Long-term Monitoring and Early Warning Mechanisms for predicting ecosystem variability and managing climate change

Authors: David Vousden and Magnus Ngoile, UNDP GEF Agulhas and Somali Current Large Marine Ecosystems Project. PBag 1015, 18 Somerset Street, Grahamstown, 6140, Republic of South Africa

Climate change and marine ecosystem management are intimately linked. The world's oceans play a vital role as part of the planetary life-support system. The oceans support vast commercial living resources that in turn support national economies. They are also important for the maintenance of global biodiversity, and represent an essential source of livelihood and food security for many coastal communities that live a subsistence lifestyle. Furthermore, the oceans regulate climate and many of the planets biological, chemical and physical cycles. Ecosystem/based management of these resources, particularly through the Large Marine Ecosystem approach, requires a detailed understanding of the ocean-atmosphere linkages. LMEs are defined by hydrological characteristics such as water quality parameters (temperature, salinity, etc) and currents, as well as trends in productivity and fisheries. Such characteristics are directly affected by climate change and, as such, can be used as indicators of such change. Monitoring of LMEs is therefore a valuable tool for understanding ecosystem variability and the impacts caused by climate change.

Global climate changes, and the resultant impact on marine ecosystems, are expected to have a significant affect on coastal communities around the world within the next 10-20 years. Sea level rise alone is expected to manifest itself through tidal inundations, increased flood frequency, accelerated erosion, rising water tables, increased saltwater intrusion, and a number of associated ecological changes[1]. These biophysical changes will cause significant socioeconomic changes as a result of coastal land loss, changes in coastal resources (species types, number and biomass, distribution, accessibility), etc. Such changes will inevitably induce loss of livelihoods, reductions in food security and food access, and a general decline in quality of life, health and well-being among coastal communities. Impacts can also be expected further inland as a result of changes in average climatic conditions which will be reflected in low rainfall levels and seasonality, winds and temperature, all of which will in turn affect agriculture and living conditions for many populations which may be relatively far-removed from the coastline. Such impacts will be scale-dependent and can be expected to be unevenly distributed within communities and countries as a result of different levels of exposure and vulnerability[2].

The 2007 report of the Intergovernmental Panel on Climate Change (whose conclusions are generally considered to be on the conservative side) predicted a rise of between 2^{o} and 6.4^{o} C before the end of this century[3]. A former chair of the IPCC has warned that the world should sensibly be preparing for 4^{o} C warming scenario over this period, and therefore should be developing concomitant mitigation and adaptation strategies as a high priority. How much time there is available to take such actions will be the key to how successfully we can deal with a warmer world. A combination of science and commonsense should place us squarely into the camp of "changes are inevitable and we need to prepare for them as a matter of urgency".

The journey into a new and ultimately hotter world has, in essence, already begun and effects will almost certainly become apparent within the next 20-30 years as coastal land is lost, ocean temperatures rise and acidity increases with associated relocation of food species and loss of sensitive, high biodiversity habitat (such as coral reefs, mangrove and seagrass beds). The 'knock-on' effects on human communities are expected to be dire and it has been noted that such climate change impacts will be unevenly distributed due to differential exposures and vulnerabilities. We can expect loss of livelihoods and food supply for many coastal communities, especially in poverty-stricken areas such as Africa and Asia.

Under the new predictions for global temperature rises, a 4^{o} C rise would result in significant (greater than 40%) species extinctions around the globe, while approximately 30% of global coastal wetlands would be lost and millions of people could expect to experience annual coastal flooding. Smith *et al.*[4] identify that climate change over the next century is likely to adversely affect hundreds of millions of people through increased coastal flooding after a further 2 °C warming from 1990 levels. Less than a 1 °C warming from 1990 levels will result in significant reductions in water supplies (0.4 to 1.7 billion people affected).

African regional environmental experts participating in the Global Ocean Observing System (GOOS) in Africa have warned that climate change will lead to oceanic acidification and increase surface water temperatures, especially around the African continent. Oceans naturally absorb CO_2 from the atmosphere. Levels of CO_2 in the air have increased due to climate change and thus oceans have been absorbing more CO_2 than previously, which has contributed to oceanic acidification. This will affect fish stocks and, as a result, threaten the livelihoods of small-scale fishing communities. Acidity levels affect fish and shellfish larvae which need calcium carbonate to build their shells and skeletons. This must inevitably pose a threat to communities that depend on fishing for their survival and which are already among the most vulnerable population groups in the world.

Yet many of these predictions, although made in good faith and with the best available tools, are all-too-frequently based on very limited data and information from many regions of the world.

One critical area that is still not receiving enough urgent attention is that of ocean-atmosphere linkages and the relationship between marine ecosystem drivers (currents, sea surface temperatures, upwellings, etc) and climate stability. The oceans are a major driving force behind climatic stability and variability (as is clearly demonstrated through ENSO and El Nino related impacts and the effects of the Indian Ocean dipole on monsoons). Equally importantly, the 'knock-on' effect from climate change will be felt through the ocean-atmosphere linkages within the large marine ecosystems of the world as current regimes alter, productivity levels change, sea surface temperatures and salinities vary. Entire ecosystems could 'shift' in terms of their physicochemical and biological characteristics as well as in terms of their boundaries and extent.

Although these linkages between the oceans and the atmosphere have significant implications to global climate as a whole, certain areas of the world are more highly affected by ocean-atmosphere interactions than others. The east African coast and the Western Indian Ocean is a point in case. Undoubtedly there is an urgent need to establish the baseline in such places in terms of water parameters (temperatures, salinities, pH, current regimes, productivity, etc). But this baseline is already changing with alterations in climate, and resultant changes in ocean-atmosphere linkages. Then there is an equal urgency to establish sustainable long-term monitoring processes that can compare present status with the baseline along with vulnerability assessments, and show how far, how fast and what the impacts are most likely to be from any changes that are occurring. Armed with this information it should then be possible to develop more accurate models and thus create an 'early warning' system upon which to base and then fine-tune adaptation measures and related governance and policy strategies.

Although climate change simulations and predictions are necessary to forecast likely changes and impacts, so far they have been limited in their capacity to predict local and regional effects because of their coarse geographic and time scales. Such large scale predictions of change are of little value to decision-makers at the regional, national or community level. The conclusion is that most vulnerability assessments using the common methodology fail to consider scales that are fine enough to provide adequate community level guidance for adaptive management[5].

It would now seem imperative that long-term mechanisms are set in place that can provide accurate and up-to-date data to feed into predictive models that are more spatially focused and targeted to the national, regional and ecosystem level than is currently the case.

The LMEs, therefore, would provide the ideal focus for any such regional and national early warning monitoring systems. The LMEs will, in any event, require sustainable long-term monitoring systems if they are to be effectively managed and governed. Such monitoring systems must focus on the expected impacts and ensure that any measurements are designed to identify the level and extent of such impacts as early and as accurately as possible.

Fine tuning of these monitoring processes at the ecosystem level and adoption of specific indicators that will identify significant changes in ecosystem variability can help to provide the necessary inputs to more accurate regional modelling of climate perturbation and change. Many of the indicators used to assess ecosystem variability are inevitably similar or the same as those that are necessary to capture related trends resulting from climate change. Furthermore, as many of these indicators would need to focus on socioeconomic parameters related to poverty, food security and livelihood stability, they also represent valuable indicators toward the overall achievement of the United Nations Millennium Development goals.

One example of this can be shown within the Agulhas and Somali Current Large Marine Ecosystems Project (ASCLME) currently being implemented by UNDP (through GEF funding) throughout the western Indian Ocean region. This Project has a system boundary that runs from Somali in the north to the tip of South Africa and out beyond Seychelles and Mauritius to the edge of the Mascarene Plateau (figure 1 below). The objective of this project is to clearly define the ecosystem boundaries, understand the major transboundary impacts within these ecosystems (through Transboundary Diagnostic Analyses) and develop Strategic Action Programmes for effective management and governance of these ecosystems.

A major focus of the ASCLME Project is the collection of baseline data within the western Indian Ocean marine environment that will identify the transboundary impacts on human societies as well as on vulnerable species and habitats. A critical component will be the translation of the scientific information and data into management and policy briefings to guide the countries and the region in the overall sustainable governance of these critical important marine resources. Community involvement and community livelihoods are important components of this science-to-governance process. In order for this to be effective, baseline studies must act as a foundation for long-term monitoring and this long-term monitoring is essential for any LME governance process to be sustainable.

In this context, the ASCLME Project is putting significant resources into both offshore and inshore data collection and monitoring within a region of the oceans that A. has a major impact on the western Indian Ocean islands and the eastern half of the continent of Africa (in terms of marine resources, community welfare and climate/weather) and B. is a region about which very little is known in terms of the marine environment and the ocean-atmosphere linkages.

Figure 2 (below) shows the planned distribution of various fixed monitoring systems that will be the foundation of a network that will not only monitor ecosystem variability in real-time, but will provide the foundation for a western Indian Ocean 'early warning' system for climate change impact and for ecosystem variability. These early warning and long-term monitoring system consists of UTRs (underwater temperature recorders), ATLAS (Autonomous Temperature Line Acquisition System) moorings and ADCPs (Acoustic Doppler Current Profilers). This will provide permanent recordings of atmospheric parameters (wind speed, air temperature, humidity, precipitation, etc) as well as sea surface and seabed temperatures, salinities, carbon flux, seawater acidity, and current direction/velocities. Many of these instruments are already in place, with further deployment and maintenance planned for 2009/2010 and beyond.

Coastal studies will also supplement this information database in terms of inshore fisheries trends as well as coastal livelihoods and the study of potential impacts to coastal communities. Part of the monitoring process will focus on measuring changes within coastal communities as a result of ecosystem variability and climate change so as to better predict long-term impacts and management needs.

It is further intended to expand this monitoring process using remote sensing and satellite imagery, specifically in terms of collecting data on ocean colour (for productivity and photosynthesis) and sea level altimetry, etc. This will be an integral part of the eventual climate and ecosystem variability modelling process at the regional and sub-regional level which will then lead to the guidelines and policy briefs at a national level.

The development of this highly effective and comprehensive monitoring network has been made possible through a number of partnerships. In particular, NOAA (the USA's National Atmospheric and Oceanic Administration) have provided all of the ATLAS systems as part of their contribution to the RAMA (Research Moored Array for African-Asian-Australian Monsoon Analysis and Prediction) network, as well as a number of floating data collection systems.

Meanwhile, the countries of the western Indian Ocean are each engaged in developing a Marine Ecosystem Diagnostic analysis in the efforts to baseline the ecosystem conditions, including the socioeconomic status of the communities, so as to record any changes induced by climate change, this being seen as a priority source of impact on the ecosystems. This will then feed into the overall regional Transboundary Diagnostic Analyses as part of the delivery from the ASCLME Project.

The ASCLME partnership toward a monitoring network potentially represents one of the most sophisticated long-term LME monitoring and early warning systems outside of the developed world. As such it can act as a pilot system for regional and sub-regional modelling, prediction and effective, adaptable governance.

In recognising the potential for effective long-term monitoring, early warning and predictive management the ASCLME initiative demonstrates cutting-edge work in the region that links the local-national as well as the regional-global needs.

REFERENCES

1. DOLAN, A.H., and WALKER, I.J., 2003. **Understanding vulnerability of coastal communities to climate change related risks.** Journal of Coastal Research, SI 39 (Proceedings of the 8th International Coastal Symposium), pg-pg. Itajaí, SC – Brazil, ISSN 0749-0208
2. CLARK, G.E.; MOSER, S.C.; RATICK, S.J.; DOW, K.; MEYER, W.B.; EMANI, S.; JIN, W.; KASPERSON, J.X.; KASPERSON, R.E. and SCHWARZ, H.E., 1998. **Assessing the Vulnerability of Coastal Communities to Extreme Storms: The Case of Revere, MA., USA.** Mitigation and Adaptation Strategies for Global Change, 3, 59-82.
3. **Surviving in a Warmer World**. New Scientist. 28th Feb 2009, Pp. 28-33
4. Joel B. Smith, Stephen H. Schneider, Michael Oppenheimer, Gary W. Yohe, William Hare, Michael D. Mastrandrea, Anand Patwardhan, Ian Burton, Jan Corfee Morlot, Chris H. D. Magadza, Hans-Martin Fűssel, A. Barrie Pittock, Atiq Rahman, Avelino Suarez, and Jean-Pascal van Ypersele. **Assessing dangerous climate change through an update of the Intergovernmental Panel on Climate Change (IPCC) - ''reasons for concern''**. Proceedings of the National Academy of Sciences of the United States of America. March 17, 2009. vol. 106. no. 11. 4137.
5. ADGER, N.W., 2001. **Scales of governance and environmental justice for adaptation and mitigation of climate change**. Journal of International Development, 13, 921-931.

Figure 1: ASCLME System boundary as defined by currents in the western Indian Ocean

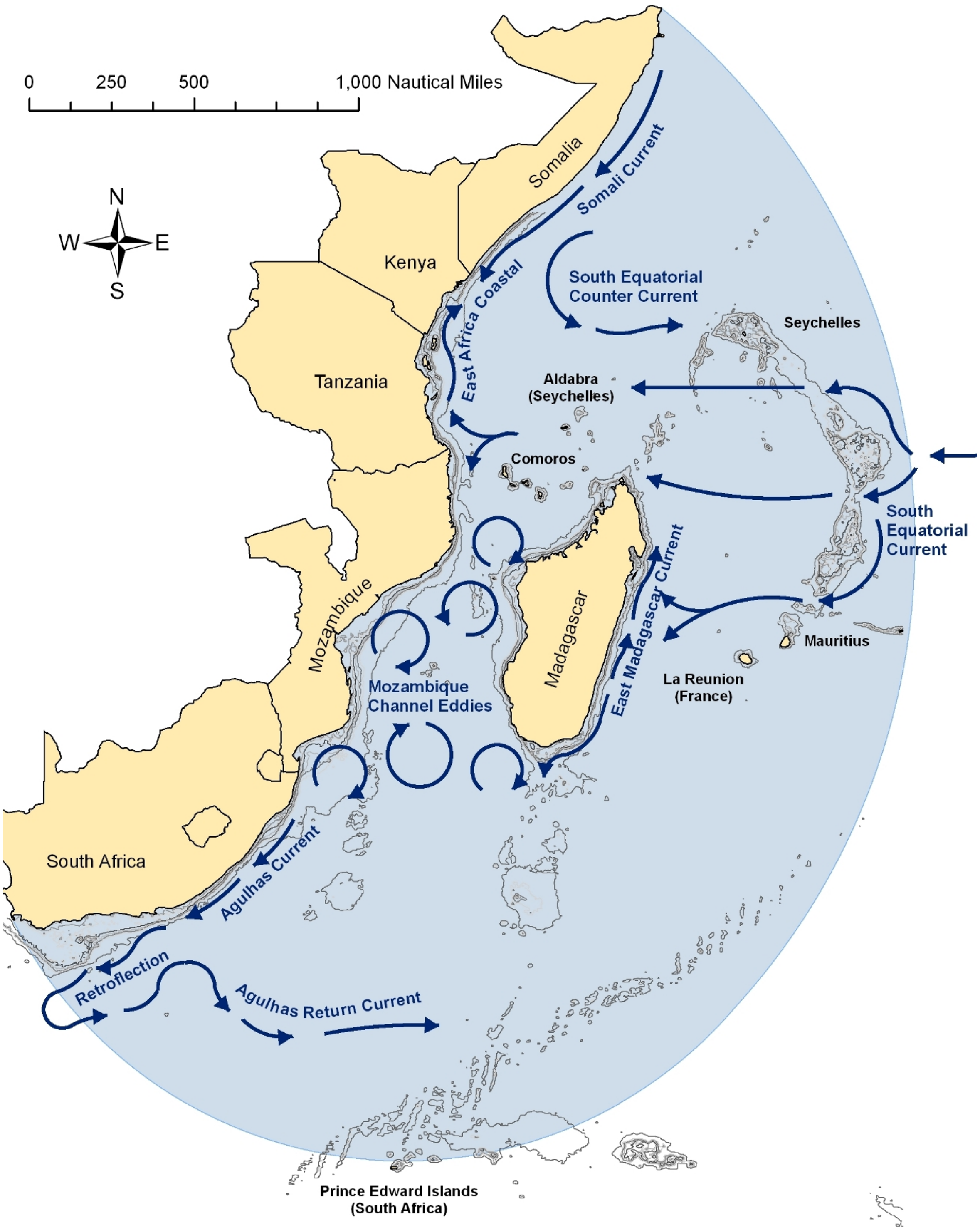

Figure 2: Future Long-Term Data Collection Planning for ASCLME region