Buying time for corals
Coral reef crisis
Marine Protected Areas and climate change
THE FIRST ANNOUNCEMENT AND CALL FOR PAPERS

The Western Indian Ocean Marine Science Association (WIOMSA) in collaboration with the Mauritius Oceanography Institute (MOI); and the Nairobi Convention Secretariat are pleased to announce the first Conference on “Climate Change Impacts, Adaptation and Mitigation in the Western Indian Ocean (WIO) region: Solutions to the Crisis”, which will be held in Grand Baie, Mauritius from 21st – 23rd March 2011.

This Conference will bring together key individuals working on climate change issues at different levels including senior Government officials, representatives of regional multi-lateral bodies, development partners, representatives of the business community and NGOs and CBOs, and scientists, to:

i) Share knowledge, experience and solutions on impacts of climate change and experience gained in implementation of adaptation and mitigation strategies.

ii) Support and facilitate WIO countries in their quest to forge a common vision on how to deal with implications of climate change.

iii) Develop a common stand in priorities for actions in relation to research, adaptation and mitigation strategies.

DATES
Monday, 21 March 2011 – Wednesday, 23 March 2011

CONFERENCE FORMAT
The Conference will have a combination of expert presentations and discussions in plenary and parallel sessions. Prominent experts from governments, business community, NGOs and multi-lateral organizations will be invited to attend the symposium and deliver keynote presentations.

CALL FOR PAPERS
Summaries are invited on any topic related to the impacts and adaptation to climate change in the WIO region. Priority will be given to summaries describing efforts undertaken by governments, NGOs/CBOs and private sector to address implications of climate changes. Summaries must be in English and should not exceed 400 words. Submitted summary must contain the following information: title, name(s) of author(s), affiliations, postal and e-mail addresses. It should also clearly state the preferred mode of presentation (oral or poster). Summary must be in Times New Roman, 12-point font, single spacing with justified alignment.

All summaries will be reviewed for merit and relevance and must be received by WIOMSA no later than 15 November 2010. Confirmation of acceptance for oral or poster presentations will be communicated to authors by 15 December 2010. Summaries should be submitted to secretary@wiomsa.org.

FINANCIAL ASSISTANCE
A limited number of travel grants will be provided to participants from the region whose summaries have been accepted. Applications for the travel grants should be accompanied by details of the support required. These applications need to be submitted by 15th January 2011 to secretary@wiomsa.org.

EXHIBITIONS
Space will be available for exhibits by organisations, programmes, projects and companies. Please contact the WIOMSA Secretariat (secretary@wiomsa.org) for more details. Deadline for confirmation by institutions participating in the exhibition is 15 January 2011.

Contact address:
Executive Secretary
WIOMSA
P. O. Box 3298, Zanzibar,
United Republic of Tanzania,
Tel: + 255 24 2233472
Fax: + 255 24 2233852
E-mail: secretary@wiomsa.org

On behalf of the organizing committee, we sincerely invite you to join us in the Conference.
News
5. MASSIVE CORALS THE NATURAL ARCHIVES OF ENVIRONMENTAL CHANGE

8. WHAT IS THE CLIMATE VULNERABILITY OF THE WESTERN INDIAN OCEAN “CORAL TRIANGLE”

8. ADAPTING TO CLIMATE VARIABILITY

Features
12. AN ASSESSMENT OF MANGROVE ECOSYSTEM VULNERABILITY TO CLIMATE CHANGE IN WESTERN MADAGASCAR

16. MARINE PROTECTED AREAS AND CLIMATE CHANGE IN NORTHWESTERN MADAGASCAR

20. INCUBATION TEMPERATURE AND INFLUENTIAL FACTORS ON Chelonia mydas REPRODUCTIVE TRAITS IN LIGHT OF CLIMATE CHANGE

Special features
23. BUYING TIME FOR CORALS

24. CORAL REEF CRISIS

Last word
28. ‘MIDDLE CLASS’ REEF FISH FEEL THE ECONOMIC SQUEEZE
Climate Change – Less Talk, More Action!

Continuing coral bleaching, changing patterns of rainfall, alteration in stratification and circulation patterns of ocean currents and increased frequency of extreme weather events. The impacts of climate change are all around us. As is the case globally, the Western Indian Ocean (WIO) region is experiencing climate-related perturbations with most of them being attributed to the outcomes of ocean warming. There is clear and present danger for coastal communities and key economic sectors including tourism, agriculture and fisheries.

Despite this recognition, coastal and marine issues are not high enough on the climate change agendas of the countries in the WIO region. This is what has prompted WIOMSA and key partners such as the Nairobi Convention, Institute of Marine Sciences and Nature Seychelles to take up leadership into bringing these issues into national and regional forums.

WIOMSA’s formal foray into the arena of climate change began during the 6th Scientific Symposium in La Réunion in 2009, where a roundtable discussion “Climate change and the Western Indian Ocean: Implications for human health, the environment and the economy” was organized. Based on the priorities identified in the discussion, WIOMSA has funded eleven projects covering different aspects of climate change impacts on coral reefs, mangroves and fisheries as well as preparedness of governments for climate change. The information generated from the research will be used to identify adaptation measures and to support strategy development for adaptation. Thus WIOMSA intends the results of the projects to be directed into reducing vulnerability to climate-related impacts and in assisting in building the resilience of coastal communities and environments.

Other exciting initiatives in the region are breaking new ground. A MASMA-funded project “The feasibility of mangrove REDD projects in the Western Indian Ocean: Linking mangrove conservation and climate change adaptation to the global carbon markets” is aiming at contributing to the development of carbon offsetting project baseline and monitoring methodologies specific to mangrove habitats and the WIO context. The Nature Seychelles managed Cousin Island Special Reserve became in September 2010 the World’s first carbon neutral nature reserve – a high point for the WIO region.

As a robust response to the less than satisfactory outcomes of the Copenhagen Summit, WIOMSA, the Nairobi Convention and the Mauritius Oceanography Institute are jointly organizing the regional Climate Change Symposium in March 2011. This symposium is expected to be solution oriented and issues driven. It will bring together senior government officials, representatives of regional multi-lateral bodies, development partners, representatives of the business community and NGOs and CBOs, and scientists, to share knowledge and solutions so as to support WIO countries to forge common priorities and actions for dealing with climate change.

In preparation for this symposium, this issue of the magazine is dedicated to climate change and the regional and local organizations in the WIO are doing in terms of research and mitigation. Some of the 11 projects indicated above have contributed articles on their work in the sector. We hope you enjoy the read.

Nirmal Shah
Co-Editor

FOR MEMBERSHIP CONTACT:
email: secretary@wiomsa.org
tel: +255224223472
www.wiomsa.org
New MASMA and Dutch research project to assess the impact of climate change and human impact on nearshore coral reefs in the Western Indian Ocean.

Soil erosion, land degradation and modern climate change pose a mounting threat to coastal nations in the western Indian Ocean. Yet vital, long-term observational data are missing to properly assess and clarify the impact of climate change and land-use changes on sustainability and to substantiate calls for action to prevent further degradation and runoff into marine catchments. Furthermore, environmental management strategies have been formulated, at best, based on short instrumental records, as proper historical time-series data are rarely available, even for the most sensitive catchments.

Environmental geochemists—dealing with the direct data acquisition on biological archives—have combined with climate scientists, environmental modellers and ecologists in a new project to examine the spatial and temporal environmental changes affecting coral reef ecosystems in the Western Indian Ocean. This partnership will allow for direct comparison of the geochemical data obtained by the geochemist with models of river discharge and pollution and ecological changes. The integration of these data should provide a far better understanding of the entire ecosystem in the region and lead to improved sustainable management of the coastal environment.

The project was engendered from the recognition that there is a dire need for pre-instrumental era data to assess the spatio-temporal variability of river-soil- and nutrient-discharge into tropical marine catchments world-wide. Further, continuous records are required that provide seasonal resolution to identify the role of discrete events—such as the El Niño related floods in East Africa from the 1970s and tropical cyclones changing their path, frequency and intensity of landfall—and multi-decadal climate variability in regional precipitation and runoff. The project will determine
The WIOMSA magazine | no. 4 – Jun 2010

6

The project is divided into two interdependent sub-projects: a coral proxy-climate-based project and a model-ecology-based project. The coral proxy climate-based project will entail the drilling of coral cores to reconstruct environmental changes in various reef complexes across the tropical Indian Ocean (Mauritius, Madagascar, Tanzania and Kenya) in relation to natural climate change and anthropogenic influences. Biological and environmental parameters in massive coral skeletons of the species *Porites* sp. and *Diploastrea* sp. which continuously grow for up to 400 years will be examined. The primary objective of this is to determine the seasonal variability in river runoff, sea surface temperature and coral growth due to climatic base-level changes, foremost of decadal-scale variability and intermittent extreme events along the path of cyclones. This climatic baseline includes hydrological reorganizations during e.g. the Medieval Warm Period around 1200 AD, the Little Ice Age around 1700 AD, and the Mid-Holocene. The secondary objective will be the assessment of anthropogenic impacts on river runoff and resultant thermal and growth anomalies in Indian Ocean catchments as offsets from the climatic baseline levels in hotspots of land degradation.

The major objective of sub-project 2 will be the quantification of land use and hydrological change in tropical catchments over decadal to century scales, and to determine the relative importance of anthropogenic versus climate forcing. The subproject aims to determine the spatial and temporal variations of four unknowns: land use change, river discharge patterns, coastal sediments, and extent of the freshwater plumes. These data will provide the link between land use changes, river runoff, sediment compositions and the coral proxy records that are required to distinguish the relative roles of natural and anthropogenic induced changes in the coral reefs.

The results of the subprojects will be linked to long-term ecological reef monitoring programmes of partner institutions to infer the impact on temporal and spatial biodiversity changes in coral reef ecosystems across the western Indian Ocean. The results of this project will provide a broader management context and to allow conservation scientists to identify environments where corals are expected to survive climate change and insure that management and conservation actions are focused on these key areas.

**Pilot study in Antongil Bay, NE Madagascar**

Recently, a group of researchers from the Royal Netherlands Institute for Sea Research (NIOZ) introduced a novel scanning technique that quantifies luminescence intensities by splitting the total emission spectrum into different spectral domains (Fig. 1).

Studies have shown that
when placed under ultraviolet (UV) light, some coral cores show bright luminescence patterns that are related to freshwater flood events and thus past river flow and rainfall dynamics in tropical environments. Variability in emission intensities were first thought to be caused by the incorporation of luminescent humic acids, soil derived organic compounds introduced by seasonal river runoff. Another cause, to be proposed, is the changing coral density and architecture since massive corals form a skeleton of luminescent aragonite, and banded luminescence is also found in corals in oceanic environments devoid of terrestrial inputs. The skeletal luminescence patterns have been classified to discriminate between faint bands and bright lines. Faint luminescent banding is attributed to the annual skeletal density banding, while the brighter narrow luminescent lines (linked to runoff) are considered to be associated with another component, e.g. humic acids, relating to skeletal chemistry. Therefore, the hypotheses formulated by our research group are that both humic acids and aragonite density determine luminescence intensities in corals; and that their deconvolution is required in order to reconstruct river runoff accurately.

In the pilot, measured luminescence intensities and calculated spectral luminescence ratios were analysed from coral cores, drilled in Madagascar, to investigate the potential for normalising the episodic bright emission bands to the overall aragonite skeleton emission, thus generating normalised luminescence data using spectral luminescence ratios. Four coral cores drilled from *Porites* sp. colonies from Antongil Bay in Northeast Madagascar were used to test a new technique of whole-core luminescence measurements. The cores are all influenced by seasonal river plumes occurring in the wet season between December and April.

The results show a significant increase in river runoff over Eastern Madagascar coupled with the accelerated warming of the central Indian Ocean after 1980. Skeletal chemistry reveals that natural decadal climate variability and Indian Ocean warming were the prominent causes of runoff variability over the past 100 years, influenced by periods of mid-century deforestation linked to the social upheaval in Madagascar. Further, northern Madagascar is strongly affected by landfalling cyclones (e.g. Cyclone “Hudah” in 2000 –Figure 1) that leave their mark in peak coral luminescence.

Figure 1. – Seasonality and cyclone impact revealed by growth banding of a northeast Madagascar giant coral. Left) Image of cyclone Hudah and corresponding high luminescent band in the coral core (blue image generated by novel photoluminescence core-scanning). Middle) Same coral core with monthly resolved Ba/Ca (black) and averaged spectral luminescence ratio (red) generated by novel UV core-scanning.

Correlation with Ba/Ca is high for the spectral G/B ratio showing seasonal runoff with a significant spike in the year 2000 corresponding to cyclone ‘Hudah’. Right) Same coral core showing high coral spectral luminescence ratios (thin line) correspond to tropical cyclones making landfall (grey shaded) in East Madagascar since 1980.
Adapting to climate variability

By David Obura

With so many people living near the poverty line, adapting to long term climate change is not a primary concern for most in East Africa. Short term variability, however, affects many millions of people, as seen in the last decade in the form of floods (Mozambique 2000, 2001, 2007; Kenya 2009/10; Tanzania 2006; Uganda 2010), droughts (Kenya 2006-09, northern Tanzania 1998-2005), cyclones (higher frequency in Madagascar 2006/07 and disease (Rift Valley Fever in Kenya in 2007).

CORDIO’s new grant from the MASMA program is investigating how to help coastal communities cope with short term climate variability. The project will address the problem of short term climate variability as a key stepping stone to also building up adaptive capacity to withstand long term changes.

The project has three modules:

**Predicting seasonal climate risk** – led by Ali Mafimbo at the Kenya Meteorology Dept, seasonal outlooks for weather and climate variables relevant to the coastal zone will be developed and updated during the seasons or when a weather event is imminent. These will be combined with coral bleaching alerts developed by CORDIO and the IUCN-CCCR that have run since 2007. An MSc student at the University of Cape Town will be supported under this module. This component is kicking off the project with a stakeholder workshop in Mombasa at the end of September 2010, to identify key risk factors and weather/climate variables to include in the seasonal predictions that will comprise the Coastal Climate Outlook.

**Assessing social vulnerability** – led by Nadine Marshall at CSIRO (Australia) the project will conduct social resilience/vulnerability assessments in the coastal zone of Kenya and northern Tanzania, building on the resilience background of the IUCN-CCCR, the SocMon WIO program, assessment tools such as CRISTAL and existing IUCN adaptation projects in the Pangani River basin. A primary goal is to identify a range of adaptation actions from those where villagers can choose actions that only require a change in
vulnerability of the region. Some of the project activities that will shed light on the issue include:

- Sampling during the ASCLME-supported Comoros cruise in October 2009, and remote sensing data, show high levels of small-scale spatial variability in water masses, related to cyclonic (cooler) and anti-cyclonic (warmer) eddies around the Comoros and in the Mozambique channel. These may significantly modulate the regional signal of high Surface Sea Temperature water masses that cause coral bleaching, causing high levels of spatial variability in bleaching among sites;
- Modeling of these parameters will experiment with ‘normal’ and ‘hot’ years based on ENSO, Indian Ocean Dipole and other large scale forcing factors, to shed further light on bleaching risk under different types of years;
- Coral species distribution patterns will be combined with information on species vulnerability to warming, to estimate the vulnerability of coral communities at multiple scales to climate change;
- Coral recruitment and size class distributions show how past mortality and connectivity patterns may have been affected by past warming/bleaching events, as well as potential responses to future changes;
- General reef resilience and fish herbivore diversity and biomass will give information on bleaching resistance and resilience of reefs in the region compared to areas outside of the core region.

The Institutions involved in the project are CORDIO (Lead organization: David Obura, Melita Samoilys), University of Cape Town (Johann Lutjeharms, Raymond Roman, Juliet Hermes, Chris Reason, Charinne Collins), University of Dar es Salaam (Albogast Kamukuru, January Ndagala), University of Eduardo Mondlane (Adriano Macia), CEPAM (Hermes Pacule). While site partners in the region are: Comoros (AIDE), Madagascar (WWF, Conservation International), Mozambique (Metundo resort), Tanzania (WWF, MPRU, IMS), Mauritius (MOI/Tara Oceans), Mayotte (Tara Oceans), Seychelles (Seychelles Island Foundation, Island Conservation Society, D’Arros Research Station), Chagos (BIOT, Chagos Conservation Trust).

Proposing mechanisms for reducing vulnerability – depending on the outcomes of the project, the short term weather predictions and social adaptation findings will be packaged into climate response plans for the coastal zone, including consideration of policies needed to implement them. This will include targeting local to national government as relevant to the issues identified during the project.

The Partners involved in the project are CORDIO (Lead organization; David Obura, Innocent Wanyonyi, Majambo Jarumani, Stellah Kulecho), Kenya Meteorology Department (Ali Mafimbo, Muhindi, Mungai, Mutai), University of Cape Town (Chris Reason), CSIRO Australia (Nadine Marshall), IUCN (Jerker Tamelander, Abdallah Shah, Katharine Cross, Mine Pabari), & Tanzania Meteorology Agency (Agnes Kijazi).
First Announcement and Call for Abstracts

The Western Indian Ocean Marine Science Association (WIOMSA) and the Kenya Marine and Fisheries Research Institute (KMFRI) have the pleasure to announce the Seventh WIOMSA Scientific Symposium that will be held in Mombasa, Kenya in October 2011.

WIOMSA is a regional professional, non-profit, membership organization, established in 1993, dedicated to promoting the educational, scientific and technological development of all aspects of marine sciences throughout the western Indian Ocean (WIO) region. WIOMSA has a particular interest in linking the knowledge that emerges from research to the management and governance issues that affect marine and coastal ecosystems.

KMFRI is a public organization that was established through the Science and Technology Act, Cap 250 of the Laws of Kenya (1979) with a wide mandate to undertake research on aquatic resources and advise the government on the sustainable management of these resources.

DATES
Monday 24th – Friday, 28 October 2011.

The week is divided into the following:
- National Annual KMFRI Conference – 24 October 2011. The joint Opening Ceremony of the National Annual KMFRI Conference and the Seventh WIOMSA Scientific Symposium will be held on the same day.
- The Seventh WIOMSA Scientific Symposium - 25th to 28th October 2011. This component will include: keynote presentations, oral and poster presentations as well as special sessions and roundtable discussions.
- Excursions and tours to different places of interest – 29th October 2011

VENUE:
Whitesands Hotel in Mombasa, Kenya.

SYMPOSIUM OBJECTIVES:
The Symposium will bring together practitioners, academics, researchers as well as students, to share knowledge, experience and solutions to the challenges experienced in our coastal and marine environment.

The specific objectives of the symposium are to:
- Present current knowledge on disciplines related to the theme of the symposium;
- Provide a forum for discussion and exchange of information and experiences on coastal and marine science issues in the western Indian Ocean region;
- Promote interaction among social and natural scientists in order to strengthen multi- and transdisciplinary research for sustainable management of the coastal and marine environment;
- Identify gaps and priority research areas for improved management of the coastal and marine environment of the western Indian Ocean region.

SYMPOSIUM THEME
The Symposium theme is “Coping with Global Change”. This theme covers the implications of changes in major drivers on the coastal and marine environment ranging from natural, physical and biological drivers. Major drivers include: demographic pressure, economic development, socio-political changes and climate change.

THEMES:
All interested authors are invited to submit abstracts on the proposed themes listed below. Authors may also submit abstracts on other topics relevant to the wider field of coastal and marine science. The main themes include but are not limited to:
- Global change and coastal and marine environment
- Climate and ocean (Impacts, mitigation and adaptations)
- Trends of extreme events and major oceanographic processes
- Biodiversity and ecological processes
• Biodiversity and diversification processes (including biology and reproduction of marine organisms; connectivity of marine populations and community resilience)
• Functional ecology of coastal ecosystems such as estuaries, coral reef, rocky shores, mangrove, etc.
• Ecology and Conservation of Endangered marine species (turtles, mammals, sharks, seabirds)
• Marine organisms and bioactive natural substances
• Ecosystem assessment and monitoring: roles of bioindicators, chemical tracers and models
• Ecosystem modeling and forecasting

**Overexploitation of resources**
• Fisheries: trends, challenges and sustainability
• The ecological impacts of fishing
• Ecosystem-based fishery assessment and management in theory and practice
• The biology, and ecology of marine birds, invertebrates, and mammals related to fisheries and ecosystems
• Human dimension and governance systems
• Economic/Social/Environmental/Cultural opportunities and challenges of economic activities in coastal and marine environment
• Interactions between conservations initiatives and poverty reduction strategies
• Effectiveness of the conservation initiatives and governance systems
• Experts are invited to consider organizing a session in any area related to the above broader topics.

**CALL FOR ABSTRACTS:**
Abstracts are invited on any topic related to the theme of the symposium. Priority will be given to multi-/trans-/interdisciplinary abstracts. Abstracts must be in English and should not exceed 300 words. Submitted abstracts must contain the following information: title, name(s) of author(s), affiliations, postal and e-mail addresses. It should also clearly state the preferred mode of presentation (oral or poster). Abstract must be in Times New Roman, 12-point font, single spacing with justified alignment.

Abstracts should describe briefly the statement of the problem, the methodology, the results and the conclusion. The abstract should be submitted in plain text only without the inclusion of tables, graphs, images, etc.

All abstracts will be reviewed for merit and relevance. Abstracts must be received by WIOMSA no later than 30th April 2011. Confirmation of acceptance for oral or poster presentations will be communicated to authors by 1st June 2011. Abstracts should be submitted to secretary@wiomsa.org.

**FINANCIAL ASSISTANCE:**
A limited number of travel grants will be provided to experts from the region whose abstracts have been accepted. Applications for the travel grants should indicate details of the support required. These applications need to be submitted by 30th June 2011 to secretary@wiomsa.org.

**SYMPOSIUM STRUCTURE:**
The symposium will have a combination of plenary and parallel sessions. Prominent experts from within and outside of the region will be invited to attend the symposium and deliver keynote presentations. Posters will be displayed throughout the symposium and a dedicated poster session will be arranged to facilitate discussions with the presenting authors.

**COMPETITIONS:**
During the Symposium, three competitions will be organized. These are:
• Best Student Poster competition
• Best Student Oral competition
• Best Photo competition Winners of these competitions will be awarded special prizes.

**REGISTRATION FEES:**
A registration fee of US$ 200 for non WIOMSA members, US $ 150 for WIOMSA members and US$ 100 for students will be charged to help cover some of the costs of the symposium.

**IMPORTANT DATES:**
Deadline for submission of abstracts -30 April 2011
Notification of abstracts acceptance - 1 June 2011
Deadline for submission of proposals for organization of side events (such as workshops, courses and meeting) - 15 June 2011
Deadline for application of travel grants -30 June 2011
Deadline for confirmation by institutions participating in the exhibition - 31 July 2011

**EXHIBITIONS:**
Space will be available for exhibits by organizations, programmes, projects and commercial companies. Please contact the WIOMSA secretariat (secretary@wiomsa.org) for more details.

**LANGUAGE:**
The official language of the symposium will be English.
Introduction

Mangrove ecosystems are amongst the biologically productive ecosystems on earth and provide invaluable ecosystem goods and services to coastal communities. Climate change is however presenting a real and severe threat to these unique ecosystems. Rising sea levels, changes in the amount and patterns of precipitation and the indirect effects of increased human exploitation are amongst the most significant pressures related to a changing climate.

To increase the understanding of the potential effects of climate change on Madagascar’s mangrove ecosystems, WWF Madagascar and Western Indian Ocean Programme Office (MWIOPO), with financing from the MacArthur Foundation, is undertaking an assessment of the climate change vulnerability of the second largest stand of mangroves in Madagascar in the deltas of the Manambolo and Tsiribihina Rivers on the west coast of Madagascar. This project is being carried out over a period of 18 months as part of WWF MWIOPO’s climate change adaptation program; a program that involves a number of research and pilot projects on climate change vulnerability assessments and adaptation planning for vulnerable natural areas and human communities in Madagascar and the Western Indian Ocean region.

The vulnerability assessment has the dual aim of identifying hotspots of climate change vulnerability that can be used to inform conservation zoning and restoration activities in the Tsiribihina and Manambolo mangroves, and of developing a methodology for mangrove vulnerability...
assessments that can be implemented elsewhere in Madagascar and the Western Indian Ocean region.

**The Manambolo and Tsiribihina Mangrove Ecosystems**

The area experiences a tropical, sub-humid climate with four distinct seasons throughout the year. The majority of the rainfall is experienced between October and March. The average monthly temperature ranges between 22°C in June and 29°C in March. The region is characterized by the "tsioka atsimo" winds which blow from north to south in May and June. These winds agitate the sea and make fishing activities impossible during this period. The area also suffers cyclones and tropical storms which can cause flooding and other damage. The local communities have witnessed changes in the climate in recent years, particularly in relation to the timing of the rainy season. Whereas historically the rains started in October, community interviews confirmed that they currently commence in November or December.

The mangroves in this area cover approximately 28,000ha and are contained in the proposed Manambolomaty and existing Menabe Antimena Protected Areas, both of which have temporary protection status. The area has critical importance for numerous endemic species listed on the IUCN Red List. These include bird species which use the mangroves for nesting and roosting: Bernier’s Teal (*Anas bernieri*); Madagascar Fish Eagle (*Haliaeetus vociferoides*); Humblot’s Heron (*Ardea humblotii*); and the Malagasy Sacred Ibis (*Threskiornis bernieri*). The mangrove ecosystems also provide important habitat for the endangered frugivore bat species, the Madagascar Fruit Bat (*Pteropus rufus*), which is subject to high hunting pressures. The Verreaux’s Sifaka lemur (*Propithecus verreauxi verreauxi*) is also known to use the mangroves. The mangrove ecosystems have important ecological functions including as a production site for aquatic resources such as crabs, shrimps and fish; more than twenty species of fish, including four endemic species exist in the area.

The project area is traditionally home to the Sakalava and Vezo ethnic groups and houses a population of approximately 50,000 people. However in recent years immigration to the area has become more pronounced and has resulted in overexploitation of fisheries and mangrove resources and increased clearing of mangroves for rice production. The literacy rate of the local population is low and access to markets, health and education is very limited. The population relies traditionally on fishing, agriculture, notably rice production, and animal husbandry. The local communities rely on mangrove resources for house and fencing construction, fuelwood and traditional medicines. The population is very iso-
lated, with very few roads existing in the area, and the major form of transport is by pirogue.

Vulnerability Assessment Methodology

Sea level rise was determined to be the most influential factor on the vulnerability of mangrove ecosystems. To determine the likely exposure of the mangroves to sea level rise in the absence of climate model projections or reliable topographic data, digital analysis of historic satellite images from 1973 to 2005 in the project area was analyzed to extrapolate data on future inundation probabilities.

An extensive field based study of the mangrove ecosystems was undertaken to allow analysis of the ecological vulnerability of the mangroves. The first step involved the categorization of existing mangroves based on their condition, regeneration potential and levels of disturbance. An inventory of the distribution and condition of the mangroves ecosystems was carried and mapping prepared based on the above categorization. Trend analysis was completed using biological survey data from 1992 in the same zone. Indicators for the resilience and sensitivity of the mangrove ecosystems were then selected and analyzed and mapped.

The evaluation of social vulnerability in the project area was carried out at two levels. A commune level analysis was undertaken for using publicly available commune level socio-economic data, and detailed village level analyses were undertaken in five case study villages using WWF’s Climate Witness approach, a participative research tool, and household surveys.

Vulnerability Assessment Results and Conclusions

In the Tsiribihina Delta, areas of mangroves with very high ecological vulnerability are found in the northern part of the zone and in isolated patches throughout the Delta. There are large expanses of mangroves with medium ecological vulnerability throughout the remainder of the delta and in general this delta exhibits a higher ecological vulnerability than the Manambolo delta to the north. In the Manambolo Delta, no areas of mangroves were determined to have high or very high ecological vulnerability. Areas of mangroves of medium ecological vulnerability are located in this zone adjacent to the coast and along inland
There are large expanses of mangroves with medium ecological vulnerability throughout the remainder of the delta and in general this delta exhibits a higher ecological vulnerability than the Manambolo delta

in 2011. The results will also be discussed with natural resource and protected area managers in the project zone to assist in developing zoning and protection plans for the mangroves.

The methodology that was developed for the vulnerability assessment was presented to a national workshop in late October 2010, and further implementation and testing in the north-west of Madagascar will be undertaken in 2011.

The project highlights the importance of developing methodologies that are specific to the local context and relevant to the resources and data that are available. It is hoped that the methodology developed by WWF MWIOPO will aid in assessing the vulnerability of mangrove ecosystems elsewhere in Madagascar and the Western Indian Ocean region, and contribute to the growing international body of research on climate change vulnerabilities in coastal zones.

In conclusion, in this zone the most vulnerable mangrove ecosystems from an ecological point of view are surrounded by the least vulnerable communities and vice versa. This situation is encouraging and will assist in the development of locally specific adaptation plans targeted on the mangroves and the surrounding human communities. WWF MWIOPO has secured funding from the MacArthur Foundation to carry out this work.

There are large expanses of mangroves with medium ecological vulnerability throughout the remainder of the delta and in general this delta exhibits a higher ecological vulnerability than the Manambolo delta

in 2011. The results will also be discussed with natural resource and protected area managers in the project zone to assist in developing zoning and protection plans for the mangroves.

The methodology that was developed for the vulnerability assessment was presented to a national workshop in late October 2010, and further implementation and testing in the north-west of Madagascar will be undertaken in 2011.

The project highlights the importance of developing methodologies that are specific to the local context and relevant to the resources and data that are available. It is hoped that the methodology developed by WWF MWIOPO will aid in assessing the vulnerability of mangrove ecosystems elsewhere in Madagascar and the Western Indian Ocean region, and contribute to the growing international body of research on climate change vulnerabilities in coastal zones.

In conclusion, in this zone the most vulnerable mangrove ecosystems from an ecological point of view are surrounded by the least vulnerable communities and vice versa. This situation is encouraging and will assist in the development of locally specific adaptation plans targeted on the mangroves and the surrounding human communities. WWF MWIOPO has secured funding from the MacArthur Foundation to carry out this work.

There are large expanses of mangroves with medium ecological vulnerability throughout the remainder of the delta and in general this delta exhibits a higher ecological vulnerability than the Manambolo delta

in 2011. The results will also be discussed with natural resource and protected area managers in the project zone to assist in developing zoning and protection plans for the mangroves.

The methodology that was developed for the vulnerability assessment was presented to a national workshop in late October 2010, and further implementation and testing in the north-west of Madagascar will be undertaken in 2011.

The project highlights the importance of developing methodologies that are specific to the local context and relevant to the resources and data that are available. It is hoped that the methodology developed by WWF MWIOPO will aid in assessing the vulnerability of mangrove ecosystems elsewhere in Madagascar and the Western Indian Ocean region, and contribute to the growing international body of research on climate change vulnerabilities in coastal zones.

In conclusion, in this zone the most vulnerable mangrove ecosystems from an ecological point of view are surrounded by the least vulnerable communities and vice versa. This situation is encouraging and will assist in the development of locally specific adaptation plans targeted on the mangroves and the surrounding human communities. WWF MWIOPO has secured funding from the MacArthur Foundation to carry out this work.
Marine Protected Areas and Climate Change in Northwestern Madagascar

By Harifidy Ralison, WWF Madagascar

In mid-2007, environmental actors in Madagascar started to realize that the impacts of climate change are already being felt at the local level. Malagasy fishing communities - highly reliant on coral reef fisheries - are likely to be severely impacted by coral bleaching and degradation. Mangrove forests, important breeding grounds for commercial fish species and shrimps, providing coastal communities with timber, fuel wood and protection from storm surges are threatened by potential sea level rise under climate change.

The Nosy Hara marine and coastal area is renowned as a biodiversity jewel of the Western Indian Ocean. Sheltered from monsoon winds on the northwestern coast of Madagascar, it offers a calm environment. Nosy Hara is located just south of the northern tip of Madagascar, Cap d’Ambre (and directly west of the town and large bay of Diego Suarez/Antsiranana). Its coastline is similar to the more well-known Nosy Be area farther south, a highly convoluted shoreline of large bays fringed by beaches and mangroves, and with rivers draining the flat/rolling hills of the hinterland. The islands, which are grouped around the main island of Nosy Hara, are karst limestone formations (the tops of the islands have the typical ‘tsingy’ or eroded sharp limestone pillars typical of northern and western Madagascar). These are set on a broad shallow flat platform that bears a series of small banks capped with coral reefs, and at its outer edge (about 5-10 m deep) is fringed by coral with a sharp drop to a sandy bottom most likely at about 20 m depth.

The Nosy Hara archipelago area has numerous smaller sand cays lying just a few meters above sea level, numerous volcanic islands, and several bays supporting a mixture of rocky shores, beaches and mangroves. Iconic species such as the Madagascar fish eagle, sea turtles, roseate terns and other sea birds, dolphins, whale sharks, and reef sharks are found there. The area has been internationally recognized as an Important Bird Area (IBA), and has been provisionally proposed as a World Heritage Site by the Malagasy Government. Nosy Hara area...
is also ranked highly in WWF’s ‘Global 200’ world-wide priorities, and ranks tenth in the list of 25 ‘hotspots’ for biodiversity within Madagascar and the Western Indian Ocean islands. The coastal and terrestrial environment in northern Madagascar is marked by very high levels of local endemism, particularly among plants which include a locally endemic family (the Di-egondendraceae family).

Two types of coral reefs are found in the Nosy Hara Marine Park, coastal fringing reefs and isolated coral banks on sediment bottoms, some distance from the coast on the broad shallow platform. Overall, the open sea coral banks are in good condition whereas fringing corals are affected by human activities. Coral reefs in the Nosy Hara Marine Park have an average coral cover of 34% (which is high for the Western Indian Ocean), with highest levels at about 53%. In the main reef areas, corals are the dominant cover type, indicating healthy coral populations. The overall condition of reefs is consistent across the park, however the degree of exposure to waves and rough conditions is not the same, with higher soft coral cover at reefs with high exposure and highest macroalgae cover on reefs with low exposure.

**MPA establishment**
With financing from the MacArthur Foundation, WWF has intervened in Nosy Hara since 2004 to promote the conservation of this high biodiversity value area. With the Malagasy National Authority for Protected Areas (ANGAP) WWF initiated the establishment of a Marine Protected Area (MPA) there. This was carried out in parallel with actions to improve awareness concerning conservation and sustainable utilization of natural resources, and the roles and values of the new protected area in Nosy Hara. Support from WWF also focused on developing efficient management structures and systems, i.e. development of a local advisory committee to ensure close liaison between project staff and communities, establishment of a community-based project monitoring committee, assessment of personnel needs and recruitment/organization of management staff, including local community participants, etc. In 2006, the Nosy Hara ANGAP management unit developed the ecological monitoring plan, and started to draft the MPA management plan, based on the conceptual model of TNC (The Nature Conservancy), and which prioritized the conservation of the vulnerable species and habitats.

In October 2007, Nosy Hara was granted national temporary protection status (decree) as an MPA. This means conservation measures and management rules can be applied with fully valid legal tools. Under this decree, the final size of the MPA is 183,111 ha. (Core area: 5,313 ha, Buffer zone: 60,721 ha, Protection zone: 117,077 ha). The year of 2007 was also characterized by the development of the PSSE1 -

---

1 Plan de Sauvegarde Sociale et Environnementale
The conservation area establishing permanent and temporary camps on the continent (Ampasindava and Vahilava). The associated use of destructive fishing practices has been the cause of the current significant diminution of the fish catch in the conservation area. Small watersheds in the Nosy Hara zone are also subject to slash-and-burn agriculture and overgrazing, which are still practiced in many areas leading to more rapid seasonal drying of watercourses.

Considering climate change
In 2007, WWF and ANGAP (The National Association for the Management of Protected Areas in Madagascar) understood that it was timely and opportune to develop a pilot project in Nosy Hara that will strive to integrate climate change into the design and planning of the MPA. This has never before been undertaken in Madagascar, and the lessons learned would be highly valuable as the effects of the global phenomenon start to be felt on several sites. With the financial support of the MacArthur Foundation, WWF is now supporting Madagascar National Parks (or MNP, former ANGAP) in this direction and is striving to strengthen governance capacity of the Nosy Hara key stakeholders.

Thus from 2008 on, aside from the usual MPA management activities, efforts have been directed towards incorporating climate change aspects (including social, cultural and economic parameters and vulnerability assessments) in monitor-
The SocMon² approach (socio-economic monitoring methodology designed for coastal and MPA managers) has been used in the MPA area as well as the WWF Climate Witness method (participatory vulnerability assessment). On the ecological side, a resilience assessment was carried out on the Nosy Hara coral reefs with the technical assistance of CORDIO (Coastal Ocean Reasearch and Development in Indian Ocean) East Africa. Training from CORDIO allowed MNP staff to undertake a monitoring of bleaching during semestrial ecological field monitoring (such as in May 2010). An expert meeting was recently organized in Antananarivo to develop action plans for the climate change integration process into the MPA planning and monitoring scheme. Overall, we aim to recommend strategies to address the priority threats to the Nosy Hara area and build resiliency in natural and human systems to cope with climate change. Involvement, including training, of key local marine resource users in vulnerability assessment and development of adaptation measures to be integrated into the MPA plans and protocols, was highly favoured to strengthen the buy-in of the local populations in the application of the climate-change-oriented management measures that will be adopted by the MPA.

Successful conservation of marine biodiversity and natural resources should have flexible, adaptive management approaches, be based on the best science available combined with effective monitoring of well-identified indicators, that can identify climate change effects and be capable of implementing mitigation measures in a timely manner. This might lead to the revision of the MPA zoning, its management plan and likely proposing more governance options adapted to the ecological, social and cultural context.

² SocMon (for Socio-economic Monitoring) is a set of guidelines on how to do socio-economic monitoring at the site level useful for fisheries and coastal management. It is also a regional initiative to improve coastal management and sustainable use of marine resources by helping managers integrate up to date, social and economic information in their decision.
Incubation Temperature and Influential Factors on *Chelonia mydas* Reproductive Traits in Light of Climate Change

T. Jacob & J. Bourjea

The influence of temperature in the reproductive life of the green turtle is becoming increasingly important to understand as the world undergoes dramatic climate change effects due to human emissions. Turtles and their ancestors have experienced change in climatic regimes before. However, the rapidity of onset and the low global population levels of green turtles reduce the ability of this species to adapt to changing environmental pressures.

The endangered green turtle (*Chelonia mydas*) is one of the large long-lived vertebrate species that has been subject to a long history of human exploitation for eggs, meat and shell with some stocks now extinct, others in decline and yet others showing significant restoration following dedicated conservation efforts. The South West Indian Ocean (SWIO) remains an important nesting and foraging region for the green turtle. The Eparses islands are five French islands scattered across the SWIO. Studies have shown that Europa, Grande Glorieuse and Tromelin remain three of the most important nesting sites for the green turtle in this region, Europa being part of the Atlantic genetic stock and Grande Glorieuse and Tromelin part of the Indo-Pacific one.

The incubation stage of the green marine turtle can last for up to 13 weeks with several characteristics of clutch success and the resultant hatchlings influenced by the temperature within the nest chamber. Higher temperatures during development have been linked to smaller sized hatchlings, greater locomotive ability and higher fitness levels. Emergence and hatching success rates have also been positively linked to increased temperatures. As with all other species of turtle, *C. mydas* exhibits the characteristic of temperature-dependent sex determination (TSD). That is, the sex of *C. mydas* hatchlings is determined by temperature at a specific point within the second third of the incubation stage. A temperature termed ‘the pivotal temperature’, results in an equal ratio of male to female hatchlings. Above and below this temperature the sex ratio of a clutch is skewed toward a female or male bias respectively. Outside the ‘Transitional Range of Temperature (TRT)’, conservatively reported as a 3°C range around the pivotal temperature, a unisex clutch is produced. Both pivotal temperatures and TRTs differ between species and rookeries and were not determined in any SWIO nesting sites. It can however be estimated to be 28.8 around Tromelin island, according to pivotal temperatures previously determined in nesting sites located on the same latitude as Tromelin.

Despite the benefits to hatchlings from higher incubation temperatures, an optimum development range of 25°C to 34°C exists for *C. mydas* eggs, over which, temperature becomes lethal.

Thermometers synchronously recorded temperatures at hourly intervals during the incubation periods across 29 randomly chosen green turtle nests in the given period. A thermometer was placed 75cm deep on the beach to record hourly sand temperature at average nest depth during the study period, acting as a temperature control of a theoretical nest called here ‘Control Nest’. These temperature recording were synchronized with those placed in green turtle nests and the thermometer was removed after all other nest thermometers.

---

The WIOMSA magazine | no. 4 – Jun 2010
The evolutionary advantage of TSD remains unknown, with this form of sex determination being disadvantageous if sex ratios are considerably skewed during short-term generation time scales due to changing environmental temperatures. The low TRT in which multisex clutches are produced increases the potential of climate change to dramatically skew sex ratios if air temperatures have a causal relationship with random mating.

A study was conducted on Tromelin Island from February to May, 2009. Tromelin is a French territory located in the SWIO (15°33′S, 54°31′E) and covers an area of 1.2km².

Thermometers synchronously recorded temperatures at hourly intervals during the incubation periods across 29 randomly chosen green turtle nests in the given period. A thermometer was placed 75cm deep on the beach to record hourly sand temperature at average nest depth during the study period, acting as a temperature control of a theoretical nest called here ‘Control Nest’. These temperature recording were synchronized with those placed in green turtle nests and the thermometer was removed after all other nest thermometers.

Incubation temperatures ranged from 29.19°C - 31.55°C, with an overall mean of 30.23°C. Second third of incubation temperature impact, and a hypothetical impact of other climatic variables (primarily rainfall), on green turtle nests. Any relationship between sand temperature at nest depth and green turtle nests would reflect an influence of climatic variables on C. mydas nests during initial stages of incubation. More importantly, the same analyses were performed on second third of incubation

The results obtained demonstrate that grain size highly influences nest temperature, thus indicating that the location of the nest could importantly change the incubation temperature and thus the sex-ratio of green turtles. During the data analysis, the control nest temperatures were taken for analyses as a reflection of ambient temperature, and a mean of 29.76°C. The variation in temperatures between nests may be an indication of local nest parameter impacts. This range of temperature indicates inter-nest variability that could influence sex ratios. This range was

Incubation temperatures ranged from 29.19°C - 31.55°C, with an overall mean of 30.23°C. Second third of incubation temperature impact, and a hypothetical impact of other climatic variables (primarily rainfall), on green turtle nests. Any relationship between sand temperature at nest depth and green turtle nests would reflect an influence of climatic variables on C. mydas nests during initial stages of incubation. More importantly, the same analyses were performed on second third of incubation

Analysis of results has shown that each nests first third of incubation temperature residuals were all significantly correlated with control nest residuals. This represents a high impact of ambient temperature and other incorporated climatic variables on C. mydas nests during initial stages of incubation. More importantly, the same analyses were performed on second third of incubation

The variation in temperatures between nests may be an indication of local nest parameter impacts. This range of temperature indicates inter-nest variability that could influence sex ratios. This range was
During the year. Moreover, periods of lower second third incubation temperatures are associated with lower incubation temperatures. According to climate change predictions and nest temperatures during second third predicted in this study, average monthly nest temperatures will not reach the lethal level of 34°C. However, higher incubation temperatures are predicted during second third of incubation temperatures recorded on Tromelin island.

To illustrate the past and future evolution of second third of incubation temperatures, monthly mean of sex stage temperatures were plotted for different year spans, simultaneously with nesting activity recorded on Tromelin island. Knowing the impacts of climatic factors on sex determination stage, the study further investigates predicted second third incubation temperatures according to climate change models. The model used (A2 emissions scenario) reported an increase in air temperatures over the southern African region (0 - 45°S; 5° - 55°E) by 3.7°C during summer (December, January, February) and 4°C in winter (June, July, August) by 2080.

Second third incubation temperatures were predicted using two methods:

a) Linear regression and associated equation to predict sand temperature at nest depth using air temperature. This model was validated using meteo France sand temperature data and comparing to predicted sand temperature at nest depth.

b) Adding average metabolic heating occurring during second third of incubation to this previous equation. As no long term data for nest temperature are available, this model could not be further validated.

Using meteo France air temperature data since 1970 and the climate change model, it was then possible to predict second third incubation temperature data.

According to climate change predictions and nest temperatures during second third predicted in this study, average monthly nest temperatures will not reach the lethal level of 34°C. However, higher incubation temperatures in 2080 will result in a mainly female production all over the year. Moreover, periods of lower second third incubation temperatures are associated with lower percentages of nesting activity. All clutches throughout the year will then be highly female skewed in 2080 according to the incubation temperature prediction model.

With the small beach of Tromelin undergoing the same climatic conditions, any ability to adapt to global climate change for this nesting population lies in peak season periods and intrabeach variability due to local factors. The effects of climate change have altered weather regimes worldwide, with temperature predicted to increase. The nesting site of Tromelin remains relatively undisturbed due to the site’s remotesness, but also under researched despite a presumed declining population. This important nesting site in the SWIO requires greater understanding of its population before the effects of climate change can be fully assessed.

We wish to provide a special thanks to Samantha O’Brian for the great job she did for this study as well as Kelonia (www.kelonia.org) for their strong support to the project.
Buying time for corals

By Tim Mc Clanahan, Wildlife Conservation Society, Kenya

The future is going to be more stressful for marine ecosystems, and corals and their dependent species top the list of taxa that are going to feel the heat. Is there any relief in sight, where can we find it, and what can be done to buy them time while people work out their carbon emission issues? These questions were asked and some answers provided in recent regional study that combined efforts to map the regional stress, the coral community’s response to this stress, and overall coral diversity in the region. The findings suggest that a region stretching from southern Kenya to northern Mozambique across to northern eastern Madagascar and the Mascarene Islands and the Mozambique-South Africa border are among the most likely to places where the combination of stress, community integrity, and species diversity have the least conflict.

The study is broad in geographic extent, ranging from the Maldives to South Africa, and includes an historical analysis of environmental data derived from satellite observations on oceanographic variables that exposure corals to stressful conditions and activate their bleaching response (photo). The researchers then compile data on the coral communities from nearly 200 sites in the region in order to create an index of the coral communities susceptibility to bleaching and their diversity. Map layers were then combined and the resulting composite map produces a holistic vision of the state of these reefs (see map). The authors argue that this map reflects what should be priorities for conservation and management where climate disturbances are one of the key factors prompting action. Reducing human impacts on these reefs will reduce the numbers of stresses and give these reefs a longer horizon of persistence into the era of global climate change.

Many of these reefs in this moderate to high priority region, such as the Mascarene Islands, have had large human impacts from fishing and other disturbances but the study removes these local disturbance effects in order to try to understand the underlying diversity. The implication is that these reefs, which have not been well managed despite the high incomes in some countries, are regionally important. These wealthy countries, therefore, have the capacity and need to step up their management to insure their reefs achieve their regional significance. Other regions, like the reefs in Mozambique and Madagascar, are priorities but the wealth, commitment and capacity to finances their management has been insufficient to assure their secure future. Here, the capacity to manage these reefs needs to be quickly built through donor and development support.

The project has its limits in terms of not having comprehensive regional data and projecting change into the future but it does provides a state-of-the-art vision and creates a window of opportunity for future research and action that can hopefully buy corals a bit more time.

Source- McClanahan TR, Maina JM, Muthiga NA. Associations between climate stress and coral reef diversity in the western Indian Ocean. Global Change Biology, in review.

Top: A the coral Goniopora undergoes the changes in color associated with coral bleaching.

Left: A map produced by combining levels of exposure to bleaching stress, the community’s susceptibility to bleaching and the numbers of coral species at the study sites. Redder colors indicate positive conditions that include less stress, more coral community integrity, and numbers of species.
Coral Reef Crisis

By David Obura.

350 or bust … coral reefs will not survive current ‘best-case’ targets for climate change mitigation. What does this mean to us?

That climate change already poses a threat to species, ecosystems and people, and that this will increase over time, is no longer in any doubt. The big question is how large will the threat become, what can we do about it, and what are the policy positions that must be made to limit the threat as much as is possible?

Climate change targets

Many leading environmental and human development organizations have taken climate change to heart, and in doing so, advocated for the best possible scenario for limiting climate change. In its 4th Assessment Report in 2007, among the scenarios derived by the IPCC for global climate change, the best case is scenario B1 (Parry et al. 2007). Stated simply, this scenario B1 (Parry et al. 2007; Richardson et al., 2009). Further, it is widely over- looked that the 2°C/450 ppm CO2 target1 gives only a 50% probability of success (fig. 1). Even more alarming, achieving this target requires massive reductions in global emissions below 1990 levels by 2050, on the order of 80% AND almost immediate reductions to minimize over- shoot and lag effects.

As we now know, UNFCCC countries in December 2009 abrogated their responsibility to identify and commit to targets for reducing greenhouse gas emissions, making it highly unlikely that the 450 target will be achieved. Whether it was China or the US that sabotaged the negotiations was immaterial. What was important was that the rest of the world was toothless while crying foul.

The prognosis for coral reefs – how bad is it?
The vulnerability of coral reefs to climate change (increasing sea surface temperatures) has become increasingly well known in scientific circles, and among protected area and resource managers. The massive impact of a climate change event to western Indian Ocean reefs in 1998 played a large part in making this known, and research here has continued to date. In 2008, the Global Marine Species Assessment (GMSA) took on the challenge of assessing the vulnerability of hard coral species to extinction, revising their status on the IUCN Red List of Endangered Species. Strict application of the Red List criteria resulted in over 1/3 of all species being listed as threatened by extinction (Carpenter et al. 2008), in part due to habitat loss related to global climate change. That a globally distributed ecosystem-building group of marine species should attain an equivalent threat status to such classically vulnerable groups as amphibians was a shock even to the participants at the meeting.

The IPCC considered how vulnerable different ecosystems and economic sectors are to climate change (fig. 2), showing coral reefs as one of the key examples. The notable feature being that among the sectors shown, global bleaching of coral reefs occurs at the lowest threshold of temperature increase, and is the first mentioned

---

1 For simplicity, “ppm CO2” and “ppm CO2 equivalent” are not differentiated in the text, and we refer to the 450 target of the IPCC. The conversion from actual measures of CO2 to estimates of CO2 EQ varies among technical groups and depends on different assumptions about the ratios of other greenhouse gases. Because of the effects of CO2 on ocean acidification, and its impact on corals, we use CO2 rather than degrees of warming, which is easily measured, as the latter is only one aspect of climate change that is relevant.

---

Fig. 1. A 2°C target is achieved at only a 50% probability under the BEST climate change scenario (B1). Projected global mean temperature change in 2090 to 2099 relative to 1980 to 1999 for the six SRES marker scenarios based on results from different and independent models. From Figure TS.27, IPCC 2007.)
indicator at risk. More accurately, reefs scientists predict that “irreversible and catastrophic decline” occurs at 1.7°C warming (Fischlin et al. 2007). Add to this the effects of ocean acidification, which were not incorporated into those estimates, and the prognosis for corals and reefs is extremely dire. The significant issue here is that 1.7°C warming is the best case scenario under consideration at the UNFCCC, at CO₂ levels of 450 ppm, and that EVEN THIS is at only a 50% probability of success.

In July 2009, the Royal Society, the Zoological Society of London and the International Programme for the State of the Ocean facilitated a Coral Reef Crisis meeting to identify key thresholds of atmospheric carbon dioxide needed for coral reefs to remain viable. The statement from the workshop is included in Box 1 (Veron 2009). If the prognosis already accepted by the scientific community and expressed in the IPCC reports was bad, these most recent clarifications were far worse.

The basic message is that the planet has ALREADY passed a critical stage for coral reefs (at about 320-350 ppm CO₂; current levels are 390 ppm CO₂), and for any hope for coral reefs to survive into the future CO₂ levels must be REDUCED below 350 ppm. That is, the current best-case target will ENSURE significant numbers of coral species are likely to go extinct and/or lose their functional capacity to form reefs.

And other systems?
Estimated to harbour around one third of all described marine species, with 500 million people (8% of the world’s popula-
The Coral Reef Crisis: scientific justification for critical CO₂ threshold levels of < 350ppm

Output of the technical working group meeting at the Royal Society, London, 6th July 2009

1. Coral reefs are the most biologically diverse habitats of the oceans and provide essential ecosystem goods and services to hundreds of millions of people.

2. Temperature-induced mass coral bleaching causing widespread mortality on the Great Barrier Reef and many other reefs of the world started when atmospheric CO₂ exceeded 320ppm.

3. At today’s level of 387ppm CO₂ reefs are seriously declining and time-lagged effects will result in their continued demise with parallel impacts on other marine and coastal ecosystems.

4. Proposals to limit CO₂ levels to 450ppm will not prevent the catastrophic loss of coral reefs from the combined effects of climate change and ocean acidification.

5. To ensure the long-term viability of coral reefs the atmospheric CO₂ level must be reduced significantly below 350ppm.

6. In addition to major reductions in CO₂ emissions, achieving this safe level will require the active removal of CO₂ from the atmosphere.

7. Given the above, ecosystem-based management of other direct human-induced stresses on coral reefs, such as over-fishing, destructive fishing, coastal pollution and sedimentation, will be essential for the survival of coral reefs on which we are all dependent.

Signatories to the statement, at the time of publication, include:
Sir David Attenborough FRS (working group co-chair), Prof. Ken Caldeira (Carnegie Institution for Science), Dr Ann Clarke (Frozen Ark Project), Prof. James Crabbe (University of Bedfordshire), Prof. Andreas Fischlin (Swiss Federal Institute of Technology, in his own capacity), Prof. Dve Hoegh-Guldberg (University of Queensland), Dr Simon Harding (Globe International), Rachel Jones (Zoological Society of London), Prof. Tim Lenton (University of East Anglia), Dr David Obura (IUCN Coral Reef Action Network), Dr John Turner (Bangor University), Prof. John Veron (Coral Reef Research).

- even the best is only half-good – is it a reasonable position for organizations mandated with protecting species, ecosystems and human welfare to lobby for a position premised on a probability of success of only 50%?

- and even that is not good enough – with strong evidence (“virtually certain” in IPCC parlance) that a 450 target may be too much for critical species and ecosystems, such
as coral reefs, how can we negotiate for a lower target that is not even between the goalposts?

- and … none of this may even be possible. We should be preparing our countries and economies for >6°C warming as an inevitable result of the global economy and value system.

Various issues frame the debate about the role of scientific, conservation and sustainable development organizations, working to minimize the risks and impacts of climate change to both nature and people:

Re-setting the boundaries on the negotiating space. As scientific understanding of climate change and impacts improve, a framework for adjusting policy targets must be available, PARTICULARLY, as in this case, where these must move the goalposts OUTSIDE of the current debate. We must proactively prepare for future negotiating positions.

Response time is rapidly running out. As time passes without sufficient action, the lower boundary for committed climate change rises. There are only 5-10 years remaining to implement the emissions reductions needed to achieve the current ‘best scenario’ 450 target.

Time lags are critical issues in climate change, not just in the effects of greenhouse gases being felt, but also in the domains of science, policy and response. The cycle from assessment through understanding to policy and action must be streamlined to minimize such lags, and NGOs and IGOs have a critical role to play in this regard.

Carbon sequestration. A 350 target calls for REDUCING CO₂ levels below present levels. Not only will this require a rapid emissions reductions response it also will require the implementation of carbon sequestration technologies and approaches that don’t themselves have unacceptable consequences, involve too-slow process rates or result in insufficient emissions reduction commitments.

Institutional policy and alignment. How can WIOMSA and partners best develop and combined policy efforts on this key issue? How do we work in the context of national and regional institutions that at present have a minimal voice in setting global climate change policy?

What are the most recent findings for other systems? What other vulnerable systems also have < 450 critical thresholds? Is there enough being invested in research and assessments to determine these BEFORE these thresholds are passed?

David Obura is the CORDIO East Africa, Kenya and Chair of the IUCN Coral Specialist Group. dobura@cordioea.org. His article was adapted from one written for the IUCN Species Magazine building up to the UNFCCC in Copenhagen in 2009.)
overfishing is a serious problem on many of the world’s coral reefs - a problem that is generally attributed to too many people. But a study from the WIO in the journal *Current Biology* found that economic development, rather than population was the main driver of overfishing on coral reefs in the western Indian Ocean. Interestingly, the heaviest overfishing on coral reefs occurs in countries part way up the development ladder. Countries with either very low or high levels of development tend to have reef fisheries in pretty good shape-about four times the reef fish biomass of the intermediate development sites.

Maybe the easiest way to explain our results is for you to imagine a valley, with steep mountains on either side. On top of the mountain at one side of the valley are the least developed places such as Madagascar-where fishing technology is pretty basic, which means it is harder to plunder the reefs. Village traditions also limit fishing. For example, in parts of Madagascar there are taboos on the days people can fish, the types of fish they can eat, the gear they use, and even sacred areas where nobody is allowed to fish. I’ve studied these types of taboos from Papua New Guinea across the Indian Ocean to Madagascar. Where they operate there is 25-300% higher fish biomass and in some places the coral cover is twice as high, too. However, these systems only seem to operate in areas with low levels of development, low populations (in Papua New Guinea the threshold seems to be about 1,000 people), and far from markets (about 16 km).

On the mountain on the other side of the valley are countries like Seychelles, with higher economic diversity and a lower reliance on reef fish for food or profit. Here scientific and management institutions help to effectively govern reef fisheries, which are in relatively good condition.

Now if you take a few steps from either mountain, you’ll quickly find yourself sliding down the slopes to the bottom of the valley. Here, societies are moderately developed, which means they have the technology to plunder their reefs, but don’t have the institutions to effectively manage them. The traditional systems have broken down, but national governments are often too inadequately resourced to effectively manage fisheries without the full support of local communities.

In this valley of depletion, the amount of fish is only about a quarter of the more or less developed places. Because of declining catches, many fishermen here have to fish harder and harder just to survive and some are caught in a ‘poverty trap’. This occurs when that short-term need to survive outweighs any long-term advantages to conservation or sustainable management. In this situation, some fishers resort to using highly destructive gear such as seine nets or explosives to make ends meet. This, of course, further damages the fishery and can lead to a cycle of poverty and reef destruction. The real danger here is that if plundered too hard, these coral reefs may lose their resilience and not come back when and if economic conditions improve.

So there is both a good and bad side to the story. The bad news is that the valley of depletion is very wide and sliding into it is much easier than climbing out. Whether the World has coral reefs in the future will not only depend on whether we tackle climate change challenges such as ocean acidification and coral bleaching, but will also largely depend on whether developing countries can navigate the transition from deep poverty to prosperity without ruining their fishery. For societies already in a poverty trap governments and donors need to get them out and couple this development with good governance and strong institutions.

The good side is that the path to reef destruction is not inevitable. Coral reefs can be sustained with the right combination of approaches, which includes fisheries closures, property rights, and gear restrictions while at the same time tackling poverty as a root cause of reef decline.  

Josh Cinner is a Senior Research Fellow at James Cook University in Australia. Josh is a human Geographer and specializes in the human dimensions of coral reefs. This article was a synthesis of several research papers resulting from WIOMSA funded projects.
Convenience, true broadband performance with upgradeable throughput, mobility and low cost charges. Get an experience with the new 3.9G communications.

INET allows you to...
- Surf the internet
- Send and receive emails and faxes
- Conduct online banking
- Make unrestricted international and local VoIP calls
- Download music and videos
- Connect to the company network

Customer Care: 0747-421181 • 024-2236711 • info@zanzinet.com

INET is a Zanzibar Datacom Ltd Product
WIOMSA’s mission is to generate the best in marine science through its comprehensive research funding pro-gramming and then use the results to ensure that the marine environment is understood, protected, enhanced and maintained for the benefit of everyone that works and lives on the coastal areas of the Western Indian Ocean.

WIOMSA’s vision and activities are based on the notion that quality science leads to better governance and management, which, in turn ensures a sustainable & stable marine envi-ronment needed in efforts to reduce poverty and ensure a better life for us all in the region.

WIOMSA, operates as a regional umbrella organization in Somalia, Kenya, Tanzania, Mozambique, South Africa, Madagascar, the Seychelles, Mauritius, the Comoros Islands and Reunion with a network of membership of over 1200 regional and interna-tional scientists, over fifty academic and marine research insitutions and in partnership with organizations like SIDA, NEPAD, UNEP, EU, USAID and IOC/UNESCO.

FOR MEMBERSHIP CONTACT:
email: secretary@wiomsa.org
tel: +25522233472
www.wiomsa.org