis, and are more appropriate for pre-nomination stages in the process (see Part A).

Information sources

Primary sources of data included the two ecoregional prioritization exercises conducted for the mainland East African coast (WWF 2004) and the Indian Ocean Islands (RAMP-COI, unpublished) plus scientific data from the literature and contributed by experts. Detailed reference lists are provided in each subsection. The ecoregional studies considered a range of data, focusing on environmental factors driving biological patterns and ecoregional boundaries, habitat distributions and representation, and species diversity patterns. They were based on compilations of data where possible, such as temperature, currents, bathymetry and cholorophyll, for physical environmental variables, and maps of major habitats and key species distributions.

Species diversity was considered on the basis of reported species presence and species richness at individual sites, where such data are available, such as in marine protected areas where surveys have been conducted in the past. It is important to note, however, that rigorous geographic databases for species and habitat distributions are not available for the WIO. Richmond (2001), Griffiths et al. (2005) and Wafar et al. (2010) all note the exceptionally large gaps in species distribution records across the WIO and the Indian Ocean. The same is true for habitat distributions, which are largely derived from localized studies or unverified interpretations from satellite images. These render quantitative assessments of habitat and species distributions inaccurate, requiring an approach based on expert knowledge to extrapolate beyond existing datasets. Both the WWF (2004) and RAMP-COI (unpublished) studies followed this approach, and this study builds on these interpretations with new data and additional insights.

An expert workshop was held in La Reunion, from 14-16 February 2012, at which initial findings of this analysis were presented to regional experts for comment and review, and consideration of additional features and sites if necessary. Further consultations with other experts were conducted by email, and in all cases supporting documentation was collected.

Marine processes and representation

Under the umbrella of the Convention on Biological Diversity (CBD) and the United Nations Environment Program (UNEP), a process to clearly identify Ecological and Biologically Significant Areas (EBSAs) has been underway. As in other processes, marine ecosystems, and particularly the open oceans and deep seas – including Areas Beyond National Jurisdiction (ABNJ) or the High Seas – have been among the last systems to be considered. The CBD process was given a significant boost when the criteria for identifying EBSAs were adopted in 2008 at COP9 (IX/20, annex 1). In response, the Global Ocean Biodiversity Initiative (GOBI) was formed, with support from the German government (President of the CBD at the time), to provide informal scientific and technical advice and guidance. Within the CBD process, scientific and technical experts met in an expert workshop in 2009 to provide additional scientific and technical guidance on the use and further development of biogeographic classification systems, and to identify sites which meet the criteria. The Saya de Malha Bank was one of the first sites to be chosen as an "illustration" of a place that could possibly met EBSA criteria 1, 2, 3 and 5.

The complementarity of the World Heritage and EBSA processes for marine sites arises first from the focus of the former on waters within national jurisdictions, while the latter is focused on the open oceans and deep seas, which are often beyond national jurisdiction, though it can also apply to waters within national jurisdiction. Second, the three main natural criteria of OUV (viii- geological and oceanographic processes; ix- ecology, species and evolution; x- habitats and conservation), overlap with the seven EBSA criteria, so that meeting the OUV standards of *World Heritage Convention*, and scoring High for the EBSA criteria should provide generally consistent results.

Another complementary process is the identification of Key Biodiversity Areas (KBAs), which has arisen from a variety of institutionally-bound initiatives such as the Important Bird Areas (IBAs) of BirdLife International, the Top 200 ecoregions of WWF and Biodiversity Hotspots of Conservation International. As IUCN states, "KBAs are places of international importance for the conservation of biodiversity through protected areas and other governance mechanisms. They are identified nationally using simple, standard criteria, based on their importance in maintaining species populations". The primary difference with the World Heritage criteria is that these are applied, and assessed, on a global basis, while KBAs, though the criteria are international in scope, are assessed and selected on a national basis. However a new initiative coordinated jointly by the IUCN Species Survival Commission and the World Commission on Protected Areas (Consolidating the global standards for the identification of sites of biodiversity conservation significance) is currently evaluating criteria and processes to standardize the identification of KBAs across the world, and for terrestrial and marine realms.

EBSA Criteria

1) Uniqueness or rarity
2) Special importance for life history of species
3) Importance for threatened, endangered or declining species and/or habitats
4) Vulnerability, fragility, sensitivity, slow recovery
5) Biological productivity
6) Biological diversity
7) Naturalness

Key references – Abdulla *et al.* (in prep); Badman *et al.* (2008); Briggs (1974); Dingwall *et al.* (2005); Ehler & Douvere F (2011); Griffiths (2005); Hillary *et al.* (2002); IUCN (2006); Kelleher *et al.* (1995); Laffoley & Langley (2010); Norse *et al.* (2005); Obura DO (in review); RAMP-COI (unpublished); Randall (1998); Richmond (2001); Roberts *et al.* (2002); Spalding *et al.* (2007); Spalding M (2012); UNESCO (2008); Wafar *et al.* (2011); World Heritage Committee (1994); WWF (2004).

3

Unique marine features of the Western Indian Ocean

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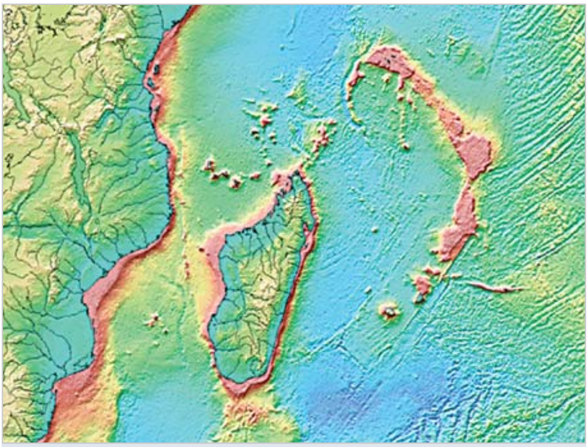
Geology



Bathymetry of the WIO showing the spreading ridge to the east, the arc of the Mascarene Plateau, deep basins to the north (Somali), center (Mascarene) and south (Madagascar), islands and ridges in the Mozambique channel and shallow plateau south of Madagascar.

© topex; http://topex.ucsd.edu/marine_topo/

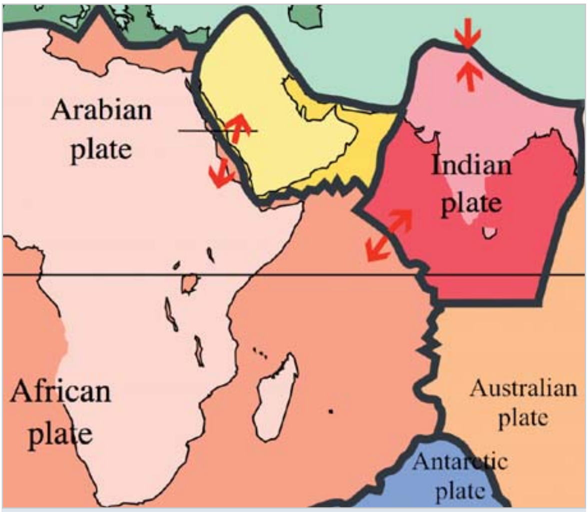


Plate structure of the Indian Ocean. © Wikimedia

The Western Indian Ocean alone contains every type of tectonic plate boundary, both active and fossil, some of the deepest fracture zones, the most complex mid-ocean ridge configurations and some of the thickest sedimentary sequences of the world's ocean basins. It is one of the most geologically diverse ocean basins on the planet. The continental land mass of Africa, the micro-continent Madagascar, and the North Seychelles Bank, are remnants of the supercontinent Gondwana, dating from pre-Cambrian times, over 650 mya, and that started to break up 180 mya.

Ocean basins – the Indian Ocean spreading ridge rises to just under 2000 m depth, isolating the WIO from deep waters to the east. The four deep basins in the WIO include the Madagascar (5500 m, southeast of Madagascar), Mascarene (4900 m, west of the Mascarene Plateau), Mozambique (5000 m, south of the Mozambique channel) and Somali basins (5100 m, between Somalia and the Seychelles). Little has been done on the abyssal plains and soft sediments of these basins, though drilling on and near the Mascarene Plateau shows thick accumulations of marine sediments, and in the Mozambique channel of terrestrial sediments.

Plate tectonics – the ocean floor is composed of three major plates, the African, Indian and Australian plates, and the Arabian plate in the north, with an active rift along the Central Indian Ocean ridge. The Indian Ocean started to form 180 million years ago (mya), when the land mass containing the future Madagascar, Australia, India and Antarctica split from the African coast. From 120 mya Australia started to separate from Madagascar-India, and from 80 mya, India started to separate from Madagascar and move northwards. From about 70-50 mya the Indian Plate exhibited among the highest recorded speeds, up to 16 cm/yr, potentially as a result of superplume activity of the Reunion hotspot. Currently the Indian and Australian plates are rifting away from the African plate, but with apparently little motion relative to one another. The Arabian plate is rifting from the African plate, forming the Red Sea, starting in the Eocene and accelerated during the Oligocene.

Hotspots and magmatic provinces – the Western Indian Ocean contains a number of these, including the Mascarene-Reunion hotpot, the Comoros hotspot and the remnants of massive magmatic extrusions including features in India (Deccan Traps), Madagascar and the underwater plateau extending southwards (Cretaceous activity) and others.

Mascarene-Reunion hotspot – at the Cretaceous-Tertiary (K-T) boundary, about 67-64 mya, a massive eruption of magma that formed the Deccan Traps in India (classified as a Large Igneous Province, or LIP) occurred as India was already moving away from Madagascar, and is implicated in the stranding of part of the Indian continent as part of the northern Seychelles bank in the middle of the ocean. The 'superplume event' that produced the Deccan Traps may have played a role in the last of five mass extinctions that have occurred in the Earth's history, at the K-T boundary, in which all the dinosaurs and up to 30 % of genera of many marine taxa (including corals), went extinct.

Following this, the Mascarene-Reunion hotspot remained active, and combined with the rapid tectonic movements of India, has produced a unique mid-ocean feature – the volcanic islands and carbonate-topped banks of the western and central Indian Ocean, the Mascarene Plateau.

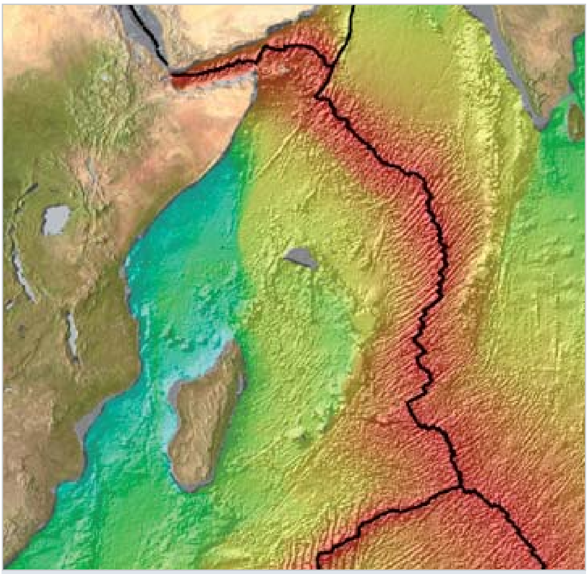
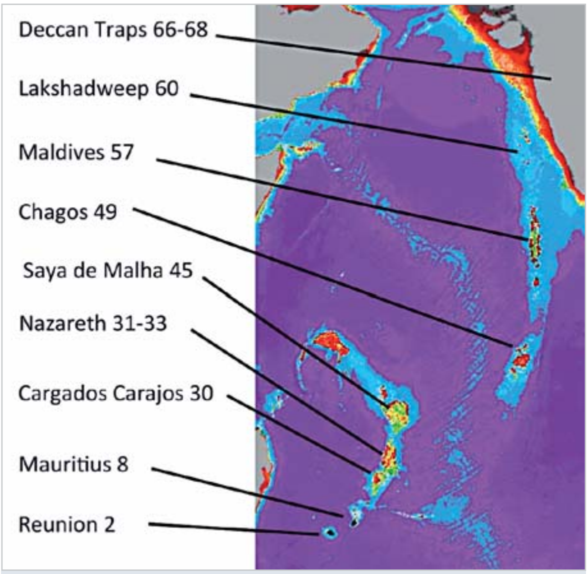


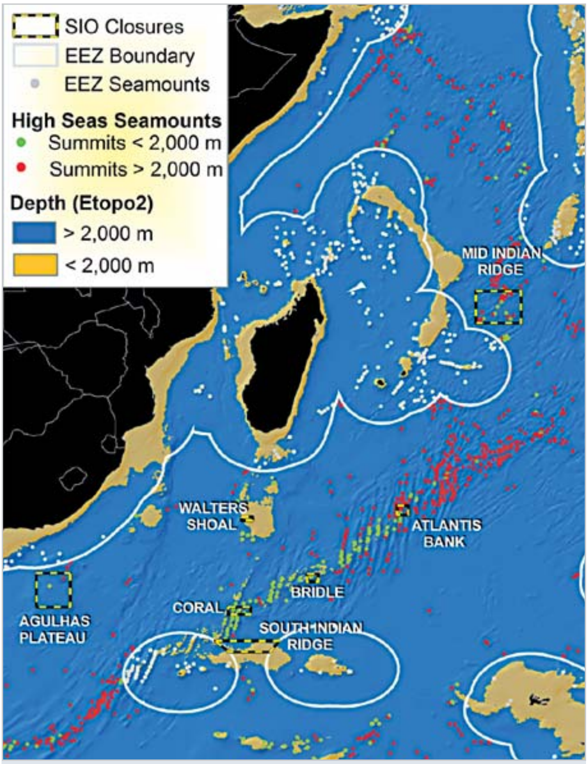
Plate structure of the Indian Ocean.



Hotspot track and approximate age of banks and islands.

Starting with the Lakshadweep – Maldives chains (57-60 mya), the series of banks and islands strung southwards down the Indian Ocean were produced: the Chagos archipelago (48mya), Saya de Malha (45 mya), Nazareth and Cargados Carajos banks (34 mya), Mauritius (7-8 mya) and finally, Reunion (0-2 mya), which is still volcanically active today. Two complications add further interest to this system: the northern Seychelles bank and its granitic islands are remnants of continental rock, stranded in mid-ocean as India passed over the spreading ridge 65 mya. Second, the spreading ridge itself moved over the hotspot about 45 mya, splitting the Chagos and Saya de Malha banks, and forming a kink in the otherwise continuous chain from India to Reunion. These islands and banks form a classic example of the progression from volcanic high islands to sunken coralline banks, from Reunion to India, charting the span of the entire Cenozoic era.

Marion hotspot - Madagascar Plateau – the continental fragment of Madagascar lay over the Marion hotspot during the Cretaceous, with significant evidence of activity during this period in south of the island. The submarine Madagascar Plateau was formed by basaltic lava from the Marion hotspot, as Madagascar and Antarctica separated during the Cretaceous. Called the Rowley shoals in maritime charts and known for highly turbulent conditions induced by the Plateau, this geological feature is a southward extension of Madagascar at depths of 1,000 – 2,000 m, rising above the deeper basins to the east and west up to 5,000 m deep. Activity of the Marion magmatic plume is also implicated in the breakup of Madagascar and India, and India's rapid migration northwards preceding the activity of the Mascarene-Reunion hotspot.



Seamounts in the Western Indian Ocean, shown as green dots.

Mozambique Channel – within the Mozambique channel, the Davies ridge runs north-south between about 13 and 18°S, rising to nearly 300 m below the surface, with origins reminiscent of old continental or lithospheric fractures left over by the initial separation of Madagascar from the African continent. The formation of the Comoro archipelago is poorly known, with one theory based on magmatic extrusion associated with these lithospheric fractures. An alternative explanation emphasizes recent volcanic activity during the Miocene from about 10 mya, such as of the Montagne d'Ambre, a large massif at the

Some consequences of these features of the WIO region		
Tectonic/hotspot implications	**Age, location and climate**	**Oceanography**
Both plate movements and hotspot activity in the WIO had major consequences in the history of not only the Indian Ocean but also the planet, including the K-T extinction event, formation of the Mascarene Plateau, and fusion of India with Asia.	The African and west Madagascan coasts are the oldest coastlines of the Indian Ocean, dating from their breakup almost 180 mya. The Mozambique Channel may be one of the oldest tropical coastlines, and perhaps a stable refuge over many tens of millions of years Africa/Madagascar have moved little over the last 65 million years (some northward migration, on the order of 15° latitude), and their relative positions have remained relatively constant.	The evolution of tectonic features and changes over time influence the pattern of ocean currents, with potentially profound and unique consequences on the evolution of life in the WIO and broader IO and adjacent seas.

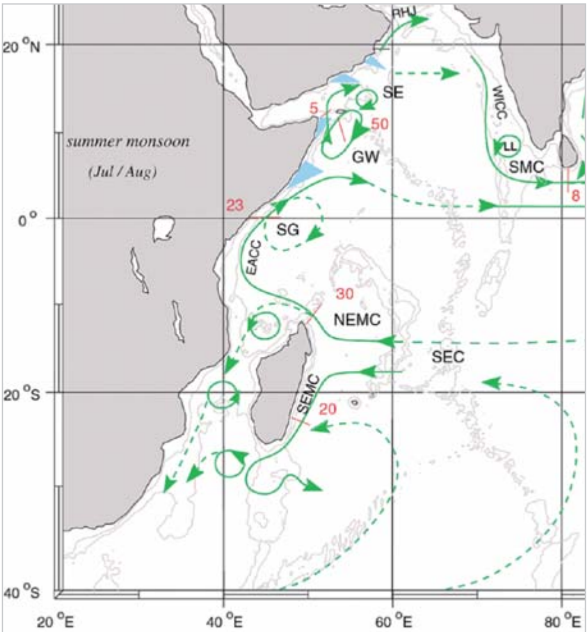
northern tip of Madagascar. This preceded activity of the Comoros hotspot which has produced the Comoros archipelago, ranging from the oldest island, Mayotte (5.4 mya), to the youngest island, Ngazidja (Grande Comore, ≈130,000 ya).

Seychelles-Mascarene activity – A complex geological history is also suggested by the multiple islands and groups in the Seychelles, such as the Aldabra group, Farquhar/Providence and the Amirantes. The island of Rodrigues is associated with the Soudan bank that stretches between it and Mauritius, and are a result of the complex fractures extending at right angles from the Central Indian Ocean ridge. Capping these diverse geological island/bank features, are a diverse array of shallow-water carbonate-producing systems, from classic island-arc subduction series of fringing – barrier – atoll – submerged reefs (Mascarene Plateau and Comoros-Glorieuses islands) to isolated carbonate caps (Farquhar, Amirantes).

Seamounts in the WIO are concentrated on the mid-ocean ridges, particularly the South West Indian Ridge to the south of the WIO, and scattered around the Mascarene Plateau, most likely a result of the same features that formed the individual island and bank systems mentioned above. These latter seamounts are the only ones within the EEZs of the regional countries.

Key references – Ali & Huber (2010); Cande & Stegman? (2011); Duncan (1990); Dyment (2004); Parson & Evans (2004); Rajan *et al.* (undated).

Oceanography



July to August (southern winter).

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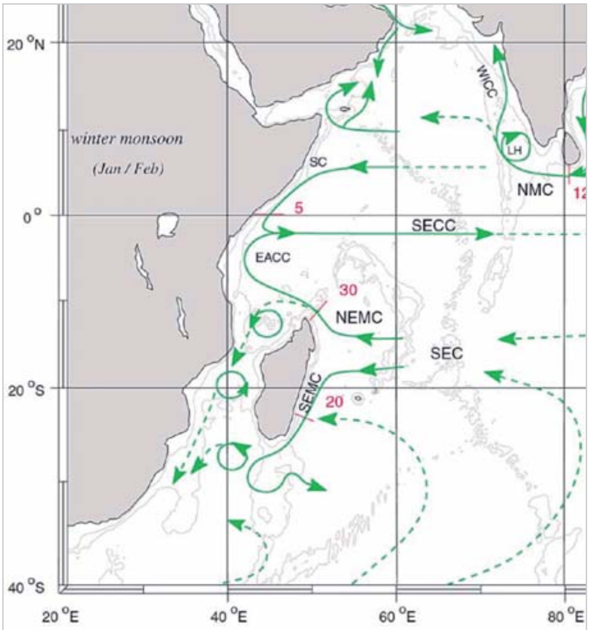

January – February (southern summer).

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The oceanography of the Western Indian Ocean is dominated by three features arising from its geology and tectonic history – the Asian landmass in the north, the island of Madagascar, and the Mascarene Plateau – and their interactions with the equatorial and western boundary currents of the Ocean basin. The Asian landmass drives the seasonal monsoon system that dominates the climate of this region of the globe, while Madagascar and the Mascarene Plateau interact with the currents imparting meso-scale (features on a scale of about 100-500 km) dynamics that are unique to the ocean. The dominant features of the oceanographic processes in the WIO are:

The **South Equatorial Current (SEC)** enters the WIO as a broad slow surface current stretching from about 5–16°S, fed from the Indonesian Through-Flow with waters from the Pacific, and passing by the Chagos archipelago at its northern edge, which forms a significant stepping stone for species and genetic connectivity. At the Mascarene Plateau the SEC is partially blocked, with 50% of its flow forced through the narrow gap between the Saya de Malha and Nazareth banks at about 12°S, a small proportion flows north of Saya de Malha to the main Seychelles Bank, and the balance flows south of the Cargados Carajos bank, concentrated at about 17–18°S. Approaching Madagascar, the main flow of the current is at about 17°S.

In the **Mozambique Channel**, the tip of Madagascar Island, the Comoros-Glorieuses chain, and the narrowest point in the channel, at 16°S, interact with the flow of the SEC and open ocean features such as Rossby waves to generate unique and highly dynamic meso-scale features. The "Glorioso Front" likely marks the transition from the SEC to the waters of the channel, where a series of cyclonic and anti-cyclonic eddies and an intermittent gyre around the Comoros chain are induced. Driven by these features, water may flow in any direction resulting in a highly mixed and dynamic water body, with a more concentrated southward flow starting at the channel narrows extending in a narrow jet of highly dynamic water offshore of the Mozambique coast. Complex forcing of biological parameters results from these dynamics, including up- and downwelling in the eddies and their interactions with the continental shelves and slopes below at least 1000m depth. As a result, the Mozambique channel is one of the most energetic western boundary zones of all the world's oceans.

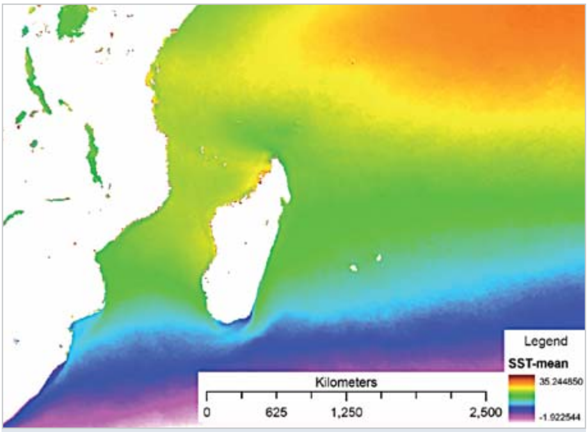
Curling around the southern tip of Madagascar, the rapid flow of the East Madagascar Current interacts with the **Madagascar Plateau**, which extends southwards over 1000 km at depths of 1000 to 2000 m. This results in highly dynamic nearshore eddies and nearshore–offshore upwelling over 100s of square km of sea, fertilizing highly productive food webs. At the transition zone between tropical and subtropical regions, this also results in unique communities and high levels of endemism.

At the SW corner of the WIO, the **Agulhas Current** receives water from these two hyper-variable and productive source regions – the Mozambique Channel and the Madagascar Plateau – merging into one of the fastest and narrowest coastal boundary currents in the world. Most of the Agulhas waters turn 180° (retroflect) and return into the southern Indian Ocean at about 40°S. Along with an east-flowing current at about 24°S that was only recently discovered, these currents influence the southern Indian Ocean and the Mascarene Islands. At the Agulhas Current retroflection a small number of 'rings' pinch off and enter the south Atlantic, feeding warmer waters into the Atlantic surface circulation.

In the north, the seasonally reversing **Somali Current** and seasonal **northern Indian Ocean** gyre are dominated by the influence of the Asian land mass and the monsoons, resulting in a highly dynamic system of currents and an intermittent North Equatorial Counter Current that returns water from the East African coast towards the Seychelles, at about 0–2°S.

Ocean-climate interactions

The Western Indian Ocean interacts with regional and global climate systems on three scales – seasonal, interannual to decadal and over the long term. The **monsoon seasonality** of the Indian Ocean is perhaps one of the strongest ocean-climate interactions on the planet. Driven by the summer-winter oscillation of solar heating over Asia, it results in oscillating trade winds and associated shifts in currents in the Indian Ocean. During the southern winter, when the sun is over Asia and North Africa, the resulting low pressure system sucks in air masses from the south resulting in southeasterly winds, associated with cooler temperatures and generally rough conditions in the Indian Ocean. During the southern summer, northeasterly winds are established drawing hotter dry air from Asia and the Sahara southwards. In between these seasons, calmer inter-monsoon doldrum conditions prevail. The alternating winds cause current reversals in the northern part of the



Mean sea surface temperatures across the WIO.

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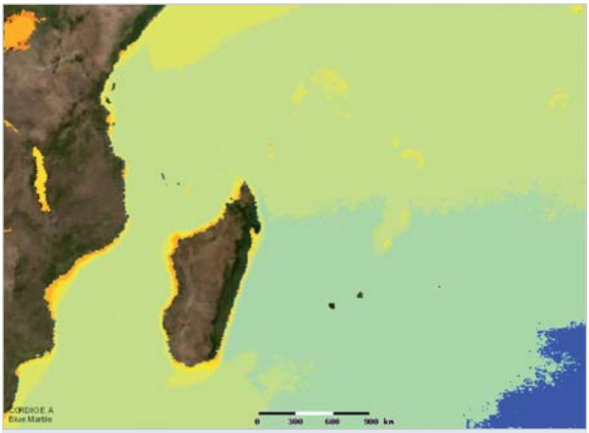

Mean cholorophyll concentrations across the WIO.

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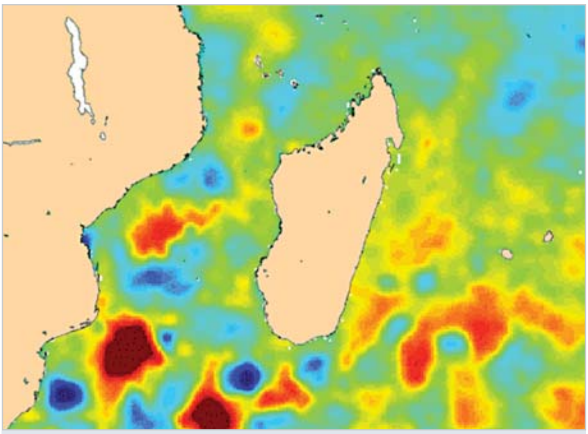

Complex eddies and currents in the WIO and in the Mozambique channel are shown as areas where sea level is slightly higher (red) and slightly lower (blue) as a result of these curesnts.

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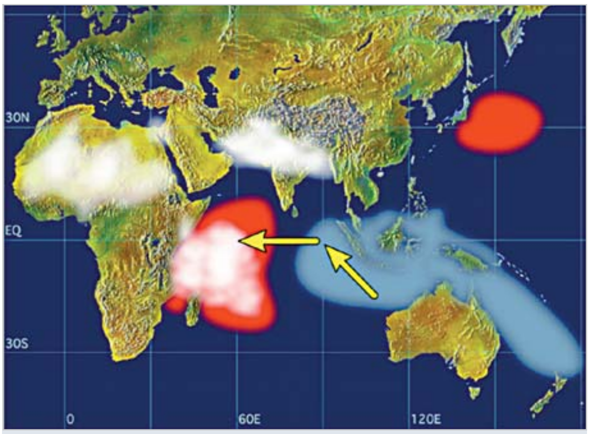

Indian Ocean dipole, showing a positive mode where the WIO is warmer with high cloud and rainfall, and the eastern part of the Indian Ocean is cooler.

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Indian Ocean, where the Somali Current and northern Indian Ocean gyre oscillate between the seasons. The monsoon does not reverse currents in the south, but it does strongly modulate their speed and variability.

Variability among years is due to the Indian Ocean's equivalent of the Pacific Ocean's El Niño Southern Oscillation (ENSO), known as the Indian Ocean Dipole (IOD). As with the ENSO, the IOD reflects differences in sea surface temperature, and therefore rainfall and winds, between the eastern and western parts of the ocean, moderating seasonal conditions across the ocean. These patterns of variability are further influenced by other oceanographic features of the WIO, including a Seychelles-Chagos 'ridge' in the thermocline that affects sea surface temperatures and thereby ocean-atmosphere interactions, and decadal features similar to the Pacific Decadal Oscillation (PDO).

With relevance to **long term global climate trends**, leakage of Agulhas Current rings into the south Atlantic may be among the main controlling factors affecting global climate dynamics historically, and perhaps under a changing climate, due to their role in the ocean circulation conveyor belt.

Paleo-oceanographic history

Little is known about the oceanographic history that influences the WIO, but emerging research is highlighting some key features that may have contributed to today's unique features in the WIO. Until the closure of the Tethys Sea (30-15 mya), it is likely that ocean currents linked the Tethys and the WIO. Equatorial currents crossing the Indian Ocean from east to west were first blocked by India as it migrated northwards (65-40 mya), and then likely by the string of islands and banks produced by the Mascarene-Reunion hotspot (45-20 mya) that now form the Mascarene Plateau. Further, before the Miocene, there was very little development of the shallow marine communities that are dominant today (e.g. coral reefs) in what is now southeast Asia. These communities only began to form at the start of the Miocene, 24 mya, when the Australian and Asian plates collided and formed the Indonesian island arc. As a result, up to 24 mya it appears that shallow marine habitats in the WIO had a primary connection with the Tethys Sea as it closed, and only subsequent to that, a primary connection with the emerging center of diversity in the Southeast Asian region.

Key references – Beal *et al.* (2010); Belkin & Cornillon (2007); Guyomard *et al.* (2006); Hermes and Reason (2008); Lutjeharms (2006); Obura (2011); Palastanga *et al.* (2006); Penven *et al.* (2006); Ridderinkhof *et al.* (2010); Saji *et al.* (1999); Schott and McCreary (2001); Schott *et al.* (2009); Ternon *et al.* (2012).

Some consequences of these features of the WIO region		
Open ocean **Shallow seas** – sheltered by the shallow but submerged eastern rim of the banks, the Saya de Malha, Nazareth and Cargados Carajos banks are essentially shallow seas (approx. 15 to >200 m deep) covering over 50,000 km^2 surrounded by deep ocean. **Productivity** – the mixing of waters by the Mascarene Plateau and banks is shown by higher levels of chlorophyll over the banks and downstream of them, fertilizing the open ocean.	**Mozambique Channel** **Connectivity** – eddies result in efficient east-west exchange, and the presence of islands within the channel increase the potential continent-island and island-island connections driven by the eddies **Seasonality** – monsoon seasonality is marked in the northern part of the Channel, enhanced by the intrinsic variability of mesoscale dynamics. **Productivity** – the mesoscale dynamics have profound impacts on food webs in the channel, and the dynamics and movement of higher level consumers such as turtles, seabirds and marine mammals. Green turtles show strong genetic differentiation into two populations, one in the north, the other in the southern and central Mozambique Channel. This may reflect the currents in the channel, that influence the dispersal of juveniles and separate sub-stocks for multiple species groups	**Ecotones** In both north and south, highly productive cooler-water systems (Somali upwelling, Madagascar Plateau upwelling & Agulhas Current) combine with currents from other regions (Red Sea/Gulfs in the north, temperate waters in the south) to produce unusual and energetic oceanographic dynamics and productive ecosystems

Biodiversity and biogeography

Biogeography

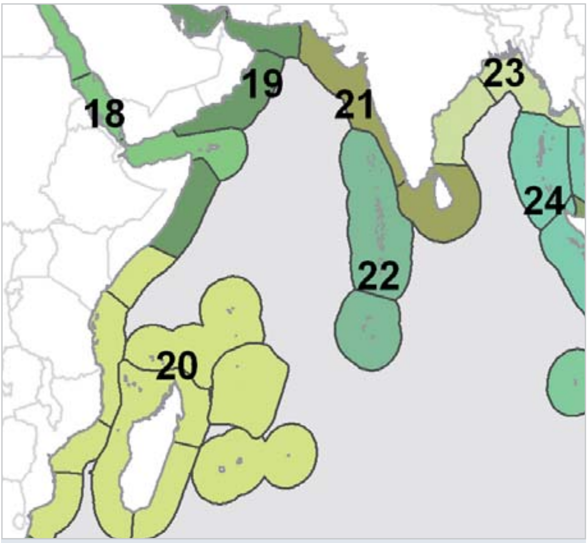
The IUCN Commission on National Parks and Protected Areas (CNPPA), now the World Commission on Protected Areas (WCPA), commissioned a study that together with a major text by Longhurst (1998) has laid the basis for recent marine biogeographic analyses. The East Africa (region 12) corresponds to the region more commonly known now as the Western Indian Ocean. In 2007 the Marine Ecoregions of the World (MEOW) classification scheme updated work done up to that point, dividing the world's oceans into 12 realms, 62 provinces and 232 ecoregions

In the MEOW scheme, the Tropical Indo-Pacific is divided into 4 realms – the West, Central and East Indo-Pacific, and the Eastern Pacific Realms. The West Indo-Pacific Realm extends from East Africa and the Red Sea to include the Andaman Sea and western Indonesia. Within it, the Western Indian Ocean (WIO) is recognized as a Province, and 6 smaller provinces are ranged along the Asian coastlines from the Red Sea to Thailand and Indonesia. Nine ecoregions within the WIO are proposed in the MEOW scheme. Within the WIO, conservation planning has been done for the mainland (WWF, 2004), and for the oceanic islands and Madagascar (RAMP-COI, unpublished), with the aim of identifying globally, regionally and nationally significant areas.

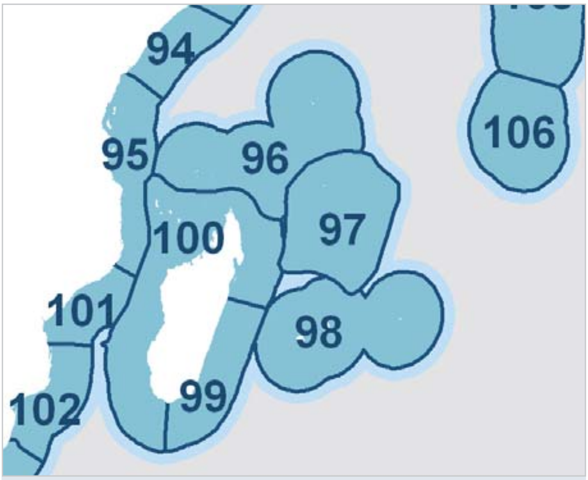
Biogeographic classifications are based on an area having a distinct fauna and flora, with unique features not found in other regions. The distinctness of the fauna and flora may relate to the geographic distributions of species, levels of species and genetic diversity and/or levels of endemism.

Drivers of biogeography – the distribution of species in the marine environment is driven principally by ocean currents, which themselves are constrained by geology. The four main oceanographic features of the WIO (see Features/Oceanography) identify the main patterns of species distributions to be found in the Province:

- an Indo-Pacific fauna common across all tropical Indo-Pacific realms, carried on the South Equatorial Current from the center of biodiversity located in southeast Asia;
- a high-diversity region in the northern Mozambique channel apparently related to the eddies that retain larvae there, the complex coastlines and its geological history;
- decreasing diversity north and south as currents flow out of the northern Mozambique Channel, with transitions towards the northern and southern extremes due to mixing with other water masses and climatic regions: in the north with the extreme environments and habitats in



MEOW – Provinces within the West Indo-Pacific Realm. The Western Indian Ocean is # 20. © Spalding et al. 2007



Ecoregions within the Western Indian Ocean, plus Chagos (#106) © Spalding et al. 2007

WIO Ecoregions (MEOW)
94 North Monsoon Current
95 East Africa Coral Coast
96 Seychelles
97 Cargados/Tromelin
98 Mascarene Islands
99 South & East Madagascar
100 West & North Madagascar
101 Sofala
102 Delagoa

the Red Sea, Gulf of Aden and Persian Gulf, and in the south, with the temperate systems off the Madagascar Plateau, South Africa and the southern Indian Ocean; and

- relative isolation of the islands (Seychelles in the north, and the Mascarene islands in the south) in ocean gyres, resulting in distinct species assemblages and higher endemism due to their isolation. In the Seychelles, mixing with tropical provinces to the north results in a distinct fauna with mixed affinities. In the Mascarene Islands, isolation from the SEC and the higher diversity ecoregions in the Mozambique Channel, and no other adjacent tropical fauna to the south, results in higher levels of endemism.

Key aspects of biodiversity and biogeographic patterns relevant to the WIO are summarized here.

Species diversity

Historically, species diversity across the Indo-Pacific region has been seen as one of generally linear decline in all directions from the high-diversity center in the southeast Asian region, or Coral Triangle, illustrated for corals by analyses up to the early 2000s that found decreasing diversity towards the African coast, with in some cases a higher peak of diversity in the Red Sea due to endemism. However recent reviews of the biodiversity literature note the exceptionally large gaps in species distribution records across the WIO and the Indian Ocean, such as on the East African coast. Thus, even today, prioritization exercises for conservation based simply on species counts should not be done without strong supporting evidence and ancillary information on ecology, oceanography and other processes that support biodiversity (see example in Features - Coral reefs).

Emerging evidence is showing that the northern Mozambique channel is a center of diversity for the WIO, very likely a result of high levels of connectivity due to the South Equatorial Current and Mozambique Channel eddies. Because the WIO may also have the highest diversity of the Indian Ocean (except for the Andaman Seas, which are faunistically more related to the Central Indo-Pacific Realm, or Coral Triangle), the northern Mozambique channel may be the second peak of shallow marine biodiversity in the world, after the Coral Triangle.

Endemism

In contrast to the high diversity core region in the Mozambique Channel, regions with highest endemism tend to be highly isolated. The Mascarene Islands (Mauritius, Reunion and Rodrigues) in the southwest Indian Ocean are the most isolated of the tropical marine fauna of the WIO. They are south and east of the strong SEC and East Madagascar currents, and in a region that experiences intermittent currents in eddies that separate from those two currents, as well as return flow from southern Madagascar in the South Indian Ocean gyre.

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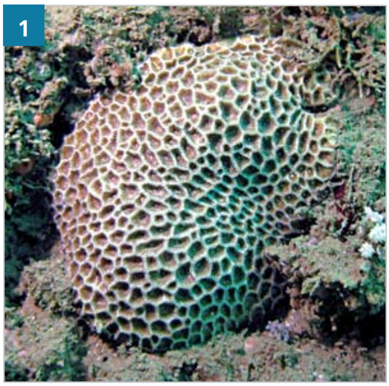

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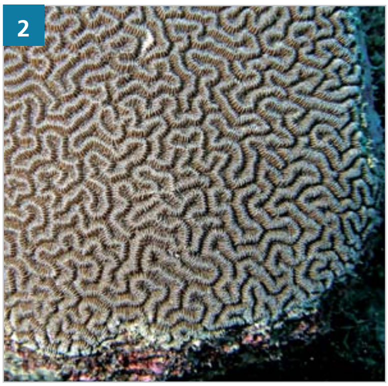

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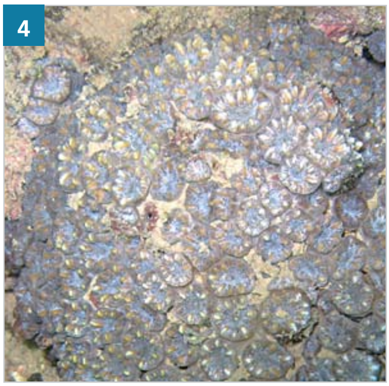


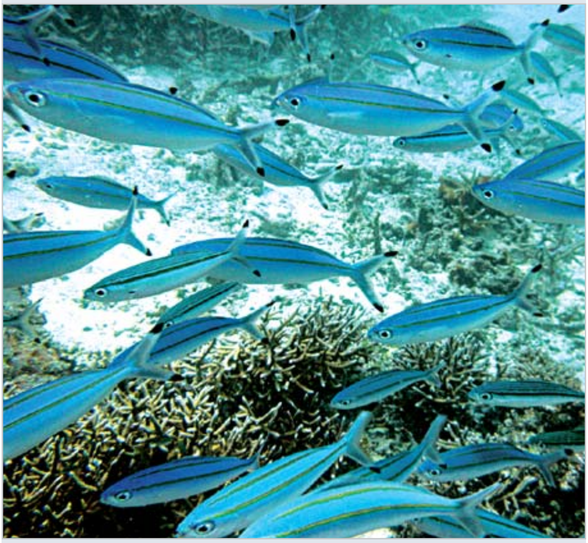
5

Endemic corals in the WIO

1. *Anomastrea irregularis*
2. *Ctenela chagius*
3. *Horastrea indica*
4. *Parasimplastrea sheppardi*
5. *Physogyra lichtensteinii*

All photos: ©David Obura

Endemic fish to the WIO



Fusiliers of the WIO are still being described – here the widespread *Pterocaesio marri* and an unidentified species. © Melita Samoilys

Chaetodon interruptus – widespread Indo-Pacific butterflyfish showing Indian Ocean colour form. © Melita Samoilys

The degree of endemism of reef fish in the Mascarene fauna is among the highest for reef fish, ranked fifth globally, comparable to levels reported for the remote island groups of the east part of the Pacific, such as the Hawaiian islands, the Galapagos and Easter/Pitcairn islands. Among 2086 reef fish known from the Indian Ocean, 25% are endemic. The highest level of endemism occurs in the Mascarene islands with 37 species endemic just to those islands out of a total of 819 species. Other reef taxa, particularly invertebrates, are too poorly sampled in the Indian Ocean to make meaningful regional comparisons. The life history of marine taxa is also important in understanding endemism – for example in the remote islands of the WIO there is a high percentage (70%) of hydrozoan species that lack the medusa stage in their life cycle, further contributing to high diversity through endemism.

Ecotones

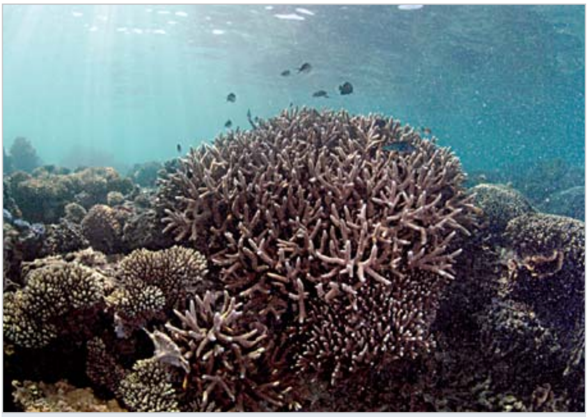
At the boundaries between major drivers of biodiversity processes, e.g. between provinces in the MEOW classification, and in some cases between ecoregions, the mixing of species from the different regions can result in unique and unusual species assemblages and habitats. Examples of these in the WIO include:

- the Seychelles islands, particularly in the north, with a transitional fauna with the northern Indian Ocean, including the Red Sea/Gulfs and south Indian and Sri Lankan coasts;
- the Northern Monsoon Coast in northern Kenya, with a transitional fauna between the main East Africa tropical zones, and the Somali-Arabian systems driven by cool nutrient rich upwelling;
- the South African, southern Mozambique and southern Madagascar faunas with a mixed fauna between tropical and temperate regions.

Key references – Allen (2008); Carpenter *et al.* (2011); Faure (2009); Fricke *et al.* (2009); Gravier-Bonnet & Bourmaud (2006); Griffiths (2005); Kelleher *et al.* (1995); Longhurst (1998); Obura (2012); Obura (in review); Pichon (2008); RAMP-COI (unpublished); Richmond (2001); Roberts *et al.* (2002); Samoilys *et al.* (2011); Sheppard (1987); Sheppard (2000); Spalding (2012); Spalding *et al.* (2007); Veron (2000); Wafar *et al.* (2011); WWF (2004).

Coral reefs

Aerial view of the reefs around Mayotte in the Comoro archipelago. Fringing reefs grow around the island shoreline. The offshore barrier reef started growing when sea level was lower, as a fringing reef around a much larger island. ©David Obura



A typical shallow coral community dominated by fast growing Acropora (staghorn) corals.
©Cheryl-Samantha Owen/ www.samowenphotography.com

Corals grow up to sea level building up the reef framework over several hundreds to thousands of years, forming all the reef types – fringing, barrier, atoll and banks.
©Cheryl-Samantha Owen/ www.samowenphotography.com

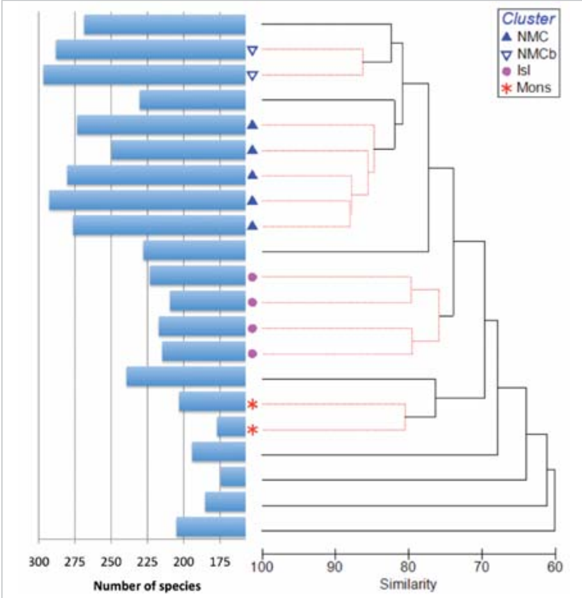
Coral reefs in the WIO extend from the most northern parts of the Indian Ocean to the South African coast at 32°S. They are found along the continental coastlines of East Africa and Madagascar where there are no major river systems, on all the small islands, and on parts of the submerged banks that are both shallow enough and have some variation in topography. They are intimately associated with seagrass beds, with much of what is called 'coral reef habitat' being flat open seagrass and sand beds in between rocky outcrops and true reef structures. In sheltered locations mangrove stands are often associated with reef and seagrass habitats, though the high-sediment and freshwater conditions supporting the largest mangrove systems in East Africa prevent the growth of immediately adjacent coral reefs. The coral reef fauna of the WIO is a mainstream component of the Indo-Pacific region, with very high faunal affinities stretching across the Indian Ocean to the southeast Asian and West Pacific regions. However, new insights into the fossil record of reefs is raising the possibility of a distinct evolutionary history of coral reefs in the WIO, and by extension, of other shallow marine habitats and their species, raising the possibility of a unique regional fauna.

Reef geomorphology

Charles Darwin first described the process of transition from fringing to barrier to atoll reefs, partly from observations in the Indian Ocean, including the Chagos Archipelago and Aldabra Atoll. The WIO has a variety of offshore bank reefs and island/continental reef systems, representing a full range of reef formations:

- **fringing reefs** are found around all the islands and the East African coast;
- **barrier reefs** are most strongly developed at Tulear (Madagascar) and around Mayotte (which also contains a second/inner barrier within its lagoon), and partially developed or poorly known in several locations - the west coast of Mauritius (Mahebourg), south side of Mohéli (Comoros);
- **atolls** are found in the Seychelles (e.g. Aldabra, Cosmoledo, Farquhar, Alphonse) and in the Iles Éparses (Europa, Bassa da India), and submerged atolls at Zélée and Geyser;
- **coral banks** are numerous, such as those offshore of major coastlines (e.g. Malindi – Kenya, Leven and Castor – NW Madagascar, African Bank – Mozambique), and the very large banks of the Mascarene Plateau - Cargados Cajaros, Nazareth and Saya de Malha, and the North Seychelles Bank.

The Millennium Coral Reef Mapping Project developed a single global classification of geomorphological classes for reefs, defining 800 different classes. Application of this method to the WIO islands conducted by the RAMP-COI project resulted in identification of 199 classes (25% of the global geomorphological diversity). Madagascar had the highest diversity with 86 geomorphological classes, followed by Seychelles and Mauritius with 54 and 53 classes respectively, then Mayotte (42), Comoros (28), the Iles Éparses (16) and Reunion (4). Using these classes, the sum of reef and non-reef areas in the islands equaled approximately 14,000 km² and 50,000 km² respectively. Madagascar and Seychelles had the largest reef areas, with 5000 and 5400 km² of reef area respectively. The atolls, banks and islands had approximately 9000 km² of reef. The Seychelles Bank alone represents 42,800 km² of non reef area. The East African continental coast has not yet been classified.



A revised view of coral diversity in the WIO, where diversity in the northern Mozambique channel (NMC) is higher than sites to the north, south and east in the islands.

© Obura 2012

Corals

Continental reefs in the WIO are distinguished from other Indo-Pacific reefs by the dominance of mono-specific stands in genera such as *Galaxea*, *Lobophyllia*, *Montipora* and *Porites*. More typical Indo-Pacific reef assemblages are also common on the islands and mainland, dominated by branching corals in the genera *Acropora* and *Isopora*, and mixed communities including genera in the families Faviidae, Mussidae, Petiniidae, Fungiidae and others. Endemic coral species in the WIO (with the ranges of some extending to the northern Indian Ocean) include *Ctenella chagius*, *Craterastrea laevis*, *Horastrea indica*, *Gyrosmilia interrupta*, *Anomastrea irregularis* and *Parasimplastrea sheppardi* with the first two species only recorded recently from Chagos and Mauritius, and Mayotte and Madagascar, respectively. Regional endemics that are so rare they have not been recorded in decades include *Astreosmilia*, *Erythrastrea* and *Machadoporites*. The taxonomic position of these species is in question, raising the possibility of endemism at higher taxonomic levels than previously thought, and a unique lineage of corals in the Western Indian Ocean. Recent genetic research has shown that the genera *Stylophora* and *Siderastrea* have ancestral species in the WIO/Red Sea region compared to younger species farther east in the Pacific, and in the former case, higher levels of genetic diversity in the WIO/Red Sea. These results are also suggestive of so-far-unknown levels of diversity in the WIO and a distinct evolutionary heritage compared to the broader Indo-Pacific.

Coral reefs support a high diversity of other taxonomic groups, such as those dependent on the corals themselves for habitat. For example damselfish (top) and crustaceans (below) have adapted to live among coral branches.

© Melita Samoilys (top) / © Keith Ellenbogen (below)

Significance

Coral reefs are among the most biodiverse of marine ecosystems, with 93,000 species of coral reef organisms currently described, of which some 4,000 are fish and 800 are corals. Depending on assumptions, scientists estimate from 1-3 million species may depend on coral reefs, representing as much as 25% of marine biodiversity.

More than 500 million people worldwide depend on coral reefs, and this number may be approximately 15-20 million in the WIO. Direct uses of reef resources include extraction of fish, invertebrates and algae for food and other goods such as for building and pharmaceuticals, recreation and the tourism industry, and as physical infrastructure for maritime transport and coastal protection. For coastal communities and societies, reefs may have cultural and spiritual significance. Reef resources and services are worth an estimated 375 billion dollars each year globally, with estimates ranging from U$ 2,000 to >100,000 per ha/year for reefs in the WIO, depending on whether they support artisanal fisheries (at the lower end) to urban coastlines and tourism industries (at the higher end).

Coral reef statistics for countries and islands of the Western Indian Ocean

	Marine area (000 km^2)	Reefs at risk [a] %	Reef area km^2 [b]	Coral diversity [c]	seagrass spp	MPAs w coral reefs [d]	Fish cons per capita (kg/yr)
Tanzania	241	99	3580	314/280	10	11	10
Madagascar	1205	87	2230/5076	315/293	10	13	7
Mozambique	565	76	1860	314/297	8	6[c]	2
Seychelles	1334	17	1690/5443	310/217	8	14	65
Mauritius	1291	81	870/2693	215/185	2	21	21
Somalia	828	95	710	308/na	4	0	2
Kenya	117	91	630	237/240	13	10	5
Mayotte	74	100	570/413	216/274	11	1 (6)	15
Comoros	175	99	430/305	314/223	4	1	20
South Africa	1525	na	<50	na	3	2	8
Reunion	318	100	<50	168/205	2	1	10
Iles Eparses	692	na	na/121	40/209	7	1	0
Tromelin				28/30			

Notes

a. Reefs at Risk country estimates reported in Spalding et al. 2001. Country estimates were not given in Reefs at Risk revisited, in 2011.

b. Reef areas are obtained from the *World Atlas of Coral reefs*, and for the islands (to the right of the '/') from the Millenium Reef Mapping project. Differences in these numbers reflect different methodologies and assumptions about reef habitats and structure.

c. The first numbers are two sources: mainland sites – Spalding et al. 2001 (World Atlas of Coral Reefs) based on Veron (2000) estimates, based on predicted numbers of species; island sites – Pichon 2009 based on based on field surveys and literature) for RAMP-COI. The second number is predicted species richness based on field surveys (Obura 2012) and are likely underestimates of true diversity. Discrepancies between these numbers are based on differences in methods and sources of information.

d. Numbers of marine protected areas with coral reefs in Madagascar and Mozambique have increased greatly since the source report publication date, these numbers incorporate estimated increases. Mayotte: only one MPA covering the entire EEZ (with 6 more strict MPAs).

Threats

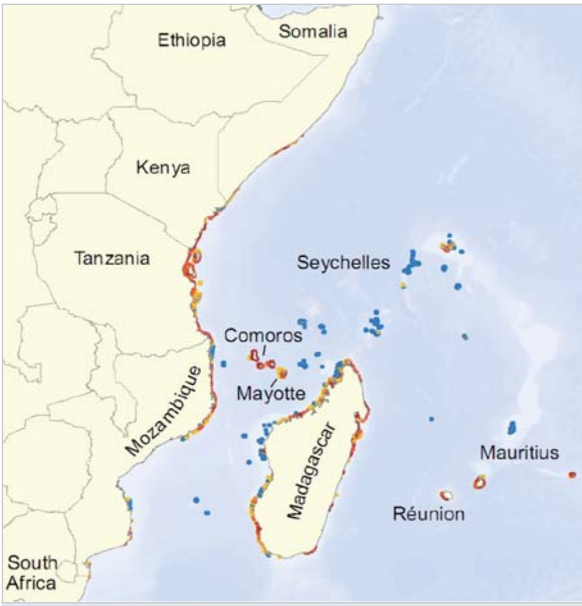
Coral reefs are highly valued for their ecosystem services, so experience significant use and threat levels throughout the WIO. The exploitation of marine resources, urban pollution, terrigenous sedimentation, coastal development and tourism are among the main anthropogenic pressures that cause degradation of ecosystems in the region. A classic example of the combined effects of these stresses is the Grand Recif at Tulear – the largest barrier reef in the Indian Ocean, which in the last 40 years has been degraded to a state of virtual death of the reef system, and the loss not only of ecosystem function, but of many species, including reef-building corals. Artisanal and small scale commercial fishing, and urban pollution and massive sedimentation are all implicated in this loss.

Fishing pressure is increasing in all countries with increasing local and global populations, and globalization of fisheries is resulting in mounting pressures to even the remote mid-ocean reefs and banks. Destructive fishing such as with small-mesh seine nets, poison and dynamite are pervasive where national governance mechanisms fail to keep them under control. Threats from pollution are less severe in the WIO than elsewhere, reflecting the low levels of industrialization and maritime trade by global standards, though these are increasing.

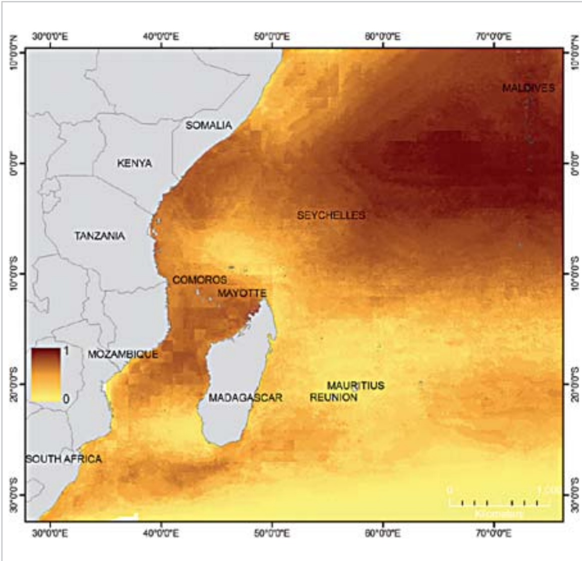
The growing global energy demands has led to increased exploration for oil and gas within the WIO (Kenya, Tanzania, Mozambique, Madagascar and Seychelles). Exploration leases off the coast and onshore sedimentary basins cover the entire west coast of Madagascar and parts of the east coast. Currently, exploration results indicate significant reserves of heavy oil and the possibilities of lighter crude and gas. Extraction of these reserves will pose a serious threat to reefs and other ecosystems.

Climate change is now recognized as one of the greatest threats to coral reefs worldwide, particularly from rising sea surface temperatures, and ocean acidification. Coral bleaching has led to substantial damage to coral reefs on a global scale (16% of reefs suffered lasting damage in 1998 alone), with some parts of the western Indian Ocean losing 50-90% of their coral cover (e.g. Kenya, Tanzania, Seychelles, Mayotte).

Regional studies of coral bleaching have revealed differential histories of bleaching, indicating high- and low- vulnerability regions to potential future climate change. Reefs in hot stable temperature regime waters in the east of the Mozambique channel and the Seychelles, and in cooler but more variable regions in Kenya have suffered greater bleaching in the past. Regions with slight cooling from upwelling and oceanographic influences – along the Mozambique coast, or in the Mascarene Islands have suffered less bleaching, or more variable levels of bleaching. For the Indian Ocean as a whole, 65% of reefs are at risk from local and global threats, rising to > 85 % by 2030.



Combined threats to reefs in the WIO, ranging from red (high) to blue (low). ©Burke et al. 2011



Susceptibility to thermal stress, with darker colours indicating higher suscptibility and risk of coral bleaching. ©Maina et al. 2008

Status of WIO coral reefs in 2008 (GCRMN)

Percent of reefs:	destroyed	critical	threatened	low threat
Mainland	15	22	28	35
Islands	9	24	39	29

Management, mitigation and restoration

The two existing World Heritage marine sites in the WIO, Aldabara and iSimangaliso, both contain coral reefs making them among the best-represented habitats so far on the World Heritage List in the WIO. This is also true globally, where almost half of the 45 marine World Heritage sites contain coral reefs as a significant feature.

Coral reefs are strongly affected by local threats, thus targeted management at local scales is the most successful course of action for conservation. Fisheries management, to reduce the proportion of fish stocks extracted, area-based management in MPAs, to protect key locations, breeding stocks and a proportion of total habitat area, and Integrated Coastal Zone Management (ICZM), to reduce land-based impacts on coral reefs are the three main tools.

MPAs have been extensively applied in the WIO with a focus on coral reefs. In the islands, there are currently over 51 marine protected areas (parks and reserves) and fisheries reserves representing around 5000 km^2, plus two whole-EEZ MPAs designated in 2011 and 2012, in Mayotte (70,000 km^2) and Glorieuses (48,000 km^2). On the mainland, a consistent audit of MPAs has not been done recently, though Kenya, Tanzania and South Africa have up to 10% of their territorial waters under some form of area-based protection. Most management areas, and certainly the large ones, are under government control, with increasing popularity of community – managed areas in the last decade, though these are mostly small in size.

With the advent of climate change as the most significant region-wide threat to coral reefs, and limited ability of regional countries to contribute to global efforts to reduce greenhouse gas emissions, commitment to local actions to buy time for corals to adapt and acclimate to the changing climate is essential. Thus management actions and planning to maximize protection to reef areas and corals that have high resistance to warming, and to preserve the features that promote recovery following mass mortality of corals are essential. Regional planning and coordination are necessary to support these, as coral reefs are connected at regional levels.

Restoration for degraded reef communities is not yet at a level where action can be taken at meaningful ecological scales. Restoring the conditions that promote natural recovery – adequate herbivore and consumer populations, a clean environment and connectivity corridors – as can be done with well-planned MPAs, fisheries and coastal management is more important at scale than attempts to manipulate local reefs such as through replanting of corals.

Key references – Allen (2008); Andréfouët *et al.* (2009); Ateweberhan & McClanahan (2010); Carpenter *et al.* (2011); Chen *et al.* (in prep); Conservation International (2008); Flot *et al.* (2011); Griffiths (2005); Hamilton & Brakel H (1984); Maina *et al.* (2008); McClanahan *et al.* (2007)b); Obura (in review); Obura *et al.* (2007); Pichon (2008); Rosen (1971); Sheppard (1987); Spalding *et al.* (2001); Stefani *et al.* (2011); Veron (2000); Wafar *et al.* (2011); Wilkinson (2000)/(2004)/(2008).

Mangroves

Mangrove forests are among the most common of coastal habitats in the WIO, typically in river estuaries, with smaller stands in enclosed lagoons and on sheltered open sea coasts. There are ten species of mangrove trees in the WIO, most of which are distributed widely, and a variety of shrubs and palms that also grow in mangrove forests. Mangroves are characterized by their resistance to salt water, enabling them to grow in brackish and full-salinity seawater, and by their ability to root in mud or sand.

The WIO has an estimated 7,900 km^2 of mangroves, 5% of the world's total. WIO mangroves represent a subset of the species found in the West Pacific region, isolated by the expanse of the Indian Ocean and the arid coastlines of the Middle East. They may thus represent a distinct subregion of the Indo-West Pacific mangrove fauna and flora.

The best-developed mangrove forests occur around river mouths where they are important in trapping river sediments that would otherwise be washed out to sea. Madagascar and Mozambique have the largest mangrove areas in the region with 2990 and 2910 km^2 respectively, along their coastlines in the Mozambique channel. The largest contiguous stand of mangroves in the WIO is the Rufiji delta (Tanzania, 480 km^2), followed by Mahajamba (Madagascar, 420 km^2), then the Zambezi and Ruvuma rivers. Coastal island chains, such as the Lamu Archipelago in northern Kenya and Quirimbas in northern Mozambique have extensive mangrove formations in river estuaries and sheltered shorelines. South Africa supports a small extent of mangrove, among the southern-most mangroves in the world, at 32°S.

In the island states, the high islands have no major estuaries, support little mangrove growth except for Mayotte and the south coast of Moheli, Comoros. By contrast, the coralline islands with major lagoons support significant mangroves, in particular Aldabra (20 km^2), Cosmoledo and Europa (Scattered Islands, 7 km^2).

Mangroves growing on the edge of a channel, showing distinctive prop roots of the black mangroves, *Rhizophora mucronata* (Kiunga, Kenya). ©David Obura

Mangrove seeds develop on the tree into seedlings, the spear shape helps them to float upright and then root in soft muds when deposited in a new location for growth.
©Rudy van der Elst

Mangroves are among the few marine ecosystems that can successfully be replanted and rehabilitated by manual planting of seedlings. ©Rudy van der Elst

Mangrove roots underwater at high tide – at low tide these are exposed to the air to breath oxygen, enabling mangroves to live in oxygen-poor silt and sand in estuaries.
©Keith Ellenbogen

Significance

Mangroves are among the most productive habitats on earth and have tremendous social and ecological value. Wood production and growth rates are very high. Mangroves support complex and rich food webs, due to high primary production, influx of nutrients from rivers and the complex structures provided by the mangrove roots. They provide sheltered nursery grounds for many fish and invertebrate species that spend their adult lives in other coastal and pelagic ecosystems.

Human use of mangroves is extensive, with harvest of molluscs, crustaceans, and fish as well as of wood for fuel, charcoal, timber, and wood chips. Mangrove wood is extremely hard, insect-resistant and with a high energy content as fuel. More indirect ecosystem goods and services include the role of mangroves as nurseries for economically important fisheries, especially for shrimp, and others such as filtering and trapping of pollutants, stabilization of coastal land by trapping sediment and protection against storm damage.

Mangrove forests are perhaps the most efficient ecosystem for carbon sequestration, with estimates of carbon storage of 500 – 1300 tonnes/ha (or 50-130 g/m^2), of which 70% is trapped in the sediment. This is from 1-3 times the amount of carbon stored in primary tropical forests.

Taken altogether, the annual economic value of mangroves, estimated by the cost of the products and services they provide, has been estimated at between $2,000 and $9,000 per ha per year.

Threats

Because mangrove ecosystems have tremendous value for coastal communities and associated species, they are being destroyed at alarming rates. Over the last 50 years, about one-third of the world's mangrove forests have been lost. Within this region, mangrove decline is estimated to have been about 8%, from 1980 to 2005, as against global projections of 25% decline by 2025.

The harvesting of mangrove trees has persisted for centuries in East Africa, with export of poles to Oman and the Middle East being a staple of trade throughout this time, and continuing today. Uncontrolled cutting of mangroves has cleared large areas of previously productive forest. Mangrove forests are also the first to be cleared for the construction of salt pans from which most of the region's sea salt is produced. Additional pressure from tourism developers, coastal construction, farmers and the ever-growing need for fuel wood, further encourages large swathes of primary mangrove forest to be cut indiscriminately with little or no replanting.

Climate change, in particular sea level rise, is a growing threat to mangroves, as their vertical zonation is pronounced, and many mangrove systems may have little space to recede inland as sea levels rise, due to topographic factors and blockage by developed and altered ecosystems on their landward boundary.

Mangrove statistics for countries and islands of the Western Indian Ocean

Country	Mangrove area (km^2)	mangrove species	PAs with mangroves	Intnl PAs
Madagascar	2990	8	6	1
Mozambique	2910	10	6	1
Tanzania	1285	10	24	1
Kenya	610	8	11	2
Somalia	48	6	1	
Seychelles	32	9	5	2
South Africa	30.5	6	14	3
Mayotte	7.1	8		
Comoros	1.2	7	1	
Mauritius	1.2	4	6	
Europa	7	4	1	

Mangrove species found in the WIO

Brugeria gymnorrhiza – variable salinity, often mixed with *Rhizophora* and *Ceriops* zones; coppices well and poles used in housing.

Rhizophora mucronata – found in the upper eulittoral forming extensive pure strands in estuarine conditions. Good source of tannins for leather and poles used for houses.

Ceriops tagal – littoral fringe on landward side of forests. Strong poles resistant to termite attack.

Avicennia marina – found on compact substrates, sand flats and new sediment. Tolerates high salinity and varied flooding regimes thus widespeard throughout the mangrove forest, found either on the landward margin as forest stands, or seaward side mixed in with *Sonneratia*, *Ceriops* and *Xylocarpus*. High tolerance therefore the most widely distributed mangrove species in the WIO. Coppices well, timber used for construction, trunks used for boats and flowers used for honey.

Lumnitzera racemosa – a landward mangrove in the littoral fringe where there is an influence of fresh water. Good fuel wood and coppices well.

Heritera littoralis – found in the littoral fringe or riverine, especially estuaries in sandy loan and inland areas. Wood very tough used in ships, boat masts.

Sonneratia alba – found in the upper eulittoral. Arial roots used by fishers as floats. Tree coppices well.

Pemphis acidula – found in the supralittoral fringe, common landward reaches of mangroves on sand beaches and more inland.

Xylocarpus granatum, *X. moluccensis* – usually landward margin of mangrove forests in the littoral fringe where there is an influence of fresh water. Fruits are known for their medicinal properties. Regarded as an mangrove associate due to the absence of specializations for coping with saline conditions.

Management, mitigation and restoration

In the WIO mangroves are more commonly managed as forest reserves than for biodiversity, falling under forestry regulations, and being viewed more from a utilization perspective than conservation. Their role as ecosystem service providers to a broad diversity of other systems (e.g. coral reefs, fisheries, prawns, land protection) generally goes unrecognized and therefore is not valued in competition with development alternatives. This is, however, changing in some countries, where community dependence on mangroves and local tourism are combining in the form of visitor-oriented boardwalks to enable tourists to experience the mangroves. Madagascar and Mozambique, with the largest area of mangroves in the region, also have the lowest coverage of existing protected areas in mangrove systems.

In restoration and reforestation of mangroves, Kenya is among the leading countries in both research and in community efforts at restoration, with broad replication of the latter throughout the region. The role of mangroves in sequestering carbon dioxide is a new issue for the region to deal with, and may potentially place high value on avoided deforestation of mangroves systems and thus their conservation, as well as on reforestation.

The *World Heritage Convention*, Ramsar Convention and Man and the Biosphere (MAB) programme are three international instruments relevant to protection of mangrove systems, and all of them have some coverage in the WIO.

Key references – Alongi (2002); Andriamalal (2007); Ellison and Stoddart 1991; Erftemeijer and Hamerlynck (2005); Ewel *et al.* (1998); FAO and UNEP 1981; IUCN (2004); Kennish MJ (2002); Lebigre (1990); McLeod and Salm (2006); Murray *et al.* (2011); Primavera (1997); Tomlinson 1986; UNEP (1994); Wells *et al.* (2006); Wilkie and S Fortuna (2003).

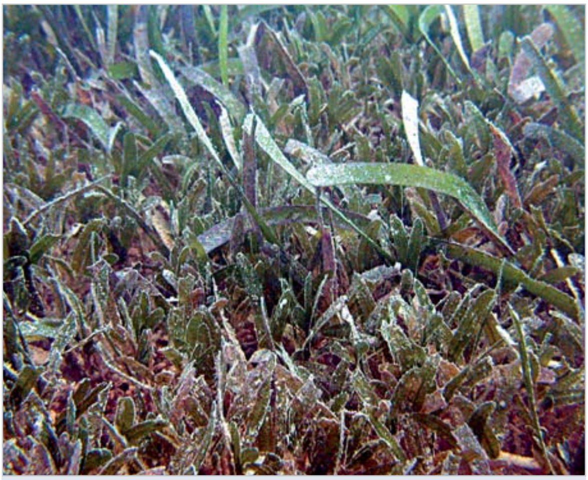
Seagrass bed, Seychelles. Seagrasses require bright sunlight and are generally restricted to < 12 m depths, though in exceptional circumstances can be found down to 30 m or more. *Thalassodendron ciliatum* is one of the dominant species, forming extensive beds on reef and sandy substrates. ©David Obura

Seagrasses

Seagrasses are marine angiosperms widely distributed in both tropical and temperate coastal waters creating one of the most productive aquatic ecosystems on earth. The distribution of seagrasses ranges from high intertidal to subtidal soft and hard bottoms, including sandy bays, mud flats, lagoons, estuaries, coral reef patches and sheltered and exposed reef platforms. They often form extensive mono- and multi-specific meadows in depths < 12 m, and in the WIO tend to be in close association with coral reefs and mangroves. With sufficient water clarity they grow up to a depth of 70 m.

Extensive seagrass beds are found in all countries of the WIO, where they have received limited scientific attention compared to mangroves and coral reefs. Of the 24 seagrass species in the tropical Indo-Pacific, the WIO holds 12 species. The greatest diversity of seagrass species is along the Mozambique, Tanzania and Kenyan coastlines, and decreases eastwards into the islands. The Saya de Malha Bank supports the largest contiguous seagrass beds in the world, which thrive on the relatively flat bank in depths shallower than 20 m.

Mixed seagrass beds with a high diversity are common, up to 8 or 10 species at the same locality have been reported for Mozambique, Tanzania and Madagascar. Two of the most common species are *Thalassia hemprichii* and *Thalassodendron ciliatum* both forming extensive beds in most parts of the region. *T. hemprichii* is found in more protected habitats or on intertidal flats, whereas *T. ciliatum* normally inhabits exposed or semi-exposed habitats, and can anchor on both sandy and rocky substrates. Also common in the region are *Halophila ovalis*, *Cymodocea rotundata*, *Cymodocea serrulata*, *Syringodium isoetifolium* and *Halodule uninervis*. *Enhalus acoroides*, *Halophila stipulacea* and *H. minor* are mainly reported from northern Mozambique to Tanzania and in some locations in Kenya. *Zostera capensis* is a more temperature species, and is only common in southern Mozambique and South Africa where large monospecific stands may occur. But the species has also been recorded in Kenya, Madagascar and Mayotte. *Halophila beccarii* is only known in Madagascar, *Halophila decipiens* is a new but relatively common species and widespread.



Common seagrasses in the WIO are *Thalassia hemprichii* in the upper photo, and *Cymodocea* (thick) and *Halodule* (thin) in the lower photo.

©David Obura (top), ©Julien Wickel (below)

Significance

Seagrass beds are among the most productive aquatic ecosystems in the biosphere. They are important as nursery grounds, foraging areas for sea turtles, fish and dugong, and predation refuges for numerous fish and invertebrate populations. Seagrass beds provide great benefits for commercial, subsistence and recreational fisheries. Due to the complex architecture of the leaf canopy in combination with the dense network of roots and rhizomes, seagrass beds stabilize bottom sediments and serve as effective hydrodynamic barriers reducing wave energy and current velocity, thereby reducing turbidity and coastal erosion. Further, seagrass beds trap large amounts of nutrients and organic matter in the bottom sediment. Through microbial decomposition, seagrass biomass may enter the marine food web as detritus and thus support productivity through recycling of nutrients and carbon. Due to their high productivity, they are often a food source for animals resident in adjacent ecosystems such as coral reefs, and may increase the biodiversity in these systems.

Due to their high productivity and trapping of carbon in biomass and sediment trapping, seagrass beds are among the most significant shallow marine carbon sinks, storing up to 500 tonnes/ha (or 50 g/m^2), of which nearly all of this is trapped in the sediment. This is equivalent to the amount of carbon stored in primary tropical forests. Along with mangroves, seagrasses are therefore of significance in carbon sequestration to reduce greenhouse gas buildup in the atmosphere and oceans.

Green sea turtles primarily feed on the cylindrical seagrass *Syringodium isoetofolium*, which is among the rare seagrasses. © David Obura

Threats

Pressure on seagrass beds in the region is increasing due to growing coastal populations and human disturbance from e.g. pollution, eutrophication, sedimentation, fishing activities and collection of invertebrates, though there is little quantitative evidence on specific threats. Reduced water clarity from land-based impacts reduces the depth at which seagrasses can grow.

Management, mitigation and restoration

Seagrass ecosystems in the WIO are valuable resources for fisheries at both local and regional scales, with much of the artisanal fishing in coral reef areas being focused in seagrass habitats on the reefs. Still, seagrass research in the WIO lags behind other ecosystems and other regions, and is mainly focusing on botanic diversity and ecology. Seagrasses have not been the focus of management in the region, though most MPAs focused on coral reefs include large areas of seagrass beds.

From 2000-2005, die-back of seagrass beds (*Thalassondendron ciliatum*) as a result of sea urchin (*Eucidarus thouarsii*) predation in Kenya caused some concern, but natural recovery apparently occurred. In Kenya sea urchin removal was found to assist seagrass recovery. In Mayotte, mortality of *T. ciliatum* on the inner barrier reef flat has been observed. More focused research, site selection and zoning of MPAs with seagrass beds as the prime focus are needed, as well as studies on land-based impacts. Restoration of seagrass beds is common practise in some parts of the world, but has not been trialled in the WIO.

Key references – Bjork *et al.* (2008); Duarte *et al.* (in press; Frouin & Bourmaud (2008); Gullström *et al.* (2002); Hily *et al.* (2010); Milchakova *et al.* (2005); Murray *et al.* (2011); Richmond (2011); Short *et al.* (2007); Uku *et al.* (2007).

Coelacanth – *Latimeria chalumnae*

The fleshy lobed pectoral fin of the coelacanth is one of its disintuishing features as a primitive fish. ©Hans Fricke

Caves on the continental slope (200m), a preferred habitat for coelacanth. all photos © Hans Fricke

The coelacanth is possibly the sole remaining representative of a once widespread family of Sarcopterygian (fleshy-finned) fish that were common from 280-100 mya, and were distributed throughout the globe. More than 120 species are known from fossils, and the family was thought to have become extinct during the K-T extinction event, 65 million years ago. Coelecanth were first identified from an English fossil by naturalist Louis Agassiz in 1836 and became known as a distinct taxonomic group in 1844. Two species of coelacanth are alive today, the western Indian Ocean species *Latimeria chalumnae*, and a more restricted Indonesian species, *L. menadoensis*.

Coelacanths are most commonly found on sloping continental shelves, below about 100 m depth, where bottom topography such as caves, and canyons/fissures leading into deep water provide shelter for them and habitat for their prey. The submarine canyons of the east and west coasts of the Mozambique Channel, and steep volcanic slopes of the Comoros have been the main areas in which they have been found, and more recently on the upper slopes of canyons in the Pemba Channel (Tanga, Tanzania).

Coelacanth can reach almost 2 m and weigh up to 80 kg or more, but are usually somewhat smaller. Males average 165 cm and are smaller than females. They are dark brown/blue with distinctive white flecks that provide camouflage against the backdrop of dark lava and rocky walls encrusted with white oyster shells. The spot patterns can be used by researchers to recognize individuals. Individuals may live as long as 60 years, but this is uncertain. Coelacanths are ovoviparous, giving birth to as many as 26 live young that develop from eggs in the oviduct, feeding off a large yolk sac until birth. Nothing is known about mating behavior or even juvenile habitat.

Coelacanths are opportunistic feeders, on or near the bottom. Stomach contents have included lantern fishes, stout beard fishes, cardinal fishes, cuttlefishes, deep water snappers, squid, deep sea witch eels, snipe eels, swell sharks, and other fishes normally found in their deep reef and volcanic slope.

In 2008, the population of the Comorian coelacanth was estimated to be about 500, and since the first capture of a coelacanth in Tanzania at Kilwa Mnoro in 2003, 80 more specimens have been landed up to October 2010, from Kenya, Mozambique and Madagascar, indicated a widely dispersed population, with some locally dense sub-populations. Genetic studies suggest there may be two distinct populations of coelacanth, though this is not fully confirmed: a southern one centered on the Comoros and extending to southern Tanzania, and a northern one in Tanga, northern Tanzania. If true, the patterns show distinct signs of gene flow to the north, but not in the reverse direction, and the ranges of the populations are consistent with high connectivity throughout the Mozambique Channel and unidirectional flow northwards in the East African Coastal Current.

History

In 1938, a living coelacanth was discovered by Marjorie Courtenay-Latimer among specimens in a trawler that had been fishing off East London, South Africa, in the southern WIO. This fish was described by J.L.B. Smith in an atmosphere of scientific excitement, skepticism and doubt. The media considered this to be the zoological discovery of the century. Up till the 1980s coelacanth were still only known from a few locations in the SWIO, with the best-known populations found in the Comoros, where fishermen were familiar with this unusual fish caught in deep-set lines. By the end of the 20th century, the fish was known to be widespread in the WIO, with the northernmost record from Malindi, Kenya, and significant populations in northern Tanzania, several of the Comorian islands and southern Mozambique/northern South Africa. As diving technology has improved, live observation or coelacanths has become possible – first from the submersible GEO, in 1987, and more recently on rebreather diving units, from November 2000.

Threats

The primary threat to coelacanth is demersal fishing on the continental shelf, between about 100 and 400 m. In Comoros, this was primarily using artisanal gears historically, so development of more mechanized fisheries, using motors for offshore fishing, resulted in decreased coelacanth catch in the 1960s. However with increasing numbers of fishers, and greater use of deep gill nets such as in Tanga, Tanzania, since 2000, large numbers of coelacanth have been caught from previously unknown populations. The larger numbers reported are also likely due to a greater awareness of the significance of coelacanths, and improved communications, such that catches that might have gone unnoticed previously are now brought to the attention of authorities. Nowhere, however, is there an indication that coelacanths exist in large aggregations.

Conservation

The coelacanth is listed as Critically Endangered on the IUCN Red List, and in Appendix 1 of CITES. The Comoros has been the epicenter of coelacanth conservation from the 1970s onwards, with the most comprehensive efforts to both study and design conservation measures appropriate to this unusual fish. The discovery of coelacanths within the World Heritage site iSimangaliso in 2000 emphasized the precautionary value of protecting critical sites of high biodiversity value. Since 1987 the Comoros has been the epicenter of coelacanth conservation efforts, led by Dr. Hans Fricke and supported by the Frankfurt Zoological Society and others. In 2002 the African Coelacanth Ecosystem Programme (ACEP) was initiated taking on a trans-frontier, ecosystem based approach to science and management of the coelacanth, with a particular focus on depths between 40–1000m in the Mozambique Channel and north to Kenya. In Tanga, Tanzania, the catch of over 30 coelecanth in the decade from 2000–2010 led to the formation of the Tanga Coelacanth MPA. Exploration and observational research, conducted by manned submersibles and ROVs, will continue to play a major role in coelacanth studies, alongside biotelemetry, underwater recording systems and physiological probes in order to answer elusive questions.

Fishermen in Tanga, Tanzania, have caught over 30 coelecanth in the last 10 years, likely due to changing fishing techniques and increase pressure, revealing a population previously unknown to science. ©Hassan Kalombo

Key references – Agassiz (1844); Erdmann (2006); Forey (1998); Fricke and Hissmann (1994); Fricke *et al.* (2000); Fricke *et al.* (2011); Green *et al.* (2009); Heemstra *et al.* (2006); Nikaidoa *et al.* (2011); Plante *et al.* (1998); Scott (2006); Smith (1939); Smith (1953); Smith (1956).

Carcharhinus amblyrhynchos. © David Obura

Hammerhead. © Alessandra Maccari

Oceanic whitetip shark (*Carcharhinus longimanus*). © Julien Wickel

Whale shark (*Rhincodon typus*). © David Obura

Porcupine ray (*Urogymnus asperrimus*) on Geyser. © Julien Wickel

Sharks and rays

One hundred and thirty-seven species of sharks and rays occur in the WIO, of which 15 are endemic to the region. The highest elasmobranch diversity in the region has been recorded from Mozambique waters, with 108 species (73 sharks and 35 rays). Ten species are endemic just to South African waters.

Sharks are at the top of the food chain especially in the coral reef environment. Sharks have slow reproductive rates with many species only producing a handful of offspring when the adults are 10-15 years old. The more primitive species lay eggs, while the most advanced species are viviparous, meaning the fetal sharks are connected by placenta in utero, and born live.

Published references on sharks and rays in the WIO are very rare, and the available data are based primarily on gray literature and testimony, often inaccurate. In the last decade, however, this situation is changing as interest in sharks from an ecological standpoint, and for conservation, has increased.

Distributions

Sharks are widely dispersed in tropical waters, including the WIO, but heavy mortality from fishing impacts has dramatically reduced their numbers in many locations. At present, the most important locations for sharks are the islands of the Mozambique Channel, and the southern islands of the Seychelles, likely due to their isolation.

The Iles Éparses (Scattered Islands) are among the few locations with good shark populations: aggregations of juvenile Galapagos sharks (*Carcharhinus galapagensis*) in Bassa da India, nursery areas for grey reef sharks (*C. amblyrhynchos*) in Juan de Nova, blacktip reef sharks (*Carcharhinus melanopterus*) and lemon sharks (*Negaprion acutidens*) in Europa and nurse sharks (*Nebrius ferrugineus*) on Geyser. Other notable sites include the Zélée bank especially for grey reef shark, and Europa for the presence of hammerhead shark schools (*Sphyrna mokarran*).

Mayotte and associated banks (Zélée and Geyser) are regularly frequented by sharks. In Mayotte, scalloped hammerheads (*S. lewini*) are observed at the beginning of the austral winter (July-September), in which schools can exceed 20 individuals.

Threats

Sharks are increasingly becoming a threatened fish group in the WIO, as they are highly vulnerable to fishing, and their misplaced reputation as man-eaters promotes an attitude of eradication or control rather than one of conservation, among the public and managers. Based on voluntary declared FAO records there is evidence that shark catches in the WIO have more than halved after reaching a peak of 180,000 Mt in 1996. About 100 million sharks are fished annually in the world, either as accidental catch in seine and/or gill nets, or direct exploitation for their fins and other products. Of this total, 30% is from the Indian Ocean, and mainly from the south-western part of the Indian Ocean. Catching of sharks for their fins, the most valuable part as they can be dried easily and sold at prices over USD 100 per kg is the greatest threat to shark populations in the WIO, and is banned in many countries.

The Great White shark (*Carcharodon carcharias*)

Great White sharks are naturally low in abundance, and range from cold temperate waters to tropical waters though in the latter they tend to prefer cooler deeper waters. In the WIO, Great Whites are most common in South Africa, and across a broad range of sizes. Elsewhere in the WIO they are rare, though individuals have been caught or seen throughout the region, and mostly as large pregnant females, suggesting they may pup in warmer waters. They have low reproductive potential, probably have a low natural mortality, and presumably possess a low capacity for density-dependent compensation to rapid declines in population size. It is therefore reasonable to conclude that populations are vulnerable to recruitment overfishing and all forms of non-natural mortality. However, their population status is poorly known over the species range owing to a lack of robust abundance indicators, and quantitative stock assessments are not currently possible.

Whale sharks (*Rhincodon typus*)

From the first whale shark described in 1828 from the Indian Ocean, the region continues to be one of the most important areas for whale sharks. Whale sharks are a broad ranging species with seasonal migration patterns over 1000s of km, though may be resident year-round in equatorial zones. Globally they are found in many areas with surface sea water temperatures of 18–30°C, and range across the entire Indian Ocean. Unusually for sharks, females give birth to large numbers, even thousands, of young.

The species has however been the subject of several targeted fisheries and thus sustained massive, rapid declines in population numbers. A number of fisheries targeting whale shark have developed within the Indian Ocean, some from traditional roots, such as in India, Pakistan and the Maldives that originated to supply the oil from the shark's liver for waterproofing boats This escalated especially in India during the 1990s to supply the demand in Taiwan for 'Tofu shark'. Reported figures indicate a peak in this Indian fishery of 279 sharks in 1999 but that despite increased effort only 160 were taken in 2000. This fishery was closed in 2001 when the species received protected status. The fishery in the Maldives previously took 20–30 whale sharks per year but proved unsustainable with declining catches and the fishery was stopped in 1995.

Whale shark tourism has rapidly grown in importance in the WIO, with predictable seasonal sightings known in Kenya (e.g. Diani), Tanzania (e.g. Mafia) and Mozambique (e.g. Tofo). In the islands, two main aggregation areas (feeding and nursery) have been identified: the granite islands of Seychelles (Mahe in particular) and the northwest coast of Madagascar, especially near the island of Nosy Be. The dynamics and inter-relatedness of these populations are unknown, but represent a significant opportunity for blending conservation, research and economic development.

Other sharks and rays

Reef and oceanic sharks are widely dispersed but their populations greatly reduced through fishing mortality. In the WIO the bull shark or Zambezi shark (*Carcharhinus leucas*) is most strongly implicated in attacks on people, in both mainland and island sites, fuelling the general fear of sharks and low commitment to their conservation in most regional countries. In austral winter in Mayotte, manta rays (*Manta alfredi*) and scalloped hammerhead sharks (*Sphyrna lewini*) are particularly abundant near steep reef slopes. Geyser Bank may constitute a nursery area for tawny nurse sharks (*Nebrius ferrugineus*) and Zélée Bank could be a nursery ground for grey reef sharks (*C. amblyrhynchos*). At Tofo in southern Mozambique, there is a major manta ray (*M. alfredi*) aggregation that has been investigated for several years. Annual population size estimates range from 150 to 450 individuals and the super-population estimate was 800 individuals.

Guitarfish are known from the region, though exploited and highly depleted.

Management and conservation

Reducing excess mortality of sharks is a fisheries issue requiring action on gear types and their operation, and preventing the most destructive markets, especially for shark fins. These actions need to be taken at regional and global levels. An additional solution is the creation of marine protected areas focused on key locations and habitats of importance to sharks, and some of the remaining high-density populations of sharks.

Because of their importance in fisheries and as charismatic species, sharks have been mentioned in multiple global legal instruments, which can support actions at multiple levels. The examples below illustrate these with reference to the Whale Shark:

IUCN Red List – the whale shark is listed as Vulnerable in the IUCN Red List

CITES – Appendix II, 2002. This status should allow for the closer monitoring of and restriction in international trade in whale shark products, and by so doing assist in the conservation of the species on a global scale.

Convention on Migratory Species (CMS) – Appendix II, 1999. On listing, a call was made for co-operative actions by 2001–2002, however, it was not until November 2005 that the CMS approved a 'Recommendation for the conservation of migratory sharks' proposed jointly by Australia, New Zealand and Seychelles.

UNCLOS – Agreement on Straddling Fish Stocks and Highly Migratory Fish Stocks. This agreement recognizes that as the whale shark is a highly migratory species, coordinated management and assessment of shared migratory populations would promote an understanding of the cumulative impacts of fishing effort on the status of shared populations. To date, no such measures have been proposed.

FAO – International Plan of Action for Sharks – there is a potential framework for whale shark conservation. Unfortunately implementation of even National Plans of Action by FAO members has been extremely limited thus hampering plans for an international instrument.

Key references – Bruce (2009); Chabanet & Durville (2005); Colman (1997); Eckert & Stewart (2001); FAO (2000); Fowler S (2000); Hammerschlag & Fallows (2005); Jamon *et al.* (2010); Kiszka *et al.* (2009); Marshall & Barnett (1996); Marshall *et al.* (2011); Romanov *et al.* (2010); Rowat (2007); Rowat *et al.* (2009); Wickel *et al.* (2009); Wickel *et al.* (2010).

Turtles

Five out of seven species of marine turtle worldwide occur in the Western Indian Ocean (WIO): Green turtle *Chelonia mydas*, Hawksbill *Eretmochelys imbricata*, Loggerhead *Caretta caretta*, Leatherback *Dermochelys coriacea*, and Olive Ridley *Lepidochelys olivacea*. The most abundant species in the WIO is the Green Turtle, and the second most common is the Hawksbill. On the IUCN Red List of Threatened Species all are currently listed either as Critically Endangered (hawksbill, leatherback) or Endangered.

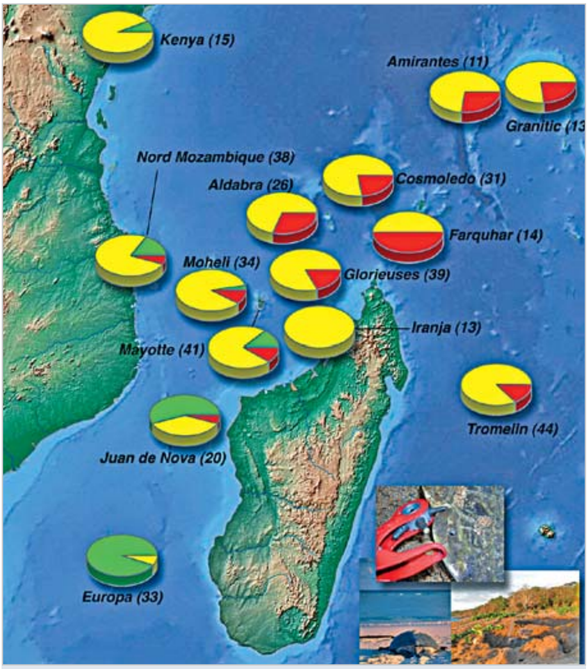
The complicated life cycles of sea turtles require them to utilize a variety of habitats. Eggs are laid and incubate in beach sand, but post-hatchlings are pelagic and inhabit the surface waters of convergence zones and major gyre systems throughout tropical and temperate oceans. These juvenile stages migrate with ocean currents over 1000s of kilometers. Most adult turtles also migrate over such distances, though post-nesting hawksbills in the Seychelles do not migrate as far as do adult green or loggerhead turtles. The feeding grounds of the bottom-feeding sea turtles include seagrass, coral reef, sand and mud flats, and mangrove ecosystems, while the pelagic leatherback feeds in oceanic surface waters of tropical, temperate, and even polar seas. Thus, the state of turtle populations is a good indicator of the overall health of coastal and marine ecosystems. Turtles may also be crucial for the functioning of healthy marine ecosystems; findings from the Caribbean suggest that the demise of the macro-herbivorous green turtles following European colonization had significant effects as few other species feed on seagrasses.

There has been extensive sea turtle research since the early 1990s in the region, but this information is still relatively scattered and not always standardized. Nevertheless, sea turtle information has been a backbone of the two subregional ecoregional planning exercises for mainland East Africa (WWF 2004) and the islands (RAMP-COI, unpublished). There is however a need for more specific sea turtle data particularly on feeding, breeding, juvenile routes and adult migratory routes in the WIO.

Genetic research has shown that there is mixing between the Atlantic Green turtle and those of the Mozambique Channel, and the south population of green turtles in the WIO (central Mozambique channel and southwards). Green turtles in the north of the channel and northwards are distinct, and there may be a distinct Seychelles population as well, with links to the Southeast Asian region. Interestingly, green turtles found between the islands of Europa and Juan De Nova were from both southern and northern genetic populations. The genetic differences could result from oceanographic features that affect the movement of the juveniles, suggesting a separation between the northern and southern parts of the Mozambique channel. Species-specific information, on sea turtles is provided below, though there are still significant gaps, particularly for parts of Madagascar and Mozambique.

Hawksbill turtle. © David Obura

Green turtles mating. © David Obura



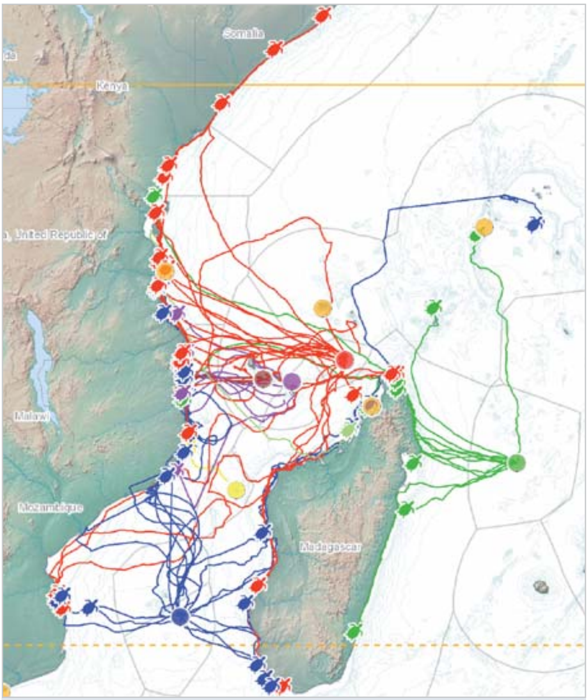
Green turtle genetic structure in the WIO. The pie charts show the proportion of different genes at each site. The green alleles are more common in the southern Mozambique channel, and yellow to the north, and red in the islands. c. Kelonia, Reunion. © Kelonia, Reunion

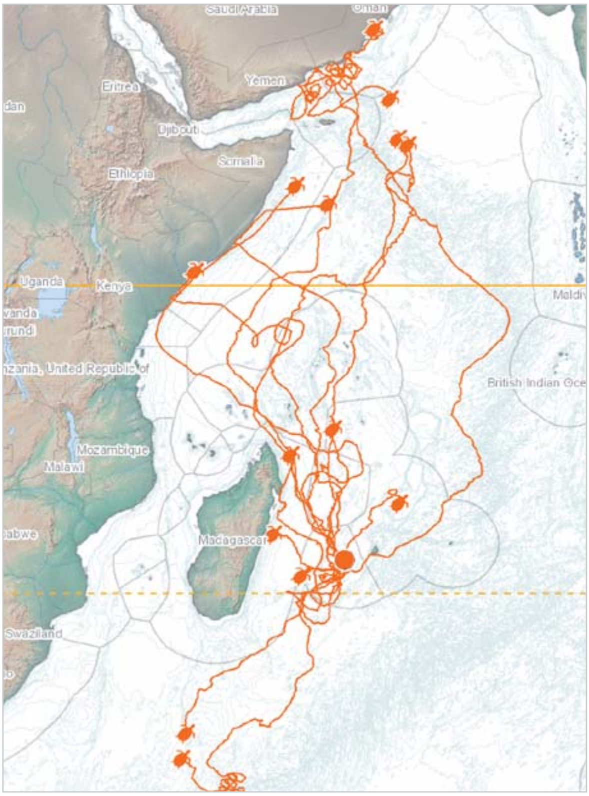
Green turtles

Area	Importance
Mozambique Channel	Used by all 5 species, genetic differentiation likely due to oceanography of the channel, separating northern and southern populations.
Isles Éparses, especially Europa, Glorieuse, Tromelin	Females nesting per annum: Europa up to 10,000; Grande Glorieuse 3000; Tromelin 1500, Juan de Nova <100. Annual trends in the number of nests over the last 20 years are positive for Europa, stable for Tromelin.
Comoros, especially Moheli	Up to 7,000 nesting females a year, and development habitat for the juveniles.
Mayotte	Up to 5000 nesting females a year, key feeding grounds and important to the juveniles.
Seychelles	Up to 10,000 female green turtles nest annually in Seychelles, predominantly in the southern islands--esp. Aldabra, Assumption, Cosmoledo, Astove and Farquhar. The species has become rare in the inner islands and Amirantes due to continuing exploitation. The Aldabra (WHS) green turtle population protected since 1968 has increased by 500-800% since 1968 and now numbers approximately 5000 females nesting annually and the population is increasing exponentially. Important feeding grounds for green turtles are adjacent to virtually all islands of Seychelles. Active conservation programmes involving nesting green turtles are underway in the Amirantes Group at Alphonse/St. Francois atolls, D'Arros/St. Joseph atoll, and Desroches, at a number of the inner islands (see following discussion of hawksbills).
Bazaruto	Nesting, feeding grounds and important for the juveniles.
Quirimbas – Mnazi Bay	Important nesting and feeding grounds, up to 200 nests per year.
Mafia – Rufiji	Key feeding grounds and some key nesting sites.
Kiunga, Kenya	Key feeding and nesting area with up to 130 nests a year.

Hawksbill turtles

Area	Importance
Saya de Malha/Banks	Feeding ground but there is limited information available.
Mozambique Channel	Migratory route.
Isles Éparses	Juan de Nova – up to 50 nesting females a year. Europa – important as development habitat (mangrove) for juveniles.
Mayotte	Up to 100 nesting females a year, key feeding grounds and important to the juveniles.
Seychelles	Most hawksbill nesting in the WIO occurs in the inner Islands (on the Seychelles Bank) & the Amirantes Group. Approximately 2,000 females are estimated to nest annually in Seychelles. Satellite telemetry indicates the Seychelles Bank is the primary feeding ground for hawksbills nesting in the Granitic Seychelles, but hawksbills feed in habitat <60 m deep throughout Seychelles and important feeding grounds for immature hawksbills are found adjacent to virtually all islands in Seychelles. All sea turtles are legally protected in Seychelles and active conservation programmes are underway at nearly all of the inner islands (especially Aride, Bird, Cousin, Cousine, Curieuse, Denis, Fregate, North, Silhouette, Ste. Anne, and parts of Mahé and Praslin) and in the Amirantes group at Alphonse/St. Francois atolls, D'Arros/St. Joseph atoll, and Desroches, as well as at Aldabra atoll in the southern islands.
Bazaruto	Nesting, feeding grounds and important for the juveniles.
Quirimbas – Mnazi Bay	Important nesting and feeding grounds.
Mafia – Rufiji	Feeding grounds and some key nesting sites however there is limited information available.
Kiunga	Feeding and nesting area with up to 10 nests a year however there is limited information available.
N. Madagascar	Very limited information is available, though nesting is present in many locations, e.g. Nosy Iranja.





Green turtle migration routes (top) and Loggerhead turtle migration (right). ©Kelonia, Reunion

Loggerhead and leatherback turtles

Known important nesting areas include the Maputo Bay – Machangulo Complex, iSimangaliso in Kwazulu-Natal (World Heritage Site), the Bazaruto archipelago and South East Madagascar.

Foraging populations of both species are found throughout the Seychelles as well as La Réunion and the Scattered Islands. East African coast (Mozambique + Tanzania + Kenya) are important feeding grounds for the loggerhead.

Olive Ridley

There is limited information on the Olive Ridley in the WIO especially on specific nesting, feeding grounds and their juvenile movements. Olive Ridleys have been recorded in the waters of the inner islands of Seychelles and in the Mascarenes, and a few nest reports have been provided from Kiunga Marine National Reserve and Malindi in Kenya.

Threats

Some of the threats facing marine turtles in the WIO include: exploitation for food (meat and eggs), oil, leather and ornamentation; mortality associated with incidental capture in fisheries; marine and land-based pollution; and disruption of essential nesting and feeding sites. Some of these threats have been going on for centuries as turtles have long been a resource of economic and cultural significance to people living in the region. Turtle meat and eggs provided protein to coastal residents, and the calipee (dried cartilage used to make turtle soup) and meat from green turtles and shell from hawksbills were exported to foreign markets in Europe and Asia. In some locations (for example, South Africa, Kenya, Seychelles, Mayotte and Madagascar) turtles also generate income as a tourism attraction.

Until the mid-to-late 1900s direct take of turtles and their eggs posed the greatest danger to their long-term survival. While this remains an enormous problem in many areas, indirect threats are growing in importance, particularly incidental bycatch in artisanal and commercial fishing gear, and loss of nesting and foraging habitats due to coastal development, pollution, and erosion resulting from poor coastal management and sea level rise. Marine ecosystems are disrupted by overexploitation, mechanical damage, pollution of all kinds and land-based runoff as well as by temperature rise associated with global warming and climate change.

Turtles are vulnerable to being caught in fishing nets, such as this one set in a channel mouth. ©David Obura

Conservation of sea turtles

According to the Sodwana Declaration (IUCN, 1996) "only a few of the discrete populations in the region are stable or growing; three of the populations are becoming extinct; most populations are either in decline or have not yet begun to recover from centuries of irrational use". Sea turtle conservation and management provide numerous challenges. Saving sea turtles requires the protection of these ecosystems on which we all depend on both small and large scales. Moreover, sea turtles are highly migratory, and individual animals may travel tens of thousands of kilometers in their lifetimes, spending various lengths of time in the open sea, and in territorial waters of multiple states. Conserving sea turtles thus also requires that people cooperate internationally and regionally. Also, although such threats are fairly well recognised they are not as well documented, and spatial and temporal overviews of threats generated from specific data sources are lacking.

Today international agreements, most importantly CITES (the Convention on International Trade in Endangered Species), prohibit international trade in sea turtles. Two regional instruments relevant to sea turtle conservation in the WIO include the Sodwana Declaration[1], which provides a comprehensive "shopping list" of priority actions and strategies in various domains, but does not hold Governments and other partners accountable for actions, and the Memorandum of Understanding on the Conservation and Management of Marine Turtles and their Habitats of the Indian Ocean and South-East Asia (IOSEA), adopted in 2001 under the auspices of the Convention on the Conservation of Migratory Species of Wild Animals (CMS). However, this too, is non-binding, but undertakes a suite of activities coordinated from a secretariat co-located with UNEP in Bangkok, Thailand. Under these programmes, several meetings have been hosted in the WIO over the last two decades, all calling for regional cooperation among countries to manage sea turtles as a shared stock, though WIO countries are still conducting turtle conservation and management largely in isolation. The *World Heritage Convention* offers a particularly powerful complement to this suite of regional instruments.

Key references – Allen *et al.* (2010); Bourjea *et al.* (2006); Bourjea *et al.* (2007); Frazier1984; Lauret-Stepler *et al.* (2007); Mortimer (2004); Mortimer & Balazs (1999); Mortimer 1984; Mortimer 1988; Mortimer and Bresson (1999); Mortimer *et al.* (2011); Remie and Mortimer (2007); WWF (2004).

1. *A Marine Conservation Strategy and Action Plan for the Western Indian Ocean* (IUCN, 1996),

Seabirds

Seabirds, i.e. species that spend a large part of their lives at sea, of the coast of mainland East Africa, associated islands and of the open sea are abundant and diverse, though they have received little attention in the region until the last 5–10 years. Recently, growing interest in how they can serve as indicators to patterns of oceanic productivity, and thereby to fisheries, has led to a rapid upsurge in studies. Further, the impacts of growing, ocean-wide fishing effort have led to greater concern about impacts, to the marine environment as well as to seabirds.

Globally, there are over 300 species of true seabirds, with about half this number reported for the WIO. The main groups of seabirds are albatrosses, petrels, shearwaters, tropicbirds, boobies, frigatebirds, gulls, terns, cormorants and penguins, many of which typically breed in large colonies on small islands or remote portions of continents. At least 31 species of seabirds breed on WIO islands, and an additional number (such as African penguins and cormorants) are known also from the mainland coast of eastern and south-eastern Africa.

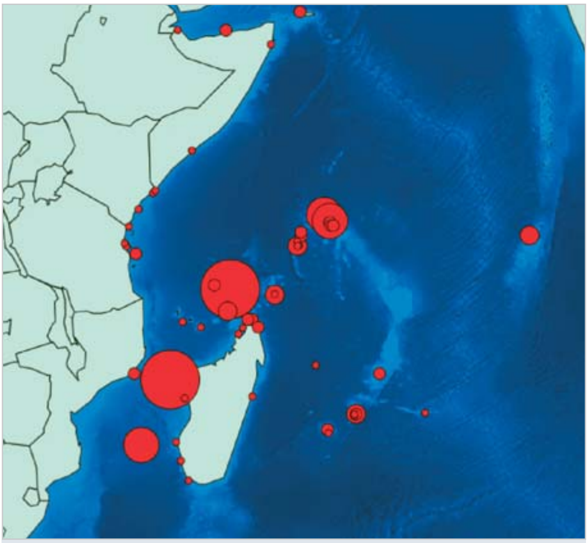
Heron. ©Cheryl-Samantha Owen/ www.samowenphotography.com

Barau's Petrel. ©Mathieu le Corre

Masked booby. ©Mathieu le Corre

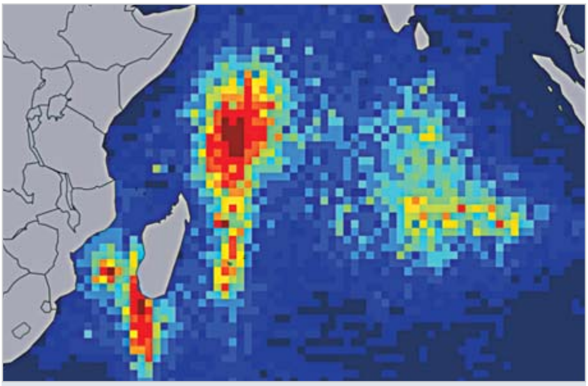
Sooty tern colony. ©Mathieu le Corre

White-tailed tropicbird. ©Mathieu le Corre



Primary seabird breeding colonies in the WIO. The largest circles represent > 1,000,000 breeding pairs.

©Le Corre et al. 2012



Seabird density based on tracking data, indicating major foraging grounds. Dark red indicates the highest density of seabirds. ©Le Corre et al. 2012

Breeding and nesting

A recent regional survey of the seabird species that breed in the WIO estimated a total seabird population of 7.4 million pairs, and found that the main breeding grounds are in the Seychelles (Aldabra and the granitic islands) and in the Mozambique Channel (Juan de Nova, Europa and Glorieuses). The Mascarene Islands also have significant breeding populations, at smaller numbers but for rarer species. In 2005, 16 species were recorded breeding in the Mozambique Channel with an extraordinarily high density of over 3 million breeding pairs, of which 99% were sooty terns (*Sterna fuscata*), concentrated at Juan de Nova (66%, 2 million pairs), Europa (25%, 760,000 pairs) and Glorieuses (9%, 270,000 pairs). Thirteen thousand pairs spread among 13 seabird species breed on islets off the West coast of Madagascar, but population sizes are low and threatened by poaching. Europa is of particular conservation interest as it holds some of the last colonies of large Pelecaniforme birds (frigatebirds, red-footed boobies and red-tailed tropicbirds), which have experienced dramatic declines in most islands of the WIO.

Foraging

Many tropical seabirds associate with tuna, as both groups feed in areas of high productivity, determined by ocean circulation patterns, and also because top predators such as tuna drive the primary seabird prey to the surface, where they become accessible to the birds. This interaction makes seabird populations highly dependent on the health of tuna and other open ocean top predators. They can also serve as indicators of the health of these top predators.

Based on foraging grounds, and their overlap with the nesting grounds, the following five areas were identified as priority regions for seabirds in the WIO:

Seychelles Basin – the Seychelles Plateau and a wide oceanic region around the Plateau is the main area occupied by wedge-tailed shearwaters (95,000 pairs that breed in the Seychelles) and white-tailed tropicbirds (6500 pairs). The Seychelles Archipelago (excluding Aldabra and Cosmoledo) supports the greatest abundance of seabirds in the tropical Indian Ocean with 14 breeding species totaling 2.2 million pairs.

Southern Mozambique Channel around Europa Island – Europa Island is one of the most important seabird breeding sites in the WIO, with 20, 40 and 8 % of the great frigatebirds, red-tailed tropicbirds and red-footed boobies respectively. The southern Mozambique Channel is a major foraging area for all 3 species, as well as for most seabirds of the island.

Madagascar Plateau (Walters Shoals) – is a major foraging ground for two of seven tracked seabird species, the red-tailed tropicbird (many of which breed on islands in the S. Mozambique channel (Europa and Nosy Vé), and Barau's petrel, which is endemic to Reunion and classified as endangered. With the limited sample size, the region is likely significant for several other seabird species.

Mascarene islands (Reunion, Mauritius, Rodrigues) and Tromelin Island – the only breeding ground of two endemic petrels, the Barau's petrel (endangered) and the Mascarene petrel (*Pseudobulweriaaterrima*, critically endangered), and other species that breed on Reunion.

Central Indian Ocean – is a wide region for foraging for at least four migratory seabirds: Barau's petrel, the red-tailed tropicbird, the wedge-tailed shearwater and the white-tailed tropicbird. There are two main subregions, both associated with seamounts and undersea topography that enhance upwelling, and therefore productivity.

Threats

The main threat to both resident and migrant birds in the WIO is habitat degradation, affecting breeding and nesting sites. Other threats are disturbance by fishers and tourists, egg collecting, and predators such as rats, cats, dogs and potentially oil spills. Invasive species such as rats and cats can decimate breeding bird populations on remote islands. Fisheries impact seabirds in various ways, the main impacts include direct mortality by fishing gear (bycatch) and competition when fisheries and seabirds target the same prey. Climate change is an increasing and more insidious threat to coastal birds. Rising sea-levels may swamp low-lying nesting colonies or lead to loss of shoreline feeding habitat. Warming and acidification of waters damages coral reefs, and may affect the distribution and abundance of key food species for some coastal and seabirds.

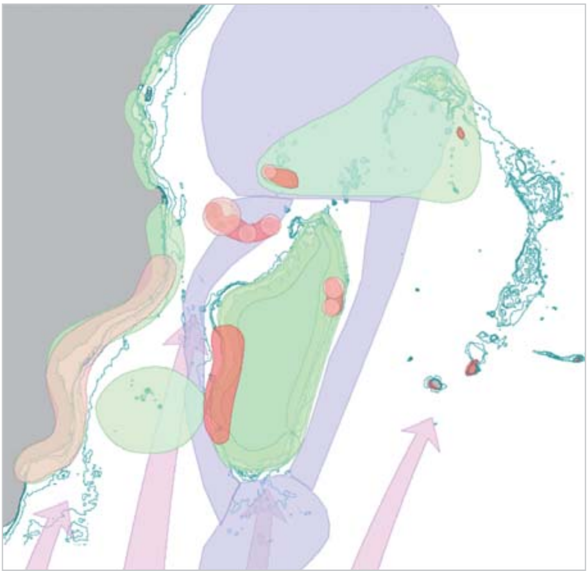
Few species breeding in the WIO region are globally threatened (i.e. on the IUCN Red List, see sheet H1) because most seabirds have very wide distributions. However dependence on remote islands for breeding makes individual populations highly vulnerable to changes and threats. The Roseate tern is of particular concern in the WIO as populations have undergone major declines, as is the status of the Reunion Petrel (Critically Endangered) and Barau's Petrel (Endangered) on Reunion.

Management and Conservation

Some of the large nesting seabird colonies and key roosting and feeding sites for coastal migrants lie within MPAs. For example, the Seychelles has a particularly large number of important breeding sites which are now protected e.g. Aldabra, Cousin Island, and Aride. Another mechanism for the protection of bird populations is through the designation of Ramsar sites under the Convention on Wetlands (Ramsar). For designation, a site must meet one of two criteria of importance to waterbirds: Criterion 5 for sites that regularly support at least 20,000 waterbirds; and Criterion 6 for sites that regularly support 1% or more of a waterbird species biogeographic population. Many of the key sites for bird species are now recognised internationally as Important Bird Areas (IBAs), under a scheme initiated by BirdLife International, and several of these are included either within or overlap with MPAs. The distribution of IBAs in the WIO reflects many of the most important breeding sites mentioned above, but further protection measures are necessary in many of them. BirdLife's Global Seabird Programme, which started in 1997, focuses on specific objectives for seabirds, with a focus on fishery interventions and regional and global scale issues affecting seabirds. In 2004 the GSP launched a marine IBA programme, and work towards identifying marine IBAs in the WIO region is well underway.

Key references – Baker and Fison 1989; Chittenden) (2007); Grant (2010); Harrison 1989; Hayman *et al.* 1986; Jaquemet *et al.* (2005); Le Corre & Bemanaja (2009); Le Corre & Jaquemet (2005); Le Corre *et al.* (2012); Message & Taylor (2005); Newman (2010); Olsen & Larsson (2004); Sinclair & Ryan (2011); Sinclair *et al.* (2002); Soothill & Soothill 1982; Stevenson & Fanshawe (2004); Watson *et al.* 1963; ZICOMA (2001); Zimmerman *et al.* (2001).

Marine mammals – Dugong, Whales and Dolphins



Cetacean zones in the WIO, emphasizing the primary zones of cetacean sightings (green), blue whale sighting zones (blue), primary feeding grounds (pink), wintering grounds (red) for humpback whales and migration routes (arrows) for humpback whales. ©RAMP-COI

There are approximately 36 species of whales and dolphins in the WIO region, of which 8 are baleen whales, 2 to 3 sperm whales, 13 toothed whales and 13 dolphins. Dugong are reduced to scattered remnant populations, probably totaling no more than 500 animals in the WIO, of which over 300 are known to exist in the Bazaruto Archipelago.

Species known to have reduced in numbers in the WIO include the dugong (*dugong dugon*) blue whales (*Balaenoptera musculus*), fin whales (*B. physalus*), sei whales (*B. borealis*) and humpback whales (*Megaptera novaeangliae*). The severe depletion of almost all stocks of 'great whales' in the Southern Hemisphere is well documented.

Dugong. ©Fergus Kennedy

Dugong (*Dugong dugon*)

Dugongs range in near shore tropical and subtropical coastal and island waters of the Indo-Pacific between southern Mozambique in the west and Vanuatu to Japan in the east, between latitudes approximately 27° north and south, in waters warmer than about 18°C. Population estimates have been made in three areas, Australia; the eastern Red Sea; and the Arabian Gulf. While the status of the dugong over a large proportion of its range remains poorly known, their populations are significantly depleted in most locations, and believed to be declining in over two-thirds of their range, and locally extinct in some locations.

Historically, WIO dugong distribution extended from Somalia to Mozambique and northern South Africa, and on the islands of the Comoros, Seychelles, Madagascar and Mauritius. Throughout this range, dugong populations have suffered a steep decline since the 1960s. Although dugongs are protected across all the WIO states, enforcement and consequent protection is strongly limited by capacity and resources.

Dugong in Mozambique

Surveys in the late 1960s suggested that dugongs were common along the Mozambique coastline from Maputo Bay, Chidenguele, Inhambane Bay, Bazaruto Bay, Mozambique Island and Pemba Bay and the Quirimbas Archipelago. Dugong herd sizes of 8 – 10 individuals were reported for Inhaca Island in 1992, although this area is now thought to support only 2 or 3 individuals. While dugong were observed throughout Inhambane Bay in October 1994, no animals were recorded during a survey of the bay in 2007. The Bazaruto Archipelago supports the largest dugong population in the WIO, and although there were suggestions that the population was declining, recent surveys suggest about 300 individuals. Only one dugong was recorded in aerial surveys of the Quirimbas archipelago of northern Mozambique in 2007, and an incidental sighting of a lone individual was made in 2009.

Key locations for dugong observations

- Mozambique, where the most significant population of about 300 in Bazaruto is intensely studied and under pressure; likely minor populations in the north in the Quirimbas and Primeiras/Segundas islands.
- Madagascar, where the most important dugong areas are the islets of Andavadoaka - Morombe; at Ambararata – Courrier and Diego Bay; the bays and estuaries of Sakoany – Bombetoka; Ambavarano – Vohémar; and Sainte-Marie Island;
- Tanzania, in the region of the Rufiji Delta and Mafia Island;
- Aldabra, Seychelles – two dugong were recorded in the lagoon in the last 5 years.
- Mayotte – the lagoon.
- Kenya – small populations of a few individuals persist off the Lamu-Kiunga coast and at Gazi in the south near the Tanzanian border;

Dugongs possibly still occur in the Comoros (at Moheli Island) and off the Somalia coast, although their current status is unknown. They appear to have become extinct from Mauritius and the Maldives.

The tail of a diving humpback whale, and a turtle hatchling. Both whales and turtles depend on ocean currents and productivity, migrating 1000s of kilometers to take advantage of the best habitats to complete their very different life cycles. © IUCN

Humpback whales (*Megaptera novaeangliae*)

Humpback whales are widely distributed throughout WIO with distinct population structure that is still under study. Four subpopulations are suggested by the IWC: 1) on the East coast of Africa from South Africa to Kenya. This is a large substock, likely >6000 animals; 2) in the Comoro Islands, a smaller aggregation, with Mayotte having a high sighting rate of mothers with calves and potential high residency, and a late season peak; 3) around Madagascar, likely the largest substock with 7000–8000 animals; and 4) the Mascarene and Seychelles Islands, a smaller aggregation, possibly a recent range expansion following recovery of numbers since protection from whaling. Current genetic evidence suggests the above may form 2 genetic substocks, with the islands (Comoros, Madagascar, Mascarenes, Seychelles) experiencing significant mixing. It may be that the Comorian stock represents a connection to the East African one.

Migration of humpbacks is primarily along north-south routes, with populations from the southern Ocean migrating along the East African coast, through the Mozambique Channel and up the Madagascar Plateau. A major wintering concentration has been identified in Antongil Bay in NE Madagascar. Key areas for humpback observations, sightings above water and for hearing whalesong underwater include, among other locations, Antongil Bay (NE Madagascar), Tofo (S Mozambique), Nacala/Quirimbas (N Mozambique), Reunion and Malindi (Kenya). Recent work suggests a major wintering ground for humpbacks off Bazaruto, Mozambique, and significant concentrations off Zanzibar.

Boat-based surveys of the waters surrounding Mayotte have been conducted in the austral winters of 1995-2002. A total of 102 individuals have been identified. Mother and calf pairs make up a large number of the total observed, and have been seen in the region as late as November. They make extended stays in the region and have been re-sighted over a two-week period. Very little behaviour associated with mating activity (competitive groups and singing) has been observed in this area. Given the high percentage of mother/calf pairs and low frequency of mating activity, the waters of Mayotte may serve as a critical wintering habitat or resting point along the migration route for mothers and calves. Some photographic matches have been made with other humpback whale wintering areas in Madagascar, providing some evidence of migratory links.

Whales and dolphins found in the WIO

Baleen Whales – Mysticeti

Eleven species are known worldwide – 8 are found in the WIO:

- Southern Right Whale (*Eubalaena australis*)
- Blue Whale (*Balaenoptera musculus*)
- Fin Whale (*Balaenoptera physalus*)
- Sei Whale (*Balaenoptera borealis*)
- Bryde's or Tropical whale (*Balaenoptera edeni*)
- Gray whale (*Eschrichtius robustus*)
- Minke Whale (*Balaenoptera acutorostrata*)
- Humpback Whale (*Megaptera novaeangliae*)

Toothed Whales – Odontoceti

Sperm Whales (Physeteridae) with only 3 species

- Pygmy Sperm Whale (*Kogia breviceps*)
- Dwarf sperm whale (*Kogia simus*)
- True sperm whale (*Physeter macrocephalus*)

Globicephalidae which includes 6 species

- Great Killer Whale (*Orcinus Orca*)
- Melon headed whale (*Peponocephalus electra*)
- False Killer whale (*Pseudorca crassidens*)
- Short-finned pilot whales (*Globicephala macrorhynchus*)
- pygmy killer whales (*Feresa attenuata*)

Beaked Whales – Ziphiidae includes 18 species worldwide including:

- Dense beaked whale (*Mesoplodon denirostris*)

Dolphins

- Spinner dolpin (*Stenella longirostris*)
- Spotted Dolphin (*Stenella attenuata*)
- Common Dolphin (*Delphinus delphis*)
- Humpback dolphin (*Sousa chinensis*)
- Indian Ocean Bottle nose dolphin (*Tursiops aduncus*)
- Risso's dolphin (*Grampus griseus*)
- Rough-toothed dolphin (*Steno bredanesis*)
- Fraser's dolphin (*Lagenodelphis hosei*)
- Striped Dolphin (*Stenella coeruleoalba*)
- Risso's dolphin (*Grampus griseus*)

Blue whales (*Balaenoptera musculus*)

Blue whales are poorly documented throughout the WIO, but have a high conservation importance globally, as their numbers are estimated to be at 1-2% pre-whaling abundance in the Southern Hemisphere. Two sub-species are recognized, and the one in the WIO is the pygmy blue whale *B. m. brevicauda*. These are likely restricted to waters north of about 55°S, and likely breed in tropical waters, though very little is known about distribution. The other subspecies is the Antarctic blue whale *B. m. intermedia*, which summers in the Antarctic but has unknown wintering/breeding areas. Based upon vocalization types (song "dialects"), there appear to be at least 3 populations of pygmy blue whales in the Indian Ocean – a Madagascar call type, a Sri Lanka call type, and an Eastern IO/Western Australia call type. The Antarctic blue has a single distinctive call type.

Blue whale sightings have primarily been in the Mozambique Channel, off the SW and SE coasts of Madagascar, and on the Madagascar Plateau. Approx 450 pygmy blue whales are estimated for the south of Madagascar on the Madagascar Plateau. Based on acoustic observations, there is some evidence for range overlap of the different call type populations, with the Madagascar Plateau having only the Madagascar call type, the northern tip of Madagascar having both Antarctic and Sri Lanka call types, and the Crozet Islands having Madagascar and Antarctic call types. Historic data from whaling suggests there is a pygmy population NW of the Seychelles (offshore Kenya/Somalia), but its current status is unknown and possibility for migratory connections with southern populations is similarly unknown.

Southern Right Whale (*Eubalaena australis*)

The primary distribution for this species is outside of the WIO, on the southwest coast of South Africa, but recent sightings have included southern Mozambique, and around Madagascar on both the east and west coasts, in Antongil Bay, off Fort Dauphin, Toliara/Anakao, and Andavadoaka. The current population is estimated at 1,500 – 4,000 individuals. The population is undergoing recovery, and the sporadic WIO sightings may indicate expansion back into a prior range, and/or may represent remnants of a more widely distributed population that was extirpated.

Beaked whales

Recent aerial surveys are providing new information on this previously little known group. The Mozambique Channel emerges as a very important high diversity hotspot, particularly off the mid-west coast of Madagascar. High diversity is also found in SW Madagascar and around the Comoro Islands extending east to NW Madagascar in

A pair of Spinner dolphin (*Stenella longirostris*) near Aldabra. © Cheryl-Samantha Owen/ www.samowenphotography.com

off-shelf waters. These surveys did not include the mainland coast of Africa, but many species are also reported along the mainland coast.

Coastal Dolphins

The 13 dolphin species known from the WIO are widespread, though four coastal species are of primary interest for conservation:

Indo-Pacific Humpback Dolphin (*Sousa chinensis*) is widely distributed along the west coast Madagascar, and eastern African Mainland from South Africa to Tanzania, and in northern Kenya. It is typically in small group sizes, and may form mixed species groups with bottlenose and other dolphins. The species prefers sheltered shallow (< 30 m) coastal waters, and is not found on Madagascar east coast sites such as Antongil Bay and Fort Dauphin. In Madagascar, it is well documented only in Toliara/Anakao, Mahajunga, Loza Bay, Nosy Be region, Mahjunga and Nosy Mitsio. It is extremely vulnerable to human activities.

Indo-Pacific Bottlenose Dolphin (*Tursiops aduncus*) is widely distributed and common throughout the region. The species is well documented in E and W Madagascar, as well as in Tanzania, Kenya, South Africa, Mozambique, Mayotte, Reunion and Mauritius. It is typically in near-shore, shallow waters, but can also be found in deeper coastal waters. In most locations it is not hunted, except on the west coast of Madagascar, but is vulnerable to human activities as there is a significant bycatch in coastal aritsanal fisheries.

Spinner dolphin (*Stenella longirostris*) is widely distributed and common throughout WIO. While it is also typically found in near-shore, shallow waters, it can also frequent deeper coastal waters and may exhibit a diel pattern of close near-shore, shallow water distribution during daylight (resting phase), and offshore, deep water distribution during nighttime (feeding phase). Unlike the other two species, group sizes can be large, in the 100s.

Spotted dolphin (*Stenella attenuata*) are most abundant than than other species of dolphin, in surveys conducted off western Madagascar and Mozambique, and also abundant in aerials surveys conducted in Kenya.

All four dolphin species have high conservation value as their coastal ranges, life history and habits make them vulnerable to human activities. This also gives them valuable as an indicator species of general human impacts in the coastal marine environment. While they are typically not hunted, dolphin hunting is a threat on the southwest and west coast of Madagascar.

An interesting aspect regarding cetaceans in the WIO is that there are a number of similarities between the cetaceans in the WIO, the eastern tropical Pacific and the Gulf of Mexico. Firstly, the same species were common or rare, regardless of ocean. Second, these differences in abundance were due primarily to differences in encounter rate, and less to school size. Third, regardless of ocean, three species comprised the majority of the cetaceans encountered, *Stenella attenuata*, *S. longirostris*, and *S. coeruleoalba*.

Threats

The near-shore zone throughout the WIO is highly productive and subject to high levels of artisanal exploitation and development, especially in nearshore habitats such as seagrass and coral reefs. Dugongs are entirely dependent on such seagrass and reef habitats. An increase in large mesh gill netting from the 1970s onwards, along with a lack of law enforcement, seine netting, commercial trawl operations, palisade fish traps, habitat destruction of seagrass beds and increased anthropogenic disturbance all contribute as threats to dugong populations in Mozambique, and in the WIO.

The greatest threats known to whales and dolphins (similar to the Dugong) include fishing net entanglement either directly (whaling) or indirectly causing death through drowning. Chemical pollution (heavy metals, pesticides and other toxins) can cause direct harm to the animals by accumulation in their tissue, via ingestion of contaminated prey. Deep water beaked whales and delphinids are known to be sensitive to acoustic disturbance in areas with rapidly expanding exploration for offshore petroleum (including seismic surveys and bathymetric mapping, implicated in disturbance and strandings in other regions). A key area is NW Madagascar where there are active offshore petroleum concessions, high species diversity including deep-water species, and a recent mass stranding of offshore dolphin (melon headed whale, *Peponocephala electra*) that was coincident with petroleum exploration activities. There was also a mass stranding of common bottlenose dolphins off Bazaruto in October 2007, coincident with offshore seismic surveys.

Conservation of marine mammals

The Bazaruto Archipelago is an existing MPA, and has the largest and possibly last viable dugong population in the Eastern African region. The survival of the dugong ultimately depends on the maintenance of adequate habitat, notably the sea grass beds.

Amongst the efforts of the International Whaling Commission (IWC) to facilitate the recovery of the great whales was the establishment of the Indian Ocean Sanctuary (IOS) in 1979. This Sanctuary consists of those waters of the Northern Hemisphere from the coast of Africa to 100°E (including the Red and Arabian Seas and the Gulf of Oman) and those waters of the Southern Hemisphere between 20°E and 130°E from the equator to 55°S. The Sanctuary offers protection from commercial whaling to the great whales. The IOS is generally established for limited time periods, and has been extended continuously to date, in 1989, 1992 and most reently in 2002.

There is critical need to investigate the status of dolphin populations and threats to them in the countries bordering the Indian Ocean. More research emphasis should in future be placed on investigating by-catch and the possible over-fishing of delphinid prey stocks, and on abundance and distribution particularly for offshore cetacean species. Within South Africa and Mozambique, there is limited evidence that the IOS has played a role in stimulating research on cetaceans to date. In Zanzibar, research on dolphins based on mortality as fisheries bycatch has revealed information on diet and population structure. Whale or dolphin watching, if developed carefully, could bring much needed income to developing countries. This has recently been developed in a number of countries including South Africa, Kenya, Seychelles and Mauritius.

Key references – Best *et al.* (1996); Branch *et al.* (2007); Cerchio *et al.* (2008); Cerchio *et al.* (2009); Cherfas 1989; Clark & Lamberson 1982; Cockcroft (1995); Cockcroft & Krohn (1994); Cockcroft & Young (1998); Cockcroft *et al.* (1994); Dulau-Drouot *et al.* (2011); Findlay *et al.* (1998); Kiszka (2010); Kiszka *et al.* (2007); Kiszka *et al.* (2008); Kiszka *et al.* (2010); Laws (1985); Leatherwood & Donovan 1991; Leatherwood *et al.* (1984); Marsh & Lefebvre (1994); Marsh *et al.* (2001); Peddemors (1999); REMMOA (unpublished); Rosenbaum *et al.* (1997); Sirenews (2001).

4

Potential marine sites of Outstanding Universal Value

Mozambique Channel

Description

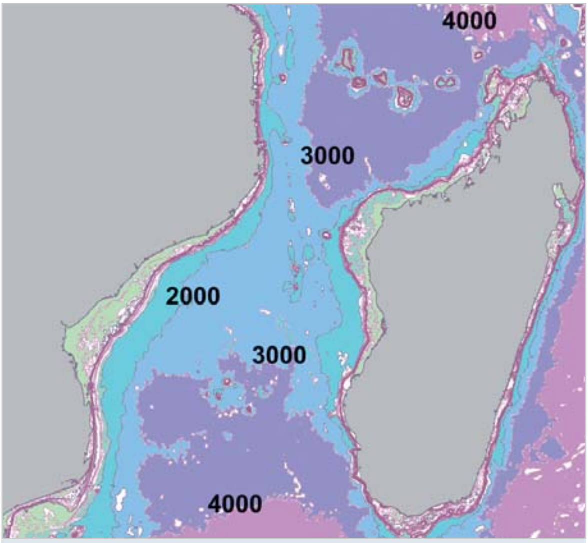
The Mozambique Channel extends from about 12°N, where the Glorioso Front marks the transition from the South Equatorial Current to the waters of the channel, slightly N of Glorieuses island, to about 25°S at a line stretching from the southern tip of Madagascar to Mozambique. It varies from approximately 800–900 km wide at its northern and southern ends, to a minimum of 400 km wide at about 16°S.

The channel started to form about 180 mya as the ancient continent Gondwana rifted and Madagascar (then joined with India, Australia and Antarctica) split off from the African coast. Since about 140 mya its configuration has remained relatively constant though during the Cenozoic the Africa-Madagascar complex has migrated northwards about 15° of latitude, and tectonic and volcanic activity has occurred in the central and northern parts of the channel. The floor of the channel ranges from about 3500 to < 2000 m, being shallowest at the narrowest point at about 16°S. Within the northern part of the channel, tectonic and volcanic activity has resulted in the formation of the Davie Ridge (13-18°S) which peaks at 300 m. A hotspot has created the Comoros islands, starting with Mayotte (5.4 mya) and ending with Grande Comore, which is estimated at 130,000 y, and still active today, and a source of earthquakes and volcanic eruptions.

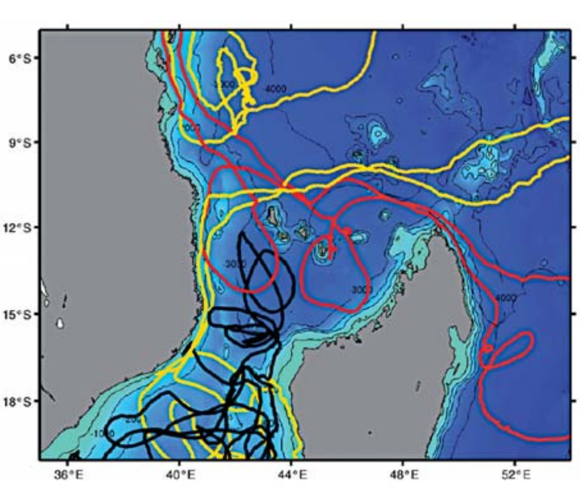
The oceanography of the Mozambique Channel was unknown until ten years ago, when the existence of highly variable eddies several 100 km across, often in dipoles (an anticyclonic and cyclonic eddy pair) that formed in the region around the Comoros were discovered. As a result of vorticity imparted into the flow of the SEC as it flows around the tip of northern Madagascar, both cyclonic (clockwise) and anticyclonic (anticlockwise) eddies are generated. At times, a larger gyre is also formed that circulates around the Comoro islands. Further dynamism in these features is imparted by Rossby waves that cross the Indian Ocean, interacting with the narrow constriction of the channel at 16°S. Often eddies are generated in pairs that move southwards through the channel, and 6-8 pairs may be formed through the course of a year.

The consequences of eddy formation ramify throughout the channel, and at all levels of biological functions. Because water flows in all directions as a result of the eddies, genetic connectivity throughout the Mozambique Channel is likely very high, particularly in the north, resulting in high retention and recruitment of larvae in pelagic and shallow marine ecosystems, and thereby high resilience of communities and populations. Due to the rotation of the eddies, they also result in down – and upwelling of water, and warmer and cooler temperatures in the centers of the eddies, and this transfers nutrients across the thermocline. Further, the eddies reach through the water column to at least 1000 m depth, and as these touch the continental shelves they draw nutrients off the slopes and into the water column. These eddy dynamics profoundly affect pelagic biological communities including phytoplankton, zooplankton, larger invertebrates, fish and marine mammals, and birds. While the full biological consequences of the eddy dynamics are not yet known these count as a unique oceanic system and likely to be critically important not only for the biology of species and ecosystem processes in the Mozambique channel, but also for fisheries and other economic uses.

The Mozambique Channel. © David Obura



Depth in the Mozambique Channel, showing the major transitions from 2000 m in the mid-point of the channel down to >4,000m towards the basins to the north and south. © David Obura



Connectivity patterns in the northern Mozambique Channel, showing drifter paths that move across the entire channel, and both north and south out of the northern channel region. © Raymond Roman

Finally, the highly dynamic eddies and net current in the channel contributes about 50% of the water transported in the Agulhas current, forming a link in the chain of transport of water masses from the Pacific back to the Atlantic. This contribution of water from the Indian to the Atlantic oceans may be a significant factor in climate regulation on a planetary scale, and a justification for new research to address this question.

The interaction of waters of the East Madagascar Current flowing southwards and over the Madagascar Plateau results in highly dynamic and productive coastal and offshore upwellings. Due to the continuity of the Madagascar Plateau with Madagascar Island, and similar turbulent interactions between the geology and ocean currents at northern and southern tips of the island, this Plateau is used here to extend what is normally considered as the Mozambique Channel boundary farther south, beyond the tip of Madagascar. Turbullent currents and upwelling waters from the Madagascar Plateau flow into the southern part of the Mozambique Channel, interact with the waters here (and hence may also influence channel dynamics farther north when carried north in eddies), and the two merge to form the Agulhas Current off South Africa. To capture these interactions, the Mozambique Channel as described here, includes features of the oceanography of the Madagascar Plateau.

Jurisdiction – the Mozambique Channel is entirely within the EEZs of the neighbouring countries, which include Mozambique, Madagascar, the Comoros, Tanzania and France.

Potential Outstanding Universal Value

Criterion viii – Geology and oceanography

The Mozambique Channel is bounded by the oldest coastlines and seabed of the Indian Ocean, and marks the first stages in the tectonic movements that created the ocean.

The eddy and gyre generation dynamics of the channel are unique globally, contributing to the western boundary currents in the Indian Ocean that play a role in the global conveyor belt of ocean circulation, and regulation of the climate system.

Similar upwelling and turbulence features are produced on the Madagascar Plateau, that feed into the southern Mozambique Channel and thence into the Agulhas Current system

Criterion ix – Ecology, species and evolution

Over an evolutionary timescale, the geology and oceanography of the Mozambique Channel may have played a key role in driving the evolutionary dynamics of the Western Indian Ocean, maintaining and accumulating species in the northern Mozambique channel in a biodiversity center second in absolute numbers to the Coral Triangle region, but with a unique evolutionary history and genetic diversity.

Genetic connectivity in the Mozambique Channel show several overlapping patterns – one of high mixing throughout the channel but distinct from points farther north in the EACC (coelacanth), and one showing a barrier at the narrow constriction of the channel, showing southern and northern populations (green turtle). Corals show highest diversity, and indications of high connectivity in the northern Mozambique Channel.

Criterion x – Habitats and conservation

The geology and oceanography of the channel profoundly affect the ecosystem dynamics and habitats of the channel. The unique eddy dynamics of the channel and upwelling on the Madagascar Plateau contribute to the highly connected and highly productive shallow benthic and pelagic marine communities, affecting the productivity of coral reefs, planktonic and pelagic communities alike, and the behavior, spatial and temporal activities of species groups including large fish, marine turtles, seabirds and marine mammals.

Seabirds: half of the breeding seabirds of the WIO breed in the Mozambique Channel, and it and the Madagascar Plateau are the two most productive of the five main foraging grounds for seabirds in the WIO.

Turtles: Europa has the most significant green turtle nesting site in the Indian Ocean, and migration patterns criss-cross the channel due to oceanographic conditions and high mixing.

Cetaceans: use the Mozambique Channel as prime wintering, feeding and nursing grounds.

Threats

The Mozambique Channel is bordered by long coastlines and nations with growing and active fishing fleets, and the increased understanding of productivity in the channel will undoubtedly lead to increased and targeted exploitation of fisheries and other living resources. Extraction for genetic resources is growing, reflecting the high genetic diversity in the channel, as are threats of mineral, oil and gas extraction, and climate change.

Management

At the level of the channel, and with respect to oceanographic processes, management within the channel is nascent. Individual countries have taken steps towards site-based management in MPAs (Mozambique and Madagascar in coastal MPAs, France in whole-EEZ MPAs in Mayotte and Glorieuses) requiring additional instruments relevant to ICZM, EEZ and fisheries instruments to regulate threats sufficiently to meet WH designation for individual sites, or the channel as a whole. The Nairobi Convention is the prime convention relevant to marine and coastal management that all countries bordering the channel are party to.

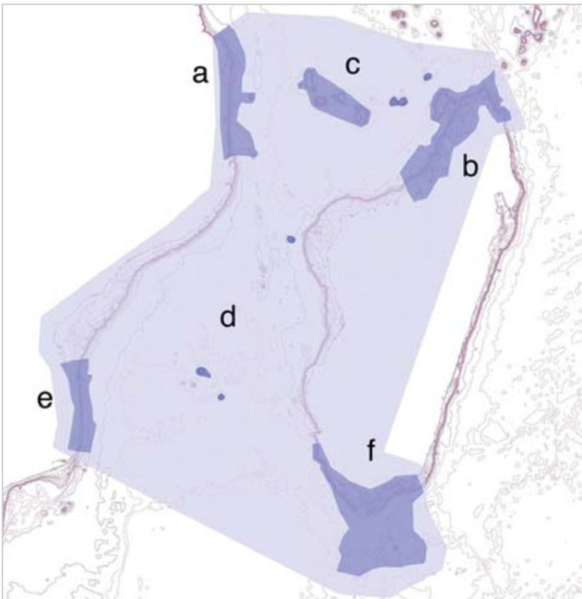
Geographic scale and integrity issues

The channel covers 13° of latitude and varies between 400–900 km wide, equivalent to almost 1 million km^2 of ocean. Whole-site designation as a World Heritage site is unlikely, offering the possibilities of designating key sites or regions within the channel that may reflect different properties. Further, different portions of the channel contain different components of the geological and oceanographic features of OUV, that support different classes of biological systems (species and ecosystems) that themselves have potential OUV. Thus, the report proposes an approach at two levels:

1) Regional/trans-boundary – recognition of the geological and oceanographic features of OUV at the level of the Mozambique Channel as a whole. These will serve to provide the integrity and governance context among the countries that share the channel to frame a consistent set of sites that can be part of an overarching trans-boundary serial site that extends across the entire channel,

2) National – within individual countries, the designation of the specific locations with potential Outstanding Universal Value that would be the individual sites in the channel-wide serial site. Based on current knowledge, the following individual sites are proposed:

   a) Northern Mozambique to southern Tanzania – Nacala – Quirimbas – Mtwara



The Mozambique channel. ©David Obura

   b) Northern Madagascar – the bays and islets of northern Madagascar, from Nosy Ankao/Loky Bay in the east to Sahamalaza/Radama in the west.

   c) The Comoros – Glorieuses crescent, including the Comoros, Mayotte, Glorieuses and the Zélée and Geyser banks.

   d) The Scattered Islands (Iles Éparses) in the central and southern Mozambique Channel

   e) Southern Mozambique – the Bazaruto-Tofo complex

   f) Southern Madagascar – the 'deep south' of Madagascar, including the coast and Madagascar plateau.

In considering these individual sites, their hydrodynamic, geological and biological integrity must be sufficiently assessed to meet the stringent criteria for World Heritage designation, so that each site on its own, as well as as part of the serial site, has OUV.

Site type – a serial (potentially transboundary) nomination would likely best address the OUV of the Mozambique channel, comprising individual sites also expressing OUV of what they contain.

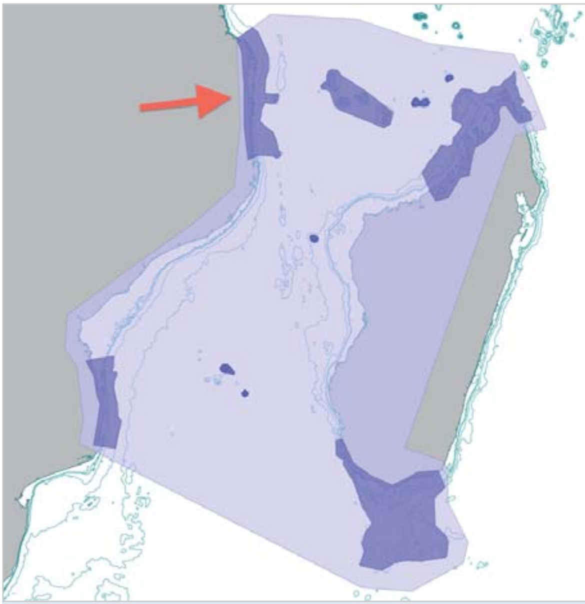
Other sites in the region – no other part of the WIO is comparable to the Mozambique Channel.

Key references – Ali & Huber (2006); Beal *et al.* (2010); de Ruijter *et al.* (2005); Obura (2012); Obura (in review); Ternon *et al.* (2012).

Quirimbas – Mnazi Bay Complex

Location

The Quirimbas archipelago is a string of coastal islands extending from Pemba Bay in northern Mozambique, 400 km to the Ruvuma estuary and the Mtwara-Mnazi Bay reef system in southern Tanzania. A series of submarine canyons continue farther south in Mozambique, to approximately Nacala in Nampula province, and we use this to define this region where submarine canyons, deep sheltered bays and coastal islands interact with the South Equatorial Current (SEC) and eddies of the northern Mozambique channel.



Quirimbas-Mtwara is at the northwest of the Mozambique channel transboundary site. © David Obura

General Description

This complex is located in the center of the East Africa Marine Ecoregion (EAME) of the WIO where the South Equatorial Current (SEC) and unique oceanographic features of the Mozambique Channel meet the mainland African coast. At the northern end of this region, the EACC flows north throughout the year, forming a one-way conveyor for marine larvae dispersed northwards to Tanzania and Kenya. At the southern end of this region, upwelling and the Zambezi delta system influence marine habitats, and past the constriction in the channel at 17°S flow is predominantly southwards. Between these two points, clockwise and anticlockwise eddies may push water in any direction, and the consistent marine climate results in the highest diversity in coral reef species west of the Andaman islands in the Indian Ocean.

Geologically, the site is in the East Karroo Rift System, composed primarily of old sedimentary deposits from the Jurassic and Lower Cretaceous. The sedimentary layers are eroded in places, such as Mnazi and Pemba Bays, with additional structure provided by past reef growth that forms the reefs and islands along the coastline. The continental shelf is very narrow, off Mnazi Bay being only about 1–3 km wide. Deep canyons are carved in the continental slope at some locations, such as Pemba Bay, which continue southwards in Nampula province, such as at Nacala.

Coral reefs of the Quirimbas-Mtwara region are among the most diverse and robust in the region, both in the shallows (left, Vamizi island) and on deeper platforms and slopes (right, Pemba Bay). © David Obura

The Quirimbas Archipelago comprises some 28 islands and the offshore Lazarus Bank. The archipelago has the highest diversity of corals recorded in the WIO (along with northern Mozambique), with almost 300 species in 60 genera. The region has important marine and terrestrial habitats, including coral reefs, mangroves, miombo woodland, acacia savannah, coastal thicket and tropical dry forest and woodland. Charismatic species include turtles, dugongs and elephants, and many rare and endemic plant species. Three species of marine turtles are known to feed and nest in the region, namely the olive ridley and green, with high abundance off Ibo island, and hawksbills off Quilalea and Sencar. Dugong are known to reside in the Quirimbas National Park area, but are scarce and their actual numbers unknown. Dolphins, whales (namely the humback whale), sharks including bull shark, white tip shark, whale sharks and large populations of manta rays are known to frequent the islands. The Quirimbas National Park protects a portion of the south-central part of the archipelago and mainland, including approximately 6,000 km^2 of mainland and 1,500 km^2 of marine and island habitats. Eleven coral islands lying close offshore and stretching for 100 km along the coast, are included in the Park. In the north, consortia comprising villages and private operators have established protected zones around Vamizi and Metundo Islands.

The Mnazi Bay is enclosed by sandy shores to the west and the Ruvula-Msimbati spit and string of rock islands and reefs to the east. The bay varies in size from 67 to 150 km^2 at low and high tides, respectively, with only one major deep channel, the Ruvula Channel in the south. As a result, the channel experiences very high tidal currents (up to 6 knots) creating a complex range of coral reef and other habitats, making it an unusual feature for East African reefs. The distinctness of the Mnazi Bay–Ruvuma Estuary Complex was recognized by the Tanzanian Government for its biodiversity value in 2000, and gazetted as Tanzania's second marine protected area, the Mnazi Bay – Ruvuma Estuary Marine Park (MBREMP) covering an area 650 km^2, of which, 200 km^2 is marine, including islands, coral reefs and mangrove forests.

Threats

The region has been remote for many years, with generally low coastal population density, however active migration by fishermen has resulted in high pressures throughout the region. The more densely populated areas, such as around Pemba Bay and Mnazi Bay show severe impacts from over-fishing, net dragging, gill netting, dynamiting and illegal and unregulated fishing. Migrant fishing along the coastline poses particular problems of regulation, as incentives to reduce over-fishing are low. Around Mnazi Bay, historical dependence on coral mining has led to stripping of shallow reefs of the primary reef building coral, *Porites*. Climate change has impacted reefs in the region, though with very variable levels of impact, perhaps reflecting complex interactions between the variable eddies and currents, and the complex shoreline of islands, bays and adjacent mangrove ecosystems.

Potential Outstanding Universal Value

Criterion viii – Geology and oceanography

Oceanography: the northern Mozambique coast experiences extremely high mixing due to cyclonic and anticyclonic eddies generated in the north of the Mozambique Channel, and is defined by breakpoints to the north, where the EACC touches the Tanzania coastline flowing north all hear, and to the south where the narrowest part of the Mozambique Channel induces changes in currents and upwelling features on the Mozambique coast.

Criterion x – Habitats & conservation

Coral reefs: the Quirimbas – Mnazi Bay complex hosts the highest diversity of corals in the region, together with the upper NW coast of Madagascar, with over 300 species.

Mangroves: the complex hosts some of the best mangrove stands in the WIO in complex bay, channel and estuarine conditions.

Connectivity: the high levels of connectivity make this coastline a critical source and refuge for the dispersal and maintenance of reef diversity to downstream areas to the north and south on the mainland coasts, and to the east side of the Mozambique channel.

Criterion ix – Ecology, species and evolution

Diversity: the complex is a critical node for accumulation and dispersal of marine organisms.

Fish: the highest fish diversity in the WIO, with high abundance found in deeper waters such as the St Lazarus bank

Turtles: notable nesting site for greens and hawksbills and foraging ground for olive ridleys, loggerheads and leatherbacks.

Marine mammals: important humpback whale mother/calf nursing zone.

Sharks and Rays: a superlative reef shark site between Vamizi/Metundo islands shows the influence of variable currents in aggregating the sharks, and in protecting them from use.

Birds: high densities of migrating crab plovers, and breeding populations of varied birds on remote islands and rocks.

The northern Mozambique coast is one of the most active regions for oil and gas exploration, with significant finds of gas offshore, and existing operations in Mnazi Bay. While one of the cleanest possible extraction activities, gas extraction and associated development may pose the greatest threat to marine ecosystems in the region, and any losses in this region may have run-on impacts more broadly in East Africa due to the region's importance as a source of larvae. A natural gas processing plant proposed north of Vamizi Island may provide a locus for focusing governance and conservation efforts for the region as a whole, with significant attention by the Mozambique government and the IUCN.

Management

National marine protected areas have been designated at the southern (Quirmbas National Park) and northern (Mnazi Bay – Ruvuma Estuary Marine Park, MBREMP) parts of this region, providing a foundation for trans-boundary initiatives. Further, private initiatives between villages/communities and the private sector are establishing successful reduced- or no-take areas (e.g. Vamizi, Metundo) with benefit-sharing with the local communities. However, successful integration of these efforts, and expanding the area of well-managed parts of the region are needed, and active transboundary initiatives will be needed to deal effectively with growing threats in particular fishing, climate change and mining.

Geographic scale, integrity and site type

The complex is unique in the WIO and globally, particularly as it acts as critical node to supplying marine organisms to the East African coast (Kenya, Tanzania, Mozambique and northern South Africa). Either the entire system, or key locations within the region, could form a potential nomination for World Heritage listing.

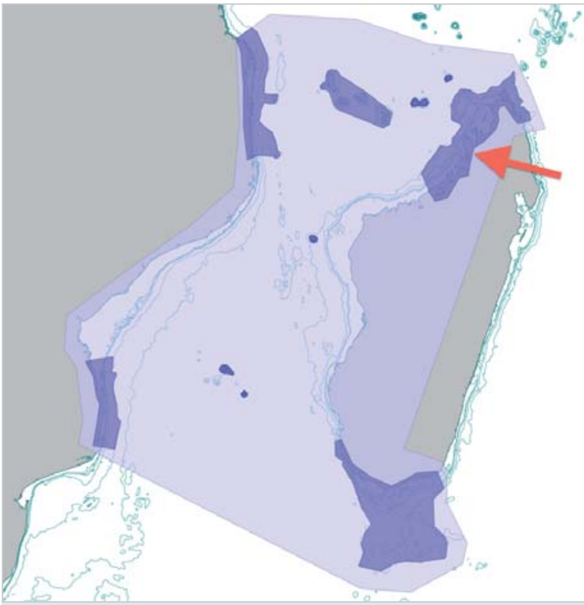
Other sites in the region – other sites in the region either have similar (N Madagascar) or lower-diversity communities of similar types as the Quirimbas-Mnazi Bay Complex, however its oceanography and coastline interactions are unique, and biodiversity at the highest level, establishing it as a critical zone for biodiversity conservation.

Key references – Garnier *et al.* (2008); Kelleher *et al.* (1996); Kemp (2000); McCarthy *et al.* (1994); Muhando *et al.* (1999); Obura (2004); Samoilys *et al.* (2011); Wagner *et al.* (2004).

North and northwest Madagascar
(from Ambodivahibe to Sahamalaza)

Location

The site is located in the north and northwest of Madagascar from from Loky/Ambodivahibe bays, around the tip of Cap d'Ambre, to the Bay of Sahamalaza/Radama to the west, and from the coastal terrestrial habitats to deep water at the 200 m contour.



Location map for the bays and islands of northern Madagascar. ©David Obura

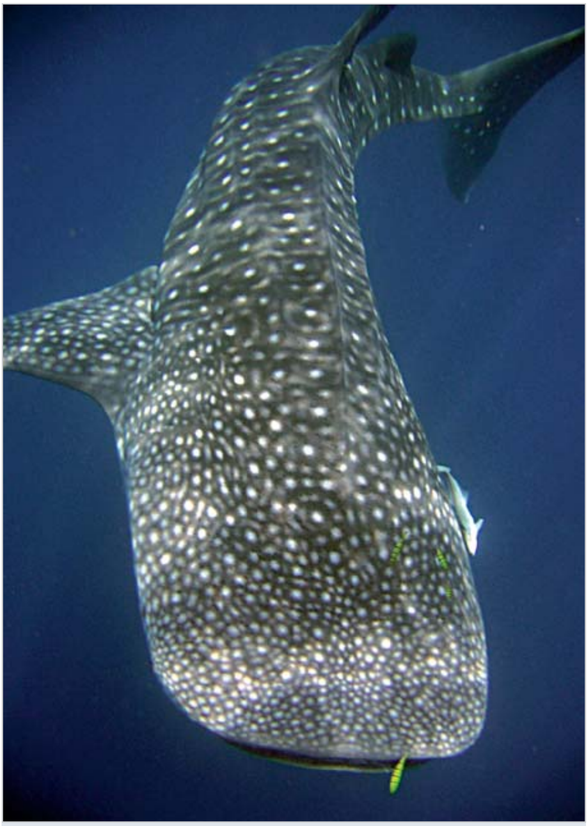
Description

The northern tip of Madagascar has a unique mix of marine habitats due to opposing physical and oceanographic features on the east and the west sides. The site covers the continental shelf from the coastline to the border of the shelf, encompassing many different types of shelves, bays and islands. In the east, the narrow steep continental shelf results in narrow deep bays with canyons leading into deep water, experiencing strong upwelling (Ambodivahibe and Loky bays). In the west, a broad shallow bank rings the coast with a fossil reef at its edge, currently at 70 m depth, sheltering large bay systems such as Narindra, Mahajamba and Ramanetaka – Sahamalaza. On both sides, the bays contain mixed habitats of coral reefs, mangroves and seagrass beds. Offshore of the west coast is the shallow submerged Castor Bank, with the edge of the bank at 30-50 m, and shallowest depths of 10 m.

Complex island systems are found on the west coast, including Nosy Mitsio, Nosy Hara, Nosy Tanikely (and the principal island of Nosy Be), being of different origins including volcanic (contemporary with Montagne d'Ambre), karstic (eroded reef structures) and sedimentary.

The northern tip of Madagascar is at the upstream end of the peak biodiversity region of the Indian Ocean, second only to the Coral Triangle in diversity of shallow marine species. Not only is it an important part of this region, its geology and oceanography may be key triggers for ocean-climate interactions, and upstream source reefs for marine species, for this high diversity region.

Jurisdiction – Madagascar



Whale shark (*R. typus*) off Nosy Sakatia. ©Jeremy Kiszka

Threats

Coastal traditional and industrial fisheries pose a high degree of threat particularly to the west coast as conditions are often calm. Overexploitation occurs of many marine resources, including holothurians, and molluscs, as well as sea turtles, dugongs, sharks and rays, and birds eggs. On

Potential Outstanding Universal Value

Criterion viii – Geology and oceanography

Geology: the coastlines of the northern tip of Madagascar are passive continental margins, parts of Gondwana at one time connected to Africa on the west and India to the east. The western shelf edge is bordered by an ancient submerged barrier reef along its length of 500-700 km. The 'tsingy' rock formations, sharply eroded limestone spikes characteristic of Madagascar are well developed at sites on the west coast.

Oceanography: the tip of Madagascar may be one of the most important features determining the oceanography of East African and Mozambique channel coasts. It forces a venturi-like acceleration and vorticity on the South Equatorial Current, contributing to meso-scale variability expressed as fronts (Glorioso Front) and eddies in the northern Mozambique channel. These eddies dominate the oceanographic and biological processes of the channel.

Ocean-climate interations: the upwelling of cold deeper waters on the NE coast, particularly in Ambodivahibe Bay may protect corals there from warming temperatures, while the warm conditions, high-turbidity and highly variable eddy conditions on the NW coast result in a complex mosaic of low- and high-impact sites during coral bleaching events.

Criterion ix – Ecology, species and evolution

The site is a mosaic of rich ecosystems: coral reefs, coral banks, mangroves, and seagrasses, and volcanic, karst or coral islands and islets, bays.

Evolutionary processes: a new synthesis proposes that the northern Mozambique Channel is a museum maintaining species over tens of millions of years due to its relative stability compared to other parts of the WIO: the coastlines are some of the oldest in the Indian Ocean (180 my), the climate of the region has remained stable during the Tertiary (67 mya to present), their structure results in little habitat change with changing sea levels, and ocean currents both bring species into the region and maintain high levels of connectivity, reducing chances of extinction.

Connectivity: as the upstream end of the core high biodiversity region for the WIO, this region is critically important for larval supply to downstream reefs, and thus for recovery following disturbances and in a connected network of MPAs.

Criterion x – Habitats & conservation

Mangroves: the region contains the largest, and some of the most important mangroves in Madagascar – Sahamalaza Bay (10,000 ha), Sambirano delta (10,000 ha), Ifasy delta (15,000 ha), Mahavavy north (15,000 ha).

Coral reefs: on the northeast and northwest coasts, reef environments are very different. The east is bathed by cool clear oceanic waters of the SEC, with strong upwelling. The west is in the lee of the SEC, in the warm waters of the anticyclonic eddies in the NE Mozambique channel, and due to high rainfall, experiences high-sediment conditions for reefs. The reefs are in the northern Mozambique Channel center of diversity for the WIO, so harbour the highest diversity of corals in the region (> 300 coral species), along with the northern Mozambique coast. The reefs also harbour 525 species of molluscs of with 11 species are restricted to the Indian Ocean and 463 species of fishes with about 30 species confined to Madagascar and adjacent regions and 8 species presently known only from the seas of Madagascar.

Birds: the area is a major seabird area for the western Indian Ocean. Important sites for several species of seagulls (*Sterna bengalensis*, *S. dougallii* and *S. bergii*); priority importance of karst habitat islands for Madagascar fish eagle *Haliaeetus vociferoides*, endemic to Madagascar (the only species of diurnal raptor listed in critical condition (CR) in Africa (in 2008). The Mitsio Archipelago has significant numbers of brown booby (very rare in the WIO), frigate birds, brown noddies, and others.

Turtles: though data are sparse, there are many nesting sites for green and hawksbill turtles on the beaches of the islands.

Sharks: the Mitsio Archipelago and Ramada have high species diversity including, grey reef, white tip, silvertip, zebra (*Stegostoma fasciatum*), scalloped hammerhead (in particular in September and October) and tawny nurse sharks. Guitarfish (*Rhynchobatus djiddensis*) are relatively common in the marine reserve of Nosy Tanikely. Shark populations are severely depleted throughout the region.

Dugong: probable presence of the last populations of dugong in Madagascar, with recent sightings in the NW between Mahajanga and Nosy Be; fishers indicate scattered reports in Nosy Mitsio.

Dolphins and cetaceans: abundant coastal dolphins in near shore waters of Nosy Be, Nosy Komba, Nosy Faly and the main coast of Madagascar. High diversity of cetaceans offshore at the shelf drop, very vulnerable to offshore petroleum development impacts. Significant migratory route for humpback whales on the NE coast.

Fishing community. ©Keith Ellenbogen

Rare coral (*Turbinaria irregularis*). ©Keith Ellenbogen

the west coast and in Antsiranana Bay, habitat destruction by dredging, and pollution are growing problems. Sedimentation is one of the most serious problems, particularly for coral reefs off the west coast. The west coast has a high susceptibility to climate change as conditions are hot throughout the year, though water turbidity and variability, and upwelling on the east coast may reduce the threat of climate change. Cyclones are a threat to both coastlines. In general, the health of different parts of the area is very patchy, with sites of high degradation interspersed with sites expressing the superlative geology, oceanography and biodiversity of the area.

Management status

There are a range of management actions already in place in the region with several existing MPAs (Nosy Hara, Nosy Tanikely, Sahamalaza), future MPAs (Nosy Mitsio, Nosy Iranja) and regulated areas for fisheries management (e.g. Biologically Sensitive Shrimp Areas of Ambaro Bay), providing a foundation for higher levels of protection, and more attention to ecosystem services provided by the marine environment. Both Nosy Hara and Sahamalaza-Radama islands National Park are Biosphere Reserves. Ambodivahibe is the focus of a community conservation and climate change protected area. Loky Bay and nearby Nosy Ankao are also the subject of conservation area planning, with local communities and private sector stakeholders, with prospects for limiting fishing and seabird depredation.

Many sites have cultural and historical importance (Nosy Hara, Nosy Mitsio archipelagos) for the Sakalava tribe. Several islands and terrestrial features represent a commemoration of this event and are taboos (forbidden to access, etc.).

Geographic scale, integrity and site type

The overall extent of the northern tip of Madagascar is large, and most likely cannot be reasonably designated as one site. Further, many areas are already degraded. Many of the outstanding locations are small, and can be part of a serial site covering the range of different features discussed here, such as Nosy Hara, Nosy Mitsio, (and possibly Radama Islands), Nosy Tanikely, Ampasindava Bay and mangroves, Ambodivahibe, Loky Bay and Antsiranana Bay.

Other sites in the region – several sites on the west coast and south of Cap St André (from 16°S), and across the northern Mozambique coast, have some similar features, but this region is the only one to have a complete set of all the features and ecosystems, they are the richest ones, and include the most varied geological and oceanographic features.

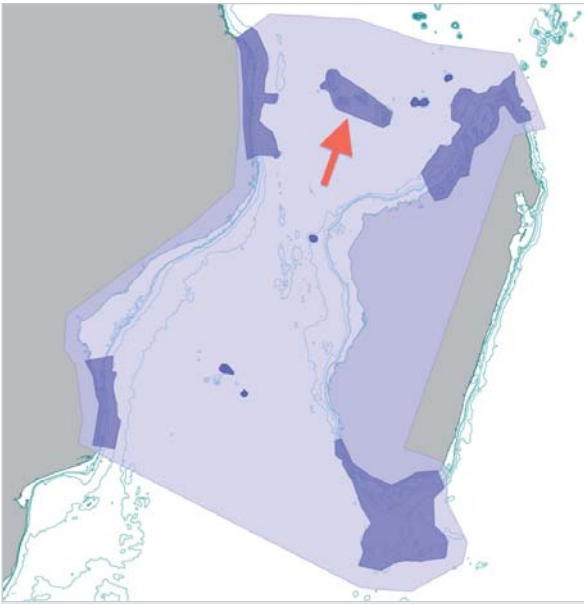
Key references – Cockcroft & Young (1998); Daniel *et al.* 1973; Maharavo *et al.* In press; Maina and Obura (2008); Maina *et al.* (2008); McKenna and Allen (2005); Obura *et al.* (2011).

The Comoros – Glorieuses crescent

The Comoros Archipelago consists of four volcanic islands – Ngazidja (Grande Comore), Moheli, Anjouan and Mayotte. These are extended to the east by several emergent (Glorieuses, Geyser) and submerged (Zélée, Leven, Cordelière) reef-banks, which are described in the next section on the "Iles Éparses" of the Mozambique Channel.

Geologically, the islands and banks have complex origins. Hypotheses include classic plate movement over the Comoros hotspot over the last 15 my, versus alkaline basaltic magma extrusion along north-west fractures remaining from southward movement of Madagascar relative to the African mainland, periodically active during the Tertiary. The age of the Comorian islands increases from west to east. The formation of Mayotte started with submarine volcanism from 15 to 10 mya, then sub-aerial island formation around 8 mya. Ngazidja is the youngest, formed c. 130,000 ya by two active volcanoes, Karthala which is still active, and La Grille, now dormant and to the north. West of Ngazidja, and rising to 10 m below the surface is the Banc Vailheu, likely the youngest seamount being produced by the Comoros hotspot. The archipelago marks the boundary between the Mesozoic oceanic Somali Basin to the north and the continental substratum of the Mozambique Channel floor.

These islands and banks are located in the northern-most section of the Mozambique Channel, and likely are a causal feature in the formation of eddies and of the Comoros gyre. The Glorioso Front was christened for its proximity to Glorieuses island, and may mark the transition from the SEC to the waters of the channel. High levels of connectivity due to the eddies around the Comoros mean the islands may play a key role in maintaining the genetic stock of the channel, and be stepping stones/refuges between the Madagascar and Mozambique coasts. Unlike other parts of the Mozambique Channel where water flows in almost any direction, the region around Mayotte, Glorieuse and to the east to the NW Madagascar coast may predominantly experience anticyclonic flow driven by the SEC, the sheltering effect of the tip of Madagascar and the Comoros gyre. Anticylones are warm-core eddies as the direction of flow pushes the thermocline deeper and traps hotter surface water – and this may be a primary causal factor of high sea surface temperature conditions in this NE corner of the Mozambique Channel, that results in higher levels of thermal stress to corals.



The Comoros-Glorieuses crescent caps the north of the Mozambique channel. This sheet presents the Comoros and Mayotte, while Glorieuses and Geyser are presented under the Iles Eparses (p. 84). ©David Obura

Comoros

Jurisdiction – the three younger islands of the Comoros are in the Republic of Comoros.

The geologically young volcanic shores of Ngazidja support coral communities and small fringing reefs, with development of more mature fringing reef systems to the north and south. More complex fringing/bank reef systems are found on Anjouan and Moheli, particularly on the south coast of Moheli, designated as a MPA in 2004, and at Bimbini in Anjouan. Because of the simpler reef structures, the diversity of coral reefs in the Comoros is less than at Mayotte, though the more complex reefs of Moheli and Anjouan have not yet been studied. Banc Vailheu, rising to 10 m below the surface induces strong upwelling and high productivity, supporting a high abundance of sharks and whales.

The Comorian islands are best known for the largest populations of coelacanth in the world, with largest concentrations on the SW coast of Ngazidja, with notable numbers at Bimbini, Anjouan. In total, a population size of 500 has been estimated for the Comoros, which lies at the northern end of the main known population of coelacanth along the shores of the Mozambique channel from KwaZulu-Natal in the south to southern Tanzania in the north, on the west side, and from Tulear in the south to northern Madagascar on the east side.

The Comoro archipelago includes a full series of geomorphologies from the young active volcano (left, Ngazidja) to eroded slopes and isolated nearly-submerged peaks (middle, Moheli) to submerged atolls and banks (right, Geyser).
©David Obura (left), ©Catherine Gabrié (middle), ©Grilhe (right)

School of Coelecanth on the SW coast of Grande Comores, near Itzounsou. ©Hans Fricke

Humpback whale sighting in the Moheli Marine Park, Comoros. ©Megaptera

Dugong are reported from the Comoros, with the most important sites being on Moheli, and Mitsamiouli on Ngazidja. The islands also host the second largest nesting site for green turtle nesting in the WIO, at Itsamia (Moheli). In common with Mayotte, the Comoros are important for humpback whales from June to November, also with high ratios of mother-calf pairs.

Potential Outstanding Universal Value

Criterion viii – Geology and oceanography

Geology: as part of the Comoros-Glorieuses crescent, the Comoro islands form the younger part of the island – bank series, combining hotspot and ancient fracture processes, and a boundary between basin features.

Oceanography: the Comoros islands may play a key role in inducing the Comoros gyre to form, and in driving variability in the anticyclonic and cyclonic gyres that travel throughout the Mozambique channel.

Criterion x – Habitats & conservation

Coral reefs: though very poorly known, the coral reef fauna in the Comoros likely covers a diverse range of habitats and morphologies, from the oldest proto-barrier reef formations (Anjouan, Moheli) to coral communities on recent lava flows and emerging seamounts (Ngazidja, Banc Vailheu).

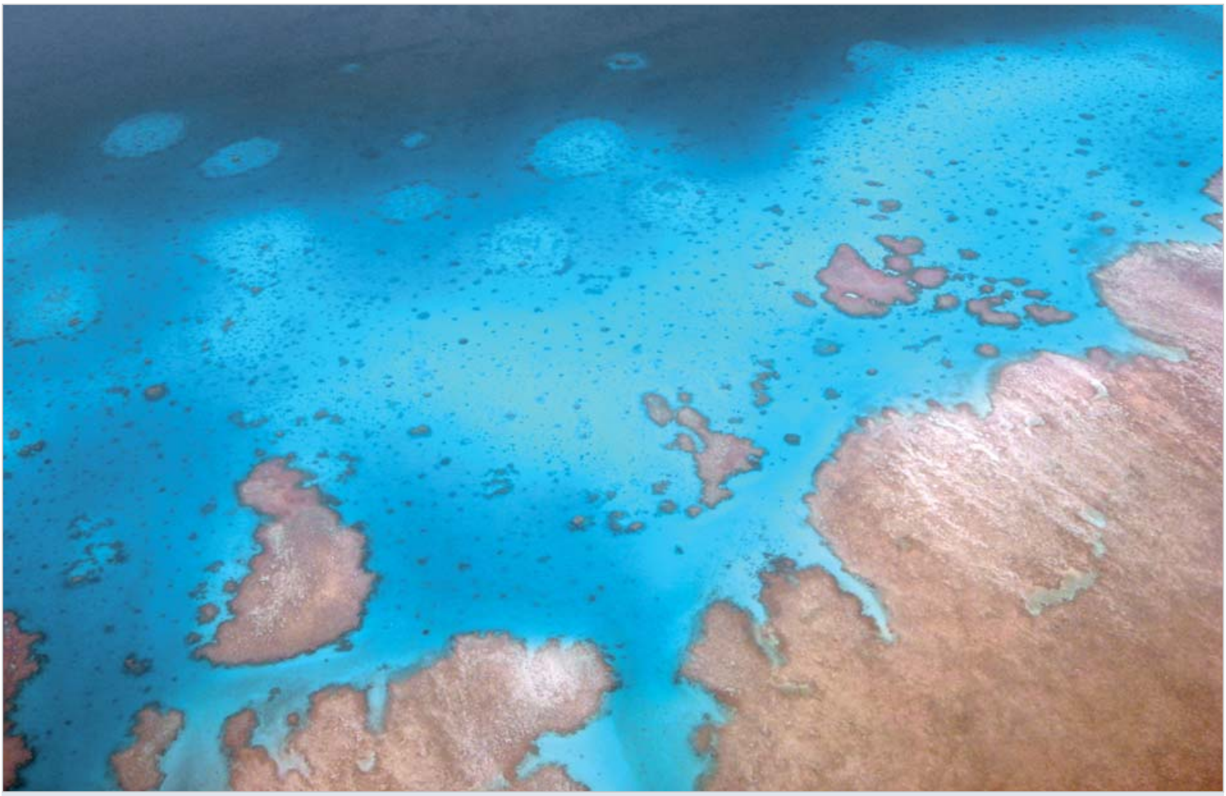
Criterion ix – Ecology, species and evolution

Diversity: in the center of the WIO center of diversity; though the true diversity of shallow habitats is not known on Moheli and Anjouan.

Coelecanth: the most significant and well known population of coelacanth (500 individ-uals), and in the center of the Mozambique channel.

Turtles: second largest green turtle nesting site.

Marine mammals: important humpback whale mother/calf nursing zone; presence of dugongs.



Inner reef structures of Mayotte, showing the complex formation of reef and sand habitats. ©David Obura

Mayotte

Jurisdiction – Mayotte is a Département of France.

Extensive geomorphological and biological studies of the Mayotte reef system reveal a detailed history of the island and reefs. Mayotte is formed by two shield volcanoes surrounded by a barrier reef system. The limestone coral reef began to build about 1.5 mya. The lagoon floor and the reef became emergent during the last Glacial Maximum 26,000 years ago when sea level was 100 m lower than today, at which time meandering channels formed in the lagoon floor and karst systems formed in the reef wall. The lagoon re-flooded 11,600 years ago. The current Holocene reefs grow on the ancient Pleistocene reefs.

The barrier reef is 220 km long with a variable width between 800 and 1500m. It is not continuous, and in the north and west is submerged. The lagoon has an area of 1 100 km^2, the largest in the region for a high volcanic island, and is up to 12 km wide and 80 m deep. Within the SW lagoon, an internal double barrier reef is present in several segments over a length of over 18 km, a unique feature in the Indian Ocean. Several other reef formations are present in the lagoon: pinnacles, inner reefs, patch reefs and fringing reefs on the island shores, with a total length of 160 km. To the north the Iris Bank extends outside the barrier reef, at depths of 15-30 m.

Threats

The Comoros is one of the least developed countries in the region, and population growth is leading to rapid increases in direct pressures on the sea for resources, principally food, and in land-based impacts such as pollution and sedimentation. Mayotte has a higher standard of living as it is a region of France, however higher consumption levels, land-based development and greater motorization of fisheries result in even greater threats to the marine environment. Fishing on the isolated banks (Geyser, Glorieuses) is a growing threat as depletion of fish on the main islands occurs, and increased nearshore management of fisheries pushes illegal fishers farther offshore. The islands are also in the center of highly active zone of oil and gas exploration driven by the neighbouring countries, so is highly vulnerable to impacts over which it has no control. The eastern parts of the Comoros and Mayotte lie in an apparently warmer zone in the northern Mozambique channel, raising the risk of thermal stress and coral bleaching.

The primary threat to coelecanths is renewed and increasing deep benthic fisheries, due to the need to feed the growing island populations.

Potential Outstanding Universal Value	
Criterion viii – Geology and oceanography **Geology:** as part of the Comoros-Glorieuses crescent, Mayotte represents the most complex phase in the island – bank evolutionary series, with both magmatic and carbonate structures. **Oceanography:** Mayotte and the banks may play a role in inducing and stabilizing the dominant anticyclonic flow of the NE corner of the Mozambique Channel, causing higher temperatures in this zone and a particular marine climate with implications on climate vulnerability of marine systems.	**Criterion ix – Ecology, species and evolution** **Diversity:** in the center of the WIO center of diversity; unusually high species richness of many taxa for an island system: > 270 species of hard corals, 750 fishes and 455 crustaceans. Mayotte has the maximum hydroid species richness known in the region (173 species) and the *Millepora* family is also more diverse. **Turtles:** Green turtles, up to 5000 nesting females a year; hawksbills: up to 100 nesting females a year. **Sharks and Ray:** winter abundance of manta rays (*Manta alfredi*) and scalloped hammerhead sharks (*Sphyrna lewini*). **Marine mammals:** high diversity of marine mammals; important humpback whale mother/calf nursing zone; the southern part of the lagoon is known to be a breeding site for *Megaptera* and high diversity of cetaceans. Dugong present in the lagoon. The banks (Geyser, Zélée, Iris) and eastern region of the Comoros may be an important area for humpback whales during the late austral winter months.
Criterion x – Habitats & conservation **Coral reefs:** the complex reef geomorphology, combined with the diverse eddy currents and oceanographic conditions in the region, contribute to high habitat diversity. Mayotte has the most complex reef geomorphology of all small islands in the WIO and the Mozambique Channel. Combined with high levels of connectivity and the importance of the channel regionally, it represents a critical refuge and stepping stone for dispersal and maintenance of reef diversity in the WIO.	

Conservation

The Tanga Coelecanth Marine Park (northern Tanzania), designated in 2010 specifically to protect the population of coelacanth being affected by fishing (37 individuals caught from 2003-2010) may be key to their survival, though further studies will be needed to determine its efficacy. The isolation of this sub-population suggests that separate actions for conservation of Mozambique Channel coelacanth are necessary. The high degree of mixing in the channel presents a classic test case of whether to designate few large or many small protected areas. The existing World Heritage site at iSimangaliso is south of the geographic border of the channel, though is linked by currents moving southwards. However there may not be any return flow of genetic material back into the channel, reducing its role in protecting coelacanth over a broader geographic range. Thus key sites in northern Mozambique and Madagascar, the Comoros, and south Mozambique and Madagascar may be necessary. The Comoros is the dominant population known to date, so is the highest priority for coelacanth protection.

Coral reef, seagrass and mangrove conservation is of strong interest for local livelihoods and security, and biodiversity protection. The Moheli Marine Park, designated in 2001, protects the most complex and diverse reefs in the Comoros on the south coast of Moheli, but impacts from fishing and terrestrial runoff within the park are very high. In 2011 the entire EEZ of Mayotte was designated as a Marine Protected Area, though zoning is yet to be established. The island has had some small no-take areas established in recent years. In 2012 the entire EEZ of Glorieuses was also established as a Marine Protected Area, excluding fisheries.

Key references – Audru *et al.* (2010); Class *et al.* (1998); Emerick & Duncan 1982; Ersts *et al.* (2011); Esson *et al.* 1970; Fricke *et al.* (1998); Maugé *et al.* 1982; Nougier *et al.* 1986; Thomassin *et al.* 1989; Wickel *et al.* (2010).

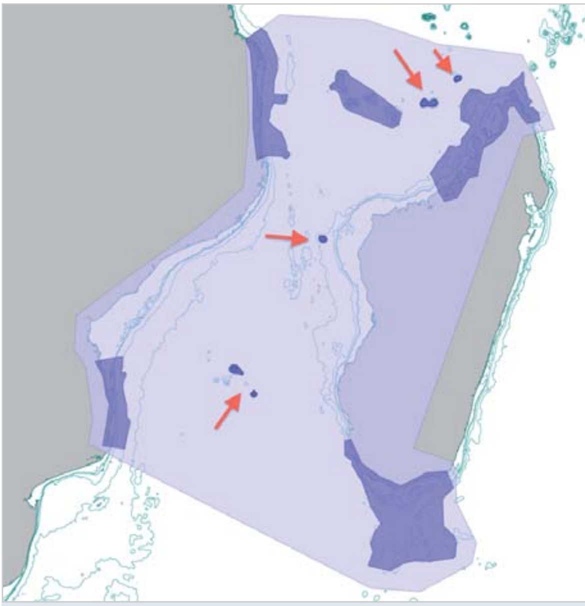
The Iles Éparses (Scattered Islands)

Location

The "Scattered Islands" (literal translation of "les Îles Éparses") stretch down the length of the Mozambique Channel, between the east coast of Africa and Madagascar. Glorieuses island (11.3°S) and Geyser Bank, close to Mayotte, are in the north, Juan de Nova is in the center, adjacent to the Madagascar coast, and Bassa da India and Europa (22.4°S) are in the south.

Description

The Iles Éparses are an administrative unit rather than a single geological unit, with the northern banks (Glorieuses and Geyser) likely being extensions of the Comoros archipelago, while the middle and southern islands are distinct geological features. Their geological history combines aspects of basaltic magma extruded through remnant fracture zones in the channel floor, as well as volcanic activity and the production of seamounts. In the north, Geyser and the Glorieuses are likely extensions of the Comoros archipelago formed by a hotspot, and intermediate in age between Mayotte and volcanic activity in northern Madagascar (e.g. Montagne d'Ambre), about 10 my old.



The Iles Éparses; from north to south: Glorieuses, Geyser, Juan de Nova, Bassas da India and Europa. ©David Obura

Oceanographically, the islands are bathed by the variable eddies of the Mozambique channel with resulting enhanced productivity driven by the eddies and their interactions with the continental slopes and island slopes, but there is strong differentiation from north to south. In the north, the "Glorioso Front" was christened for its proximity to Glorieuses island, and may mark the transition from the SEC to the waters of the channel. Juan de Nova is at a point off the Madagascar west coast characterized by significant aggregations of marine mammals, an indicator of high productivity likely driven by interactions between eddies and the shallowest sections of the Davie Ridge. Europa and Bassa de India, in the center of the southern Mozambique channel, experience mature eddy systems.

Glorieuses is a coral bank 17 km long and covering 165 km^2 with two main coral islands, Grande Glorieuse (7 km^2) and Lys island (600 m long). Grande Glorieuse is a sandy cay, with a set of dunes in the east and northeast that reach a maximum altitude of 12 m. Lys island and fossil rocks on the coral bank appear to be the remains of Pleistocene coral growth 125,000 years old, composed of limestone benches with Tridacna. Geyser is an active coral bank with a small sandy cay. The banks are currently subsiding, thus have active coral and bank formation to keep up with sea level.

Juan de Nova is a small coral island (about 6 km^2) on a 250 km^2 coral reef platform. It consists of beachrock and sand dunes up to 12 m in height. The coral structures extend 12 km north and 2 km south of the island. The asymmetry of the reef bank, linked to the tilting of the island results in different reef morphologies: in the south the island has a well defined reef flat between 0 and 3 m depth, while in the north it slopes down slowly to 20 m deep before dropping to >2000 m to the channel bottom. On the island, phosphate deposits in the form of guano were exploited from 1900 to 1968.

Bassa da India is a subcircular atoll 12 km in diameter, with a shallow sandy lagoon and is almost entirely submerged at high tide. The atoll is currently growing and the reef slope is very steep, dropping to 3000 m to the bottom of the Mozambique Channel.

Europa is a raised atoll of 6-7 km in diameter and 28 km^2 area, a remnant of a Pleistocene atoll from 125,000 years ago. The island is a low sandy cay surrounded by a small cliff of raised dead coral, interrupted by sandy beaches. A dune fringe, to a maximum height of 6 to 7 m, in places is up to ten meters wide. The shallow inner lagoon, in the process of filling, covers about 900 ha with some 700 ha of mangrove, communicating with the sea via an underground karst system and a reef spillway covered by seagrass.

Glorieuses ©Gelabert 2008

Bassa de India ©Marine Nationale

Geyser ©Grilhe

Juan de Nova ©V. Duvat Magnan

Europa ©TAAF

Jurisdiction – the Iles Éparses are under French jurisdiction, and since 2007 have been part of the French overseas territory called "French Southern and Antarctic Lands" (Terres australes et antarctiques françaises - TAAF), which also includes the southern islands of Crozet, Kerguelen Archipelago, St. Paul, Amsterdam and Terre Adelie. The EEZs of the Iles Éparses total 640,000 km^2, and abut the EEZs of the neighbouring countries. The islands are subject to claims from these neighbouring countries, including Madagascar (Bassa da India, Europa, the Glorieuses islands and Juan de Nova) and from the Comoros for the Glorieuses islands.

Statement of Potential Outstanding Universal Value

The islands cover a broad latitudinal range and section through the Mozambique Channel, giving them value together, in addition to the individual values of the islands.

Potential Outstanding Universal Value

Criterion viii – Geology and oceanography

Geology: the island series illustrates a diversity of geomorphological forms, mainly atolls and coral banks occupying the top of volcanic cones or peaks, as well as different phases of reef island construction, including growing atolls, atolls with filling lagoons, raised reefs, and karstic formations such as pinnacles.

Oceanography: the oceanography of the Mozambique Channel is highly complex and the placement of the Iles Éparses along the length of the channel results in variable hydrographic forcing factors on the islands and marine communities, such as the Glorioso Front, located NW of Glorieuses and marking the northern boundary of the Mozambique Channel.

Criterion ix – Ecology, species and evolution

Biogeography: the Scattered Islands are located at the western border of the West Indo-Pacific Realm, cover a range of latitudes from the center of the high diversity core region of the northern Mozambique channel to the southern part of the channel, have small habitat size which promotes speciation and extinction events and thus the generation and presence of endemic species.

Migratory species: the Iles Éparses are important places for migratory species such as turtles, marine mammals, sharks, and seabirds, with both breeding and foraging zones of significance, and seasonal migrations determined by local and regional scale phenology.

The extensive *Halimeda facies*, well represented in Glorieuses and Juan de Nova are unique in the context of the Indian Ocean islands, reflecting high productivity in surrounding waters.

Criterion x – Habitats & conservation

Connectivity: In the context of ecological resilience and the health of ecosystems in the Mozambique Channel, the high connectivity across the channel suggests the Iles Éparses can be important reservoirs for reproduction and seeding of larvae to the more heavily utilized and impacted Comoro, Mozambique and Madagascar coastlines.

Green turtles: show strong genetic differentiation into two populations, one in the north, the other in the southern and central Mozambique Channel. This may reflect the currents in the channel, that influence the dispersal of juveniles and separate sub-stocks for multiple species groups.

- **Europa:** the breeding stock of green turtles is between 8,000 and 15,000 females, the third largest atoll nesting site for green turtles in the world and the largest in the Indian Ocean; blacktip reef sharks (*Carcharhinus melanopterus*), lemon sharks (*Negaprion acutidens*), shooling hammerhead sharks (Sphyrna mokarran); eight breeding seabird species including an endemic subspecies of the white-tailed Tropicbird (*Phaethon lepturus europae*), the most diverse seabird fauna of the Scattered Islands, and the richest in the WIO; unique mangrove system (700 ha) in its lagoon.
- **Juan de Nova:** important nesting site for hawksbill turtles; nursery areas for grey reef sharks; largest population of sooty terns in the Indian Ocean and one of the largest in the world with > 2 million breeding pairs; presence of coconut crab *Birgus latro*.
- **Glorieuses:** second largest population of sooty terns, with 760,000 breeding pairs; presence of coconut crab *Birgus latro*.
- **Bassa da India:** aggregations of juvenile sharks *Carcharhinus galapagensis*.
- **Zélée Bank:** potentially a nursery ground for grey reef sharks (*C. amblyrhynchos*).

Marine mammals: humpback whales are present during the southern winter to breed and give birth.

The remote Iles Éparses are among the last refuges for many sharks, including the silvertip shark (left) and tawny shark (right).
©Jeremy Kiszka

Threats

The Iles Éparses are at not far from populated islands and the continental coastline, making them vulnerable to exploitation. Fisheries in the coastal waters surrounding the islands is banned but does occur by commercial boats, as well as recreational and small-scale targeting of reef fish, by fishers from e.g. Mayotte or South Africa, depending on the island. Moderate shipping traffic passes through the Mozambique channel, thus there is a pollution risk from tankers. Two petroleum exploration permits wihin the EEZs of the Iles Éparses were approved in December 2008, and exploration in the EEZs of neighbouring countries may have spillover impacts in the islands. As with other sites, climate change is a significant threat, with the added uncertainty of how changing water temperatures and currents will affect the dynamic eddies in the Mozambique Channel that influence these islands in areas such as connectivity, primary productivity, prey populations for higher order predators, and fishing stock dynamics.

Management status

Europa, Bassa da India, and Glorieuses were declared Nature Reserves in 1975 (arrêté préfectoral de 1975), and there is a permanent presence on the islands, for military and/or civil (meteorology) purposes. As a result, access to the islands is strictly and effectively controlled, with permits only being given for research. In support of this, a Scientific Committee of the Scattered Islands (CSIE) has been established, as an advisory body to the administration. In 2012, the EEZ of Glorieuses was declared a MPA, and steps are underway to declare Europa as a national natural reserve. Europa was designated a Ramsar site in 2011.

Geographic scale and site integrity

While the individual islands are all small, as a group they cover a large geographic range across the whole of the Mozambique Channel. This property gives them a natural identity as a serial site. The integrity of the serial/island group is very high as the islands are uninhabited and human pressure very low. All studies show that marine habitats are in good health despite recent climate change impacts, and the composition of the trophic chain, with abundance of top predators is a sign of good health. Nevertheless, each island has a distinctive character, and provided the productivity and dynamics of open sea areas that are critical for feeding and migration remain in good condition, each island has a high integrity.

Other sites in the region – the islands are unique in the region.

Key references – Battistini (1996); Belkin Cornillon (2007); Caceres (2003); Chabanet & Durville (2005);

Bazaruto – Tofo, Inhambane

Location

The site is located in Inhambane Province in the southern part of Mozambique, stretching from the Bazaruto archipelago in the north, to the Tofo peninsula in the south.

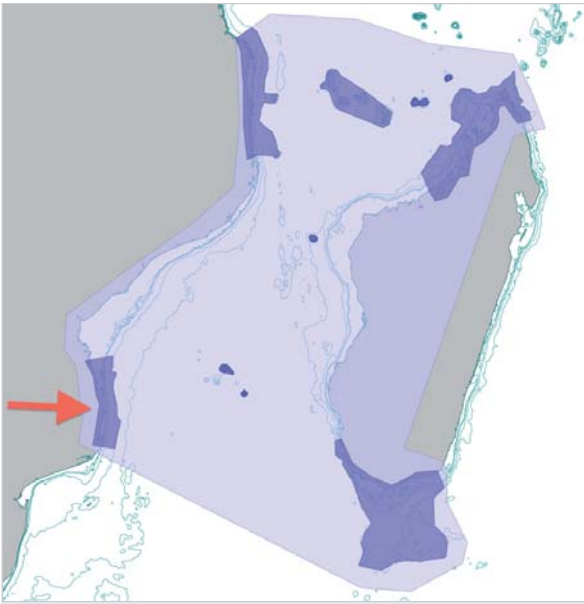
Description

The dominant ocean currents show a clear influence on the coastal morphology, the north-trending headlands a result of northward transport of sediment poured into the sea by rivers, to form headlands (Tofo, Cabo São Sebastião) and the string of islands forming the Bazaruto archipelago. While the dominant flow of water in the southern Mozambique channel is southwards, inshore processes result in northward flow.

The Bazaruto barrier island archipelago comprises a chain of five islands extending ~70 km north of the mainland peninsula of Cabo São Sebastião, and up to 20 km off the coast. The islands are separated by tidal inlets linking the 10-26 km wide back barrier lagoon with the Indian Ocean. The largest Island is Bazaruto (12,000 ha), followed by Benguérua (2,500 ha), Magaruque (600 ha), Santa Carolina (500 ha, previously called Paradise Island) and the minuscule Bangué (5 ha). The archipelago was formed from the present Cabo Sebastiáo Peninsula about 7000 years ago, forming the Bazaruto-Sao Sebastio complex of very high sand dunes and coastal barrier lakes found only in southern Mozambique in the Parabolic Dune subregion.

Bazaruto has a wide range of terrestrial and marine habitats including coastal sand dunes, rocky and sandy shores, coral reefs, mangrove forests and seagrass meadows. These habitats provide refuge for a great variety of plant and animal species. Over 180 species of birds, 45 species of reptiles, the dugong, four turtle species, five dolphin species, three whale species, four shark species and 2000 species of fish have been recorded here. Bazaruto also has the largest and possibly last viable dugong population in the WIO, dependent on the abundant seagrass meadows between the islands and the coast. The area has populations of six species of bird that exceed 1% of the global population for the species. It is also known for its complex of coral communities with six endemic gastropod mollusc species.

Jurisdiction – Mozambique



Locator map. ©David Obura

The dunes of Tofo and Bazaruto island are among the best developed along the East AFrican coast.
©Erik Cleves Kristensen

Dugong photographed from boat, Bazaruto.
©Almeida Guissamulo

Whale shark feeding on surface plankton, attracted by the high productivity created by eddies and their complex interactions with the continental shelf.

Potential Outstanding Universal Value

Criterion viii – Geology and oceanography

Geology: the coastline has some of the largest parabolic sand dunes on the coast, in Bazaruto forming a unique mosaic with coastal lakes, coral reefs and seagrass beds that support a unique combination of terrestrial and marine fauna.

Oceanography: the region receives variable eddies from the north in the Mozambique Channel, and from the south from the East Madagascar Current-Agulhas Current region, resulting in high mixing and productivity attracting large aggregations of megafauna.

Criterion x – Habitats & conservation

Parabolic dunes and coastal lakes: these are of global importance and critical to the Bazaruto Archipelago's diversity and ecological wealth.

Coral reefs: there are three main coral reef types: submerged sandstone reefs, submerged fringing reefs and patch reefs. There are also some sedimented rocky shelves and isolated rocky massifs. The over 30 species of soft corals (Alcyonacea) and 70 species of hard corals (Scleractinia) represent a transition between northern and southern regions.

Seagrasses: a critical habitat in the archipelago, supporting the large turtle and dugong populations.

Mangroves and salinas (salt marshes): three of the five islands (Bazaruto, Benguérua and Santa Carolina) support mangrove communities and Salinas.

Criterion ix – Ecology, species and evolution

Ecology: wide range of ecosystems from terrestrial and marine habitats including coastal sand dunes, rocky and sandy shores, mangrove forests, seagrass beds, coral reefs and open ocean.

Diversity: there are over 2000 species of fish, over 500 species of mollusks.

Dugong: the most significant and well known population of dugong (300 – 350 individuals) in the WIO, with possibly the last remaining viable population in the region.

Turtles: five species known to nest and feed in Bazaruto, including the green, hawksbill, loggerhead, olive ridley and leatherback.

Birds: more than 180 species have been recorded in the Archipelago and 6 species exceed 1% of the global population for the species.

Sharks and Rays: major manta ray (*M. alfredi*) aggregations estimates range from 150 to 450 individuals in Bazaruto and the largest aggregation of 800 individuals at Tofo.

Whale sharks: Tofo represents one of the largest aggregations of whalesharks in the WIO.

Humpback whales: new discoveries suggest Bazaruto may have one of the largest wintering populations of humback whales.

Threats

The continental shelf off Mozambique holds considerable mineral resources such as oil, gas and heavy metals, posing significant threats to biodiversity when extraction occurs. Overexploitation occurs of many marine resources, including fish, holothurians, and molluscs, as well as sea turtles, dugongs, sharks and birds eggs. A significant net fishery is based on the mainland coastline, targeting the extensive shallow waters that also host the main seagrass beds and dugong habitat. Of particular concern is that a large proportion of the dugong population occurs outside of protected areas, where they face a high risk of net entanglement. Habitat destruction, particularly of seagrass beds is a huge concern for the dugong population. Tourism developments, if not well managed could be a serious threat to the ecosystems and habitats, particularly the sensitive sand dune and Salinas terrestrial habitats. Natural events such as storms and cyclones, and climate change, have also had negative impacts on habitats.

Dugong are particularly vulnerable to capture in nets. This juvenile dugong was released alive from a net in the Kiunga Mairne Reserve, Kenya.

©WWF Kiunga Marine Reserve Project

Management status

Bazaruto Archipelago was first formally gazetted as a MPA in 1971, by the colonial government, with the aim of protecting species of high conservation value, such as dugongs, dolphins, and sea turtles. The three southern islands of Bangué, Magaruque and Benguérua were proclaimed National Parks, including waters to 100 m deep east of the islands and 5 km to the west. Bazaruto and Santa Carolina islands were defined as areas designated for "special monitoring activities" (Zonas de Vigilância). In 2001, a much larger Bazaruto Archipelago National Park was proclaimed, including more extensive marine areas and adjusting the boundaries to include all the islands to promote an integrated management approach. Two years later, the Cabo de São Sebastião peninsula was given statutory protection that now protects the natural resources of the nearby peninsula and adjacent waters.

Around Tofo, efforts are underway to establish protected areas following participatory models, involving the dive and local tourism industry and local authorities, to protect the charismatic species and habitats that sustain the local economy.

Geographic scale, integrity and site type

Both the Bazaruto Archipelago and Tofo are distinct headlands, the former with a string of islands, defined by the interactions between the land and ocean currents. As such, they are each well defined units, though separated by 200 km of open coastline. They might exist as distinct sites, or a serial site.

Other sites in the region – there is no similar headland/archipelago systems in the region, nor with a similar complement of fauna such as dugong or whale sharks and manta rays.

Southern Madagascar the 'deep south'

Location

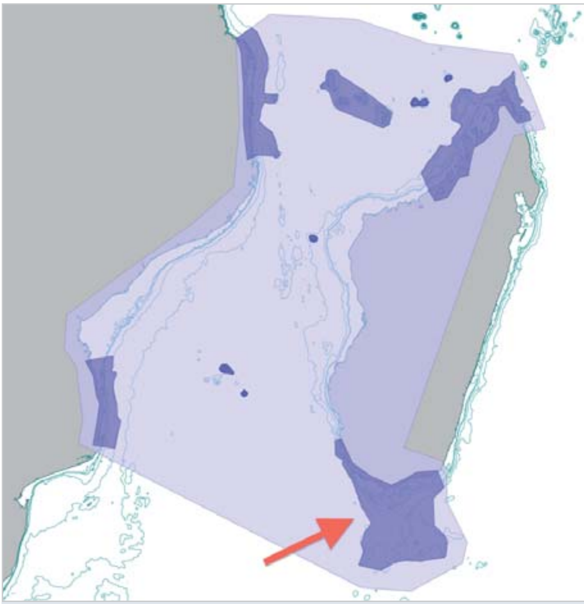
The zone of interest is from Lokaro/Ste Luce (old name, Fort Dauphin, in the east) to Androaka (in the west). The continental shelf is very narrow between the Linta and Mangoky deltas and falls steeply down the continental slope.

Description

The shallow marine habitats of the coast are mainly rocky and experience very rough conditions exposed to the south. There is minor coral reef development at the east (Lokaro, Ste Luce) and the west (Androka, banc de l'Étoile) extremities. Coastal habitats are varied, with distinctive coastal dune formations, such as at the Mangoky delta. The coastal dune systems were formed during the Quarternary, with a width of up to 30 km. In places, the dunes are carved into cliffs up to 150 m high.

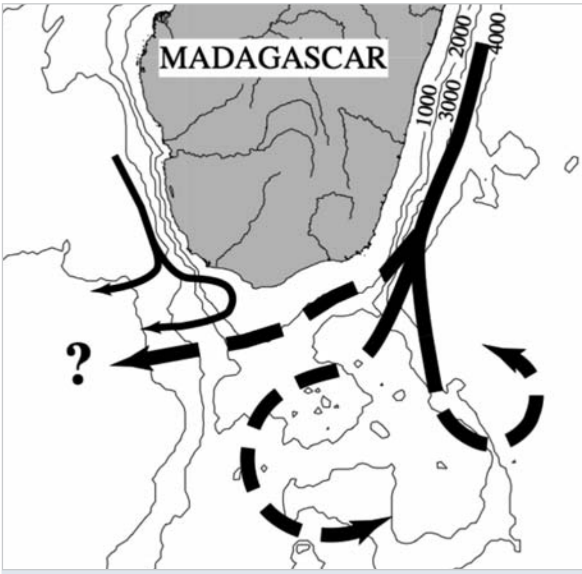
Extending south from Madagascar, an extensive underwater plateau or ridge varies from about 1000 to 2500 m deep, for a distance of nearly 1000 km. At its southern end it forms a shallow platform that reaches to 100 m below the surface. The platform was formed by basaltic extrusion from the Marion hotspot during the Cretaceous, as Antarctica and Madagascar moved apart. The region experiences complex oceanography caused by the strong boundary current of the East Madagascar Current impinging on the undersea Plateau, resulting in strong coastal and offshore upwelling, eddies and turbulence. These cause a large phytoplankton bloom in the austral summer that fertilizes waters downstream and into the southern Mozambique Channel. Eddies generated over the plateau may progress into the Mozambique channel, interacting with those of the channel and potentially move north up the west coast of Madagascar.

The plateau extends southwards into temperature waters and ecoregions, resulting in mixed tropical and subtropical species and habitats. Even on land and in shallow waters, this region is poorly documented. A recent expedition 'Atimo Vatae', focused on the algae and invertebrates of the shallow and upper-slope marine fauna, has already shown preliminary results reporting kelp beds and over 500 species of algae, richer than the tropical algal flora of Mozambique. By contrast, diversity of animal species is lower than in tropical areas, but with extremely high levels of endemism and shared species with subtropical South Africa. Ascidians are among the first groups analysed, revealing 20% new species, 26% shared with S. Africa, and 31% shared with tropical areas. Other groups with preliminary numbers include molluscs (1200–1500 species), decapod crustaceans (766 species) and fish (253 species).



Madagascar's deep south, extending over part of the Madagascar plateau to about 2000 m depth.

©David Obura



Complex currents affected by the submarine plateau result in eddies and upwelling. To the west, the shallow currents feed into the Mozambique channel and to the Agulhas Current in South Africa. ©diMarco et al 2000

Offshore, the undersea Plateau, because of its upwelling and productivity, provides critical feeding grounds for multiple marine species, including seabirds, large fish and marine mammals. The red-tailed tropicbird and Barau's

Typical landscapes of the deep south include sandy bays (left) backed by large dunes and rocky shores pounded by ocean swell from the Southern Ocean (right). ©Bruno de Reviers / MNHN-PNI

petrel (endemic to and nesting on Reunion) feed on the plateau, indicative of a high number of species that also do this. Blue, sperm and humpack whales aggregate in these waters due to its raised productivity, with estimated population sizes of about 450 individuals for pygmy blue whales. Humpback whales also use the SW and SE coasts (near Toliara and Lokaro, respectively) as breeding grounds, and for nursing by mothers and calves.

Jurisdiction – Madagascar.

Potential Outstanding Universal Value

Criterion viii – Geology and oceanography

Geology: the Madagascar Plateau is a product of Cretaceous hotspot activity as Madagascar moved north away from the Marion hotspot.

Oceanography: Interaction of the plateau with the strong western boundary current, the East Madagascar Current results in high turbulence, upwelling and productivity.

Criterion x – Habitats & conservation

Large coastal dunes, lagoons and coastal ponds, forming unique coastal habitats and wetlands.

Shallow benthic communities dominated by hard substrate communities, with small isolated coral reefs at the extremities.

The highly productive waters of Madagascar's 'Deep South' are critical feeding grounds for the highly migratory species of the region, including seabirds and cetaceans.

Criterion ix – Ecology, species and evolution

Because of its southerly location, this is a transition zone (ecotone) in the Indian Ocean between the tropical waters and the temperate waters, at the crossroads of the fauna of South Africa and that of the Indo-Pacific, with an African affinity as one approaches the Mozambique Channel.

Very specific communities adapted to local conditions – high energy, upwellings, cooler waters.

High levels of endemism have been found, 25% for mollusks, with many new species likely to be described in coming years.

Leatherback, loggerhead and green turtles are found in the region, one of the few locations important for leatherbacks in the WIO

Threats

The area is highly remote, with little development on land. Thus offshore fisheries by commercial fleets, targeting fish that feed on the high productivity off the plateau will likely develop as other fishing grounds become depleted.

Management status

There is currently no management structure for the overall area, though one coastal site, Faux Cap is a Ramsar site.

Geographic scale and integrity issues

This is a large and remote region, with very rough and inaccessible coastlines. It will provide significant challenges to management, though at the same time, these help protect it from impacts, and confer its values.

The Madagascar plateau extends southwards for 1,000 km into the High Seas. For initial consideration, limiting a site to the EEZ, 200 nm from the coastline, to encompass the main nearshore components of the system, is advisable. The High Seas component of the plateau may be suitable for consideration under the EBSA process (Ecologically and Biologially Sensitive Areas). Two hundred km north of the point where the western edge of Madagascar Plateau, a submarine canyon leading into the Bay of St. Augustin (at Toliara) results in high diversity of cetaceans due to accessibility of deep water, offshore species. The canyon is also an important site for coelacanths. These may justify extending the boundary of this site to include the Bay of St Augustine

Site type – may be considered as a single entire site, or potentially a serial site of the key locations for each of the primary attributes of OUV.

Other sites in the region – this is a unique site in the Western Indian Ocean.

Endemic species of Madagascar's 'deep south' include the snail *Lyria patbaili* (above) and a likely new species of crab in the family Hymenosomatidae (below).

Saya de Malha bank, Mascarene Plateau

Location

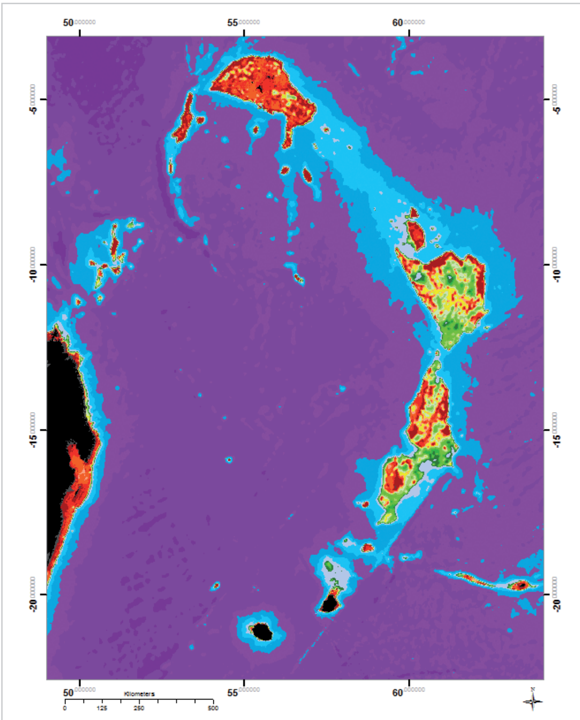
The Mascarene Plateau includes the products of the Mascarene-Reunion hotspot in the WIO, thus extends from the island of Reunion in the south to Saya de Malha in the north. Loosely, it can also be extended northwards to include the Ritchie Plateau and North Seychelles Banks, which are continental fragments left behind as India migrated northwards. The Saya de Malha bank, located between 8°30 - 12° S and 59°30 - 62.30° E, is the largest of the banks on the plateau, with an area of approximately 40,000 km^2.

Description

The basement rock of the bank was formed by the Mascarene-Reunion hotspot about 40-45 mya, as part of the island-arc series that started with the Deccan Traps in India (64-67 mya) is still active forming the island of Reunion (2 mya to present). The Cretaceous-Tertiary (K-T) extinction event associated with the superplume event that started activity of the Mascarene-Reunion hotspot drove approximately 30% of marine genera to extinction, along with the dinosaurs, opening evolutionary space and potentially a unique evolutionary history for marine species in the Western Indian Ocean.

The S. de Malha Bank is now capped by carbonate deposits due to sedimentation of carbonate-forming plankton along with shallow carbonate reef growth where possible. An oil drilling core taken at the northwest corner of the main bank found carbonate rock to a depth of over 2400 m, of which the top 1250 m were described as 'reef carbonates'. The volcanic rock may have been exposed as a large island up to 300 km across its longest diameter, from the time of its formation and for several 10s of millions of years subsequently. A classic example of island subduction and sinking and coral reef and carbonate platform growth over time, as first theorized by Charles Darwin, the Saya de Malha bank is now a submerged carbonate plateau. The bank is described as being flat, but considerable depth variation occurs across its top, with the shallowest being a crest less then 75 m deep to the north and east, with patches west of this and at the northwest side, and depressions down to 300–400 m depth in the center of the bank. The entire bank is clearly differentiated at the 500 m contour from the deep ocean surrounding it. With no exposed island mass, the waters over the bank are a globally unique mid-ocean shallow sea.

The Mascarane Plateau, stretching from the N. Seychelles Bank in the north to St. Brandons Island in the south (with the isolated Mascarene Islands shown to the south). The S. de Malha bank is the eastern point of the arc, and the largest bank. ©David Obura



The Mascarene plateau, colour-coded by depth: red and yellow show areas shallower than 125 m, green to 500 m, and blue to 4000 m. ©etopo

The Saya de Malha bank may host the largest seagrass beds in the world, on its shallow east and northern rims.
© Cheryl-Samantha Owen/ www.samowenphotography.com

The remote banks may be among the last refuges for Napoleon wrasse (*Cheilinus undulats*). This species is highy vulnerable to fishing, and was listed as Engangered on the IUCN Red List, in 2010. © Melita Samoilys

The smaller northern bank, the Ritchie plateau, is separated from the main bank by a transform fault, and is part of the granitic continental rocks of the Seychelles bank and the ridge extending between them in a NW-SE direction. South of the Saya de Malha bank, the Nazareth and Cargados Carajos banks are of similar construction, but younger, and only St. Brandon's island, at the southern end of the Cargados Carajos bank, has any aerially exposed landmass.

The Saya de Malha bank sits in the path of the South Equatorial Current (SEC), that dominates the oceanography of the WIO, and together with its sister plateau to the south, the younger Nazareth bank, concentrates flow of the SEC into a narrow passage between them at 12.5–13°S. The bank thus has a major influence on the oceanography of the WIO and regions to the west. Only a small proportion of the SEC passes north of the bank as a slow, broad current, and island wakes and eddies in the lee of the bank may result in higher oceanic productivity due to mixing and upwelling. The influence of these features on the connectivity of the marine fauna of the bank and plateau system, with other coralline islands in the Seychelles, and for the WIO in general, is presently unknown.

Current knowledge holds that the bank supports the largest contiguous seagrass beds in the world, with 80–90 % of shallow surfaces being covered by seagrasses dominated almost exclusively by *Thalassondendron ciliatum*, from depths up to 30–40 m, with additional records of *Halophila decipiens* and *Enhalus acoroides*. Coral reefs appear limited to rocky patches and outcrops, and likely to the edges of the bank.

Enhanced oceanic productivity caused by interaction of the banks with the South Equatorial Current is likely important for ocean food webs, and as indicated by seabirds using the Seychelles Basin (shown for wedge-tailed shearwaters and white-tailed tropicbirds), and for the pygmy blue whale (*Balaenoptera musculus brevicauda*) as a feeding and breeding ground.

Jurisdiction – historically considered to be beyond national jurisdiction, the Mascarene Plateau was the subject of a successful joint application by the governments of the Seychelles and Mauritius, under the United Nations Convention on the Law of the Sea (UNCLOS) Commission on the Limits of the Continental Shelf, to extend their Outer Continental Shelf. Hence, the seabed is jointly managed by Mauritius and the Seychelles, while the water column remains in the high seas.[1] Approved in 2010, this gives the governments the opportunity to exploit the marine resources in an additional maritime zone of 396,000 km^2 on the Mascarene Plateau.

The Saya de Malha bank has been identified as globally important in two independent processes:

a. The technical process in support of the Convention on Biological Diversity used the bank as an illustration of a likely Ecologically or Biologically Significant Area (EBSA), satisfying four of the seven criteria: 1. Uniqueness or rarity; 2. Special importance for life history stages of species; _3. Importance for threatened, endangered or declining species and/or habitats; and 5. Biological productivity. A CBD Indian Ocean regional workshop to formally describe EBSAs will further this work in August 2012.

b. A separate analysis by WWF, as part of the Western Indian Ocean Marine Ecoregion (WIOMER) and 'Réseau des Aires Marines Protégés' project of the Indian Ocean Commission (RAMP-COI) scored Saya de Malha as high for the other 3 EBSA criteria: 4. Vulnerability, Fragility, Sensitivity, or Slow recovery; 6. Biological diversity; and 7. Naturalness; and has selected it as a priority seascape of global significance for its ecoregional conservation strategy.

1. This is not as unusual as it sounds. Several seabed areas of the world ocean fall under national control with the overlying waters being high seas. Seamounts and a hydrothermal vent in the Northeast Atlantic on the Portuguese continental shelf have been protected as part of the OSPAR marine protected area network.

Potential Outstanding Universal Values	
Criterion viii – Geology and oceanography The Mascarene Plateau presents a superlative example of hotspot/spreading ridge interactions and mid-ocean example of island subsidence and carbonate reef and bank formation. The Saya de Malha Bank is the largest bank of its type in the Indian Ocean. Ocean-platform interactions result in raised productivity on and downstream of the banks.	**Criterion x – Habitats & conservation** The S. de Malha Bank supports the largest sea-grass beds in the world, and it and the other banks form a large contiguous and unexploited shallow marine habitat that supports production in the surrounding ocean. Breeding grounds for the pygmy blue whale *Balaenoptera musculus brevicauda*.
Criterion ix – Ecology, species and evolution The Mascarene Plateau is part of the earth and climate processes that played a role in the K-T extinction (superplume event) and cenozoic evolutionary mechanisms in the WIO.	

Threats

The remoteness of the bank has protected it from threats, much as it has prevented much research and data collection. Nevertheless, vessels from distant-water fishing nations (DWFN) operate in the Indian Ocean and and Mauritian vessels target the bank and adjacent ones. Prospecting for seabed metals and oil and gas mining have returned weak results, so the threat from them is currently considered low. Climate change is a significant threat for the carbonate-dominated food webs of the shallow banks.

Management

Future management of the S. de Malha bank will depend on joint arrangements by the Seychelles and Mauritius, and national priorities such as in fisheries. Management, surveillance and enforcement of a distant marine zone with no emergent land to host a management base will be challenging, but increasingly possible with the advent of remote sensing surveillance technologies, and existing operationalization of them in, for example, fisheries management and vessel surveillance. National legislation to enable management of this type of distant marine site would be necessary. WWF is proposing for discussion with Mauritius and Seychelles to carry out a "feasibility study" to (i) analyse the existing international and regional conventions and conservation and management tools that provide guidance for appropriate legal regime, conservation and fisheries management measures and type of governance for the Saya de Malha Banks, and (ii) propose a statement of strategy and action plan for the short, medium and long-term.

Geographic scale and integrity issues

The S. de Malha bank is the largest single bank in the Indian Ocean, larger than the Great Chagos Bank. There is no human habitation on or near the bank as there is no emergent land. Thus the ecological integrity of the bank is very high, and a nomination that includes the whole bank will meet the highest level of integrity possible. Nomination of a portion of the bank would result in slightly lower integrity of the nomination site, but the lack of current threats, and successful management planning in the future, would ensure high enough integrity for sustainability of a site.

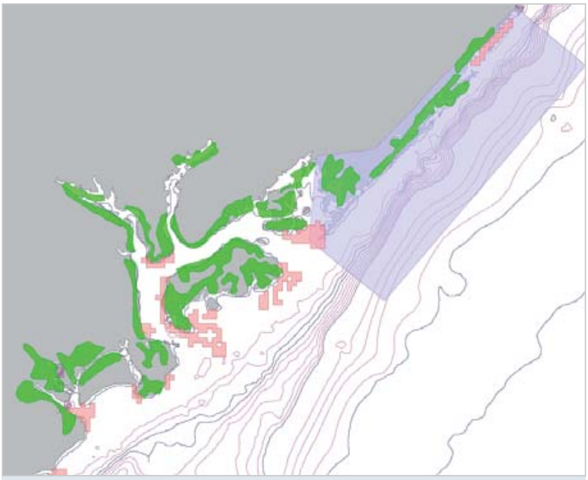
Site type – as presented here, the Saya de Malha bank could either be considered as a transboundary single site nomination, jointly by the governments of the Seychelles and Mauritius. Alternatively, if only part(s) of the bank is(are) selected, single-country nominations would be possible. With different geological origins, sites on the south bank and north/Ritchie bank could be selected. Further, the EEZ extension application by the Seychelles and Mauritius applies to the seabed, while the water column is an ABNJ, and in the High Seas.

Other sites in the region – the Mascarene Plateau is a unique geological feature globally.

Lamu-Kiunga Archipelago

Location

The site is located at the northern extreme of the Kenya coast, against the border with Somalia. The Kiunga archipelago is some 60 km long, part of the string of islands that starts at Lamu Island, about 50 km to the south. The islands shelter an extensive system of creeks, channels and mangrove forests. The islands are fully enclosed within a protected areas, the Kiunga Marine National Reserve (KMNR) and adjacent to the Dodori and Boni National reserves on land. The marine ecosystem incorporates a chain of about 50 calcareous offshore islands and coral reefs.



Map showing the Kiunga Marine Reserve (blue polygon) and Pate and Lamu islands to the southwest. The extent of mangrove (green) and coral reef (pale orange) is shown.
© David Obura

Description

The area is in the Northern Monsoon Current Coast ecoregion, with closer ties to the Somali coast and northern locations, than to the East African Coastal Current (EACC) to the south. It experiences seasonal reversal in the flow of the two currents with the monsoon seasons. This affects the

A typical tidally-dominated channel between the islands of the Kiunga archipelago and the mainland. © Julie Church oceanography of the area, which is characterised by upwellings of cooler, nutrient rich waters. The upwelling results in a highly productive marine ecosystem with rich populations of fish, crustaceans and molluscs, and high abundance of migratory species such as seabirds and turtles. Marine habitats include extensive seagrass beds and patchy coral reefs. The intertidal environment of the creeks and basins of the region holds 60% of Kenya's mangrove forests, some 345 km^2 in the greater Lamu area, of which the KMNR hosts about 40%.

The terrestrial environment is a mixture of coral rag and sand beaches, backed by coastal scrub and forest. The beaches provide nesting sites for numerous bird species and three species of marine turtle, while wildlife from the adjacent Dodori Game Reserve frequent the dunes and beaches, including African Wild dogs, buffalo and lions.

The KMNR area is renowned for its aesthetic beauty, hardy yet unique ecological conditions, species diversity, turtles and occasional sightings of dugong, whale and sharks. It is also the home to over 12,000 Bajun people who live adajacent to and within the protected area. Their livelihoods (fishing – lobster, gill, purse seining, crab - mangrove harvesting, trade) are and have traditionally been sustained by the waters in the KMNR.

Jurisdiction – Kenya.

Threats

The region is remote, so less exposed to fishing and other direct uses, though this is changing as waters closer to major markets become depleted. Fisheries in the KMNR and even farther north in Somalia are facilitated by boats and container trucks bearing ice, to buy fish and seafood cheaply locally, and transport it to markets in Kenya and as far afield as Singapore for lobsters. The challenges of regulation and management of fisheries in this remote region result in heavy use of illegal and destructive gears, and no consideration for sustainability. Mangrove poles have been harvested for over a century in the area. Climate change has impacted reefs and mangroves of the area, with over 90% coral bleaching and mortality recorded in 1998, and die-back of mangrove areas due to excessive fresh-water inflow. Because of the area's remoteness, recruitment of corals is limited, retarding recovery.

Emerging threats to the region include that of insecurity due to proximity to Somalia, with growing threat of piracy in the last few years. This hampers development and management. In addition a large port development is being planned in Magogoni Creek between Manda and Pate islands and the mainland. Weak regulatory frameworks have resulted in significant conflict and uncertainty about the scale of the development, its potential impacts and how the local envirionment and people will be

Potential Outstanding Universal Value

Criterion viii – Geology and oceanography

Oceanography: the area is greatly influenced by reversals between the Somali and EAC currents during the two monsoon seasons, characterised by influence of upwelled cool, nutrient rich waters resulting in a highly productive marine ecosystem with a high degree of endemism.

Criterion x – Habitats & conservation

Mangrove forests: the overall area has the largest mangrove forests in Kenya (345 km^2) with 40% of this being in the KMNR. The area hosts all nine species of mangroves found in the WIO.

Coral reefs: there are approximately 180 species of corals, with a mix of East African and Gulf of Aden species adapted to the colder upwelling conditions.

Connectivity: the area has mixed species assemblages comprising East African and Gulf of Aden species, representing a key locus of genetic interaction and biogeographic changes.

Criterion ix – Ecology, species and evolution

Ecology: wide range of ecosystems from terrestrial and marine habitats including coastal sand dunes, rocky and sandy shores, mangrove forests, seagrass beds, coral reefs and open ocean.

Turtles: three species are known to nest and feed in the area (green, hawksbill, Olive Ridley) whilst the leatherback has been sighted offshore.

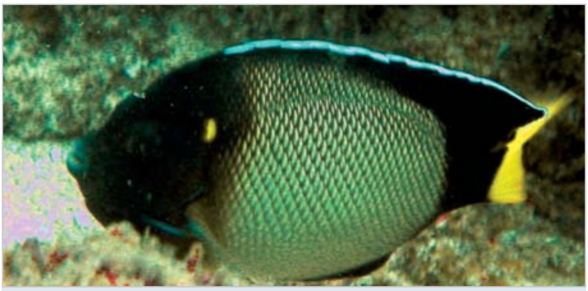
Birds: key nesting site for 10,000 breeding pairs of roseate terns.

Dugong: a dugong refuge though numbers are unknown.

Whales: humpback, sei, sperm and pilot whales known to breed and feed in the offshore waters.

Cultural World Heritage – criteria ii, iv and vi

Lamu island itself is designated as a Cultural World Heritage Site, for its historical and cultural significance in the Swahili and Islamic cultures of the region. Currently the WH site only includes the town, but plans are underway to designate a buffer zone to include historic sites in the general area, as far north as Kizingitini on Pate Island, just south of the KMNR boundary.



The Red Sea angelfish (*Apolemichthys xanthotis*), an example of the transition fauna of the Kiunga-Lamu region, as this fish is endemic to the Red Sea/Gulf of Aden, and this is the southern-most record of it's presence.
© David Obura

affected. Dredging for port construction and maritime pollution may have devastating impacts on the marine habitats and species of the region, including in the KMNR. Finally, growing interest in oil and gas exploration, and a pipeline for oil from South Sudan to the port make it likely that in future there will be a refinery at the port.

Management

The Kiunga Marine National Reserve (KMNR) was established as a protected area in 1979, and the following year (1980) was designated as a Biosphere Reserve (Kiunga and Kiwaiyu) of 60,000 ha under UNESCO's Man and the Biosphere (MAB) Project with the adjacent Dodori National Reserve in recognition of the international conservation importance of the region. In 1996, the World Wide Fund for Nature (WWF) and Kenya Wildlife Service (KWS) formed a working partnership to develop long-term management strategies integrating conservation and development priorities, and several private and civil society groups are also active in marine and cultural conservation in the region. Extension of the Lamu Town Cultural World Heritage buffer zone to include other parts of the historic archipelago to Pate Island would mean the entire archipelago could be designated for cultural or natural values under some form of management.

Geographic scale, integrity and site type

In geological and natural terms, the KMNR and the broader Lamu-Kiunga archipelago are an integral unit, representing the entire Northern Monsoon Coastal Current eco-region in Kenya. Lamu Town is already a Cultural World Heritage site, complementing the KMNR. However the port development at Magogoni represents the single largest threat to the integrity of the natural and cultural systems of the area.

Other sites in the region – none.

The Kwazulu-Natal Sardine Run

Location

The Sardine Run occurs off the East Coast of South Africa during the months of May to June. The area just falls outside of the tropical zone of the WIO, however the uniqueness of this phenomenon, occurring on the boundary of the WIO and touching its southern extreme, is of importance and interest.

Description

The Southern African pilchard (*Sardinops sagax*) spawns in the cool waters of the Agulhas Bank. As the spawning season matures, the shoals move northward along the east coast of South Africa. The run can contain billions of individual sardines, trapped in a cold current of water between the coastline and the Agulhas Current itself (that heads southwards), which can cause the fish to be concentrated into the dense shoals of the 'sardine run'.

Limited information suggests that the water temperature has to drop below 21°C in order for the migration to take place. More recent observations have noted that cooling temperatures, calm conditions, light northwesterly land breezes and stable atmospheric conditions promote the development of the run. In terms of biomass, researchers have estimated the sardine run could rival East Africa's great wildebeest migration. The shoals are often more than 7 km long, 1.5 km wide and 30 meters deep, and are clearly visible from spotter planes or from the surface.

The sheer numbers of sardine create a feeding frenzy of higher predators. For instance, up to 18,000 dolphins are estimated to aggregate to feed on the sardines, mostly the common dolphin (*Delphinus capensis*) but also the bottlenose (*Turisops aduncus*). They round up the sardines into bait balls, which instinctively group up as a defense mechanism. These bait balls can be 10–20 meters in diameter and seldom last longer than 10 minutes as a large number of other predators take advantage including sharks (bronze whaler, dusky, grey nurse, black tip, spinner and zambezi), other fish (billfish, kingfish), birds (gannets, cormorants, terns and gulls), and cape fur seals.

Like the wildebeest migration, the biomass of sardines and central role it plays in the life history of the predators of the region, and the potential for nature-based tourism to view the phenomenon, make it a unique event.

Jurisdiction – South Africa.

Threats

Climate change would lead to changing conditions (temperature, phenology and timing of seasonal events, etc) which may have a devastating effect on the Sardine Run and all it effects. The frequency of the run could be altered.

Management status

Observed, monitored, researched and enjoyed.

Geographic scale, integrity and site type

The sardine run is a mobile phenomenon, so presents challenges in ensuring its integrity, as barriers to movement along the shoreline may significantly impact it.

Other sites in the region – there is no other fish shoaling phenomenon of of this type in the WIO or elsewhere in the world.

Antongil Bay, Northeast Madagascar

Location

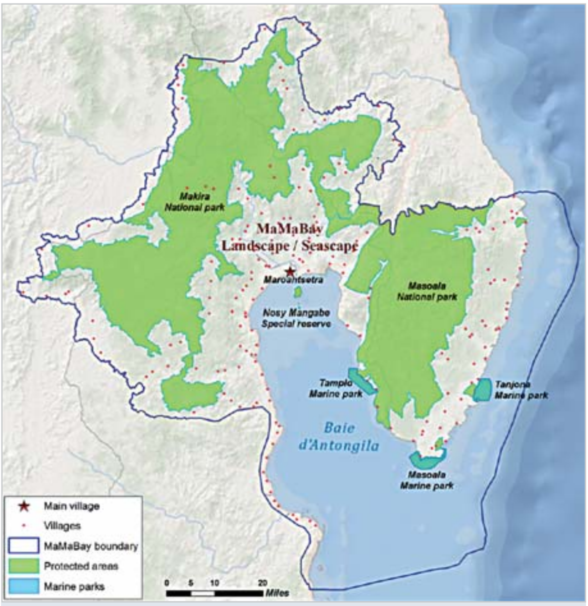
Antongil Bay is in the NE of Madagascar (16°00'S, 49°55'E).

Description

Antongil Bay is the largest bay in Madagascar, covering 2800 km^2, of which half is less than 50 m deep and 270 km of coastline. It is situated where the South Equatorial Current (SEC) hits the east coast of Madagascar and splits north and south, and is sheltered from the southeast swell and winds by the Masoala Peninsula. Situated in a high rainfall area, the bay is surrounded by lush tropical forests, with 9 rivers flowing into it. The bay is among the most productive in the Indian Ocean, with a very high biomass of small pelagic fish (27,000 tonnes), also serving as a mating and nursery ground for many marine species. .

The forests surrounding the bay host an estimated 50% of Madagascar's floral and faunal diversity, and are designated under three protected areas – the Masoala National Park, which is a natural World Heritage Site, the Mananara National Park, which is a UNESCO Biosphere Reserve, and the Makira Protected Area.

Jurisdiction – Madagascar.



Antongil Bay is on the upper NE coast of Madagascar, some 300 km south of the sites mentioned in the N Madagascar site page. ©Wildlife Conservation Society

Potential Outstanding Universal Values

Criterion viii – Geology and oceanography

Oceanography: the bay is situated where the SEC hits the east coast of Madagascar and splits north and south, so is among the first settling sites for larvae transported across the ocean. It may play a key source role for downstream regions, such as in the Mozambique Channel.

Criterion x – Habitats & conservation

The bay contains many marine habitats: estuaries, mangroves, rocky shores, coral reefs, and seagrass beds. Coral reefs on the east coast of Madagascar have shown potential resilience to coral bleaching due to climate change.

The bay is globally important for its role as a mating ground for humpback whales, and is one of the largest and best-studied wintering sites in the Indian Ocean. Research in Antongil Bay from 2000 to 2006 suggests that the population of humpback whales utilizing the Bay is composed of approximately 7000 individuals and is continuing to recover from depletion by commercial whaling that occurred in the 19th and early 20th centuries.

Criterion ix – Ecology, species and evolution

The bay contains more than 140 species of fish, of which 19 are sharks. Three turtle species frequent the bay: green turtles (*Chelonia mydas*), hawksbills (*Eretmochelys imbricata*) and leatherback (*Dermochelys coriacea*). At least 13 marine mammal species are reported in the bay and adjacent offshore region: the dugong (*Dugong dugon*), one pinniped (*Arctocephalus tropicalis*), and 11 species of cetaceans (humpback whales *Megaptera novaeangliae*, southern right whales *Eubalaena australis*, sperm whales *Physeter macrocephalus*, beaked whales *Ziphius cavirostris* and *Mesoplodon sp*, bottlenose dolphins *Tursiops sp*, spinner dolphins *Stenella longirostris*, pantropical spotted dolphins *Stenella attenuata*, Fraser's dolphins *Lagenodelphis hosei*, false killer whales *Pseudorca crassidens*, and melon-headed whales *Peponocephala electra*).

Threats

Antongil Bay faces similar exploitation threats to other parts of the region, particularly from high fishing pressure and illegal fishing, depletion of mangrove forests, sedimentation from terrestrial runoff, and petroleum industry exploration and production.

Management status

The bay has had a variety of regulations and management zones decreed. In 2010, the entire bay and its outer reaches, an area of about 4400 km^2 were put under temporary full protection by an interministerial decree (n°52005/2010), to enable measures to be put in place to assure long term sustainable resource use. Prior to this, within the Masoala National Park, 3 marine protected areas covering 100 km^2 were established in 1997, and the Marine Park of Nosy Antafana, created in 1989, has an area of 10 km^2. Since 2009, 7 community protected areas were established, covering a total of 2000 ha. In 2006 the first regulation of its kind in Madagascar was imposed, banning the use of destructive gears such as beach seines, and fine-mesh (mosquito net) nets. In 2011 this was extended as a ban on the manufacture, sale and use of beach seines in the Région Analanjirofo, in which the bay is found.

French Southern Territories
(Crozet, Kerguelen, Saint Paul and Amsterdam)

Location

This group of islands is south of the Western Indian Ocean, about halfway to the Antarctic continent and midway between South Africa and Australia.

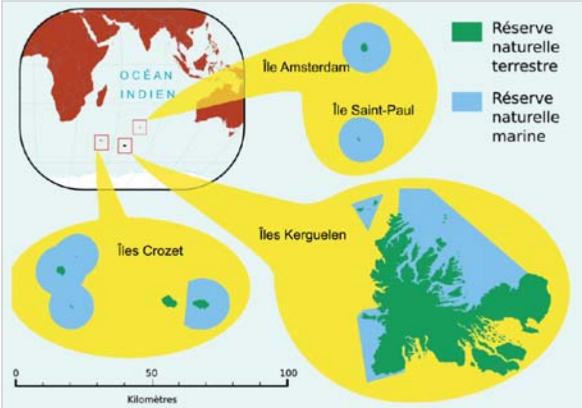
Description

The region is classified in a common biogeographic province with temperature South Africa in the MEOW classification. In spite of not being within the WIO, its importance and distinctiveness have been raised repeatedly during this study, so is mentioned in this report.

Geologically, the Kerguelen Islands are most distinctive, composed of a large island and more than 300 islands and islets covering a total area of 6500 km^2, on a massive continental shelf covering 100,495 km^2, itself on the submarine Kerguelen-Heard shelf of 2.2 million km^2 at a depth of approx. 1000 m. This shelf was produced by hotpost activity approximately 118–90 mya associated with a "superplume event" during the separation of India from the landmass of Australia and Antarctica, after the breakup of Gondwana. The plateau represents one of the largest volcanic outpourings globally, along with the Ontong Java Plateau in the western Pacific. The shelf interacts with the strong currents ringing the Southern Ocean, causing massive upwelling and productivity, supporting massive fish populations, marine mammals, seabird aggregations and others.

The Crozet and Kerguelen islands are among the world's richest seabird zones with 34 breeding species. The most distinctive of these is the Critically Endangered endemic Amsterdam albatross (*Diomedea amsterdamensis*), whose sole population is estimated at 180 individuals (30 couples breeding on site per year). The Crozet Archipelago also hosts the largest colony of King Penguins worldwide (*Aptenodytes patagonicus*) with more than one million individuals. Overall, more than 25 million seabirds breed each year at Crozet, and at least as much to Kerguelen. This represents unique concentrations of birds world wide.

The islands are equally important for multiple species of marine mammals, including the southern elephant seal (*Mirounga leonine* – 400,000 breeding annually, the second largest population in the world), the only population of Commerson's dolphin subspecies (*Cephalorynchus commersonii ssp.*), the Antarctic fur seal (Kerguelen sea lions, *Arctocephalus gazella*) and Amsterdam sea lions (*A. tropicalis*), numbering up to 50,000 individuals, from just 100 surviving in 1956.



French Southern Territories, showing existing terrestrial and marine nature reserves. ©Taaf

Plaine Ampère, Kerguelen. ©F. Lepage–Taaf

Jurisdiction – France. The shelf defines the Exclusive Economic Zone of Kerguelen, operated under the Terres australes et antarctiques francaises (TAAF), with the neighboring islands of Heard and MacDonald and their EEZ belonging to Australia.

Threats

The remoteness of the islands has protected them from threats, though this also contributes challenges to effective management. Also, because of their remote mid-ocean location, ocean and fisheries management has involved multi-country agreements. Nevertheless the integrity and condition of the area is very high as they are uninhabited islands, and they have good scope for consideration as a potential World Heritage site.

Management status

All the waters in the zone are covered by the area of jurisdiction of the Commission for the Conservation of fauna and flora of Antarctic Marine Living Resources (CCAMLR), a maritime extension of the system of the Antarctic Treaty. In addition, a Franco-Australian agreement on cooperation for the implementation of legislation relating to fishing is in effect.

5

Appendices

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Workshop participants and experts

	State World Heritage Focal Point	
1	MANGCU Chumani	South Africa
2	CHUTTAN Fareed	Mauritius
3	MACAMO Solange Laura	Mozambique
4	MARO E. Eliwasa	Tanzania
5	DEXCIDIEUX Laure	La Reunion
6	NJOGU G. James	Kenya
	Site Managers	
7	FLEISCHER DOGLEY Frauke	Seychelles
8	ZALOUMIS/Andrew	South Africa
	Project Team	
9	DEBONNET Guy	France
10	DOUVERE Fanny	France
11	OBURA David	Kenya
12	GABRIE Catherine	France
13	CHURCH Julie	Kenya
14	ODIDO Mika	Belgium
15	MEES Jan	Belgium
16	HERNANDEZ Francisco (Tjess)	Belgium
	Marine Ngo	
17	ANDREWS Tim	Tanzania
18	RALISON Harifidy	Madagascar
	Marine Scientists	
19	MARTINEZ Carole	France
20	HUSSEY Nigel	Canada
21	COLLIN Gerard	France
22	RICHMOND Matt	Tanzania
23	MACIA Adriano	Mozambique
24	MORTIMER Jeanne A.	USA
25	LE CORRE Mathieu	Reunion
26	BIGOT Lionel	Reunion
27	CHABANET Pascale	Reunion
28	CERCHIO Salvatore	USA
29	STAUB Francis	France
30	GRAVIER BONNET Nicole	Reunion
31	BOURJEA Jerome	Reunion
32	LAGABRIELLE Erwaan	Reunion
33	TERNON Jean-François	Reunion
34	QUOD Jean-Pascal	Reunion
	Hosts	
35	RADJASSEGARANE Soudjata	Reunion
36	PROVOT Laurence	Reunion
	Other Participants:	
37	POTHIN Karine	Reunion
38	LATREILLE Catherine	Reunion
39	TARNUS Gisèle	Reunion
40	MARGUERITE Eric	Reunion
41	THIERY Gwenaelle	Reunion
42	RANJATO Andriamia	Reunion
43	RIBES Sonia	Reunion
44	DENIS Bertrand	Reunion
45	RAIMBAULT Jerome	Reunion
46	MARTEAU Cedric	Reunion
	Other consulted experts	
47	ADBULLA Ameer	
48	COCKROFT Vic	
49	KISZKA Jeremy	
50	SAMOILYS Melita	
51	WANLESS Ross	

Workshop agenda

Day 1

Tuesday,14 February 2012
Location: Regional Council of La Reunion (Hôtel de Région, hemiciclo)

16.00 Registration of participants

17.00 Welcome and Opening remarks
Mr Guy Debonnet, Programme Specialist, World Heritage Centre
Ms Marylene Hoarau, Director, Parc national de La Reunion (TBC)
Mr Didier Robert, President of Région Réunion (TBC)
17.45 Introduction of the participants
18.30 Purpose and Introduction to the Indian Ocean project for marine World Heritage
Dr Fanny Douvere, Coordinator, UNESCO World Heritage Marine Programme, World Heritage Centre

19.00 Opening reception

Day 2

Wednesday,15 February 2012
Location: Regional Council of La Reunion (Domaine de Moka)

09.30 *World Heritage Convention* for ocean conservation: An introduction
Dr Fanny Douvere, Coordinator, UNESCO World Heritage Marine Programme, World Heritage Centre, Paris

10.00 Introduction to the criteria and requirements of Outstanding Universal Value under the 1972 *World Heritage Convention*
Mr Guy Debonnet, Programme Specialist, World Heritage Centre

10.30 Questions and Discussions

11.00 *Tea/Coffee Break*

11.30 Sharing experiences from Aldabra Atoll, marine World Heritage site
Ms Frauke Fleischer-Dogley, Chief Executive Officer, Aldabra Atoll, Seychelles

12.00 Introduction to the regional comparative assessment of potential areas with Outstanding Universal Value in the Indian Ocean
Dr David Obura, Project Coordinator, CORDIO East Africa

Overview of the work and outputs – 5 min
Preview of Day 3

12.30 Questions and Discussions
13.00 *Lunch break*

14.30 World Heritage designation: A potential for sustainable development and poverty reduction
Mr Andrew Zaloumis, Chief Executive Officer, iSimangaliso Wetland Park, South Africa

15.00 Web-based data support tool for States Parties for site nomination
Dr Jan Mees / Dr Francisco Hernandez, Flanders Marine Institute, Belgium

15.30 Questions and Discussions

16.00 *Tea/Coffee Break*

16.30 UNESCO-IOC – Ocean Data and Information for Sustainable Development Areas in Africa: ODIN AFRICA
Dr Mika Odido, regional activities coordinator, Intergovernmental Oceanographic Commission

17.00 Discussions and conclusions of Day 2
Preparations for Day 3

17.30 Closing

Day 3

Thursday, 16 February 2012
Location: Regional Council of La Reunion (Domaine de Moka)

09.00 Welcome and review the overview of Day 2
Dr Fanny Douvere, Coordinator, UNESCO World Heritage Marine Programme, World Heritage Centre, Paris

09.30 Presentation of the findings from baseline regional comparative assessment
Dr David Obura, Coordinator, CORDIO East Africa

10.30 Marine expert discussion "*Where we have got to*" (1 hour)
Dr David Obura, Dr. Catherine Gabrie, Julie Church

PRESENTATION of the findings from baseline regional comparative assessment

INDIVIDUAL WORK – validation of information – 20 mins
- *what are we missing for your taxa/area – on features and sites*
- *more info for the sites we have identified – description, OUV, integrity, threats/management*
- *what other sites – have we missed any specific site in the WIO*
- *additional sources/references, maps databases – other experts if there are information gaps*

GROUP WORK – thematic (species/habitats/processes).
- *cross reference individual work*
- *validation and gap analysis of priority sites*
- *comments on prior regionalizations/ prioritizations*
- *What has been left out? Justification*
- *emerging issues for the region that may influence/impact potential WH marine sites*

PLENARY – reporting/cross-referencing of group work
- *presentation of each group results*
- *cross-referencing of group work*

16:00 Presentation of the results of the regional comparative assessment
Dr David Obura, Coordinator, CORDIO East Africa

16:15 Discussion: Next Steps, with the World Heritage Focal Points

17:45 Closing remarks and end of the meeting
Dr Fanny Douvere, Coordinator, UNESCO World Heritage Marine Programme, World Heritage Centre, Paris

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