WWF

The University of Queensland
AUSTRALIA

THE CORAL TRIANGLE AND CLIMATE CHANGE:

ECOSYSTEMS, PEOPLE AND SOCIETIES AT RISK

A COMPREHENSIVE STUDY INVOLVING OVER 20 EXPERTS AND BASED ON 300 PEER-REVIEWED SCIENTIFIC ARTICLES

First published in May 2009 by WWF Australia

GPO Box 528
Sydney NSW Australia
Tel: +612 9281 5515
Fax: +612 9281 1060
ISBN number 978-1-921031-35-9

Cover designed by www.threeblocksleft.com.au.
Full report designed by Nina Narvsten

WWF and The University of Queensland would like to thank the following organisations for their support of this report:

- Coral Reef Targeted Research Project (www.gefcoral.org)
- ARC Centre for Excellence in Coral Reef Studies
- Australian Institute of Marine Sciences
- EcoAdapt
- Economic Strategies
- Center for Ocean Solutions, Stanford University
- WorldFish Center
- James Cook University
- Silliman University
- The Nature Conservancy
- United States National Ocean and Atmospheric Administration
- University of Diponegoro
- University of Melbourne
- University of the Philippines

Citation of this report: Hoegh-Guldberg, O., Hoegh-Guldberg, H., Veron, J.E.N., Green, A., Gomez, E. D., Lough, J., King, M., Ambariyanto, Hansen, L., Cinner, J., Dews, G., Russ, G., Schuttenberg, H. Z., Peñaflor, E.L., Eakin, C. M., Christensen, T. R. L., Abbey, M., Areki, F., Kosaka, R. A., Tewfik, A., Oliver, J. (2009). The Coral Triangle and Climate Change: Ecosystems, People and Societies at Risk. WWF Australia, Brisbane, 276 pp.

This report is available at: www.panda.org/coraltriangle

Turing Foundation This report was made possible in part by the Turing Foundation

PREFACE

The world is currently facing the greatest challenge of all time. Rapid climate change is transforming the conditions under which life has persisted for millions of years. These changes are threatening the life-support systems upon which we depend.

Humanity is at the crossroads. The message is quite simple and the choice stark: act now or face an uncertain, potentially catastrophic future.

Concentrations of atmospheric carbon dioxide are increasing at a rate that dwarfs any seen over the last million years at least. Temperatures are rapidly rising, weather patterns changing and biological systems responding profoundly. And the oceans, having nurtured life on this planet, are now approaching crisis.

World leaders can change the history of the planet and directly influence the survival of millions upon millions of people, and generations to come. But to do so, they must identify those steps that will have the greatest and most lasting impact on the problem.

One of these opportunities lies in a heavily populated area of our planet, the Coral Triangle, which stretches across six countries in Southeast Asia and Melanesia. In an area that is no more than 1% of the Earth's surface, evolution has produced ecosystems unrivalled in diversity and colour. On land, some of the richest rainforests and unique terrestrial species can be found. And beneath the seas, lie the most diverse marine communities and ecosystems to be found anywhere on planet Earth.
This incredible cauldron of evolution should be protected in its own right. However, its value is much greater. In addition to the incredible biological diversity of the Coral Triangle, over 300 million people from some of the most diverse and rich cultures on our planet live here.

Many of these people live on coastlines of the Coral Triangle, depending on healthy coastal ecosystems for their survival. Ecosystems such as coral reefs, mangroves and seagrass beds provide food, building materials, coastal protection, industries such as fishing and tourism, and many other benefits. The services that these ecosystems provide are essential to the 150 million people living in and around the coastal areas of the Coral Triangle.

Unfortunately, the coastal ecosystems of the Coral Triangle are in deep trouble – 40% of coral reefs and mangroves have been lost in Southeast Asia over the past 40 years. Coastal deforestation, wetlands reclamation for urban development, aquaculture and agriculture, declining water quality, pollution, sewage, destructive fishing and over-exploitation of marine life have led to severe impacts on these essential ecosystems. These changes are now starting to affect the people of the Coral Triangle.

Rapid changes in the Earth's climate are now also beginning to affect the terrestrial and marine ecosystems of the Coral Triangle. Changing weather patterns are increasing the risk of floods, landslides and severe storms in some parts of the Coral Triangle, while causing crippling drought in other areas. Rising sea levels are putting pressure on coastal communities through storm surge and inundation of fresh water supplies. Damage to coastal vegetation from storms and wildfires are breaking down barriers to erosion.

PREFACE

Coastal ecosystems in the Coral Triangle are already being impacted by warming, acidifying and rising seas. Coral reefs have experienced severe mass bleaching events across the region, which, if they increase in intensity and frequency, threaten to seriously degrade these important ecosystems. Mangroves face similar problems with rising sea levels threatening their future. With the build up of coastal infrastructure, there is no place for mangroves to retreat. The downstream effects on human beings of losing these critical coastal ecosystems are enormous.

Basically, the future is looking very gloomy unless we act immediately and decisively.
This report brings together a vast amount of information from the climate, biological, economic, policy and social sciences to build credible pictures of two potential worlds. These two worlds are instructive in terms of the impact of the decisions that we take today.

In one world, based on the Intergovernmental Panel on Climate Change (IPCC) A1B scenario, our attempts to stabilize the Earth's climate fail, as does our resolve to deal with the multitude of local threats to the coastal ecosystems in the Coral Triangle. In this world, temperatures soar and the current rich coral reef and mangrove ecosystems disappear, with huge impacts on food security, human survival and regional security. This is a world that we must avoid at all costs.

In the other world, based on a modified version of the B1 scenario of the IPCC, the international community takes decisive and effective action which rapidly reduces greenhouse gas emissions, and resolves to assist countries like the Coral Triangle nations develop effective solutions to the growing problems they face. These actions, while not without challenges, limit the impacts of the changing climate and maximise the resilience of biological, ecological and socioeconomic systems to those climate change impacts that are currently unavoidable. This is a world in which the poorest people are not abandoned to the impacts caused by the developed world.

This report delivers a sombre warning that action must be taken immediately. There are a number of actions (discussed in detail in chapter 10), which, if implemented by regional and world leaders, will avoid this crisis. Let us hope that these actions become central to the future of the Coral Triangle.

EXECUTIVE SUMMARY

This study brought together the experience, viewpoints and analysis of over 20 experts from the climate, biological, economic, policy and social sciences. The major focus of the study was to examine how the future might unfold for one of the most ecologically rich yet most populated regions of the planet. In doing so, this report has developed a series of policy recommendations which must be taken on board if we are to avoid a major environmental and human catastrophe. If we don't do this, hundreds of thousands of unique species, entire communities and societies will be in jeopardy.

THE EARTH'S EVOLUTIONARY CAULDRON

Stretching across six countries in Southeast Asia and Melanesia (Indonesia, the Philippines, Malaysia, Papua New Guinea, Solomon Islands and Timor Leste), the Coral Triangle contains the richest marine ecosystems on earth. While encompassing just over 1.5% of the world's oceans (and 1% of the earth's surface), it contains a staggering proportion of the world's marine diversity: 76% of reef-building coral species, and 37% of coral reef fish species. The Coral Triangle is the epicentre for the biodiversity of not only corals and fish, but many other marine organisms as well. Like the land-based ecosystems of this region, the marine ecosystems are of enormous significance and priceless value in terms of our biological inheritance and future.

The significance of the marine ecosystems lining over 132,800 km of coastline within the Coral Triangle goes far beyond their biological value or evolutionary significance. Coastal ecosystems in this region are critically important for human livelihoods and communities, providing food and resources to over 100 million people. Many people in this region forage on coral reefs and other coastal ecosystems such as mangroves, to collect their daily food and income. Commercial fisheries provide over $3 billion per year to the six nations. These ecosystems also contribute to the maintenance of water quality along coastlines, with mangroves and seagrass beds stabilising sediments and acting as filtration systems as water runs from land to sea. Coral reefs provide important coastal barriers in many regions, reducing the power of waves and preventing damage to human communities and infrastructure. These functions cannot be replaced if these ecosystems are removed.

COASTAL ECOSYSTEMS IN TROUBLE

Unfortunately, coastal ecosystems throughout the Coral Triangle are being severely threatened by the activities of humans. These threats arise from two distinct sources. The first set arise from local sources such as destructive fishing practices, deteriorating water quality, over-exploitation of key marine species, and the direct devastation of coastal ecosystems through unsustainable coastal development. The second set arise from rapid anthropogenic climate change, which is caused by the build up of greenhouse gases such as carbon dioxide in the Earth's atmosphere. These threats are escalating and ecosystems like coral reefs are already showing major changes to sea temperature and acidity. Further changes are putting the future of these important biological systems in serious doubt.

EXECUTIVE SUMMARY

Examination of the trends of how the climate is changing reveals that sea temperatures in large parts of the Coral Triangle are increasing at ~0.4oC per decade, while other parts are increasing at lower rates (~0.1°C per decade). Disturbances to the hydrological cycle in the region will almost certainly lead to changes in rainfall across the region, with rainfall intensity increasing in some regions, and dramatically decreasing, causing drought, in others. This may bring about large-scale changes in sediments and river effluent flowing into coastal areas. Rises in sea level represents a serious threat with world-leading scientists at the recent climate science meetings in Copenhagen (March, 2009) suggesting that sea level change may have been severely underestimated by the International Panel on Climate Change (IPCC 2007) Fourth Assessment Report and that seas may rise by at least one metre (if not more) by the end of this century. At the mid to upper end of these scenarios, sea level rise could have devastating impacts on coastal ecosystems such as coral reefs, mangroves and seagrass beds, as well as inundating coastal communities.

The combination of local and global stresses puts enormous pressure on coastal ecosystems throughout the Coral Triangle. The coral reefs of Southeast Asia are the most seriously threatened, with 40% of reefs effectively lost, 45% under threat, and 15% at low threat. In contrast, more reefs in the Pacific Islands and nearby Australia, including Melanesia, are in better condition, with 2 to 8% effectively lost, 2 to 35% under threat, and 44 to 90% at low threat. Similar proportions of mangroves and seagrass beds have also been lost across the Coral Triangle, affecting the primary habitat for thousands upon thousands of species. Most importantly, these changes have resulted in a reduced ability of coastal ecosystems to provide food and benefits to coastal communities.

A CRITICAL LEVEL OF ATMOSPHERIC CO_2 TO AVOID: 450 PPM

Climate change and its impacts are accelerating and suggest a very worrying future for the people of the Coral Triangle if both local and global stresses are not reduced. Coral reefs appear to be particularly sensitive to increases in sea temperature. Corals, which are the fundamental organisms that build coral reefs, bleach and die if temperatures increase by a couple of degrees above long-term average temperatures. Increases in atmospheric CO_2 that exceed 450 parts per million (ppm) seriously reduce the ability of corals to grow and maintain reefs. Mangroves and seagrass beds face similar threats from the accelerating sea level rise associated with these changes.

These changes are driving major changes in the health of coastal ecosystems, and are increasingly exposing coastal populations to the erosion of food security, income, deteriorating coastal protection and other challenges. They are affecting people who are, ironically, already impoverished and are among the least able to respond to the changes that are occurring in their environment. If they are allowed to continue, these changes will exacerbate poverty and social instability within the region, with wider consequences for the region and the world. It is an imperative that we address the core issue of climate change while at the same time addressing the key threats that are rising from local stresses. Only if we deal with both of these challenges, will these coastal ecosystems of the Coral Triangle, and the many people that depend on them, have any future at all.

This study explored the strong links between people and coastal ecosystems within the Coral Triangle, and established two scenarios of the future in the face of a changing climate. The scenario planning was done after a comprehensive review of a multitude of social, environmental and economic drivers.

EXECUTIVE SUMMARY

TWO WORLDS: OUR CHOICE

The global scenarios used in this exercise are based on those originally developed by the Intergovernmental Panel on Climate Change (IPCC 2001), adjusted to accommodate recent insights into how the world is changing. Since the Fourth Assessment Report, it has become clear that many of the physical and chemical changes associated with human driven climate change are accelerating, or were simply underestimated by the IPCC.

The best case scenario presented in this report is based on an updated interpretation of the IPCC's B1 scenario, with its global cooperation and environmentally friendly policy framework.

The current fossil fuel intensive A1FI (extreme variant of the A1 scenarios of the IPCC) is widely regarded as extremely risky and dangerous. This scenario (A1FI) is explored in the report but is soon set aside as being too extreme given the impacts and devastation it would have on our natural world and global economy. Therefore, the intermediate case, A1B scenario, was used as the worst case scenario for this report. This scenario describes a world in which fossil and renewable fuels are used in what the IPCC called a 'balanced mix'.

After exploring the economic drivers for the two scenarios (B1 and A1B) from global to regional economic drivers, the impacts of the alternative scenarios for the coastal ecosystems and the people that depend on them in the Coral Triangle were explored. The potential state of coastal ecosystems were estimated from our current understanding of how these ecosystems are likely to be impacted as climate conditions change.

WORST CASE (A1B) SCENARIO: FAILURE TO REDUCE CLIMATE CHANGE AMID ESCALATING LOCAL THREATS

In the A1B world, atmospheric CO_2 rises above 700 ppm by the end of this century. This results in global temperatures (NB tropical sea temperatures roughly follow global temperature increases closely) that lie between 1.5 and 6.4°C above today – with an 89% chance that temperatures would rise above the critical level of 2°C, which is enough to destroy coral communities due to widespread bleaching and mortality. At the same time, seawater within the Coral Triangle falls below the critical aragonite saturation value of 3.3, which is the amount of calcium and carbonate ions required to build and maintain carbonate coral reef ecosystems. The significant chance of catastrophic breakdown of ice sheets in Greenland and Antarctica coupled with sea level rise due to thermal expansion will almost certainly push sea levels to one metre above today's levels, if not higher.

The world that has these characteristics will not have healthy coastal ecosystems such as coral reefs and mangrove forests. It will be a world in which human poverty grows rapidly, destabilising societies and leading to the movement of people towards large sprawling urban centres, exacerbating issues within those cities. The destabilisation of communities and societies will also pose a potential threat to regional security. No amount of managing other stresses within the region will make much difference to the declining health of ecosystems, which would have little chance of recovering if and when atmospheric CO_2 had been stabilised.

BEST CASE (B1) SCENARIO: DECISIVE INTERNATIONAL ACTION ON CLIMATE CHANGE WHILE BUILDING SUSTAINABLE COASTLINES AND COMMUNITIES

In the B1 world, there is a high level of environmental and social consciousness combined with a coherent global approach to sustainable development. Heightened environmental consciousness might be brought about by clear evidence that impacts on natural resources pose serious threats to human livelihoods and economies. As argued within the scenarios, a range of demonstrative lessons might lead to these types of changes in our approach. Economic development in the B1 world is balanced, and efforts to achieve equal income distribution are effective. As in A1B, the B1 storyline describes a fast-changing world but with different priorities. Whereas the A1 world invests its gains from increased productivity and know-how primarily into further economic growth, the B1 world invests a large part of its gains into improved efficiency of resource use, equity, social institutions and environmental protection.

In the B1 scenario, the stabilisation of atmospheric CO_2 at or below 450 ppm leads to sea temperatures in tropical oceans that increase by between 0.8 and 2.7°C. Both the concentration of CO_2 and increased sea temperature will bring corals very close to the point where their ability to maintain complex carbonate reef systems is marginal. Mass coral bleaching will occur every two to three years on reefs within the Coral Triangle, and the accumulation of calcium carbonate onto coral reefs would slow to a point where reefs will be fragile and easily damaged. Similar changes will occur to mangroves and seagrass beds, again with the possibility that they would be lost if local threats were not managed and reduced. The benefits of the B1 scenario would be indistinguishable from the A1B scenario up to the middle of the century, but would become increasingly clear as the century ended. At that point, atmospheric CO_2 will be stabilising, with the result that the global stresses on coral reefs start to diminish, with the real possibility that the re-assortment of corals with different tolerances around the planet would see a slow increase in coral cover over the first part of the 22nd-century.

These ecosystems will be relatively fragile compared to their current condition today, and will be less able to cope with local stresses such as poor water quality, overfishing and pollution. For this reason, the management of local stresses would have a significant effect and will slow the rate of loss of these systems this century and potentially speed up their recovery in the next.

The B1 scenario clearly makes the case for deep and effective action on greenhouse emissions internationally while at the same time aggressively addressing local threats to coral reefs. Only if these two things are done together will the Coral Triangle have a sustainable future.

EXECUTIVE SUMMARY

URGENT ACTION IS REQUIRED TODAY NOT TOMORROW

Analysis of the potential impacts of climate change on the Coral Triangle leads to a number of policy actions for international leaders to consider.

First and foremost we must prioritise significant CO_2 emission reduction in order to reduce the severity of the effects we can otherwise expect - leading us toward the best case rather than worst case scenario. This is essential as even the best case scenario is rife with challenges to communities and natural resources in the region, with very significant losses to be expected.

Second, climate change adaptation strategies must be applied as rapidly as possible, since delays in applying these strategies will result in insurmountable change, missed opportunities, reduced options and a more daunting task with less chance of success.

This report delivers a sombre warning that decisive action must be taken immediately or a major crisis will develop within the Coral Triangle over the coming decades. There are a number of actions, which, if taken up by regional and world leaders, will help Coral Triangle countries avoid this crisis. The policy steps recommended by this report include:

1. **Create a binding international agreement to reduce the rate and extent of climate change.** To do this, emissions should peak no later than 2020, and global warming limited to less than 2°C above pre-industrial temperatures (i.e. atmospheric CO_2 < 450 ppm) by 2100. This will require steep global cuts in emissions that are 80% below 1990 levels by 2050. Inherent to this recommendation is the creation of an aggregate group reduction target for developed countries of 40% below 1990 levels by 2020, and a reduction from business-as-usual emission levels for developing countries of at least 30% by 2020.

2. **Take immediate action to establish national targets and plans to meet these commitments such that the international agreement can be achieved.** This report shows that nations in the Coral Triangle region have a great deal at stake if climate change continues unchecked. They must become part of the solution and must do this expeditiously. Lag-times and non-linear responses in the climate system mean that every day we wait to take action, the problem becomes dramatically more difficult and costly to address successfully.

3. **Pursue the establishment of integrated coastal zone management across the region to reverse the decline of the health of coastal ecosystems.** This should include implementation of policies that eliminate deforestation of coastal areas and river catchments, reduce pollution, expand marine protected areas, regulate fishing pressures and abolish destructive practices. It is important that these actions not aim to restore or protect ecosystems for past conditions, rather they must prepare for conditions under a changing climate.

4. **Support the establishment of a global fund to meet the adaptation needs** of developing countries. While some of the cost of adapting to climate change can be met by redirecting current resources that are being used in a manner that is vulnerable to climate change, the growing challenge of climate change will result in new and increasing costs. Funds will be required to meet these costs given the nature of the problem and that the disproportionate brunt of the hardship caused by the problem is borne by developing countries. International funds will be necessary to meet these needs.

5. **Build adjustable financial mechanisms into national budgeting to help cover the increasing costs of adaptation to climate change.** Climate change will require not only new funds, but also a reassessment of current spending so that funds are not spent in ways that are not 'climate-smart', in other words on efforts that are not resilient to climate change. Every effort should be made to avoid spending funds and taking actions that exacerbate the problem of climate change

6. **Establish governance structures that integrate resource and development management to provide robust protection of both in the face of climate change.** Adaptation plans cannot be developed on a sector-by-sector basis. Doing so risks creating problems such as adaptation being effective against one issue but maladaptive against another. It will be important to plan holistically and create governance structures that can support, implement and monitor these efforts.

7. **Build the socio-ecological resilience of coastal ecosystems and develop stakeholder and community engagement processes for communities to improve their ability to survive climate change impacts.** Involving coastal people and communities in planning provides greater stability and efficacy for solutions to social and ecological systems within the Coral Triangle. Fundamentally, it will be local knowledge that generates innovative adaptation strategies which may prove most successful. Reducing the influence of local stress factors on coastal ecosystems makes them able to better survive climate change impacts. Protecting the diversity of components (communities, populations, and species) under the guidance and actions of local people strengthens the resolve of these systems in the face of climate change.

8. **Critically review and revise conservation and development efforts at the local, national and regional levels for their robustness in the face of climate change.** Business-as-usual conservation and development will not achieve success. The new mode of action requires integration between conservation and development, and the realisation that many past approaches are no longer effective due to the impacts of climate change.

9. **Build capacity to engage in planning for climate change. Climate change planning, both mitigation and adaptation, will require that we educate current and future practitioners, as well as the concerned constituencies.** Mechanisms must be created to develop current resource managers and planners so that they can immediately implement these new approaches. As the problem of climate change is not one that we will be solving in this generation, planning and responses to climate change will be iterative as the target continues to move over the coming centuries. Therefore, it will also be necessary to develop training for future capacity through education in academic settings. Informed stakeholder and community engagement is at the core of successful adaptation, so in addition to professionals and students, civil society must be given access to the information they need to understand and respond to climate change.

10. **Focus adaptation on playing a role in economic stimulus, especially in job creation and financial mobilisation.** Private-public sector incentive schemes, regional/international arrangements and investment partnerships (e.g. national insurance reform and special-access loan schemes) need to better incorporate risk management and adaptation strategies to reduce investment risk and maintain positive financial conditions.

TABLE OF CONTENTS

TABLE OF CONTENTS

TABLE OF CONTENTS

TABLE OF CONTENTS

TABLE OF CONTENTS

“If we look at a globe or a map of the Eastern Hemisphere, we shall perceive between Asia and Australia a number of large and small islands, forming a connected group distinct from those great masses of land and having little connexion with either of them. Situated upon the equator, and bathed in the tepid water of the great tropical oceans, this region enjoys a climate more uniformly hot and moist than almost any other part of the globe, and teems with natural productions which are elsewhere unknown.”

So begins Alfred Russel Wallace’s seminal book *The Malay Archipelago*, first published in 1869 (Wallace 1869) and destined to become one of the foundations of modern biogeography.

SCIENTIFIC BACKGROUND

Wallace, concurrently with Darwin, looked for an interpretation of terrestrial modern faunal distributions in the light of past evolutionary events. In 1863 he read a paper to the Royal Geographical Society (Wallace 1863) which had a red line on a map starting at the deep strait between Bali and Lombok and passing up the Makassar Strait. To the west he wrote ‘Indo-Malayan region’ and to the east, ‘Austro-Malayan region’. This line, dubbed ‘Wallace’s line’ by T.H. Huxley in 1868 has since become one of the best-known demarcations in the history of biogeography, yet it is one that was constantly questioned. Huxley re-drew it to run west of the Philippines, Wallace himself changed his mind (Wallace 1910), and different lines were drawn by other authors as a result of studies of different animal distributions (Fig. 1).

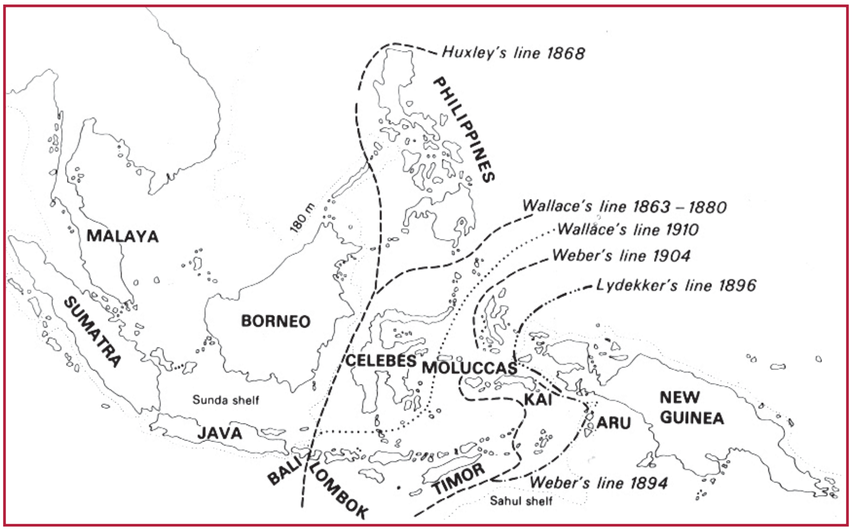


Fig. 1 Historical demarcations between the Oriental and Australian faunal regions (after (George 1964)).

The marine realm was virtually ignored by these as well as other authors of the time although there were occasional attempts to map marine life, notably by the American geologist James Dana (Dana 1853), the British naturalist Edward Forbes (Forbes 1856) as well as Charles Darwin himself (Darwin 1859). There were a few scattered publications on the distribution of some marine taxa during the latter part of the 19th century (George 1981), but it was not until the publication of Bartholomew's Atlas in 1911 (Bartholomew et al. 1911) and Ekman's historic compendium in 1935 (Ekman 1935) that marine biogeography became established as a science in its own right.

Over the past several decades, biogeographers have proposed centres of marine biodiversity of varying shapes, all centred on the Indonesian/Philippines Archipelago. Some stem from biogeographic theory or geological history, others from existing coral and reef fish distributions. These centres have been given a variety of names: Wallacea, East Indies Triangle, Indo-Malayan Triangle, Western Pacific Diversity Triangle, Indo-Australian Archipelago, Southeast Asian centre of diversity, Central Indo-Pacific biodiversity hotspot, Marine East Indies, among others (Hoeksema 2007).

CENTRE OF MARINE BIODIVERSITY

It was not until the post-war era that coral biogeography came to the forefront of marine biogeography, a position effectively launched by the American palaeontologist John Wells (1954) when he published a table of coral genera plotted against locations. Many re-iterations of this table formed the basis of a sequence of published maps (Rosen 1971; Stehli and Wells 1971; Coudray and Montaggioni 1982; Veron 1993). These publications, all at generic level, highlighted the Indonesian/Philippines Archipelago as the centre of coral diversity. More importantly, they also included the Great Barrier Reef of Australia as part of that centre (Fig. 2).

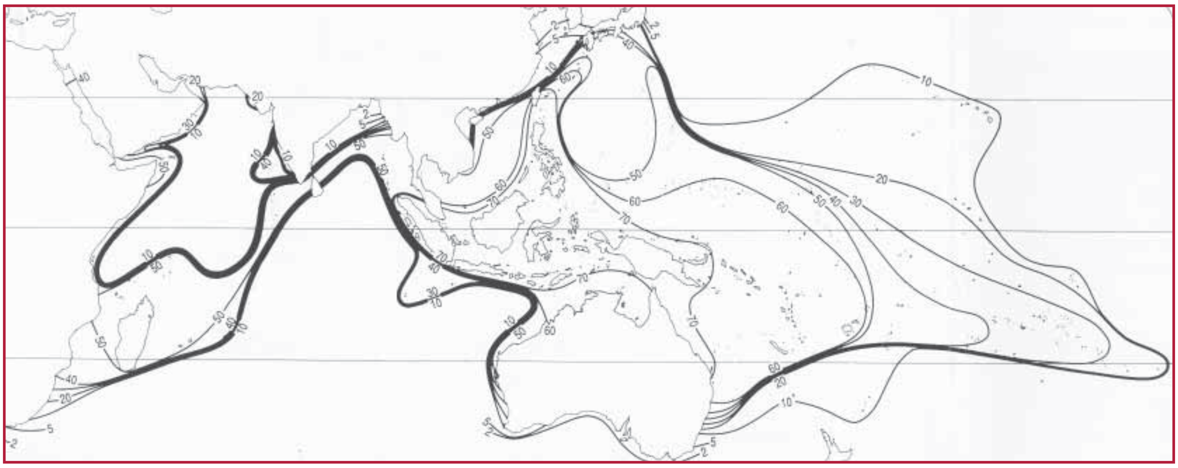


Fig. 2 Contours of coral diversity of Veron (1993). The Great Barrier Reef of Australia has the same generic diversity as the Indonesian/Philippines Archipelago.

This view was fundamentally altered when global distributions were first compiled at the species level, an undertaking which needed a computer-based spatial database. This compilation clearly indicated that the Indonesian-Philippines archipelago, and not the Great Barrier Reef, was the real centre of coral diversity (Veron 1995), a pattern now well-established (Fig. 3).

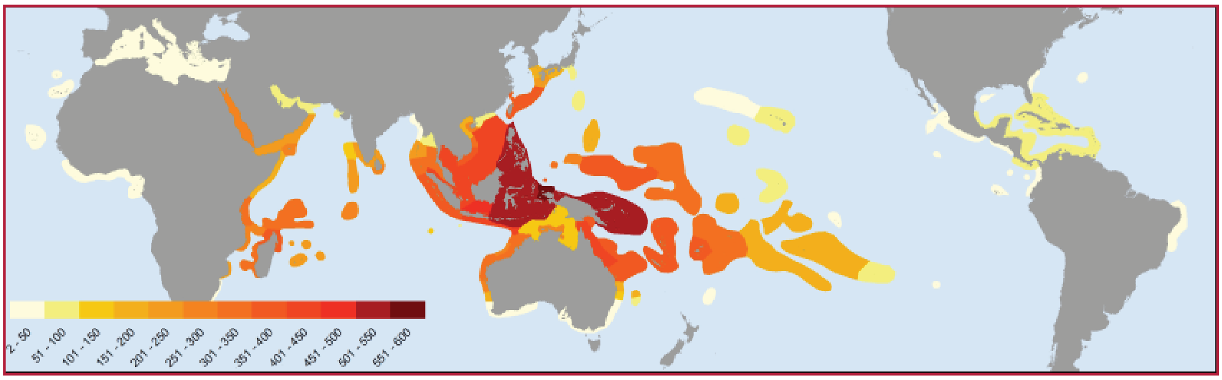


Fig. 3 The global biodiversity of zooxanthellate corals. Colours indicate total species richness of the world's 141 coral biogeographic 'ecoregions' (after Veron et al., submitted).

The significance of this seemingly innocuous finding was not lost on conservationists. It meant that the focus of coral and (by extrapolation) reef conservation was effectively taken away from the highly regulated World Heritage province of the Great Barrier Reef and turned over to an area that was relatively under-studied, where reefs were largely unprotected, and where human population densities and consequent environmental impacts were high by most world standards.

Political response to the delineation of the Coral Triangle was prompt. In September, 2007, twenty-one world leaders attending the Asia Pacific Economic Cooperation (APEC) summit in Sydney proposed the Coral Triangle as a mechanism to conserve key components of the global centre of coral reef biodiversity. The Government of Indonesia through the leadership of President Susilo Bambang Yudhoyono hosted a two-day symposium on the subject in parallel with the Bali UN Framework Convention on Climate Change. This meeting developed the framework for a Coral Triangle Initiative Plan of Action to be developed during 2008 and adopted at the highest political level.

THE CORAL TRIANGLE

Importantly, the name "Coral Triangle" has spread well beyond specific relevance to corals. It was introduced to science in relation to fish and other biota in1998 (Werner and Allen 1998) and since then, this engaging concept has attracted an enormous array of biogeographic, conservation and faunistic accounts ranging from scientific reports to television documentaries.

The Coral Triangle was delineated by the spatial database *Coral Geographic* (Veron 2009) which divides all the coral reef regions in the world into 141 'ecoregions' (Veron et al., submitted). Sixteen of these ecoregions each have >500 species: these delineate the Coral Triangle (Fig. 4). In total, the Coral Triangle has 605 zooxanthellate corals amounting to 76% of the world's total species complement. 66% of these species are common to all ecoregions in the Coral Triangle.

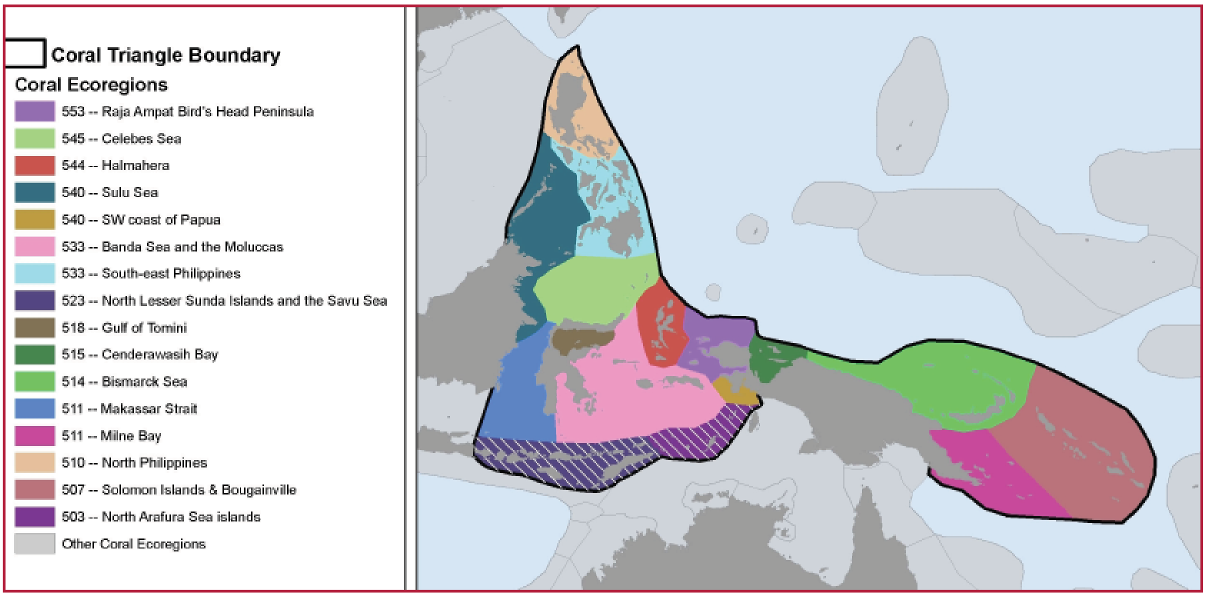


Figure 4. Ecoregions and species richness of reef-building (zooxanthellate) corals of the Coral Triangle (after (Veron et al. 2009)). A total of 1118 sites were studied within the 16 ecoregions of this province (left panel, showing number of species per ecoregion), however some islands of southern Indonesia (the two hatched ecoregions), especially their southern coastlines, remain data-deficient. Note that this differs slightly from the broadly accepted classification of 11 ecoregions of Green and Mous (2008) as discussed in Chapter 2 (see Figures 4 of that chapter).

Within the Coral Triangle, highest richness resides in the Bird's Head Peninsula of Indonesian Papua (the western end of the island of New Guinea), which hosts 574 species. Individual reefs there have up to 280 species ha-1, over four times the total zooxanthellate Scleractinian (hard coral) species richness of the entire Atlantic Ocean (Turak and DeVantier). Within the Bird's Head, The Raja Ampat Islands ecoregion has the world's coral biodiversity bullseye, with 553 species (Turak and Souhoka 2003).

Importantly, boundaries of the Raja Ampat 'bullseye' and the Bird's Head diversity centre are not strongly delineated. Indeed, more than 80% of all Coral Triangle species are found in at least 12 of the 16 Coral Triangle ecoregions. Nor is this region markedly distinct from neighbouring ecoregions to the south and southeast. Ninety-five per cent of Coral Triangle species are found in one or more adjacent ecoregions - notably other parts of Southeast Asia and the Pacific Islands, including Malaysia, Thailand and Vietnam, Micronesia, the Great Barrier Reef, Vanuatu, New Caledonia and Fiji although all exhibit marked declines in species richness and ubiquitousness beyond the Coral Triangle.

The Coral Triangle also encompasses the highest diversity of coral reef fishes in world, comprising 52% of Indo-Pacific reef fishes and 37% of the reef fishes of the world (Allen, 2007, unpublished data). Patterns of reef fish diversity (Fig. 5) are very similar to those of corals (Figs. 3), and since the Indo-Pacific is the most diverse region of the world, they identify the global centre of marine diversity for reef fishes – an area very similar to the Coral Triangle defined based on coral diversity (Figs. 3 and 4).

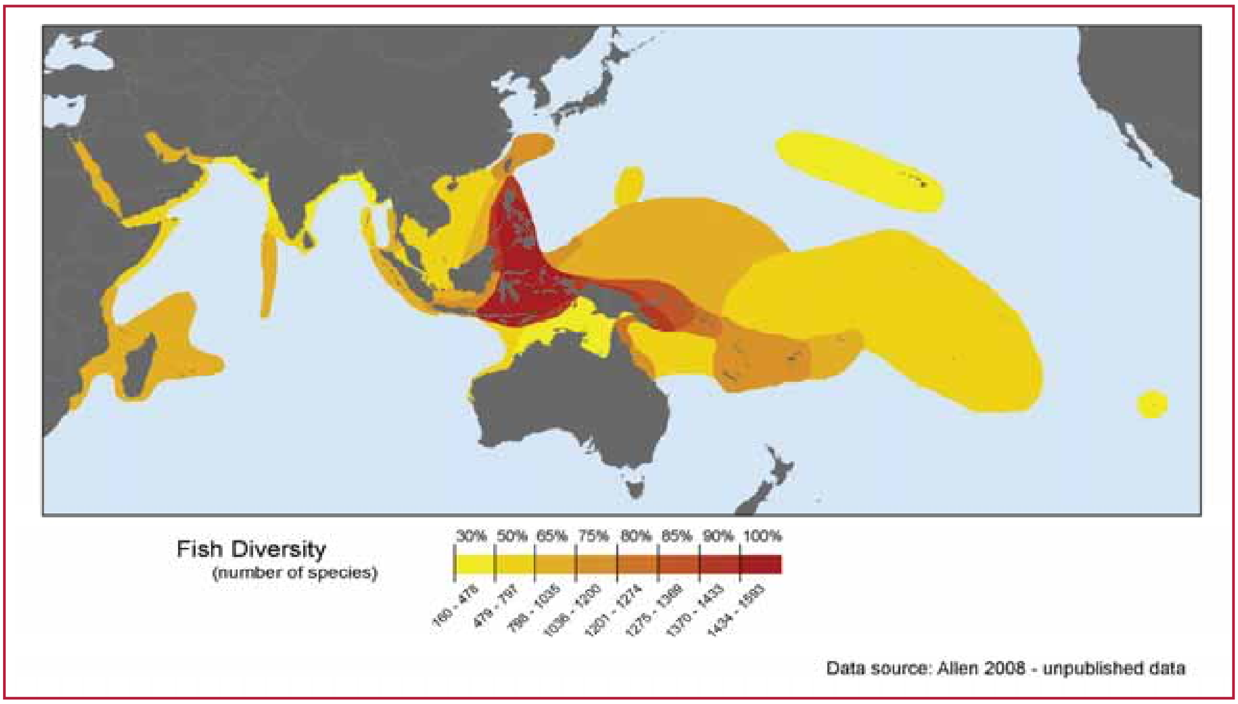


Fig. 5 Coral reef fish diversity in the Indo-Pacific Region (Allen 2007, unpublished data). The highest diversity areas (90-100% of species) include most of the Coral Triangle.

Other major faunal groups, notably molluscs (Wells 2002) and crustaceans (Grave 2001), have very high numbers of undescribed or cryptic species and thus are relatively little-known at species level (Meyer et al. 2005). However, many biogeographic publications indicate that a wide variety of taxa not necessarily associated with reefs reach maximum diversity in areas within the Coral Triangle (Briggs 2005). Although most of these taxa occupy shallow marine habitats, coral reefs are sometimes of secondary importance, as seen in the distributions of mangroves (Ricklefs et al. 1993; Hogarth 1999; Groombridge and Jenkins 2002) and seagrass (Spalding et al. 2003) which also have highest diversity within the Coral Triangle. Even non-reef-building corals, which have none of the physiological restrictions of zooxanthellate species, have a centre of global diversity within the Coral Triangle (Cairns 2007). These diversity maxima of fauna and flora, especially those not associated with reefs, are only seen in areas large enough to contain an extreme diversity of habitats created by the complex coastlines of island archipelagos.

THE EVOLUTIONARY CAULDRON

So much interest from so many points of view begs the question: why does the Coral Triangle exist? There is no one simple answer. There are several explanations which will now be described.

A. Geological inheritance

Two aspects of the geological history of the Coral Triangle are relevant:

(1) The southern half of the Coral Triangle has been tectonically unstable as far back as the Eocene (38 million years ago), creating a constantly changing geography leading to repeated environmental perturbations, habitat complexity and (we can only presume) evolutionary changes. The fossil record suggests that the corals of the Coral Triangle are the world's youngest – less than half the mean age of their Caribbean counterparts. These relatively young genera either evolved in the region of the Coral Triangle or have survived there since going extinct elsewhere (Fig. 6) (Stehli and Wells 1971; Veron 1995).

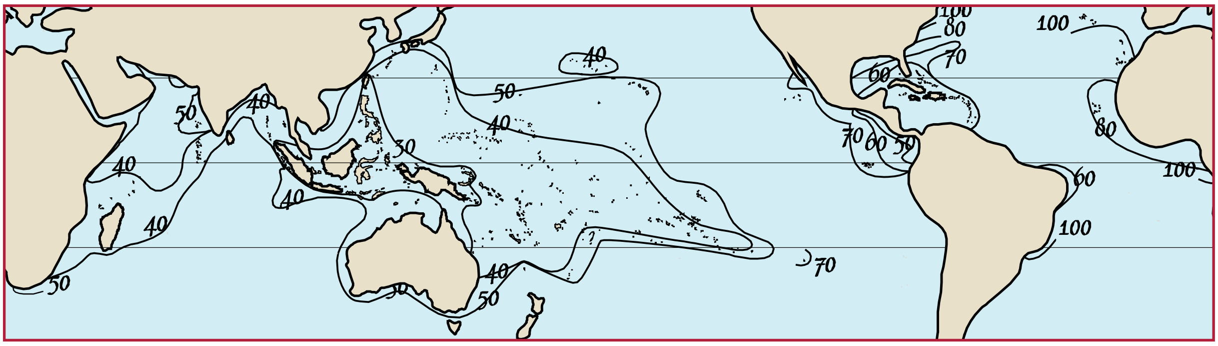


Fig. 6 Contours showing the average age of now-living reef coral genera (in millions of years). This pattern is due to the Indo-Pacific inheriting most genera of the ancient Tethys Sea (an ancient sea that existed between the continents of Gondwana and Laurasia during the Mesozoic era) and also having many other genera found nowhere else. Reefs enclosed by the 30 million year contour indicate the area where the most recent evolution took place (after Veron, 1995).

(2) However important plate tectonic movements were to ocean circulation patterns of the distant past, they are small when compared with the impacts of sea-level changes during the Pleistocene. At least eight times during the last two million years the shorelines of the Coral Triangle region have alternated between those shown in Fig. 7. All reefs (which cannot be viewed at this scale) were repeatedly aerially exposed, yet deep water remained in close proximity. The Coral Triangle is thus characterised by complex island shorelines creating diverse habitats and adjacent deep (>150 m) ocean. This created conditions for minimal dislocation, where coral species could exist, during times of rapid sea-level change.

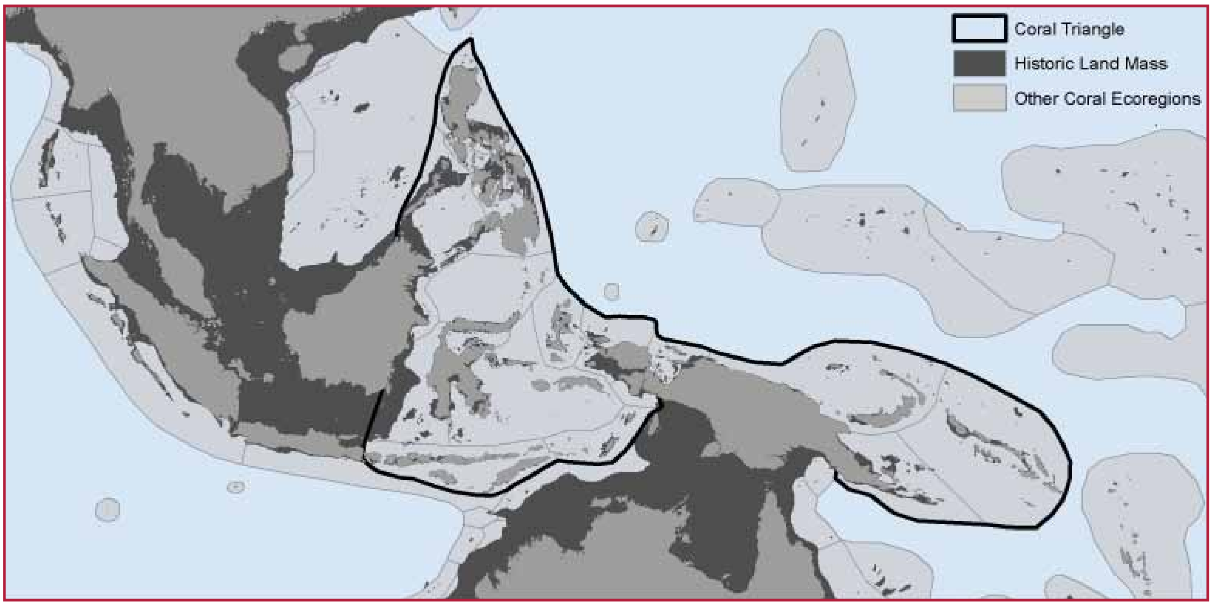


Fig. 7 At least eight times during the last two million years the shorelines of the Coral Triangle region alternated between those shown here (existing land masses, and the existing land masses plus darkest grey areas).

B. Dispersion

Dispersion also attempts to explain the high biodiversity of this region by looking to the oceanographic conditions that characterise the Coral Triangle. The key parts of this hypothesis are as follows:

(1) The Coral Triangle acts as a 'catch-all' for larvae moving towards the region, entrained in both the South Equatorial Current and the North Equatorial Current (Jokiel and Martinelli 1992; Veron 1995).

(2) As also seen in Figures 3 and 8, dispersion occurs away from the Coral Triangle so that, at progressively increasing distance, species attenuate (latitudinally) according to ocean temperature (a) northward to mainland Japan, dispersed by the Kuroshio Current, (b) southward along the west Australian coast, dispersed by the Indonesian Through-flow and the Leeuwin Current and (c) southward along the east Australian coast, dispersed by the East Australian Current (Wells 1955; Veron 1995). This suggests that the Coral Triangle is the most diverse part of this whole central Indo-Pacific simply because all other regions have reduced (attenuated) species richness away from the region.

(3) Complex eddies created by the Indonesian Through-flow (Gordon and Fine 1996b) drives genetic mixing which constantly changes with wind, season and (over geological time) sea level. Genetic mixing of this nature creates genetic heterogeneity through vicariance (see below); it also drives reticulate evolution (see below).

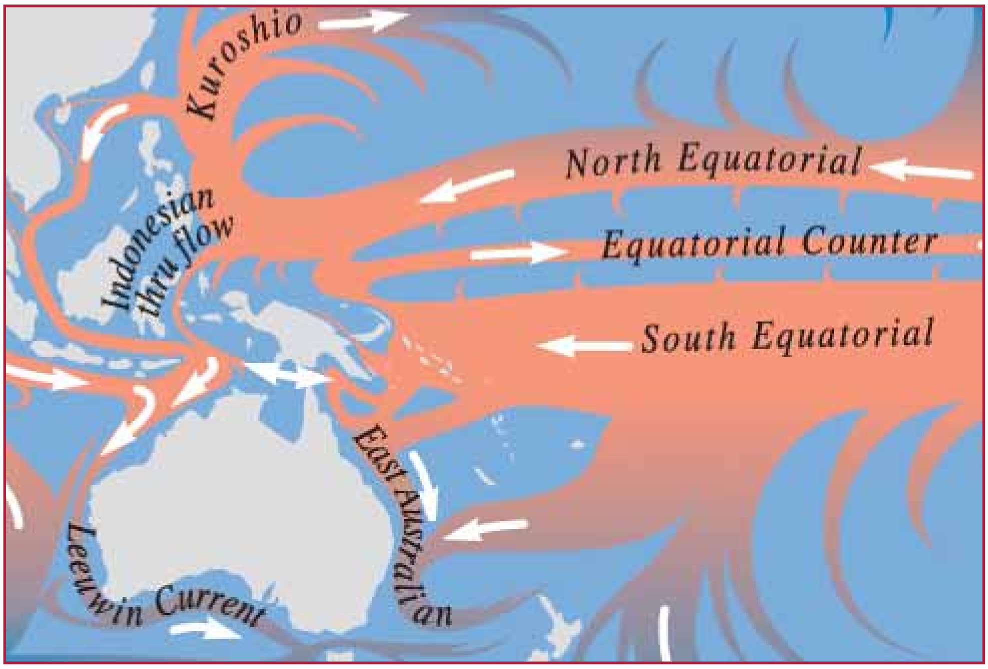


Fig. 8 Major ocean currents flowing towards, and away from, the Coral Triangle (after Veron, 2000).

C. Biographic patterns

The boundaries of the Coral Triangle are defined based on patterns of biodiversity of corals and reef associated organisms, particularly fishes and other invertebrates (Green and Mous 2008, Allen 2007, Veron et al., *submitted*). These boundaries are not intended to provide new biogeographic insights, and the Coral Triangle comprises portions of two biogeographic regions based on corals: the Indonesian-Philippines Region and the Far South-western Pacific Region (Veron 1995, Green and Mous 2008).

Here we focus on the way that biodiversity reflects biogeographic patterns and the environments that created those patterns:

(1) Diversity may be the result of (a) a high level of endemism (locally restricted species) (b) the overlap in the ranges of species with wide ranges. Importantly, the first category contributes only 2.5% of the coral diversity of the Coral Triangle (Veron, et al. unpublished). The biodiversity of corals is therefore due to the overlap of species ranges, ranges which extend eastwards into the Pacific and westwards into the Indian Ocean. Endemism becomes relatively more important with coral reef fishes (Allen and Gillooly 2006) and other taxa in which species longevity is less than that of corals or which have a lesser capacity for long distance dispersal. For coral reef fishes, Coral Triangle countries have some of the highest numbers of endemic reef fish species in the world, particularly Indonesia, Philippines and Papua New Guinea. 8% (225) of coral reef fish species in the Coral Triangle are endemic (Allen 2007, unpublished data).

(2) Ocean temperatures of the Coral Triangle are commonly near the thermal cap of 31ºC (Kleypas and Lough 2008). This temperature, or maxima close to it, is commonly maintained for months during the summer of much of the Coral Triangle. It is a well-established maxim of biogeography (‘Rapoport’s Rule’) that the mean latitudinal range of major taxa increases with increasing latitude (Stevens 1989). This is another way of saying that increasing latitude is correlated with increasing environmental tolerance. Perhaps this is less well established for marine life (Clarke 1992), but it does suggest that temperature tolerance is least limiting at equatorial latitudes. Abnormal extremes of high temperature in recent decades are another matter because they are beyond the evolutionary experience of most species (Veron 2008).

D. Evolution

In linking diverse scientific disciplines including taxonomy, biogeography and genetics, the subject of evolution has led to several general theories, two of which have special relevance to marine biodiversity, biogeography and (therefore) the Coral Triangle.

Darwin’s Centres of Origin Darwin (1859) proposed that dispersion was primarily driven by the evolution of new species through natural selection, a process where older and less competitive species become displaced from their place of origin to more distant places by fitter and more competitive descendant species.

Darwin’s Centres of Origin theory, or refinements of it, dominated all marine biogeographical thinking until the theory of continental drift appeared to make a fundamental aspect of it – geographic centres – untenable (Briggs 1984). Interest in this theory, at least as far as corals are concerned, is historical for there are no identifiable centres of origin, only centres of diversity primarily created by overlapping species ranges.

Vicariance Once heralded as the theory that puts an end to Darwinism (McCoy and Heck 1976), vicariance evolutionary theory proposes that, if one or more barriers forms across a species' distribution, the divided population might diverge in time forming two or more distinct populations. If these remain reproductively isolated after the barriers are removed, then they may exist as two or more distinct species. This process on a larger scale leads to patterns of species that have no centre of origin. There is no requirement for dispersion to occur.

Vicariance is the forerunner of the theory of reticulate evolution. Vicariance may indeed have relevance to many genetic processes, however it is a concept that leads to unending exponential increase in species numbers and lacks relevance to most marine taxa that have great powers of long distance dispersal. Furthermore it necessitates be that species be considered genetically isolated.

Reticulate Evolution This is arguably the main mechanism of evolutionary change in most life, especially marine life. It recognises (a) that oceanic currents are both genetic barriers (as in vicariance) and paths of genetic connectivity, (b) that 'species' fuse as well as divide in time and space, (c) that species are not genetically isolated units and (d) that evolution is driven by the physical environment (ocean currents) rather than biological mechanisms (competition for survival)(Veron 2002). Furthermore, reticulate evolution does not deny the existence of Darwinian evolution which could become uppermost were genetic mixing to become sufficiently weak to isolate gene pools. This would allow evolution to occur through biological selection.

Conditions which promote reticulate evolution are at a maximum in the Coral Triangle because of habitat diversity and the ever-changing complexity of ocean surface currents.

SUMMARY

The diversity of the Coral Triangle has no single explanation. Plate tectonics created the biogeographic template for the region; one of complex island coastlines and extreme habitat heterogeneity. Patterns of dispersion, mediated by ocean currents, have formed sequences of attenuation away from the equator leaving the Coral Triangle with the region's highest biodiversity. Many environmental parameters, especially ocean currents and temperature, underpin this pattern. Evolutionary patterns, the genetic outcomes of environmental drivers, show why the Coral Triangle is a centre of biodiversity, but not of evolution.

CHAPTER 2

THE GEOGRAPHY, BIOGEOGRAPHY AND ECOSYSTEMS OF THE CORAL TRIANGLE

The Coral Triangle includes all or part of six countries in Southeast Asia and Melanesia: Indonesia, Philippines, Malaysia (Sabah), Timor-Leste, Papua New Guinea, and the Solomon Islands (Fig. 1). The total area of the Coral Triangle is 6.8 million km^2, consisting of 5.4 million km^2 of ocean and 1.4 million km^2 of land. Most marine areas are deep (4.6 million km^2), with shallow coastal shelves (less than 200m deep) occupying approximately 840,000 km^2 (Green and Mous 2008; TNC 2009d)

The Coral Triangle also comprises over 18,500 islands, of which only a few thousand are inhabited. This geography dictates an enormous significance of coastal processes within the region, with up to 132,000 km of coastline (NB this estimate is higher than Green and Mous 2008, TNC 2009a who have updated the CIA 2008 estimates with careful satellite measurements) lining terrestrial areas that represent only 15% of the total territorial claims of the six Coral Triangle countries. Activities on land are by definition connected to those occurring within coastal waters, with only the centre of larger islands such as New Guinea being isolated to any real extent from the influence of the sea, and vice versa.

The Coral Triangle lies between the Pacific Ocean and Indian Ocean, and two continents (Asia and Australia). This unique geographical position means that the Coral Triangle region is influenced by major currents that flow from the Pacific to Indian Ocean (part of the "Indonesian Flow-through"), the strength and direction is strongly dependent on seasonal and annual climate. These currents have great influence on the distribution of marine fauna, across the Coral Triangle. These currents also play a major influence in the world's climate system through their influence on the balancing of temperature and salinity between the Pacific and Indian Oceans (**Murray** and **Ariel 1988**; Gordon and Fine 1996a; Gordon et al. 1999).

The climate of the Coral Triangle region is typically hot and humid all year round, with a large annual rainfall (CIA 2008). Seasonal oscillations are dominated by a wet and a dry season, which are driven ultimately by the position and activity of the Northeast monsoon. Annual rainfall ranges between 2000 and 6000 mm per year, with the wet season lasting from November to March for the southern regions and from June to September in the Philippines. All countries within the Coral Triangle have mountains running down the spine of their larger islands, with the highest point being Puncak Jaya (4884 m) in West Papua, Indonesia. Many of these mountains climb to more than 2000 m above sea level and remain covered with dense forests that are also rich in biological diversity.

The boundaries of the Coral Triangle are defined by the diversity of reef building corals, with similar patterns evident for reef fishes and other invertebrates (see Chapter 1). Within the same boundaries, however, there is unparalleled terrestrial as well as marine biodiversity.

Figure 1. Location of Coral Triangle (Green and Mous 2008). Please use high definition file available at: http://conserveonline.org/workspaces/tnccoraltriangle/documents/coral-triangle-maps

TERRESTRIAL BIODIVERSITY WITH THE CORAL TRIANGLE

The biodiversity of terrestrial ecosystems within the Coral Triangle is enormous and four major biodiversity hotspots (Mittermeier et al. 1998; Myers et al. 2000) are recognized within the Coral Triangle and adjacent areas (Fig 1). The hotspots are defined (CI 2009) as containing more than 1500 species of vascular plants of which 70% or more are threatened (other plant and animal biota tend to correlate with plant biodiversity as discussed in Chapter 1). These regions contain large numbers of endemic plants (45% of all species) and vertebrates (50% of all species), many of which are now threatened by extinction (Table 1, (CI 2009)). Vegetation that houses this tremendous terrestrial biodiversity is poorly protected and is rapidly being eliminated by deforestation for timber products and agriculture. Deforestation over the period from 2000 to 2005 proceeded at a rate between -1.68% and -1.98% per annum across the four biodiversity hotspot regions (CI 2009). As will be discussed later in this chapter, this rapid rate of deforestation and its effect on coastal ecosystems has implications for both terrestrial and marine biodiversity within the Coral Triangle. It is also important to recognize that this assessment of which areas should be classified as biodiversity hotspots is based on the global assessment under one particular set of criteria and expert opinion. Much of Papua New Guinea, for example, contains an enormous and unique biodiversity comparable to other hotspots defined under these criteria, and while it has not included up to this point, it certainly has an excellent chance of gaining recognition as an important biodiversity centre in its own right.

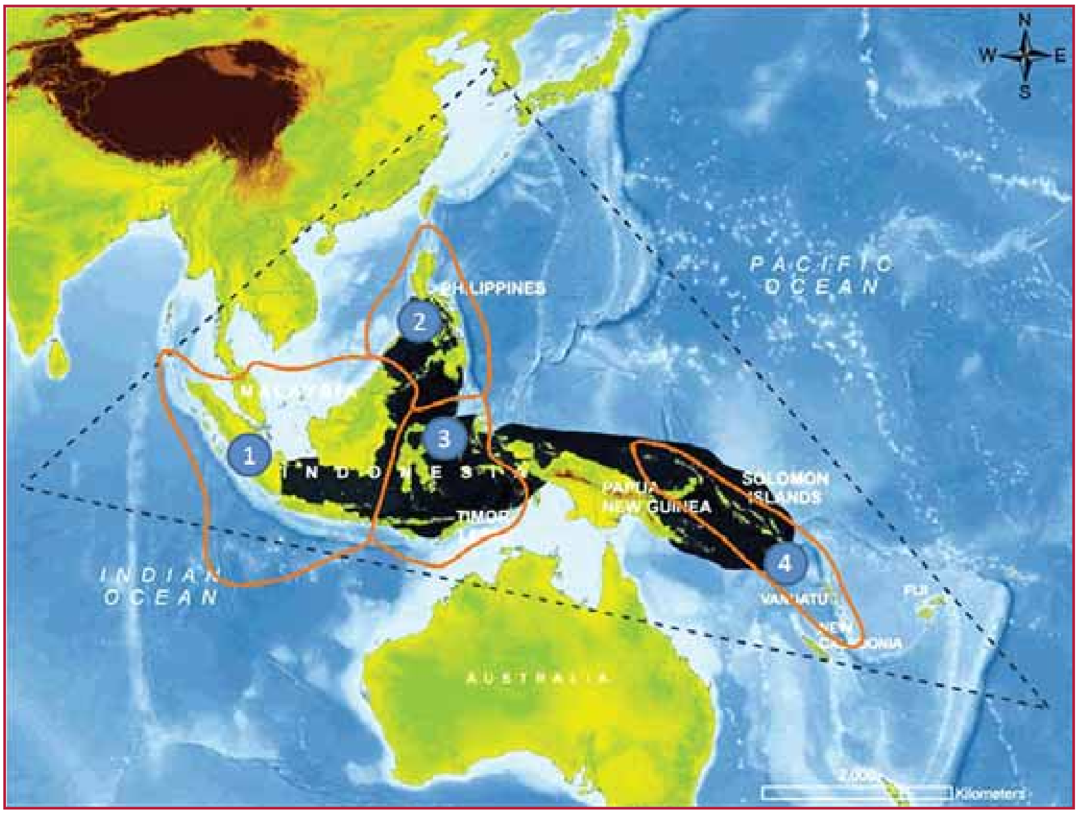


Figure 2. Terrestrial biodiversity hotspots within Coral Triangle region. 1. Sundaland, 2. Philippines, 3. Wallacea and 4. East Melanesian islands. Note: dark areas denote Coral Triangle.

Table 1. Characteristics of biodiversity within the Coral Triangle region.

	East Melanesian islands	Philippines	Wallacea	Sundaland	TOTAL
Hotspot Original Extent (km^2)	99,384	297,179	338,494	1,501,063	2,236,120
Hotspot Vegetation Remaining (km^2)	29,815	20,803	50,774	100,571	201,963
Endemic Plant Species	3,000	6,091	1,500	15,000	25,591
Endemic Threatened Birds	33	56	49	43	181
Endemic Threatened Mammals	20	47	44	60	171
Endemic Threatened Amphibians	5	48	7	59	119
Extinct Species	6	2	3	4	15
Percentage of endemic terrestrial plants	38	66	15	60	45 (average)
Percentage of endemic terrestrial vertebrates	66	47	46	39	50 (average)
Human Population Density (people/km^2)	13	273	81	153	98 (average)
Area Protected (km^2)	5,677	32,404	24,387	179,723	242,191
Area Protected (km^2) in Categories I-IV*	0	18,060	19,702	77,408	115,170
Deforestation rate (2000-2005, % per year)	-1.68	-1.98	-1.91	-1.91	

A. Sundaland hotspot

The Sundaland hotspot overlaps with the western portion of the Coral Triangle and includes the western half of the Indo-Malayan archipelago. It is dominated by some of the largest islands in the world, Borneo (725,000 km^2) and Sumatra (427,000 km^2), which include tall mountain ranges and fertile soils that are dominated by over 20 active volcanoes. Key habitats within this region include lowland rainforests, mangroves and peat swamps, with montane forests at higher elevations which eventually develop into less dense sub-alpine forests. Sundaland is one of the richest hotspots for terrestrial life, with 25,000 species of vascular plants (60% of endemic) including 3000 species of trees and 2000 species of orchids. Birds (770 species, 18.5% endemic), mammals (170, 45.5% endemic), reptiles (450 species, 53.8% endemic) and amphibians (240 species, 80.3% endemic) occupy the rich forests of this region. Flagship species include the Orangutan, Proboscis monkey, as well as the Javanese and Sumatran rhinos.

B. Philippines hotspot

Over 7100 islands dominate the Philippine archipelago, which originally was covered in rainforest prior to the extensive deforestation that has occurred over the past century. The country was originally blanketed by lowland rainforests dominated by hardwood trees of the family Dipterocarpaceae. Like with many locations within the Coral Triangle, montane and mossy forest dominate the higher altitude areas, giving way to scrubby sub alpine forests at the higher elevations and before forest gives way to open treeless areas at the tops of the mountains. The Philippine hotspot used to be extensive but is now limited to less than 10% of the original vegetation. As with Sundaland, many of the plants and animals in this region are endemic (CI 2009). 65% of over 9253 species of plants are endemic. Similar percentages hold for Philippine birds (535 species, 34.8%), mammals (167 species, 61.1%), reptiles (237 species, 67.5%) and amphibians (89 species, 85.4% endemic).

C. Wallacea hotspot

As described in Chapter 1, Alfred Russel Wallace, first recognised the distinct biogeographic boundary between Java, Borneo and the Philippines, and Sulawesi, Papua New Guinea and Australia. Wallace noticed that Asiatic species such as monkeys, rhinos and elephants dominated areas to the west of what is now called the Wallace Line (Wallace 1869), while more Australian/Papua and New Guinea species such as marsupials (e.g. kangaroos and possums) dominated the eastern regions. The separation of fauna and flora is echoed in the distribution of many other taxonomic groups across the region.

Wallacea is primarily an Australian/PNG associated terrestrial hotspot, taking in Sulawesi, much of Indonesia and Timor-Leste but excluding West Papua, which is highly species-diverse but apparently not regarded as being critically threatened according to the definition of biodiversity hotspots. The animals and plants of Wallacea are highly varied and many islands have distinct communities.
The vegetation vary significantly across the hotspot, with Sulawesi and the Moluccas being mostly dominated by tropical rainforest, while other islands such as those in the Lesser Sunda group only having rainforest along mountain slopes and in areas that receive rain. Other areas, typical of the more Australasian flora, are composed of Savannah Woodlands including eucalyptus forests. 15% of over 10,000 species of plants are endemic (CI 2009). Wallacea wildlife shows higher levels of endemism: birds (647 species, 40.5 %), mammals (222 species, 57.2%), reptiles (221 species, 44.6%) and amphibians (48 species, 20% endemic). One of the flagship species for Wallacea is the Komodo dragon (*Varanus komodoensis*) from Komodo, Rinca, Flores, and Gili Motang islands in Indonesia, which is the largest living lizard species.

D. East Melanesian islands hotspot

The comprehensive description of biodiversity hotspots by Myers and colleagues (Myers 1990; Myers et al. 2000) did include the East Melanesian Islands. Subsequent analysis revealed the enormous diversity and unique fauna and flora of this region, and it was added to the list of biodiversity hotspots by Conservation International. It has also received listing as one of 200 outstanding ecoregions by World Wildlife Fund (WWF) and joined the original Global 200 designation of ecoregions (Olson and Dinerstein 1998; Olson et al. 2001). The hotspot is closely associated with Papua New Guinea although it does not include it, and is defined by the rich and unique biodiversity associated with the Solomons-Vanuatu-Bismarck moist forests.

The East Melanesian Islands hotspot is one of the most geographically complicated areas and involves a diverse set of islands of various ages and histories. Many of these islands are extremely mountainous, with peaks that exceed 2000 m. Habitats within this hotspot include mangrove forests, freshwater swamps, coastal vegetation, lowland rainforests, seasonally dry forests and grasslands and montane forests. Most of these habitats are species poor by comparison with New Guinea. As with other terrestrial hotspots associated with the Coral Triangle, there is a high degree of endemism among its plants and animals. Most are diverse and endemic (CI 2009): birds (360 species, 41.4 %), mammals (86 species, 45.3 %), reptiles (117 species, 46.2%) and amphibians (42 species, 90.5% endemic). A great deal of diversity (8,000 species) and endemism (50%) occurs within the plants. Signature organisms of the East Melanesian Islands hotspot include tree kangaroos, birds of paradise, echidnas, bowerbirds and gliding possums.

COASTAL MARINE ECOSYSTEMS WITHIN THE CORAL TRIANGLE

The Coral Triangle includes marine environments that are exceptionally rich and unrivalled anywhere else (Roberts et al. 2002). While the Coral Triangle has been defined as the area where reefs include more than 500 coral species in each ecoregion, it is also the epicentre of biodiversity for a vast array of other marine organisms including reef fishes, mangroves, seagrasses, algae, molluscs, crustaceans and many other organisms (Roberts et al. 2002 ; Hoeksema 2007; Allen 2008).

Putting the human value of these ecosystems aside, the Coral Triangle has enormous importance in terms of the conservation of marine life globally, since it comprises the highest marine diversity on earth and a large number of endemic species (Chapter 1).

Understanding marine ecosystems of the Coral Triangle has been hampered by a lack of information about their composition and distribution (Roberts et al. 2002 ; Spalding et al. 2007). This effort has been complicated by the sheer diversity of habitats, which of course underpins the mega-biodiversity of the region. These factors have meant that the identification and mapping of particular marine ecoregions has lagged behind that which has been done for terrestrial ecosystems in the region.

In the last few years, regional governments, NGOs, and other partners have been systematically addressing this need for more information by conducting as series of rapid ecological assessments of coral reefs and associated ecosystems in the Coral Triangle (e.g. (Donnelly et al. 2003; Green et al. 2006). These surveys have provided the basis for a more detailed analysis of marine ecosystems of the Coral Triangle in recent years.

Biogeographic classifications represent an important step in defining the boundaries to key components of ecosystems, and are therefore critical for research and conservation efforts. They are also required for application of international conventions such as the Convention on Biological Diversity and the Ramsar Convention.

Recent efforts by Green and Mous (2008) have established a widely accepted classification which includes 11 ecoregions and 32 functional seascapes in the Coral Triangle (Figures 4 and 5). These ecoregions were used by Spalding et al (2007) who systematically applied biogeographic tools to establish a nested system of 12 realms, 62 provinces, and 232 ecoregions for the world's coastal and shelf areas. The Coral Triangle ecoregions were spread among two biogeographic provinces: Western Coral Triangle and Eastern Coral Triangle (Spalding et al 2007). These biogeographic regions differ from those of Veron 1995 (coral biogeographic regions and ecoregions: see Chapter 1), because they take into account on a wider range of biological and physical characteristics (i.e. beyond just corals).

Within each of the ecoregions in the Coral Triangle, there are a number of centrally important coastal ecosystems (coral reefs, mangroves, seagrass and salt marsh) which interact ecologically to underpin Coral Triangle biodiversity and human dependents. Like reef-building corals and reef fishes (Chapter 1), the highest concentration of mangrove and seagrass species occurs within the vicinity of the Coral Triangle (Figure 6). In addition to the ecosystems that these organisms build, a series of rocky shore and soft bottom habitats such as sandy beaches and mudflats also develop in association. These high values when coupled with the fact that most people live in the coastal regions of these countries emphasise the major role that these resources play in human well-being.

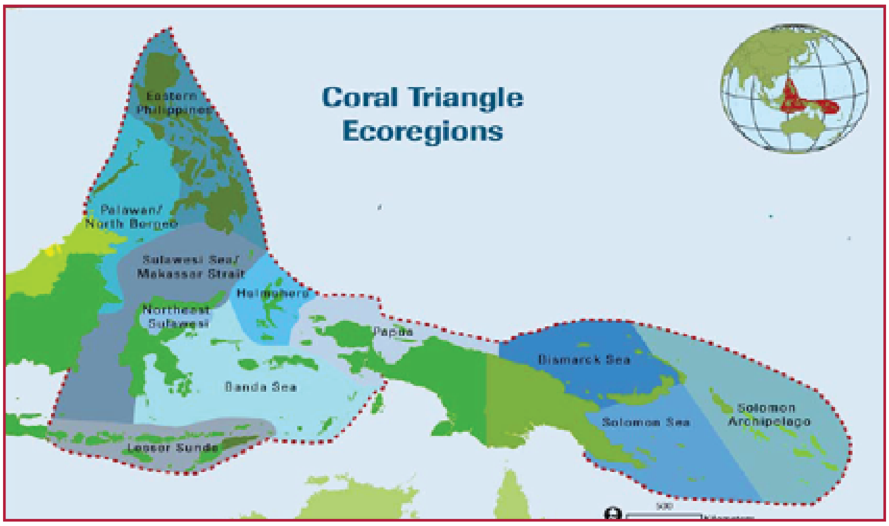


Figure 4. Ecoregions recognized within that Coral Triangle (Green and Mous 2008)

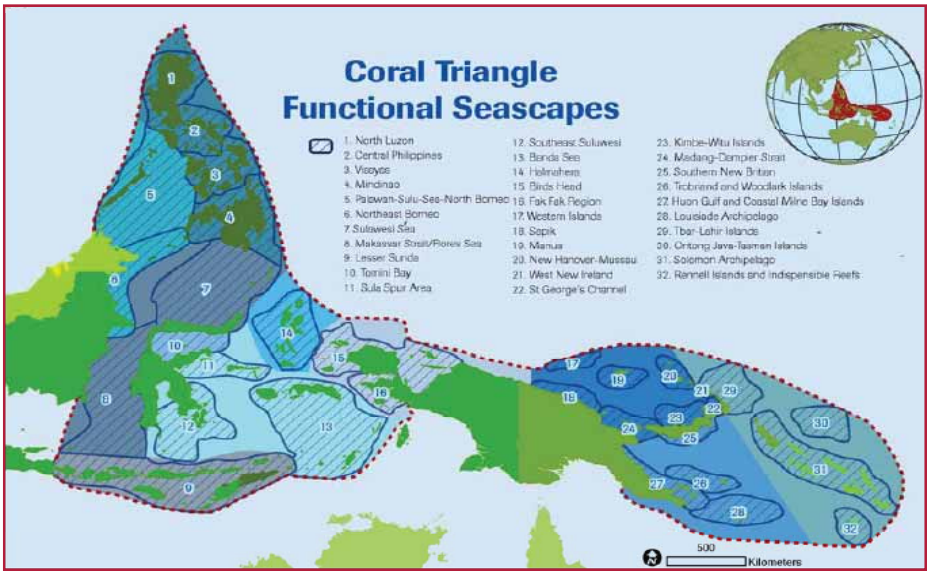


Figure 5. Functional seascapes defined within the Coral Triangle (Green and Mous 2008)

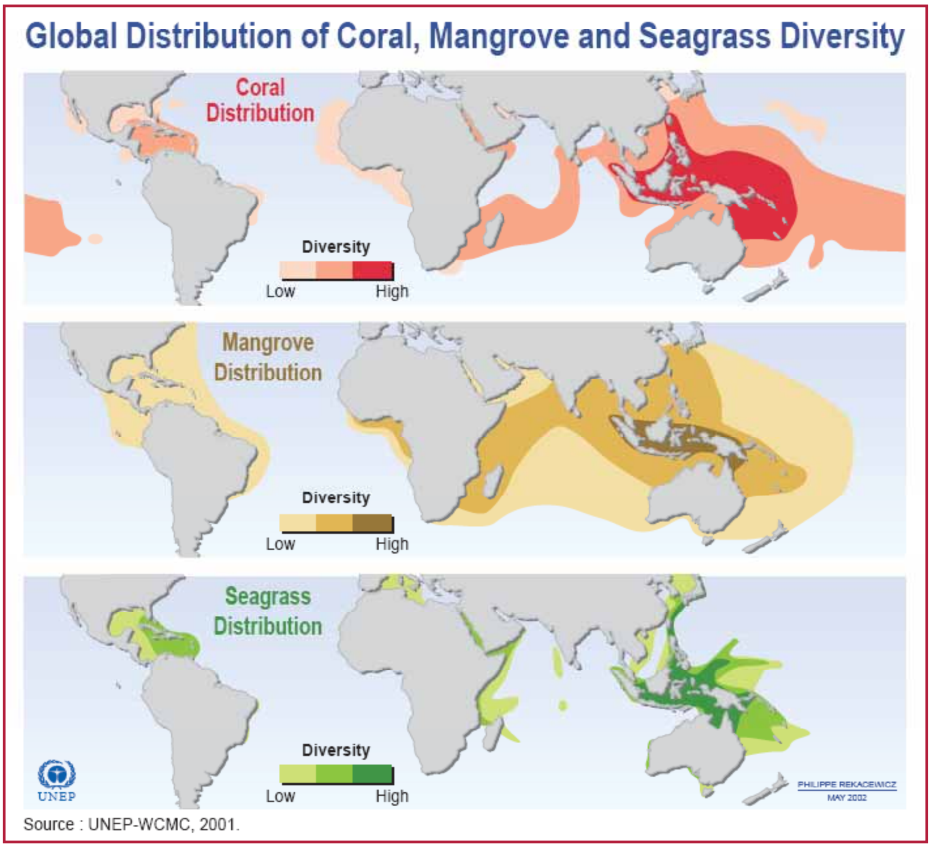


Figure 6. Similar to corals, the region of greatest mangrove diversity is in Southeast Asia, particularly around the Indonesian Archipelago (Burke et al., 2001). There are three distinct areas of seagrass diversity in the Pacific region: the Indo-Pacific (areas around Indonesia, Malaysia, and Papua New Guinea), the seas around Japan, and southwest Australia (Spalding et al., 2002). This graphic illustrates the distribution and biodiversity (low, medium and high diversity) of corals, mangroves and seagrass in the world's coastal and marine areas (http://www.unep.org/dewa/assessments/ecosystems/water/vitalw).

E. Coral reef ecosystems

Coral reefs are found in both temperature and tropical waters, extending down to depths of 100 m in those areas where waters are clearest (Kleypas et al. 1999a). Whereas high latitude coral reefs do not build extensive calcium carbonate structures, reefs such as those found within the Coral Triangle build significant carbonate structures which form the habitat for 1 - 9 million species of other organisms (Reaka-Kudla 1997,2001). Coral reefs like mangroves and seagrass meadows are at their most diverse within the Coral Triangle (Veron and Stafford-Smith 2000; Veron et al. 2009). Reefs within the Coral Triangle contain 605 of the approximately 798 coral species (Veron et al. 2009), and literally hundreds of thousands of other species, making them the most biologically diverse cosystems in the ocean, and rivals of rainforests in terms of biological diversity and complexity (Reaka-Kudla 1997).

The corals that build reefs are also symbiotic with tiny dinoflagellate algae (zooxanthellae) from the genus *Symbiodinium* (Trench 1979). Living within the gastrodermal (endodermal) cells of the coral, single celled dinoflagellates photosynthesize and release over 95% of the captured energy to the host (Muscatine 1990). As a result, corals and their symbionts are extremely efficient and are able to create the enormous amounts of energy required to build the limestone-like structures typical of carbonate coral reefs. Without this superstructure, the topology of reefs would be greatly diminished, and the habitat for the bewildering diversity of coral reef organisms unavailable.

The role of reef-building corals as the key framework builders on coral reefs is assisted by a range of other organisms, including coralline algae which act to cement the dead skeletons of corals together to form reef matrix. Other organisms such as molluscs, crustaceans and single-celled foraminifera, whose skeletons build up over time, contribute to the formation of the reef. The process of calcification on coral reefs is balanced by physical and biological erosion, which acts to break down and remove the calcium carbonate laid down by corals and other reef calcifiers (Kleypas et al. 1999a). Waves, through sheer physical force, often destroy corals and even parts of the reef infrastructure into pieces. Organisms such as grazing fish and sea urchins grind away at deposited calcium carbonate from the outside, while boring worms, bivalves and sponges slowly destroyed the calcium carbonate within skeletons. On a healthy reef, calcification occurs at a rate that balances the forces of erosion, leading to the longevity of reef structures. If erosion exceeds calcification, coral reefs will crumble over the years and decades, and eventually disappear as significant coastal structures (Kleypas et al. 1999a; Hoegh-Guldberg et al. 2007; Manzello et al. 2008).

The intricate relationship between corals and their symbiotic dinoflagellates avoids the diluting effects of the water column and allows the recycling of nutrients between primary producer and consumer (Muscatine and Porter 1977). As a result, coral reefs are highly productive despite the low abundance of nutrients in tropical oceans, which would normally limit primary production. Nutrient cycling is also a major theme within coral reef ecosystems, with highly efficient capture and regeneration mechanisms for nutrients within the sandy habitats and lagoons associated with coral reefs (Muscatine and Porter 1977). These habitats are often also the site of nutrient generation by cyanobacteria, which fix atmospheric nitrogen to create dissolved inorganic nitrogen that subsequently enters the reef ecosystem (Capone 2001; Vitousek et al. 2002).

Fish are one of the most prominent components of the coral reefs within the Coral Triangle (Carpenter and Springer 2005; Allen and Gillooly 2006). Almost 2230 species of reef fish live within this region, the highest diversity for any region worldwide (Allen 2007, unpublished data). Coral reef fishes are critical to the health of coral reefs, and perform numerous vital roles within coral reef ecosystems. Grazing of benthic algae (seaweeds), for example, appears to be critical for maintaining the balance between reef building corals and fleshy algae. When grazing fishes are eliminated, coral reefs can shift from being coral dominated, to having seaweed (macroalgae) as the predominant benthic organism (Hughes 1994; Jackson et al. 2001; Hughes et al. 2007; Mumby et al. 2007). Predatory fishes are also suspected to play key roles in maintaining the ecological balance between other organisms such as coral-eating star (*Acanthaster planci*) and corals (Dulvy et al. 2004). Combined with other perturbations such as increased nutrients from coastal run-off, the removal of large predatory fish may lead to significant shifts in the ecological balance of species such as starfish (Brodie et al. 2005a).

Coral reefs are often intimately associated with seagrass meadows and mangrove forests, often forming the ramparts that protect these two ecosystems from the power of ocean waves. Many organisms that live on coral reefs may have their earliest life history stages in seagrass and mangrove areas (Baran and Hambrey 1998; Mumby et al. 2004; Faunce 2006,2008; Nagelkerken and Faunce 2008). Nutrients and energy in the form of detritus from all three ecosystems may pass from one to the other (Kruyt 1994; Marguillier et al. 1997; de la Moriniere et al. 2003). Islands may form as a result of coral reefs, leading to terrestrial habitats that are important for birds and marine reptiles such as turtles and sea snakes.

There is over 100,000 km^2 of coral reefs within the Coral Triangle (Green and Mous 2008; CIA 2009; TNC 2009b), which comprise 30% of the coral reefs of the world (TNC 2009b). These coral reefs are fundamental to human livelihoods within the region and take a variety of forms. Rocky islands and coastlines may be lined with fringing reefs, which grow outward from the intertidal region. These may be extensive, creating large areas of intertidal reef flat. At the opposite extreme, coral reefs may form offshore, creating barrier reefs which are often separated from the mainland or island by a deep lagoon. Within this region, there may be a number of smaller patch reef formations or platform reefs. While these preceding reef types are typical of those found within the Coral Triangle, fewer coral reefs take the form of true atolls that arise when coral reefs grow around volcanic islands that later subside. Notable exceptions are many coral reefs in the South China Sea west of southern Philippines (e.g. the Spratlys), which are true atolls (Alcala 2008).

Two thirds of the 150 million people that live in the Coral Triangle dwell along coastlines and depend heavily on ecosystems such as coral reefs and other coastal ecosystems for their livelihoods (see chapter 5). This dependency is intensified by the extreme poverty that exists within many coastal societies within the Coral Triangle. Coral reef ecosystems in the region provide food through fisheries, trade through the export of reef organisms, employment through tourism and recreation, and coastal protection (Spalding et al. 2001). Coral reefs also have value as a source of genetic diversity, and have in a number of cases, provided new pharmaceuticals and materials for industry (Salm 1994a; Spalding et al. 2001; CI 2008).

Obtaining a precise economic value of coral reefs is complicated for a number of reasons. Firstly, considerable value of coral reefs comes in the form of food obtained through subsistence harvesting by impoverished individuals and families, which does not involve a market value.

Secondly, any valuation of the services provided by coral reefs will necessarily be an underestimate given that services such as protecting coastlines, creating sediments for the beaches and exchanging gases typically are not included in the valuation. Estimates based on economic net benefits, therefore, are underestimates. With this in mind, the annual economic net benefits per km^2 of a healthy coral reef in Southeast Asia ranges from $23,100 to $270,000 arising from coastal protection, fisheries, tourism, recreation and aesthetic values(Burke et al. 2002). An example in the central Philippines is Apo Island Reef (area ca 104 ha), where fish catch ranging from 15 to 20 tons per year has been reported (Alcala et al. 2005) and where approximately 170,000 tourists paying an estimated $700,000 US in user fees visit yearly (data from official records of Department of Environment and Natural Resources made available to A.C. Alcala). A further discussion of the value of reefs can be found in Chapter 3.

F. Mangrove ecosystems

Mangrove ecosystems are made up of a number of trees, shrubs and vines that have evolved (often independently) to live at the saline interface between land and sea. They occupy almost 60,000 km^2 of coastal area within the Coral Triangle countries (Spalding et al. 2001), and are represented by around 50 species of mangroves, which is more than anywhere else in the world making the Coral Triangle also the ‘Mangrove Triangle’ (Spalding et al. 1997). Mangroves have developed a complex set of physiological adaptations which allow them to overcome problems of salinity, anoxia, desiccation and frequent tidal inundation associated with living in the intertidal region. These plants form complex and dynamic ecosystems along the quieter intertidal coastal areas where they stabilise sediments as well as provide habitats for many key fisheries species (Baran and Hambrey 1998; Mumby et al. 2004; Faunce 2006,2008; Nagelkerken and Faunce 2008).

As a result of high nutrients and abundant sunlight, primary productivity in and around mangrove forests is considerable (Alongi 2002b), and there are numerous fisheries focused on estuarine fish and invertebrates such as crab and prawns. In addition to directly stabilising coastlines and providing habitats with rich biodiversity, mangroves (along with seagrass beds) serve as important habitat for fish, with a large number of juvenile estuarine and coral reef fish being found there (Baran and Hambrey 1998; Mumby et al. 2004; Faunce 2006,2008; Nagelkerken and Faunce 2008). Mangroves provide protection from predators and an abundance of food due to their three-dimensional complexity, existence in relatively turbid water and higher productivity (Nagelkerken et al. 2000). The productivity of mangrove forests arises from the enormous amount of energy and nutrients that are assimilated through photosynthesis and stored in their leaves. The eventual leaf litter from these trees feed a detrital-based ecosystem, which often provides the basis for adjacent marine and terrestrial food webs.

Coastal communities use mangroves as a source of fuel for cooking and heating, and as construction material for houses, fences and scaffolding (Walters et al 2008). They are also drawn on for a number of other uses including tannins and resins for leather making and clothing dyes, furniture construction, and for medicine (Bandaranayake 1998). Mangrove forests also support honey making and other non-extractive uses for income generation. Mangrove intertidal areas can be used sustainably for culture of fish and shellfish. Unfortunately, the history of shrimp farming in mangrove habitat has been one of large scale destruction, with culture ponds being a major driver of mangrove loss (Primavera 1997,2005). Mangroves show a propensity to absorb heavy metals and other toxins associated with coastal effluents, play important roles by protecting shorelines from direct wave action and by trapping sediments being carried to sea through estuaries and river mouths (Furukawa et al 1997). This can be particularly critical in many parts of the Coral Triangle where mangroves provide protection for human infrastructure against storm surge and coastal erosion (Spalding et al. 1997).

Mangroves have been impacted heavily by human activities throughout the Coral Triangle despite their importance to ecosystems and people. Mangroves have been cut down to make way for coastal aquaculture and agriculture, including the grazing of livestock along coastal areas. Increasingly, mangrove forests have been affected by the removal of trees for fuel and construction, dredging to make way for harbours and ports, and general coastal development. As result, a third of all mangrove forests worldwide have been lost (Valiela et al. 2001) with 20% being lost in the last 15 years. (FAO 2008).

G. Seagrass communitites

Seagrasses are true flowering plants principally from four plant families (Posidoniaceae, Zosteraceae, Hydrocharitaceae, and Cymodoceaceae) that form dense communities in environments that are characterised by a low wave stress (Green and Short 2003). In these waters, seagrasses form extensive beds or meadows, which may be made up of one or several species. They form extensive and diverse ecosystems throughout the Coral Triangle and are intimately connected to coral reef and mangrove ecosystems through life history as well as the flow of energy and nutrient. Many important fisheries species, for example, have life history stages that spend some or all of their time within seagrass meadows. Other charismatic mega-fauna like dugongs and sea turtles are largely dependent on the presence of healthy seagrass mats. Human impacts likewise connect coral reefs with seagrass beds and mangroves (UNESCO 1983).

The distribution of seagrass meadows within the Coral Triangle although extensive and of clear importance, is largely undocumented, although Fortes provides an overview of the seagrasses of East Asia which includes most of the CT countries (Fortes 1995). More recently, the Philippine National Seagrass Committee (PNSC 2004) provided a country report in the context of the recently concluded UNEP/GEF South China Sea Project: Reversing Environmental Degradation Trends in the South China Sea and Gulf of Thailand (www.unepscs.org). The update of the report in 2008 suggests that seagrass habitats of the country inhabit a total area of 27,282 km^2, mostly on the western side of the country. This figure is roughly the lower limit of the coral reef area in the country. Information about seagrass in Malaysia and Indonesia are also available (UNEP 2004).

More detailed information is available from some of the rapid ecological assessments in the region. For example, Mackenzie et al (2006) completed the first extensive survey of seagrass resources in seven of the nine provinces in the Solomon Islands in 2004. They found 10 species of seagrass, and 6,633 hectares of predominately intertidal and shallow subtidal seagrass meadows. Most (54%) of the seagrass meadows were in Malaita Province, while the other six provinces each included less than 12% of the seagrass meadows. Most seagrasses were found in water less than 10m deep and meadows were monospecific or consisted of multispecies communities, with up to 6 species present at a single location. The dominant species encountered were *Enhalus acoroides* and *Thalassia hemprichii*.

In the Solomon Islands, seagrass distribution appears to be primarily influenced by the degree of wave action(exposure) and nutrient availability, and seagrass habitats can be generally categorised into four broad habitats: estuaries (incl. large shallow lagoons), coastal (incl. fringing reef), deep-water and reef (e.g., barrier or isolated: McKenzie et al 2006). Most seagrass meadows are relatively healthy condition compared to many other regions globally, with only localized impacts. However, high sedimentation/turbidity in coastal waters, primarily the result of logging activities, was identified as a major threat at some locations. Other impacts were similarly localised, and included soil erosion related to coastal agriculture (coconut plantations), sewage discharge (human and agriculture), industrial pollution, port/village infrastructure/dwellings and overfishing.

Seagrasses are important for providing habitat and for their extremely high rates of primary productivity, gas exchange and protection against coastal erosion. The quantity of seagrass carbon available for storage in the sediments represents approximately 0.08 Pg C/yr in the ocean as a whole (or 12% of the total carbon storage in the ocean despite its 1% contribution to the total oceanic production)(Duarte and Cebrian 1996) Despite their importance, seagrass communities are under threat globally (Orth et al. 2006). Seagrass communities face a range of problems that include declining water quality, physical destruction by coastal development and chemical pollution in the form of herbicides and pesticides flowing off agricultural land. These local influences have lead to a contraction of seagrass beds in most parts of the world (Orth et al. 2006). Hence, considering the extent of seagrass in CT countries, their strategic location as the 'ecotone' between coral reefs and mangroves, and their great potential to adapt relatively easily to climate change impacts (Bjork et al. 2008), seagrasses may play a substantial role in mitigating and adapting coastal ecosystems and communities to the adverse effects of climate and other environmental changes.

SUMMARY

An extraordinary proportion of world's terrestrial and marine species are found within the Coral Triangle, which is named for being home to 76% of all coral species found worldwide. Four terrestrial biodiversity hotspots cover most of the Coral Triangle, and 11 ecoregions and 32 functional seascapes recognized within its marine environments. Whether it be corals, fish, mangroves or seagrass, the greatest number of species worldwide dwells within the waters of the Coral Triangle. For this reason, the Coral Triangle is of huge significance to the conservation of tropical life forms across the planet. In addition to the extraordinary biodiversity of the Coral Triangle, 150 million people live within the six countries that make up the Coral Triangle, 100 million of which are highly dependent on coastal ecosystems. These people predominantly live on islands and in close proximity to coastal ecosystems which supply food and resources. Three coastal ecosystems stand out as being particularly important to the well-being of coral Triangle people. Coral reefs, mangroves and seagrass beds occupy several hundred thousand km^2 of seafloor, providing a range of ecosystem services that include food, fuel, income, housing materials and coastal protection. The ecological services and cultural contributions provided by these ecosystems are crucial to the sustainability of coastal societies within the Coral Triangle, and are discussed in subsequent chapters.

The Coral Triangle is characterised by large numbers of people that live on 132,800 km of coastline within the region (CIA 2009). These people and their communities are highly dependent on the food resources of this region, which largely stem from marine and coastal ecosystems such as coral reefs, mangroves and seagrass (Moberg and Folke 1999; McLean and Tsyban 2001; WRI 2005). These coastal ecosystems also provide a series of other services that include coastal protection, flood mitigation, and water quality maintenance. Coastal ecosystems may also have significant cultural and spiritual significance. The benefits derived from coastal ecosystems are extended by the exploitation of other natural resources such as offshore tuna fishing, timber, minerals and tourism (WRI 2005).

In this chapter, the linkages between human communities and coastal ecosystems are explored in the context of the Coral Triangle. While broad details of these linkages are presented here, each of these linkages is described in context and in greater detail for each individual Coral Triangle country in chapter 6.

COASTAL FISHING

Coastal resources are critical to the well-being of the largely coastal dwelling people of the Coral Triangle. Much of the activity surrounding the use of this resource occurs in shallow water near-shore habitats where fish and invertebrates are trapped, netted or speared. Much of this fishery occurs through non-market channels which do not register in the mainstream economy. In this respect, it is estimated that 95% of the total catch fishery fleet production in Indonesia and traditionally more than 50% in the Philippines may consist of small-scale and largely undocumented fisheries. Tens of millions of people in the Coral Triangle directly depend on the goods provided by coral reefs for their food and livelihood. Many coastal communities engage in fishing, although its importance relative to other occupations can vary considerably across different parts of the Coral Triangle countries. An example of the variability between households in terms of the extent of fishing in Papua New Guinea and Indonesia is shown in figure 1.

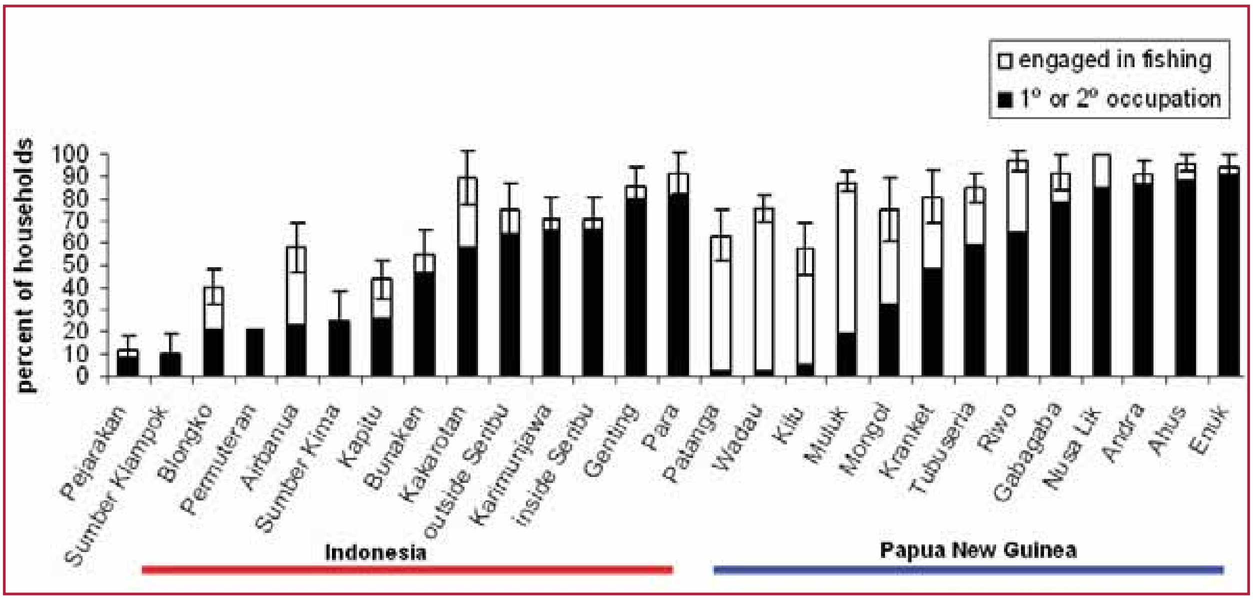


Figure 1. Percentage of households from a survey of 27 coastal communities in Papua New Guinea and Indonesia that engage in fishing (white bars) and the proportion of those households that rank fishing as a primary or secondary occupation (black bars, referred to as 'dependent'). Source: J. Cinner, James Cook University, unpublished data.

Demand for fish as a food source and various other products from the sea are driven by population growth, human migration towards coastal areas and rising incomes and hence demand for luxury seafood (McLean and Tsyban 2001). Fish consumption in many island states is remarkably high with rural communities generally having a high dependence on subsistence fishing, which is vital for well-being, but the high dependence on fish should not be interpreted as a lack of development but rather it is an indication of ‘subsistence affluence’ (Bell et al. 2009). The extent to which fisheries can provide for future needs varies across the Coral Triangle and associated Pacific regions. For example, Bell and colleagues found that while the coastal fisheries production of Pacific Island Countries and Territories such as New Caledonia, Marshall Islands, Palau, Cook Islands, Tokelau and Pitcairn Island is expected to meet the future needs of the resident population, other countries such as PNG and Solomon Islands are not expected to be able to supply the fish required for food security into the future (Bell et al. 2009). The drivers for these differences between nations include population growth and development, as well as other factors such as travel time to and from fishing grounds, fishing access rights and external factors such as fuel prices. Given the uncertainty around factors such as the latter, these predictions have large uncertainties associated with them. Other factors such as the impact of climate change on stocks and how factors such as the incidence of ciguatera varies, will also influence whether or not these conclusions hold. Overall, however, these trends and drivers suggest that regional, national and local habitat and fisheries management will be vital for food security. Bell et. al (2009) concluded that in order to maintain fish supplies for 2030 there has to be access to the oceanic (e.g. tuna), coastal and freshwater fisheries, and suitable conditions for the development of aquaculture.

ECONOMIC VALUE OF CORAL TRIANGLE FISHERIES

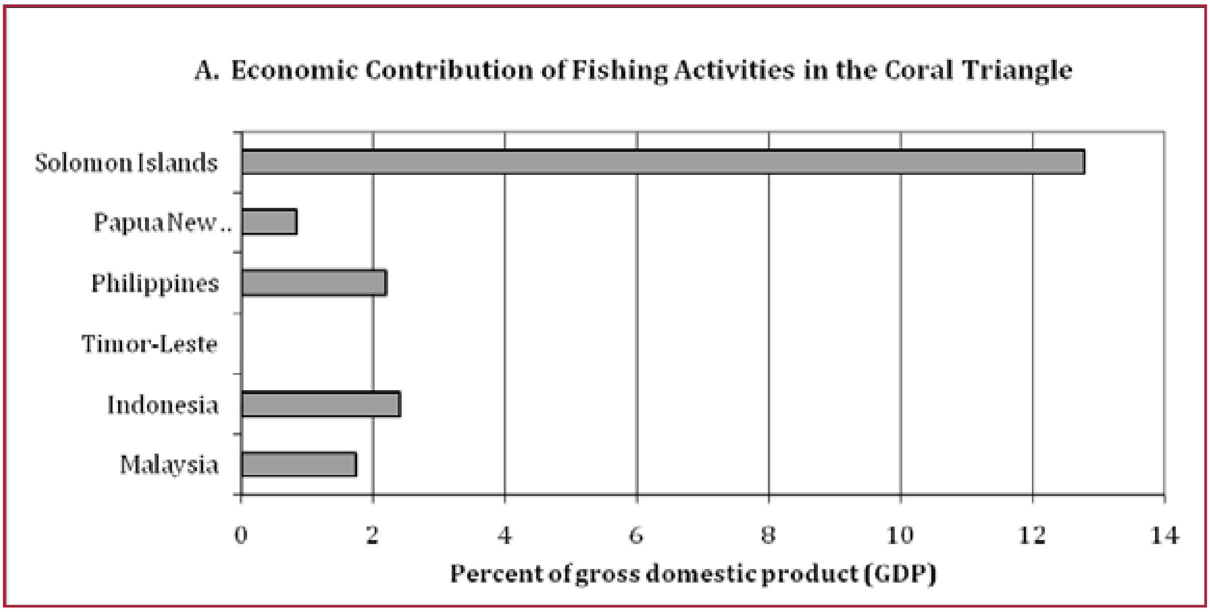
The Coral Triangle is home to 150 million inhabitants, approximately two thirds of whom are directly dependent on the coastal and marine resources for their livelihoods (see chapter 5 for the basis of this estimate). Commercial fisheries are an important sector within the economies of the six Coral Triangle countries. This section explores the economic contribution of these industries, and the intra- and inter-regional dynamics. Overall, fishing activities contribute between 1.4% (Papua New Guinea) and 12.8% (Solomon Islands) to the annual gross domestic product (GDP) of Coral Triangle countries. In terms of jobs supported by the fisheries sector, between 10,000 (Solomon Islands) and 7.3 million (Indonesia) people were employed annually by the fisheries sector, either directly or indirectly. Though this very wide range in employment may be more a reflection of limited data availability rather than actual jobs supported, it illustrates the potential contribution of marine ecosystems to local livelihoods.

The existing fishery data and information collection system in the region reflects traditional monitoring systems that focus on total catch and value. To support development and implementation of sound policies and sustainable management, more appropriate indicators are required. Small scale commercial and artisanal fisheries are not given due attention and little quantitative or even qualitative information is available about these activities. It is also necessary to actively develop and implement an ecosystem approach to fisheries management i.e. multi-sectoral approaches that include socio-economic and livelihood aspects, in data collection and analysis of small scale fisheries.

The principal sources of information for the section were (FAO 2009) for Malaysia, Indonesia, the Philippines, Papua New Guinea, and the Solomon Islands, and (MAF 2009) for Timor Leste. Additional information came from FAO/SEAFDEC (FAO/SEAFDEC 2005). While there are many uncertainties and inconsistencies in these statistics, they provide the best base we have for an assessment of the economic importance of fisheries. Additional information was obtained from (Gillett and Lightfoot 2001).

A. Contribution of fisheries to Coral Triangle economies

One way of assessing the value of fisheries to the economies of the Coral Triangle countries is compare the economic contribution of fishery activities to the Gross Domestic Product of each country (Figure 2A). The Solomon Islands stand out as having the heaviest dependence on fishing, with Indonesia, Philippines, Malaysia and then PNG. Another measure is the amount of protein in people's diets (Figure 2B). Under this comparison, Malaysia and the Solomon Islands stand out as having a considerably greater intake of protein than that seen in the other 3 countries. Note that while fisheries statistics are scarce for Timor Leste, the amount of fish in their diet is probably low for cultural and recent historical reasons.



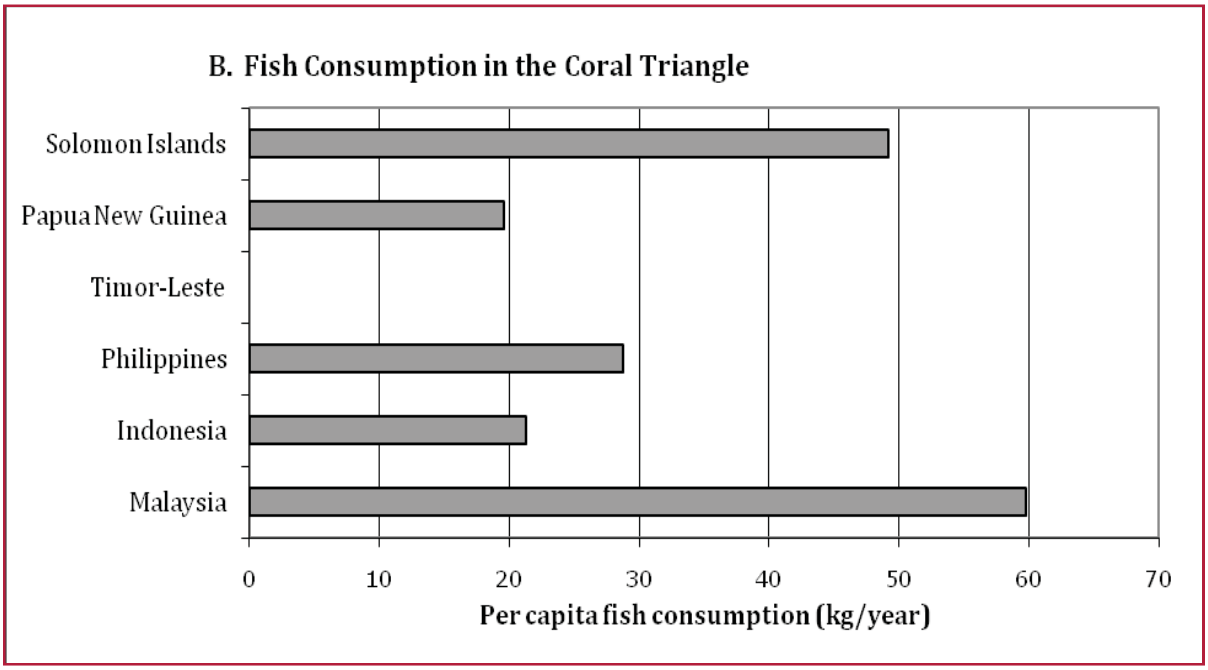


Figure 2. Economic contribution of fishery activities to Gross Domestic Product

Malaysia

In 2004, the fisheries sector contributed US$2.1 billion to Malaysia's total GDP of US$121.4 billion, or 1.73% of GDP. Marine capture fisheries contributed approximately 87% of total fishing activities (US$1.8 billion) and aquaculture contributed approximately 13% (US$273,000). It is noted that the contribution of aquaculture is reported to be higher (25%) in Sugiyama et at. (2004). Inland fishing activities are report to be very small, roughly 0.3% of total fishing activities. Direct employment from the fisheries sector supported 111,000 jobs in 2004, with 89,500 fishermen employed by capture fisheries and 21,500 fishermen employed by the aquaculture sector. However, this figure is considered an underestimate because these employment numbers only report jobs supported directly by the fishing sector and do not take into account jobs supported indirectly by these fishing activities.

Indonesia

Indonesia's fisheries sector in 2004 contributed US$5.47 billion to the country's GDP, or 2.4% of GDP. Marine capture fisheries contributed 57% to the fisheries sector (US$3.13 billion), while aquaculture contributed 37.9% (US$2.07 billion) and inland fisheries contributed 4.9% (US$266 million). In terms of employment, Indonesian fisheries supported 7.3 million jobs in 2005. Jobs related to marine capture fisheries supported 53.6% of these jobs, while inland fisheries supported 12.5% and aquaculture supported 33.8%. Total employment derived from fishing activities has generally increased over the past six years, an average of 7.3% each year. However, there was a 52.4% increase in employment between 1999 (4.8 million jobs) and 2005 (7.3 million jobs).

Timor Leste

In contrast to Malaysia and Indonesia, fishing activities in Timor-Leste are far less and per capita fish consumption is also estimated to be low, at least partly because of restrictions on fishing activities during the Indonesian occupation, when legal fishing grounds were restricted to three miles around the coast (now 150 miles to the south and up to 15 miles to the north). Furthermore, 90% of the coastal fleet, fishing gear and in-shore infrastructure was destroyed during the fighting in 1999 (Jasarevic 2002). There are now significant attempts to promote fisheries as a source of protein for communities in Timor-Leste. Projects include development of fish ponds and promoting the production of dried fish products as a source of healthy protein and for easier transportation into the interior of the country.

Philippines

In the Philippines, the fisheries sector contributed US$1.8 billion to the national GDP in 2003, or 2.2% of GDP. In 2002, over 2 million jobs were supported by fisheries directly. Capture fisheries employed approximately 89% of this total and aquaculture employed 11% according to FAO (2009), but (Sugiyama et al. 2004) put aquaculture at 55% and the total contribution of all fisheries production at 4.8% of GDP in 2001. Employment estimates for support industries was not available.

Papua new Guinea

Fishing activities in Papua New Guinea contributed 1.4% to the nation's GDP in 1999, or US$48.8 million, although Sugiyama et al. (2004) has capture fisheries alone worth 3.3% of GDP in 2001. Subsistence fishing is estimated to contribute 0.84% to fishing activities or US$409,700. In terms of employment, fishing activities in Papua New Guinea supported between 256,500 and 506,500 jobs in 1996. Of these, between 97.6% and 98.7% are estimated to be associated with subsistence fisheries.

Solomon Islands
Fishing activities contributed 12.8% to the GDP of the Solomon Islands in 1999, or US$35.8 million of the nation's GDP of US$279.5 million (FAO 2009). It is noted by Sugiyama et al. (2004) that capture fisheries as 7.8% of GDP in 2001. Fishing activities supported over 10,000 jobs in 1999, with 53.1% associated with subsistence fishing activities. Since approximately 90% of the population in the Solomon Islands lives in rural areas, artisanal and subsistence fishing activities are concentrated in coastal and near shore reefs and lagoons, and is considered widespread and of great importance. Small-scale commercial fisheries near more urban areas are of lesser importance to total fishing activities.

A. Food security
Per capita fish consumption in Malaysia was 59.8 kg in 2003. In contrast, Indonesians consumed 21.3 kg per capita in 2003, an 8.7% increase from 1999 levels (19.6 kg per capita) but 64.4% less than their Malaysian counterparts. As mentioned earlier, per capita fish consumption in Timor-Leste is estimated to be very low due to the conflict over independence, with 2002 UN estimates suggesting that 90% of the East Timorese coastal fleet, fishing gear and on-shore infrastructure was destroyed. In the Philippines, per capita consumption of fisheries products was 28.8 kg, 35% above Indonesia's per capita consumption. Papua New Guinea's per capita fisheries consumption was 19.6 kg, the lowest among the Coral Triangle nations (with the possible but unknown exception of Timor Leste). However, this was a 1999 estimate and it is unknown whether fish consumption has changed in recent years. In contrast, Solomon Islanders consumed 49.2 kg of fisheries products per capita in 1999, two-and-a-half times more than in Papua New Guinea. Within PNG, there are quite strong differences between highlanders' and coastal people's consumption, so the low average can be at least partly explained by the large inland area of the island.

In summary, reliance on fish products in terms of consumption per capita in the Coral Triangle from highest to lowest is: Malaysia, Solomon Islands, Philippines, Indonesia, Papua New Guinea and Timor Leste. This per capita number must be reconciled with the fact that total consumption in countries like Indonesia is much higher than those of countries such as the Solomon Islands.

B. Fishmarkets - imports and exports
The value of fisheries imports into Malaysia was US$527.9 million in 2004, with exports of fisheries products valued at US$583.7 million. Exports of aquarium fishes for the ornamental or aquarium fish trade was valued at an additional US$28.7 million. The majority of exported products were destined for Thailand, Singapore, and Japan.

In terms of volume, Malaysia has been a net importer of fish, with capture fisheries and aquaculture activities unable to keep up with domestic demand for fisheries products. This situation is worsened by the exporting of high value fish species such as shrimp and tuna. To close this shortfall in domestic supply, fisheries products are imported from neighbouring countries such as Thailand, Indonesia, China, and India. Demand for fisheries products within Malaysia is expected to increase due to increasing affluence and greater recognition that fish is a healthier source of animal protein.

The value of Indonesia's fisheries imports was US$139.8 million in 2004, with exports valued at US$ 2,258 billion. Ornamental fish US$ 7.305 million, life fish 23.478 million, seaweed US$ 66.959 million (MMAF 2007). The majority of fishery export products went to China, Thailand, Japan, the U.S., Singapore, and the Republic of Korea. Information about Timor-Leste's fisheries imports and exports was not available.

Fisheries imports into the Philippines were valued at US$80.4 million in 2003. In contrast, fisheries exports from the Philippines were valued at US$525.4 million. The Philippines ranked 11th in the world in terms of fish production, accounting for 2.2% of global production or 2.63 million tons of fish, crustaceans, molluscs, and aquatic plants such as seaweed. Major export destinations for tuna was Japan and the U.S., with exports of shrimp destined for Japan, Spain, and the U.S. and exports of dried seaweed destined for China, France, the Republic of Korea, and the U.S. Carrageenan, a seaweed product, was primarily exported to Denmark, France, and the U.S.

Fishing activities in the Philippines is comprised of marine fisheries (an estimated 30% of marine capture fisheries come from coral reefs and associated ecosystems; (Alcala and Russ 2002)), inland fisheries, and aquaculture. Recreational fisheries have not been developed in the country to any real extent. In 2001, inland fisheries in particular are attributed to providing subsistence livelihoods for thousands of fishermen in the country. In terms of aquaculture production, the Philippines' ranking in the world has steadily declined from 4th in 1985 to 12th in 2003. However, demand for fisheries products within the Philippines is considered robust with 22.4% of total protein intake per capita coming from fish. Human consumption of fisheries products is the largest single use of fisheries products produced in the country, 2.3 million tons consumed of the 2.63 million tons produced or 87.5%.

Imports of fisheries products from Papua New Guinea were valued at US$43.6 million in 1996. Exports were valued at US$49.0 million. In 1999, the value of fisheries exports dropped slightly to US$48 million, comprising 1.8% of the value of all commodity export from the country. Revenues from fishing access fees, training levies, observer fees, and technical assistance generated US$11.2 million in 2000, contributing 2% of total government revenue.

Subsistence fisheries are considered the most important component of PNG's domestic fishery in terms of both volume and value. However, very little information is available. Estimates of subsistence production vary; 26,000 tons is a commonly-cited figure but may be an underestimate. As mentioned earlier, between 250,000 and 500,000 people participate in fishing activities but this number is thought to have decreased at an annual rate of 1.5% between 1980 and 1990 (see also (Gillett and Lightfoot 2001).

In 1999, imports of fisheries products into the Solomon Islands were valued at US$ 237,000. Exports of fisheries products were valued at US$35.5 million. Tuna and tuna-related products comprised over 90% of marine product exports, primarily in frozen or canned form. Revenue from licensing foreign fishing vessels to fish in the Solomon Islands' EEZ also contributes to GDP. Over a hundred vessels were licensed to fish in the early 1990s, resulting in approximately US$2 million in fees per year. However, this dropped to US$273,000 in access fees in 1999, an 86.4% decrease in revenue from earlier in the decade.

C. Summary

Fisheries, by creating jobs, providing protein sources, and supporting trade are clearly important to the economic health of the Coral Triangle. These Coral Triangle countries are likely to be earning income from fisheries as more of the word's marine resources dwindle and the demand increases from the growing wealth of China and other increasingly import-dependent countries. It is clear that our assessment would benefit from more complete information – especially in the area of localized catch and economic data sets, which provide greater insight 'into the ground' realities.

Without this information, better decision making and responsible fisheries management is difficult. With an increasing number of countries in the region decentralizing and delegating management of fisheries to provincial and district bureaucracies or existing management systems, management efforts are imperilled if these agencies cannot carry them out. Juxtapose the need for more intense data collection under the Coral Triangle Initiative – to carry out the myriad of local and regional activities as described in the National and Regional Plans of Action - with the ‘on the ground’ reality of not having the ability to do it leads to some rather dramatic gaps. Additionally, as more people become savvy to the issues, they will want to know more about the value of their resources and what the government is doing to help sustain them. It is clear that data will not only inform the bureaucracies that manage the resources but also result in a more informed and demanding public.

Regional corporation within the Coral Triangle region is, perhaps, the first comprehensive and holistic effort to bring these six countries, their NGO partners and other governments together to collaboratively address the health of the local marine environment. Data, whether that comes as trade information, the number of commercial and artisanal fishers or consumption of coastal and marine resources is singularly important to allowing for the CT6 countries to manage their resources in a way that benefits the countries through food security, a resilient economy and long-term economic opportunity. Without a concerted effort to increase the collection, synthesis and application of data to the management process, it is hard to assess just what they are missing.

TOURISM INCOME

In addition to fisheries production, coastal ecosystems throughout the Coral Triangle generate export earnings through their role in attracting income from international tourists, who are attracted to the exotic coastal habitats of the Coral Triangle. Ecosystems such as coral reefs add significantly to coastal tourism by providing revenue generating activities such as scuba diving, snorkelling and scenic glass bottomed boat tours. Coral reefs are also critical to the formation of white calcareous sandy beaches, which are often the most prominent tourist feature drawing people to Coral Triangle coastal resorts.

Tourism is the world’s largest industry, with tourism generated by coastal ecosystems such as coral reefs representing $9.6 billion of the total $29.8 billion estimated global net benefit associated with coral reefs (Cesar et al. 2003). Tourism has great potential as a generator of revenue for the six Coral Triangle countries, although it currently is not a major contributor. Although care has to be taken to distinguish tourism generated by the attractiveness of coastal areas from other forms of tourism, it is clear that a major proportion of the tourist income to the CT6 is associated with the attractiveness of healthy coastal areas.

This is said it is important to put the current level of tourism in the Coral Triangle into perspective. Indonesian statistics in Appendix 4 show that tourism remains a relatively modest activity in all the nation’s eastern provinces except Bali – where the coral reefs north and north-east of the island are manifestly not a major contributor. In continuation of this, the examples below really deal with quite modest contributions in the total picture, though of course these contributions are important at the local level. This is not to say that, given the right circumstances, coral reefs could not develop into extremely important contributors to economic development of regional areas of the Coral Triangle.

In many parts of the Coral Triangle, tourist income may dominate local economies. For example, the Pulau Weh Marine Protected Area on Weh Island in Indonesia (NB: not strictly inside the Coral Triangle but indicative of tourism within the Coral Triangle) contributes more than 60% of the regional Gross Domestic Product, which amounts to $230,000 in entrance fees per year.

In this particular instance, the presence of an attractive marine protected area boosts per capita income to children $216 per annum as compare to $150 per annum which is paid by other sectors of the local economy (Pabon-Zamora et al. 2008). Reef tourism accounts for 44% of the total net benefits of the $11.54 million in ecosystem services generated by the Bohol Marine Triangle, in the Philippines (Samonte-Tan 2007). Eco-tourist revenues generated by the coral reefs in Indonesia's Wakatobi National Park in Southeast Sulawesi provided almost $1,320 per km² in 2004 and an expected present value of $286,000 (Hargreaves-Allen 2004). There are many other examples, some of which are mentioned with respect to each country in chapter 6.

While tourism, especially ecotourism, is often promoted as a sustainable economic alternative to other livelihoods, it may have a number of negative effects on coastal communities. For example, the benefits of tourism within a region are not always distributed evenly or even locally, and some of its impacts in turn lead to social dislocation, disruption of traditional economic systems, damage to ecosystems and impacts on local cultures (Hall 1994). These must be taken into account when establishing eco-tourist developments.

COASTAL PROTECTION

One of the key contributions that coastal ecosystems such as fringing coral reefs make is the role that they play in dissipating wave energy and thereby protecting human communities and infrastructure. Healthy reefs and mangroves will dissipate 70-90% of the incoming wave energy under average wave conditions (WRI 2005), although the extent to which these ecosystems dissipate wave energy depends on structure and characteristics such as tree density and aspect in the case of mangroves (Kerr et al. 2006; Alongi 2008). In addition to protecting human infrastructure, fringing coral reefs as the first line of defence against ocean waves also provide protection for mangrove, seagrass and wetland ecosystems, which are in turn important for coastal ecology and fisheries. Removal of the coastal protection provided by ecosystems like coral reefs leads to damage to infrastructure and these critical ecosystem components. The damage inflicted by wave stress naturally increases with storm surge and will inevitably interact with rapid sea level rise to exacerbate the impacts of reduced coastal protection (Nicholls 2002; Nicholls 2004).

While reefs and mangroves will not completely dissipate catastrophic wave energy such as that seen during tsunamis, there is considerable evidence from India (Dahdouh-Guebas et al. 2005) and the Philippines (Walton et al. 2006) that coastal protection provided by these ecosystems does reduce the impacts of tsunamis, cyclones and typhoons (Williams 2005). These studies point to the increasing impact of tsunamis that result when mangroves have been removed by clearing for shrimp aquaculture.

There is a complex interrelationship between coastal foliage such as mangroves and storms. While mangroves may provide extensive protection, they themselves can become the victims of storms. In this respect, severe impacts on mangroves can arise from hurricanes and cyclones. Hurricane Mitch, for example, destroyed 97% of the mangroves in and around Guanaja, an island in Honduras (Cahoon et al. 2003a). Once destroyed, mangroves can take years to regenerate, and subsequent storms can have greater impacts further inland. These impacts may increase as tropical oceans increase in temperature, driving more intense storms (Webster et al. 2005).

MAINTENANCE OF COASTAL WATER QUALITY

Intact coastal vegetation provided by mangroves and wetlands play important roles in trapping sediments and nutrients as water flows from land and out to sea. This limits the amount of sediment and nutrient laden water flowing out onto ecosystems such as coral reefs, which are highly sensitive to the impact of nutrients and sediments (Koop et al. 2001; Brodie et al. 2005b). These roles are often underappreciated or set to one side when mangroves and seagrass meadows are in-filled or removed for aquaculture for other reasons.

These coastal ecosystems also play a critical role in stabilising coastal settlements and in preventing erosion. Mangroves are also capable of absorbing heavy metals and other toxic pollutants (Lacerda and Abrao 1984). In this regard, they can play an important role in stopping the influx of these pollutants into deeper waters where they may impact other important ecosystems such as coral reefs and seagrass meadows. In some cases, activities within catchments may exceed the ability of mangroves and wetlands to absorb pollutants, resulting in mangrove die back (Duke et al. 2005) These relationships emphasise the important connection between activities on land, with those in the coastal strip and surrounding marine environments.

CULTURAL AND SPIRITUAL BENEFITS

Coastal ecosystems play a prominent role in the cultural and spiritual light of many people within the Coral Triangle. These cultural and spiritual benefits provide a social backbone to many coastal societies, and underpin cultural identity and pride. Many of these beliefs also underpin land tenure and the management of coastal resources by governments in countries that traditionally considered ocean resources to be part of the public domain and not owned exclusively by any one group of people. These groups base their management of ocean and coastal resources on a stewardship ethic and their resolution of multiple-use conflicts on fairness and equity. In some groups, however, community, village or kinship-based systems govern reef tenure and ownership of coastal/ocean resources (Ehler et al. 1997). This is particularly evident in the Pacific Islands whereby the traditional ownership and stewardship of land and sea tenure is still practised. Through customary ownership, many communities particularly in the Pacific follow traditional management systems of use rights. These can include: closed seasons, prohibitions, closed areas, size limitation, equipment control, limit to the number of users and quotas, all of which are used in the traditional Pacific Island societies (Johannes 1981; Veitayaki 1997). Community-based marine management systems were suitable for the sustainable utilisation of marine environmental resources in the Pacific Islands because they involved people and incorporated the necessary features of their culture and tradition. The system of authority, land and marine tenure, custom and tradition, enforcement, beliefs, conflict and dispute settlement protocol made the systems better suited to many societies in Palau, Solomon Islands, Papua New Guinea and Fiji (Veitayaki 1997).

Coral reefs have a very important meaning for the coastal community from economic and cultural point of view. One third of the Indonesian population living in coastal areas depend on shallow water fisheries which originate from coral reefs, mangroves and seagrasses. The largest proportion of them consists of traditional fishermen using simple fishing gear to capture small benthic and pelagic fish. The dependency of their livelihoods needs to the attachment of strong cultural values to sea life. Some tribal groups such as the Bajo, Bugis and Maduranese dramatically follow fishing opportunities in groups of 5-10 boats, catching what they will and selling it to the nearest market. The take all practices of these wandering fishermen leave the locations that they exploit highly degraded with very few fish stock left. This behaviour contrasts other traditional stationary communities that live in relative harmony with local coastal resources.

These differences in the resource gathering behaviour of different cultures within the Coral Triangle must be taken into consideration in any effort to understand and develop management plants at the local level. This regard, the effectiveness of community based marine management systems have also been reduced by changing behaviours brought on by increased population numbers, densities and a transition from subsistence to a cash economy. It should also be noted that traditional/customary systems are critically important, but not always a panacea and can result in overfishing. For example, in Kimbe Bay, Papua New Guinea, locally managed marine areas are the primary method for establishing and managing MPAs, but require the backup of local level legislation to be effective.

Some countries view the sea as important in a cultural context linking their heritage or ancestry to its resources. For example, in parts of Papua New Guinea, the totem animals for certain clans are reef-related species such as grouper or sharks. In Tatana village, Papua New Guinea, the people collected dead fish from the sea for burial on land to protect their fishing ground from pollution and from the big and dangerous fish that may be attracted to their fishing areas. The association with the super-natural ensures that the sacred ground was respected and protected at all times - not only when some enforcement officer is visiting. In such cases ‘a close association was perceived between the living and the dead, whose spirits inhabited sacred areas, and who showed offence when customary taboos and rituals were not adhered to. Similarly, in the Solomon Islands people believe in the guardian shark that protects the fishing ground and punishes those who abuse their fishing rights (Toata Molea, Pers. com. 1994). Likewise, amongst the turtle fishermen of Qoma, Fiji, the belief is that their gods will provide a catch for them that will meet the purpose for which the fishing was asked for and conducted. The fishers know that once a turtle swims through their net that their catch on that occasion is enough for whatever purpose the fishing was conducted and that they will not catch any more on that trip. These strong beliefs make people adhere to the fishing traditions and customs and render superfluous the involvement of full-time enforcement officers (Veitayaki 1997).

SUMMARY

While the absolute value of healthy coastal ecosystems in the Coral Triangle is difficult to define precisely, it is very clear that the benefits are enormous in terms of food, income (tourism, fisheries), coastal protection, water quality maintenance and spiritual/cultural values. Despite the difficulty in defining the value of the systems, the total potential sustainable annual economic net benefits per km² of healthy coral reefs in Southeast Asia produce values which range from $23,100 to $270,000 (Burke et al. 2002), suggesting even higher values across the couple of hundred thousand km² of coral reef and mangrove ecosystems within the Coral Triangle. These values underscore the close linkages between coastal ecosystems and people throughout the Coral Triangle, emphasising the vulnerability of these relationships in a changing world.

SPECIAL FOCUS 1: LIVELIHOODS AND CLIMATE CHANGE

Geoff Dews and Melanie King

Fisheries provide food and protein sources to households and the wider public. Around 38 million people worldwide are employed in fisheries and aquaculture industries and 95% of them are in developing countries (DIFID). This case study illustrates a direct and tangible link between fisheries and the livelihoods of remote communities in the Kahua District of the Makira Province of the Solomon Islands and climate change implications.

In the broad sense fishing not only provides an important contribution to the protein requirements of coastal communities, but also in social terms fishing plays a large part in many people's well-being. Fishing is usually gender specific and each gender has different roles which vary from area to area, culture to culture and the type of fishing activities undertaken. Fishing is usually seasonal or it may be a part-time activity to supplement other rural activities in addition to providing income to a family, protein for subsistence, and; reducing vulnerability to poverty. Fishing is rarely carried out alone and is often a social activity, strengthening bonds between people and community cohesion (DFID). Because there is no alternative income to fishing in some areas, people hesitate to join conservation programs that may alienate them from the means of a livelihood. This is despite the concerns that overfishing, the loss of marine diversity, coastal zone degradation and coral reef destruction are major problems in tropical fisheries (Minura 2008). Rural communities focus on marine resources that are easy and cost effective to catch or harvest.

Fishing in the Kahua District of the Solomon Islands is mostly for subsistence as there is no access to any substantial markets and due to a lack of infrastructure in the Province, (there are no roads only walking tracks), and therefore trading between communities is limited. Men fish from dugout canoes using baited lines or spear fish on the coral reefs. The fishing effort and hence the amount of finfish landings depends on weather conditions and seasonal abundance. The supporting habitat for the fish is the narrow band of coral reef that runs along most of the sheltered part of the coast. The target finfish species are either associated with coral reefs (grouper, cods etc) or the small migratory pelagic tuna species. Complementing the fishing is the collection of shellfish along the narrow rocky shoreline, usually undertaken by women and children. The collection of shellfish contributes to some of the protein needs of the community, especially in times when high seas prevent fishing from dugouts. The abundance of reef fish is directly dependant on the health of the adjacent local coral reefs and the level of local fishing effort. Household surveys carried out in 2006 indicated communities were recognising a decline in catches and a subsequent survey in 2008 showed that the catch of shellfish had declined both in total landings and size of individuals. All the evidence suggests that there is either a level of overfishing and/or low annual recruitments, but most fishermen interviewed agreed that overfishing was the main reason for the decline in fish and shellfish.

The critical issues for the communities in the Kahua District are the rapid increase in population, the lack of suitable agricultural land to allow for an increase in crops, and the decline in fish and shellfish landings. The lack of arable flat land is due to the narrow coastal flat areas along the coast, land ownership issues (some of the clans have migrated to the area from other islands and have no land tenure) and in some cases poor agricultural practices have increased the amount of soil eroded from the hill slopes. All this leads to a lowering of natural resilience to natural events and climate change.

The lack of agricultural expansion will increase the pressure on the already overfished marine sector. Increased sea-level rise will reduce the habitat suitable for shellfish recruitment, which plays a very important part in food security for some families because shoreline gleaning can be carried out at low tide and is not dependant on the sea conditions as is fishing from the dugouts. Climate change will see the narrow rocky shoreline becoming flooded as the sea level rises and the cliffs will experience more erosion, increasing the sediments into the coastal waters making the recruitment of some species unlikely.

The level of impact sea-level rise has on food security and local community livelihoods will depend on the community access to other sources of protein such as aquaculture or agriculture but other climate change impacts such as increased rain events, more severe storms leading to increased run-off may make alternative livelihoods difficult to maintain. There is a need for good local environmental and resource management actions to be taken in the communities in order to reduce the present impacts on the local habitats to allow for as much time as possible to adapt to new climatic conditions and to maintain community livelihoods.

Figure 3. Spear fishing for reef fish Kahua District Makira Province Solomon Islands

SPECIAL FOCUS 2: IMPLICATIONS OF NATURAL DISASTERS ON COASTAL LANDSCAPES & LIVELIHOODS

Alexander Tewfik and Jamie Oliver

Coastal areas contain some of the most productive ecosystems yielding abundant fisheries and aquaculture resources as well as being stand-out areas for coastal recreation that together support the economies of many coastal communities. For the people of the Coral Triangle, human well-being is on average much higher than that of people in inland communities (although this does not hold in some countries, e.g. Tanzania). However, the large size and complex interactions between habitats, organisms and people across the broader coastal zone, the often ambiguous nature of resource ownership and increasing level of anthropogenic disturbances provides great challenges for balancing economic development, livelihoods, and environmental management.

There are considerable physical risks associated with living in some coastal areas which may be highlighted by the catastrophic impacts of cyclonic storms and offshore seismic events. Such impacts include direct and indirect damage to coastal resources resulting from flooding, seawater intrusion, erosion, and tsunamis. Tectonic movements may also result in sinking or uplifting of reefs, mangroves and seagrass habitats. Such disaster impacts will have profound effects on coastal communities and their livelihoods with potential reductions in catch, losses of aquaculture production, and disruption of processing, transport and market infrastructure. The synergistic impacts of such disasters with climate change induced sea level rise and increased storm surge flooding will result in significant reduction in the well-being of affected people and an increase in poverty. In the Coral Triangle region, the impacts of two recent earthquakes and associated tsunamis – Indonesia (Aceh Province) and the Solomon Islands (Western Province) - provide insights into the environmental and, socio-economic impacts which might result from climate change related increases in tropical storms and sea levels.

INDIAN OCEAN TSUNAMI IMPACTS ON ACEH PROVINCE

Events following the Great Sumatra-Andaman Earthquake and tsunami of 26 December 2004 made it clear that systems with healthy natural environments and diversified livelihoods are more resilient to shocks. Unfortunately, much of the region was characterized by degraded coastal environments, limited livelihood opportunities, and diminished ecosystem services. In Aceh Province, more than 200,000 people died or were displaced and 500,000 were made homeless. More than 127,000 homes were totally or partially destroyed and over 60,000 ha of agricultural land were damaged by seawater inundation. Among the most severely affected were poor coastal communities (estimated population: 468,000) engaged in fishing and aquaculture activities. Loss or damage to principle livelihood assets included an estimated 10,000 boats, 6,700 engines, 20,000 individual fishing gears and 37,000 ha of ponds for fish and shrimp cultivation. In addition, much of the supporting infrastructure (wharfs and processing facilities, markets, transportation and communication networks) was lost or severely damaged. The tsunami is also estimated to have damaged more than 84,000 ha of mangrove, with some areas reporting 100% loss. This may have resulted in changes to the production and recruitment of aquatic species (e.g., finfish, shrimp & mud crab) important to subsistence and commercial fishing. Other coastal habitats, including coastal forests, beaches and dunes, were also heavily damaged or completely lost. This has increased the overall vulnerability of coastal communities to future impacts from seasonal monsoons, unpredictable storm surge, and chronic rise in sea level.

SOLOMON ISLANDS EARTHQUAKE AND TSUNAMI

On April 2nd 2007, a magnitude 8.1 earthquake, centred off Gizo, generated a tsunami that killed 52 people and devastated many villages, including the loss of houses, paddle canoes and fishing gear in the Solomon Islands Western and Choiseul Provinces. Because of the high dependence of most rural communities on coastal marine ecosystems, any disaster-related impacts on the basic assets used to extract such resources (i.e. fishing gear), has the potential to severely affect food security and cash livelihoods (e.g. trochus and bêche-de-mer) with additional long-term consequences on health and education. Damage to marine habitats varied across sites and included broken reef structure and burial of reef areas with the potential for significant changes to resident fish and invertebrate populations. Uplifting of reefs and mangroves also resulted in the significant losses of gleaning areas, reduced water exchange, and compromised natural migration and canoe access routes. In one area all formerly intertidal mangrove fauna have perished most surviving mangrove propagules stranded and deteriorating rapidly from rot, desiccation, insect borers and rats.

RESTORATION OF LIVELIHOODS IN DISASTER AFFECTED AREAS

In both the Solomon Islands and Aceh a key relief measure was the replacement of fishing boats lost or damaged during the disaster. In the Solomon Islands, a program to contract local boat builders was initiated, which helped to keep much of the aid funding within the local communities. These activities have focused on replacement of traditional dug-out/out-rigger canoes made from locally available materials thereby avoiding any increase in fishing effort. Boat relief efforts in Aceh were much more ambitious, but met with mixed success. The distribution of aid appeared to be done without consideration of the former structure of the fleet and resulted in a new fleet of reduced diversity and a strong focus on the smaller boat types. This may have further exacerbated the pre-existing economic and geographic marginalization of some remote communities. In addition, the reduced capacities of the fleets to engage in multi-species/multi-gear harvesting strategies may have also increased the risk of ecologically unsustainable exploitation in both sub-tidal near shore and inter-tidal areas. A number of other livelihood focused rehabilitation activities are presently underway (e.g. tilapia cage culture, deployment of fish aggregating devices, lobster post-larvae collection, giant clam grow-out) including some with strong links to habitat rehabilitation (e.g. mangrove replanting) in both Aceh and the Solomon's.

Key lessons learned from the disaster events in Aceh and the Solomon Islands:

1. Healthy coastal habitats will help to dampen the physical impacts of acute storm surge and chronic sea level rise while also providing critical and ongoing livelihood opportunities;

2. Attempts to correct pre-existing problems such as overfishing through selective aid programs may unintentionally exacerbate these problems and compromise efforts to restore habitats and livelihoods in a timely and sustainable manner;

3. Understanding the diversity of local livelihood strategies, social dynamics (e.g. traditional marine tenure) and sources of vulnerability as well as early engagement in community consultations will help in the design and implementation of responses aimed at long-term resilience-building within coastal communities.

References

Andrew, N.L., Béné, C., Hall, S.J., Allison, E.H., Heck, S., and Ratner, B.D. 2007. Diagnosis and management of small-scale fisheries in developing countries. Fish and Fisheries 8: 227–240.

Schwarz, A., C. Ramofafia, G. Bennett, D. Notere, A. Tewfik, C. Oengpepa, B. Manele, N. Kere. 2007. After the earthquake: An assessment of the impact of earthquake and tsunami on fisheries related livelihoods in coastal communities of Western Province, Solomon Islands, 81 p. The WorldFish Center and WWF–Solomon Islands Programme.

Pomeroy, R.S., Ratner, B., Hall, S.J., Pimoljinda, J., and Vivekanandan, V. 2006. Coping with disaster: Rehabilitating coastal livelihoods and communities. Marine Policy 30: 786-793.

Tewfik, A., C. Béné, L. Garces, and N. L. Andrew. 2008. Reconciling poverty alleviation with reduction in fisheries capacity: boat aid in post-tsunami Aceh, Indonesia. Fisheries Management and Ecology 15:147–158.

WorldFish Center 2008. Waves of Change: Lessons learned in rehabilitating coastal livelihoods and communities after disasters. Policy Brief no. 1866. WorldFish Center, Penang, Malaysia.

Figure 4. Remains of mangroves after tsunami impacted coastline on Dec 24 2004 near near Calang, Aceh Jaya, West coast – 2007 (Photo: A. Tewfik, WorldFish, Penang, Malaysia).

CHAPTER 4

THE IMPACT OF LOCAL ACTIVITIES ON CORAL REEFS, MANGROVES AND SEAGRASSES

The incredible biological diversity of the Coral Triangle is associated with some of the highest human population densities and growth rates in the world. Many of these people live within the coastal regions of the Coral Triangle, with the livelihoods of over 100 million people being supported directly by the coastal resources of the region (TNC 2009b)(see also Chapter 5). Over 70% of the human population of the Coral Triangle lives within 50 km of coastline (Chou 1994; Dahuri 1999). Escalating population growth and unrestrained coastal development have begun to put extensive demands on marine ecosystems within the Coral Triangle. This has led to coral reefs, seagrass beds and mangroves of the region being among the most stressed on the planet (Spalding et al. 1997; Spalding et al. 2001; Burke et al. 2002).

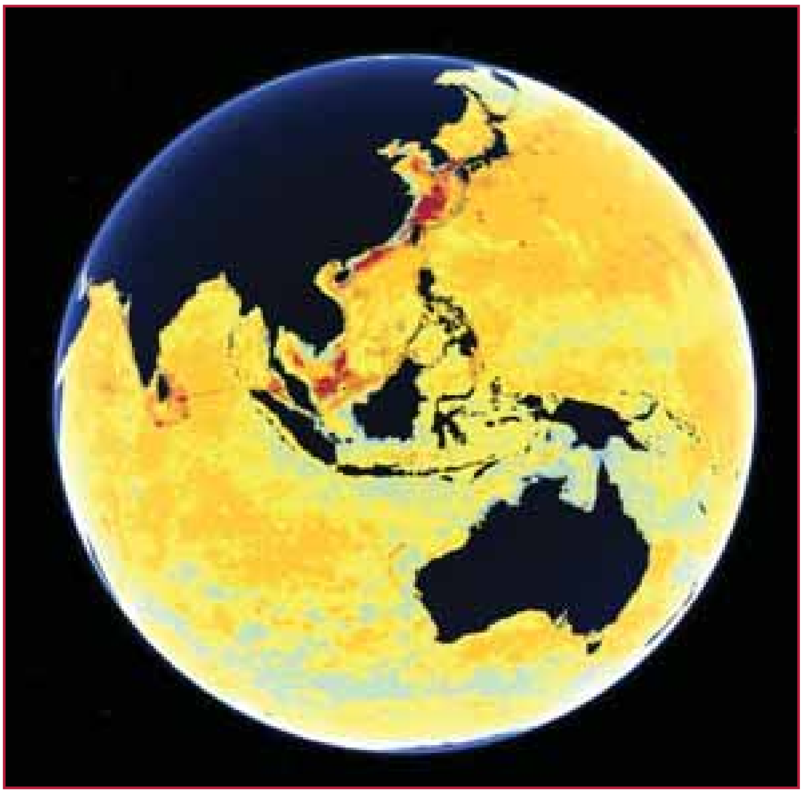
Halpern and colleagues assessed the human impact on marine ecosystems across the entire planet, and concluded that there are few areas on the planet that have not been affected by human activities (Halpern et al. 2008). Within this analysis, the Coral Triangle shows evidence of medium to high impact relative to other areas in the world (Figure 1).

The stressors of coral reefs, mangroves, and seagrasses within the Coral Triangle can be divided into two broad categories. The first set is often referred to as 'local' threats, which originate directly from activities within the region. Declining water quality, over-exploitation of resources, sewage discharge, and destructive fishing are some of the direct impacts that humans are having on coastal ecosystems within the Coral Triangle (Burke et al. 2002). An earlier overview of local environmental problems of the region was prepared nearly two decades ago (Gomez 1988) which listed various threats that were considered of importance then. While many of those threats remain to this day, the review did not anticipate the global or "systemic" threats at the other end of the spectrum, that arise principally from the burning of fossil fuels, deforestation and land-use change. Rising carbon dioxide in the Earth's atmosphere is driving the warming and acidification of the world's oceans. These two factors are changing both the chemical and physical attributes of the marine environment in which coral reefs, mangroves, and seagrasses are trying to persist.

Given the importance of these ecosystems to the Coral Triangle, and the hundreds of millions of people living along coastal areas within this region, an exploration of both of these categories of threats is required before a complete understanding can be constructed of how the future will unfold. In this section, the impacts of local activities within the Coral Triangle are described, first by reviewing each category of threat, and then by reviewing the specific context of each country (Chapter 6).
In the latter case, systematic information across all six countries on the impact of local activities is not possible. For this reason, an in depth exploration of examples from each country is included here. A description of how global threats are likely to impact coastal ecosystems in this region is included in a later chapter, following an in-depth description of the economic profile of each of the CT6 countries.

Figure 1. The extent to which human impacts can be detected within the Coral Triangle, from information provided to Google Earth by Halpern et al. (2008). The key to the different colours is as follows:

Very Low Impact (<1.4) | Medium Impact (4.95–8.47) | High Impact (12–15.52)
Low Impact (1.4–4.95) | Medium High Impact (8.47–12) | Very High Impact (>15.52)



COASTAL DEVELOPMENT

The expansion of human populations has led to the rapid development of coastal areas within the Coral Triangle (Salm 1994b; Burke et al. 2002). Expansion of urban and agricultural activities has both directly and indirectly affected coastal ecosystems. Land reclamation to build human dwellings, airports and tourist venues has directly removed coral reefs and mangroves from coastal areas. Corals have also been mined directly for coral rock and lime to make cement. Mangroves, seagrass beds and salt marsh areas and coral reefs have also been affected by dredging and port development. The growth of towns and cities along coast lines has led to a massively increased influx of sewage and garbage into coastal ecosystems such as mangroves and coral reefs (Chou 1994).

The growth of tourist activities, which often occurs in pristine and sensitive locations, can have a disproportionate impact on the environment through physical impacts such as anchoring, coastal development, as well as contributing sewage, solid and liquid wastes into often valuable coastal ecosystems. Coastal development associated with towns and tourism can also drive other activities such as the mining of reef carbonates the building materials and cement. These activities can have a direct impact on the three-dimensional structure of coral reefs, and is still occurring throughout the Coral Triangle.

Coral reefs that thrive in clear and low nutrient waters disappear once coastal waters become clouded with sediment and laden with nutrients such as nitrogen and phosphorus. Sediments reduce the amount of light falling on coral and other photosynthetic organisms, while elevated nutrients tend to tip the balance away from coral-dominated reefs to those dominated by organisms such as seaweeds, which often do well under high nutrient conditions. Sediment can also physically smother coral reefs. Seagrasses also require clear water and are degraded or killed when water becomes too turbid.

Overall, about 25% of coral reefs in the Coral Triangle are threatened by coastal development (Burke et al. 2002). While coastal development is most intense within the Philippines and Indonesia (particularly Sulawesi and Java), it represents a growing threat throughout the Coral Triangle (Fig 2A - threat maps from Burke et al. 2002).

MARINE-BASED POLLUTION

The Southeast Asian region is a major hub for shipping traffic, including several mega-ports as well as a complex network of shipping channels as part of these activities. One of the two most important sea lanes in Southeast Asia passes through the Straits of Lombok and Makassar (Coutrier 1988) which form part of the Coral Triangle. Other important sea lanes include those passing through also include areas such as the Sawu Sea, Arafura Sea, Banda Sea, Seram Sea and Maluku Sea. A number of threats arise from this intense shipping activity including oil spills (Lu et al. 1999), pollution from ports, ballast/bilge discharge, as well as garbage disposal. Impacts also arise from groundings and anchor-damage, leading to the direct destruction of coral reefs formations.

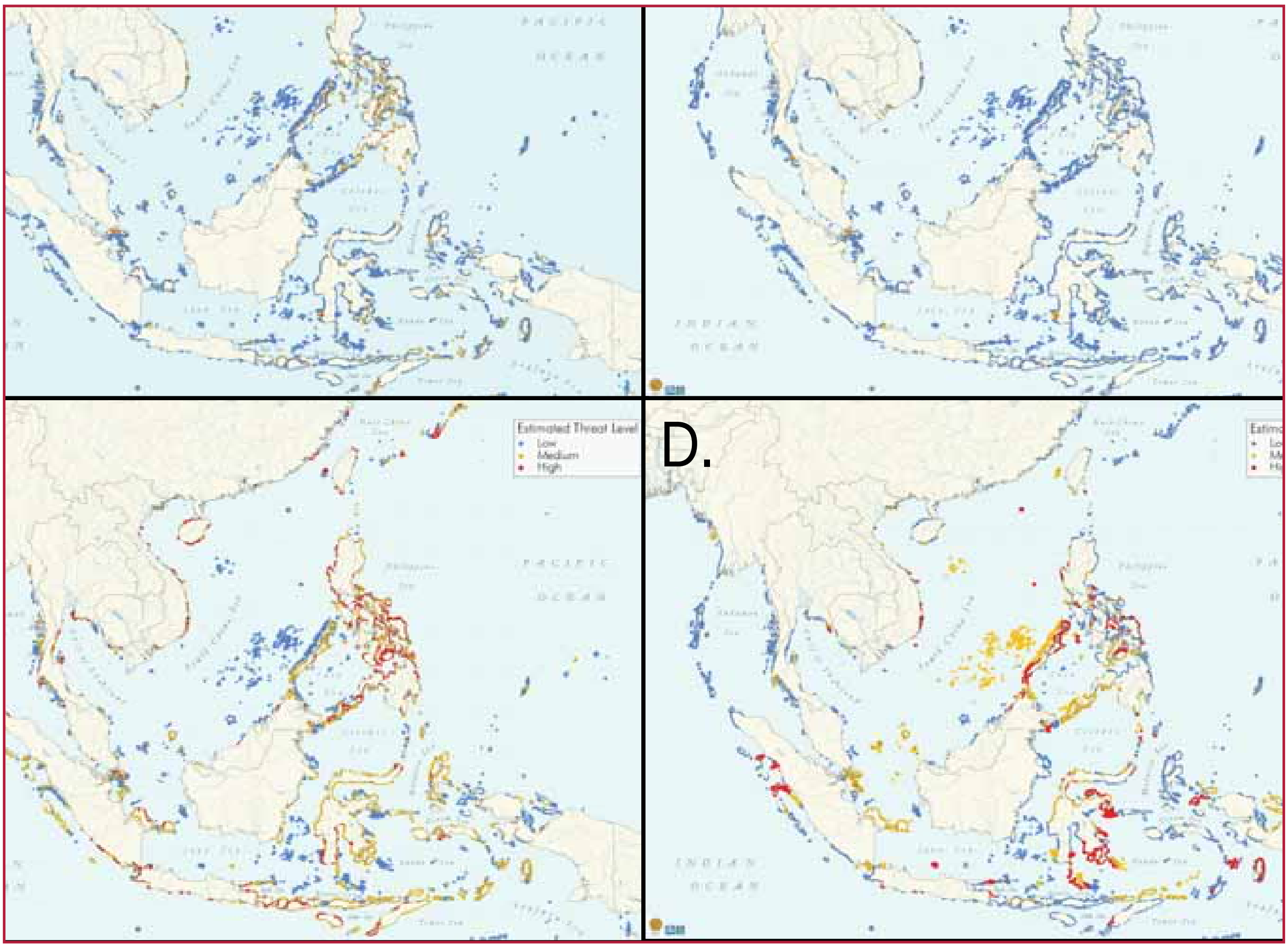


Figure 2 . Distribution and intensity of ‘local’ threats throughout South-east Asian region. A. coastal development, B. marine-based pollution, C. Overfishing and D. destructive fishing (Source: (Burke et al. 2002).

A number of impacts arise from these threats. Oil spills can damage adult coral populations directly (Loya and Rinkevich 1979,1980), or can have serious effects on the ability of corals to recruit to new areas as settling larvae and juveniles (Loya and Rinkevich 1979; Epstein et al. 2000). Oil can also enter the marine environment via a number of activities including leakages from storage facilities and regular maintenance activities in harbours and ports. Oil can have insidious effects via its bioaccumulation within invertebrates, and can severely reduce the resilience of coral reef, mangrove, and seagrass ecosystems to other stresses. Ships discharging bilge and ballast water may also release oil, nutrients, chemical pollutants and invasive species(Burke et al. 2002).

According to recent systematic analysis, marine-based pollution is the least threatening of the human related stresses arising within the Coral Triangle. Approximately 7% of coral reefs are facing threats from (Burke et al. 2002) marine-based pollution. Threats from marine-based pollution are highest in the Philippines and heavily populated areas of Indonesia (Fig 2B). In the Philippines, the release of untreated sewage into coast areas is one major threat to coral reefs. Marine-based pollution has increased rapidly where urban centres and ship-based activities have expanded.

LAND-BASED RUN-OFF

The environments within which coral reefs and associated ecosystems thrive are influenced directly by the activities that occur on adjacent coastlines in terms of land-use. In undisturbed settings, coral reefs and seagrasses thrive in clear water that allows light to penetrate and drive the photosynthesis of symbiotic corals and other coral reef organisms such as giant clams and macro-algae. These waters also tend to be low in inorganic nutrients such as nitrogen and phosphorus, which would otherwise drive phytoplankton blooms and decrease the clarity of water.

The conversion of coastal forests and landscapes into grasslands, agriculture and aquaculture diminishes the ability of coastal areas to retain soil and nutrients, which otherwise run off into coastal areas. Road construction and other infrastructure activities in coastal areas can therefore have serious effects on adjacent water quality. When coupled with poor tillage practices and the loss of riparian vegetation around rivers and creeks flowing into coastal areas, these activities can have devastating effects on coastal ecosystems such as coral reefs and seagrasses.

The growth of heavily populated regions such as those in the Philippines and Indonesia (especially Java and associated islands) has resulted in almost all natural forests and landscapes being altered. Coastal water quality is an increasing concern in areas such as the Solomon Islands, where unrestrained logging continues. Approximately 21% of the coral reefs of Southeast Asia are threatened by land-based run-off. This figure is higher in the Philippines and Java, where approximately 35% of coral reefs are threatened by nutrients and sediments running off destabilised coastal areas (Burke et al. 2002). Large river systems on large islands in the Philippines contribute enormous amounts of sediments that smother coral reefs (A. Alcala, Silliman University, Philippines pers. obs.).

Figure 3. Distribution and intensity of land-use change throughout South-east Asian region (Source: (Burke et al. 2002).

OVERFISHING

Human populations residing in the coastal areas of the Coral Triangle are heavily dependent on local marine ecosystems for their food and livelihoods. Much of the recent growth in demand for marine resources has come from people living at subsistence levels. In this respect, it is interesting to note that small-scale fisheries make up 95% of the total marine fisheries production in Indonesia and traditionally more than 50% in the Philippines. Many local people spend their time foraging local waters for fish, invertebrates and seaweeds for either direct consumption or sale in local markets. In addition to local subsistence fisheries, communities may also participate in pelagic fisheries such as tuna, the live reef fish trade, as well as the trade in aquarium fish. The live reef fish trade has flourished in recent years due to the growing demand from China and Taiwan.

The pressure on fish stocks has escalated in concert with population growth, and represents one of the most significant threats facing coastal ecosystems within the Coral Triangle (Figure 2C). Few countries or coastlines remain unaffected. The over exploitation of fish stocks embodies a complex set of threats involving both internal and external pressures, cultural and economic constraints, and is closely connected to human livelihoods and poverty. The live fish trade for restaurants in major Asian cities is an excellent example in this respect. The trade involves cartels that provide boats to impoverished people who then strip reef systems across the region of large fish (e.g., Napoleon wrasse and groupers), which are then shipped to major cities such as Hong Kong and Singapore. The live fish trade crosses international boundaries and circumvents the ability of local people to control the state of their fish stocks (Johannes et al. 1995; Cesar et al. 2000; Sadovy and Bank 2003).

In cases where overfishing is controlled by large-scale commercial operations, regulation through government enforcement may suggest a solution. The problem becomes much more complex when coral reefs are located adjacent to crowded coastlines. In these cases effective fisheries management is difficult, though crucial. These solutions are discussed in detail in subsequent chapters of this report. Large proportions of the Coral Triangle have already been severely impacted by overfishing, with high threat areas ranging over most of the Philippines, Indonesia, Malaysia (Sabah) and Timor Leste (Burke et al. 2002). Papua New Guinea and the Solomon Islands (not shown on map) are by comparison less impacted although some regions close to major human settlements have been impacted from a moderate to severe extent (Fig 2C).

An example of overfishing that has led to the extirpation of many local populations is that of the true giant clam, *Tridacna gigas*, which was fished out of the Western Pacific by Chinese fishers (Brower 1989) by the 1970's, prompting a mariculture effort in the 1980's to restore populations with Australian support (Copland and Lucas 1988). Some headway has been made in the Philippines (Gomez and Mingoa-Licuanan 2006), with natural, local recruitment of juveniles becoming evident 20 years after the start of the program. Thus, it is better to conserve local populations at a sustainable level than to try to restore extirpated species. Overfishing represents one of the greatest threats throughout the Coral Triangle region (Silvestre and Pauly 1997; Burke et al. 2002). Approximately 64% of coral reefs are at medium to high threat from overfishing. The Philippines is the most threatened with over 90% of their coral reefs threatened by overfishing which is manifest by the fact that only 5-10% of the normal biomass of target fish species exist in most parts of the Philippines (Alcala, Silliman University, unpublished data). Similar although less publicised threats from overfishing exist for seagrass and mangrove forests. In these cases as well, ecosystems shift as ecological functional groups are removed, with consequences for overall coastal ecosystem health.

DESTRUCTIVE FISHING

Expanding coastal populations with limited financial resources has led to the proliferation of destructive fishing practices. Generally located near heavily populated cities and coastlines, destructive fishing has taken a toll on habitats and on non-target species. In addition to the impact of anchors and nets on coral reefs from regular fishing and trawling activities, there are two main fisheries techniques that cause major damage to coral reefs: fishing using poison or using explosive devices.

A. Fishing using poison

Poison fishing has long been used throughout South-East Asia by traditional communities (Johannes et al. 1991; Cesar et al. 1997). Products extracted from mangroves and other plants are mixed into the water column by the fisher, impairing or killing the fish prior to collection. At low density and under traditional control, poison fishing is unlikely to have a major impact on coastal ecosystems.

The use of poisons today has proliferated from its use in the Philippines in 1960s (E. Gomez, pers. obs.) and has spread throughout the Coral Triangle, with the exception of the Solomon Islands. Modern poison fishers use sodium cyanide or insecticides, delivering the poison to the fish in plastic squirt bottles that are operated by divers (Cesar et al. 1997; McManus et al. 1997). The poison anaesthetises the fish, making them easy to capture. Both the live fish and aquarium trades use poisons extensively. The impacts on coral reefs range from non-specific and widespread impacts on other fish, to direct impact on corals. The application of dilute solutions of cyanide will disrupt photosynthesis and cause corals to bleach and die (Jones and Hoegh-Guldberg 1999), and if applied at higher concentrations will kill entire communities of corals (Pet-Soede et al. 1999; Mous et al. 2000).

The full extent of the use of poison for fishing is unknown, largely because it tends to be used in more pristine and isolated coral reefs where observations are limited or difficult (Burke et al. 2002). The limited information available on fish poisoning suggests that it is widespread in the Philippines, Malaysia (Sabah) and Indonesia (Fig 2D).

B. Fishing with explosives

Blast fishing is currently outlawed throughout Southeast Asia. Despite this, it is regularly used on coral reefs in the Coral Triangle. Blast fishing originated after World War II when the combatant armies left behind large numbers of unexploded shells, which were cannibalized to make explosives for use in fishing (Alcala and Gomez 1987). Most of the stocks of explosives from WWII have been used up or removed, and blast fishers now use dynamite from building sites, or potassium nitrate, which is an artificial fertiliser and which can be prepared as an explosive using commercial fuses or blasting caps. In some cases, there are reports that small scale fishers reportedly buy explosives from commercial and government sources (Cesar et al. 1997; Pet-Soede et al. 1999).

Blast fishing kills fish by rupturing their internal organs through the pressure wave that is created by the blast. Once an explosive has been set off, fishers enter the water and collect the stunned and dead fish. Economic estimates indicate that the market value of the fish far exceeds the cost of the explosive. The ecological costs of blast fishing are much greater, however. A typical 1 kg bomb often made using a beer bottle will leave a crater of coral rubble 1-2 m in diameter (Alcala and Gomez 1987). The recovery of reefs from the physical damage inflicted by explosives may take many decades. In some regions, blast fishing is so common that reefs have been more or less destroyed completely. Reefs that are bombed regularly usually exhibit less than 10% coral cover and a vastly reduced reef framework. With the three-dimensional typography of the reef gone, most of the other organisms that normally inhabit coral reefs disappear as well.

Approximately 56% of coral reefs in South-East Asia are at risk from destructive fishing practices (Burke et al. 2002). The proportions are high as for the Philippines with 66% of reefs being threatened by destructive fishing, and Indonesia, where more than half of the reefs are threatened. Damage to coral reefs from blast fishing appears to be minimal in the Solomon Islands.

SUMMARY

The large human populations that occupy the coastal areas of the six Coral Triangle countries have put significant pressure on the natural resources of this region. Around 100 million people are directly supported by coastal resources (see chapter 5) within the Coral Triangle, with the provision of food and livelihoods to the large numbers of impoverished people. Rapidly rising coastal populations and unrestrained coastal development, however, have resulted in serious impacts on the very coastal resources that support people. Impacts have also arisen from the expansion of urban and agricultural activities which have directly and indirectly affected coastal ecosystems such as coral reefs and mangroves. Large cities have developed in the region with poor planning for sewerage and wastewater, leading to large areas of coastline being polluted and destroyed. Increased shipping that is servicing expanding cities and industries in the region have put pressure on open sea as well as coastal ecosystems, while the destruction of coastal forests has led to an increased flux of sediments and nutrients into coastal waters.

One of the most serious pressures on coastal ecosystems has arisen due to the spiralling demands for fish and other seafood. Much of this demand for fish comes from small-scale fisheries which may represent between 50 to 95% of the total fisheries production in countries such as the Philippines and Indonesia respectively.

Demand for fresh (and even live) fish by countries outside the region has driven the overexploitation of fish species across the region. These demands have led to a massive reduction in fish species which otherwise perform importance roles such as have every within coastal ecosystems. The over-exploitation of fishery stocks has consequently led to changes in the ecological structure of coastal ecosystems, such as that seen in coral dominated reefs which have changed into systems dominated by large seaweeds and other non-coral organisms as well as disappearance of the top carnivore trophic level. The overexploitation of fisheries is also being accompanied by destructive fishing methods, which are being driven by an increasingly desperate bid by coastal people to obtain enough food and income from their coastal ecosystems.

The pressures from local stresses on Coral Triangle reefs are escalating, and in combination increasing impacts from global warming and oceans acidification, are rapidly destroying the ability of coastal ecosystems to provide resources to the millions of people that depend on them. The imperative to understand and reduce these pressures underpins one of the key responses that is required if these resources are to have any future in a globally changing world.

SPECIAL FOCUS 3: AQUACULTURE AND DAMAGE TO COASTLINES

Professor Edgardo D. Gomez

Coastal aquaculture has been practiced in Southeast Asia going back many decades, with tambacs going back more than a century. Traditional brackish water pond culture was sustainable until the advent of modern commerce and trade. In the 19th century, only limited areas of mangroves were converted into fishponds, but early in the 20th century, larger areas were affected. Thus, in the Philippines, as many as 80% of mangrove areas were destroyed, principally by conversion into brackish water aquaculture ponds, with a smaller proportion giving way to agriculture and coastal development. The large turnover occurred from the early 20th century until towards its end. [See Primavera 2000 for mangrove development issues.]

The conversion of mangrove areas into fish and shrimp ponds meant their alienation from the commons, resulting in the loss of traditional fishing grounds for many coastal fishers, as it was generally the wealthy who could afford to construct fishponds. In addition, losing nursery and feeding grounds for coastal fisheries meant reduced catch for the capture fishing communities. The negative impacts of mangrove conversion soon included siltation and pollution of adjacent coastal areas, which may include seagrass beds and coral reefs.

On the other side, large scale pond culture meant an increase in fish and shrimp production, contributing to the economies of countries like the Philippines, Indonesia, and Malaysia. In the Philippines, aquaculture production (although more than half of which is seaweed culture) now represents more than 40% of the total fisheries production (DA/BAS 2008), which is up from a contribution of only 10-15% about 50 years ago. Some questions have been raised about equity distribution of benefits, however.

The shrimp and prawn industries grew very rapidly in the last quarter of the 20th century, only to crash throughout the region because of bacterial diseases that affected virtually all farmed shrimp species. The diseases were no doubt helped by overstocking and poor water management practices. Because contaminated water travels alongshore, the problems spread over vast regions in a relatively short time. Partly because of the above and the growing demand for food fish, a new type of coastal aquaculture for finfish began to develop in the last decade of the 20th century.

Instead of raising the aquatic species in fresh or brackish water, many now grow them in seawater, using fish pens in very shallow water and fish cages in deeper water. This development has brought along its own environmental impacts. Where management has been weak, many coastal areas have been overcrowded with mariculture structures, limiting the water exchange along coastlines and channels, not to mention providing obstacles to navigation of coastal crafts. This changed hydrography also has its chemical and biological consequences. The large numbers of fish that need to be fed are living generators of excessive organic wastes, whether the materials go through their guts or not. Eutrophication (i.e. too many nutrients) of the water bodies may result. A considerable amount of feeds do not get ingested by the fish and end up on the bottom. The rain of feces and unconsumed feeds adversely affects the seafloor below or near the cages and pens, greatly increasing the BOD on the bottom.

The plants and animals that normally inhabit the area are thus adversely affected. The benthic fauna is changed, with the chemistry of the substrate and the burrows of infauna being negatively impacted. (Santander et al. 2008). Where cages have been unwisely placed over seagrass beds or coral reefs, these ecosystems are essentially sacrificed. However, even if the cages are not directly over, the negative impacts of pollution may be extended some distance downstream. And a recent study indicates that bacteria similar to those from fish cages can now be detected on corals some distance away, which may indicate the potential for adverse effects. (Garren et al. 2008)

Seaweed farming is also practised in several countries in the Coral Triangle. Fortunately, it is not as detrimental to coastal environments as fish or shrimp culture, principally because there is no feeding involved. It is not entirely without adverse effects, however. Farming near or above coral reefs may lead to physical damage of the corals, or their shading by floating racks of Kappaphycus spp. (=Eucheuma spp.), the red algae that is much in demand for its carrageenan, may result in slowed growth.

Global warming may have adverse impacts on fish and shrimp culture in the tropics in two ways. Higher temperatures may result in lower stocking densities in the culture structures, as hypoxia may become an issue in crowded enclosures. Additionally, higher temperatures may be stressful to cultured animals in enclosures, whether mobile fish or shrimp, as well as to sessile benthic invertebrates. Future ocean acidification may also adversely affect some molluscs.

Potential actions: The further conversion of mangroves must be managed and stopped where needed. Restoration should be done where feasible, particularly in abandoned fishponds. Coastal fish cage and fish pen culture should be managed sustainably so that capture fisheries and biodiversity are not compromised.

REFERENCES:

DA/BAS Dept. of Agriculture/Bureau of Agricultural Statistics (2008) http://www.bas.gov.ph

Garren M, Smriga S, Azam F (2008) Gradients of coastal fish farm effluents and their effect on coral reef microbes. Env. Microbiol. 10:2299-2312

Primavera JH (2000) Development and conservation of Philippine mangroves: institutional issues. Ecol. Econ. 35:91-106

Santander SMS, San Diego-McGlone ML, Reichardt W (2008) Indicators of Diminished Organic

Matter Degradation Potential of Polychaete Burrows in Philippine Mariculture Areas. Philipp. Agric. Scient. 91:295-300

Figure 1. A. aerial photograph of fish farms in the vicinity of Bolinao, in the Philippines.

B. Feed being applied to fish cage in the same area (G. Jacinto, Marine Science Institute, University of the Philippines)

CHAPTER 5
ECONOMIC PROFILE OF THE CORAL TRIANGLE COUNTRIES

This chapter contains general descriptions of each country in the Coral Triangle in an overall comparative framework. Chapter 6 then goes into more regional detail, both on socioeconomic features and on the geography and biology of the Coral Triangle. It refers to the section of the Sundaland hotspot area that overlaps the Coral Triangle from Bali north along the east coast of Borneo, and the hotspots of the Philippine archipelago, Wallacea (east and south of the Wallace Line between Bali and Lombok, Kalimantan and Sulawesi, and Indonesia and the Philippines which separates largely East Asian fauna from animals ultimately of Australian descent), and the East Melanesian islands.

As described in chapter 2, all four areas are official biodiversity hotspots, designated by Conservation International, four of only 25 on the planet. To qualify as a hotspot, a region must meet two strict criteria: it must contain at least 1,500 species of vascular plants (above 0.5% of the world's total) as endemics, and it has to have lost at least 70% of its original habitat to qualify as threatened. As explained in chapter 2, the hotspots are also species-rich in other endemic organisms, including the coral reefs in the Triangle.

To confine the description as far as possible to the Coral Triangle itself, the descriptions of Malaysia and Indonesia in Chapter 6 are supplemented by a focus on the 15 Indonesian provinces adjacent to the Triangle, and on Sabah. These areas are generally poorer than the western parts of the two countries, though Bali and the oil- and timber-producing East Kalimantan and Sulawesi are exceptions.

The collection of basic data for each country in total is shown below, with the usual qualification that even overall statistical data can be somewhat 'rubbery' but all attempts have been made to tell the story as straight as can be done despite these deficiencies. It is based on a number of general sources described in the footnotes to Tables 1 to 8, and the results are fed into the general country descriptions in Chapter 6, which describe the CT6 resources from a largely socioeconomic viewpoint.

COMPARISON TABLES

The tables below provide general information on the six CT countries in their entirety. Tables 1 to 3 contain data the CIA Factbook, latest version accessed March 2009 (CIA 2009). The CIA material is mostly quite up to date, with most indicators from 2007 or 2008, and in the case of the demographic indicators even using estimates for 2009. Possibly associated with the desire to be as up to date as possible, some indicators appear to be less reliable than what seems to be more thoroughly researched information from other sources (see below).

Table 4 has an environmental bent, coming from the World Bank's 2007 edition of the *Little Green Data Book* (World_Bank 2007), representing "a succinct collection of information from the Bank's World Development Indicators and its accompanying CD-ROM. It represents collaboration between the World Bank's Development Economics Data Group and its Environment Department."

Table 5 shows a small part of the monitoring of the United Nations' Millennium Development Goals, part of a program that was unanimously voted by all United Nations members in 2000 to set eight crucial goals for 2015. The program is briefly described alongside the table, with reference to the rich material available on the Internet. The last three tables, 6 to 8, are from the United Nations' work to monitor its Human Development Index, from the 2007-08 editions.

The six countries in Tables 1 to 8 are arranged from west to east, which helps identify two broad groups: three larger nations in the western section which are or may be on the way to industrial development status, and three small much less developed nations to the east. The Malaysian state of Sabah and the Indonesian provinces which surround the Triangle are also generally poorer than other parts of Malaysia and Indonesia but still benefit from being part of the larger entity.

Table 1: Geographic indicators

	Indonesia	Malaysia	Philippines	Timor-Leste	PNG	Solomons
Total area (sq km)	1,919,440	329,750	300,000	15,007	462,840	28,450
Coastline (km)*	66,760	4,484	34,343	794	16,483	9,921
Territorial sea (nm)	12	12	Other	12	12	12
Exclusive economic zone (nm)	200	200	200	200	200	200
Land use						
Arable land	11.0%	5.5%	19.0%	8.2%	0.5%	0.6%
Permanent crop	7.0%	17.5%	16.7%	4.6%	1.4%	2.0%
Other	81.9%	77.0%	64.3%	87.2%	98.1%	97.3%
Irrigated land (sq km)	45,000	3,650	15,500	1,065	na	na
Renewable water resources (cu km)	2,838	580	479	na	801	45
Freshwater withdrawals (cu km)	82.8	9.0	28.5	na	0.1	na
of which						
Domestic	8%	17%	17%	na	56%	na
Industrial	1%	21%	9%	na	43%	na
Agricultural	91%	62%	74%	na	1%	na
Per capita withdrawals (cu m/yr)	372	356	343	na	17	na

Source: CIA Factbook accessed March 2009.

Length of coastlines within the Coral Triangle - Nate Peterson, Stu Sheppard, The Nature Conservancy, based on Shuttle Radar Topography Mission (SRTM; NASA) using metadata from SRTM Waterbodies: U.S. Geological Survey Center for Earth Resource Observation and Science (EROS), National Aeronautics and Space Administration (NASA), National Geospatial-Intelligence Agency (NGA), ESRI, 20061001, ESRI® Data & Maps 2006 World, Europe, United States, Canada, and Mexico, ESRI, Redlands, California, USA

GEOGRAPHIC INDICATORS

Indonesia dominates the other five countries in the Coral Triangle in terms of size: almost 2 million square kilometres of land area compared with 300,000 to 460,000 km^2 in PNG, Malaysia and the Philippines. Timor-Leste and the Solomon Islands are relatively tiny (Table 1). Coastlines, however, are obviously another relevant geographic indicator where the archipelagos come out strongly: Indonesia with nearly 66,760 km and the Philippines with 34,343 km according to Peterson and co-workers who have recently used detailed satellite measurements to estimate CT country coastlines. They estimate a total coastline length of 132,800 km for the Coral Triangle region. The Solomons also have a high ratio of coastline to total area: the total coastline is larger than PNG's despite the land area being only 6%. The Solomon Islands coastline is also twice as long as East Malaysia's, which includes Sabah. Timor-Leste has only 700 km of coastline but in a geographic and biological context is really part of the Lesser Sunda ecoregion stretching east from Lombok (part of the Wallacea hotspot region).

Other geographic indicators include land use, divided into three parts: arable land for crops replanted after each harvest, such as grains and rice, permanent crops that are not replanted after each crop (excluding land under trees grown for wood and timber), and the vast majority of all land in all six countries consisting of forests and woodlands, pastures and meadows, built-up areas, roads, and barren land. The proportion of this 'other' land varies considerably from 64% in the Philippines (that is, 36% of that country's total area is used for crops), to 77% in Malaysia, 82% in Indonesia, 87% in Timor-Leste, and 97-98% in PNG and the Solomons. Again, land is used for crops to the greatest extent in the more developed areas around the Coral Triangle.

Indonesia dominates the total area in amount of irrigated land (45,000 km^2 followed by the Philippines with 15,500 km^2), and on renewable water resources and freshwater withdrawals. Per capita withdrawals are fairly comparable in Indonesia, Malaysia and the Philippines, at around 350 cubic meters per year. The little information we have for the three eastern countries suggests that withdrawals per head are a small fraction of these quantities.

DEMOGRAPHIC INDICATORS

The population in the six countries varies between 240 million in Indonesia according to CIA's mid-2009 estimate, and almost 100 million in the Philippines, towards 6 million in PNG, one million in Timor-Leste and 600,000 in the Solomon Islands. Malaysia's total population is around 26 million (Table 2).

Population growth and age distributions are correlated. Indonesia has the lowest population growth, through long propaganda calling for small families starting in the Soeharto years. The country also has by far the lowest birth rate, the highest median age, and the lowest total fertility rate (number of children born to the average woman through her life).

Table 2: Demographic indicators

	Indonesia	Malaysia	Philippines	Timor-Leste	PNG	Solomons
Population (million)	240.3	25.7	98.0	1.1	6.1	0.6
of whom:						
0-14 years	28.5%	31.4%	35.2%	34.7%	36.9%	39.5%
15-64 years	66.0%	63.6%	60.6%	61.9%	59.0%	57.1%
65+ years	6.0%	5.0%	4.1%	3.4%	4.1%	3.5%
Growth rate (% pa)	1.1%	1.7%	2.0%	2.0%	2.1%	2.4%
Median age (years)	28.1	24.9	22.5	21.8	21.7	19.8
Birth rate (per thousand population	19.2	22.4	26.4	26.5	28.1	28.5
Death rate (per thousand populatio	6.2	5.0	5.2	6.0	7.0	3.8
Infant mortality rate (deaths/ thousand live births)						
Total	30.0	15.9	20.6	40.7	45.2	19.0
Male	34.9	18.3	23.2	46.7	49.2	21.7
Female	24.8	13.2	17.8	34.3	41.1	16.3
Life expectancy at birth (years)						
Total	70.8	73.3	71.1	67.3	66.3	73.7
Male	68.3	70.6	68.2	64.9	64.1	71.1
Female	73.4	76.2	78.2	69.8	68.7	76.4
Total fertility rate (children/ woman	2.31	2.95	3.27	3.28	3.62	3.52
Literacy (age 15+ who can read and write)						
Total	90.4%	88.7%	92.6%	58.6%	57.3%	na
Male	94.0%	92.0%	92.5%	na	63.4%	na
Female	86.8%	85.4%	92.7%	na	50.9%	na
Education spending share of GDP	3.6%	6.2%	2.5%	na	na	3.3%

Figures in red are doubted. Life expectancy according to Table 6 are 10 years lower.

Source: CIA Factbook accessed March 2009.

The Philippines provides some contrast with a birth rate considerably higher than in Indonesia and Malaysia, a significantly lower median age, and a relatively high population growth rate (2% pa), comparable with Timor-Leste and PNG though less than the 2.4% pa in the Solomons.

The statistics of infant mortality tell an interesting and not entirely expected story, relating to the Solomon Islands. The numbers are doubted because the related demographic of life expectancy at birth is plainly wrong (see next paragraph). The infant mortality rate as shown is lowest in Malaysia at 15.9 deaths per thousand births, followed by the Solomons at 19 and the Philippines at 20.6. Infant mortality is much higher in PNG at 45 deaths per thousand births, and in Timor-Leste at 41 – and it is also quite high in Indonesia (30).

Similarly, life expectancy at birth according to the CIA Factbook was actually highest in the Solomon Islands (73.7 years), but this is contradicted by United Nations human development statistics in Table 6 showing only 63 years, which is accepted as much more likely to be correct. Malaysia then shows the highest life expectancy at birth (73.3 years). Indonesia and the Philippines were in an intermediate position at around 71 years, and Timor-Leste and PNG lowest together with the Solomon Islands (as amended to fit with Table 6).

These statistics show that socioeconomic data must be interpreted carefully in the process of building up a picture of where a country may be going. However, patterns may be discerned and adjustments made even though the original figures are not always very reliable.

The statistics of literacy, measured by the percentage of people aged 15+ who can read and write, again show a clear distinction between the three major countries to the west, and Timor-Leste and PNG (there are no statistics for the Solomons).

The final indicator in Table 2, education expenditure as percent of GDP, shows Malaysia supplying a hefty 6% and Indonesia, the Philippines and the Solomon Islands at around half that level or below. Given that the literacy rate in Malaysia trails that of Indonesia and the Philippines by a few percentage points, this indicates an effort on the part of the Malaysian government to improve its education system in a country which has achieved a higher living standard than other members of the Coral Triangle. In this it would be aided by higher average income per head of population shown by the economic indicators in Table 3.

Religion is another important characteristic which has an undoubted influence on the character of the people in many respects, and as the world has experienced can give rise to conflict and terrorism – as well as being important for the welfare of many people. Indonesia and Malaysia are predominantly Muslim (86% of Indonesians, 60% of Malaysians), though there are important minorities. In Indonesia, ethnic groups such as Chinese are often Christians, and so are many people in the easternmost part of Indonesia, including Maluku and Papua (a total of 9% of all Indonesians are either Protestants or Roman Catholics). In Bali, most are Hindus (1.8% of all Indonesians). In Malaysia, Buddhism (19%), Christianity (9%), and Hinduism (6%) form important minorities.

Two countries are predominantly Roman Catholic: Timor-Leste (98%) and the Philippines (81%). There are about 12% Protestants in the Philippines and a Muslim minority: 5% of the national total living mostly in southern and western Mindanao, southern Palawan, and the Sulu Archipelago. The two easternmost countries are mainly Protestant: 78% of the Solomon Islanders and 69% in PNG. Evangelical churches are prominent though there is a broad mix in both countries. The other main religion is Roman Catholicism (27% in PNG, 19% in the Solomon Islands).

POPULATION OF CORAL TRIANGLE AND ITS COASTAL DEPENDENTS

A key but often poorly-defined demographic statistic is how many people live within the Coral Triangle and how many of these people directly dependent on coastal resources. The current report takes the latest information and comes to the conclusion that the total population of the Coral Triangle is close to 150 million, with around 100 million of these people living close to (and being highly dependent on) coastal resources. The reasoning is as follows.

The total population in the Coral Triangle (in 2009) is estimated as follows from Table 2 (Demographic indicators): Total population of Philippines, Timor-Leste, PNG and the Solomon Islands (106 million), plus Sabah at 3 million (Leete 2008a), plus 15 provinces of eastern Indonesia. The total population of these provinces in 2000 was 35.7 million, when the Indonesian total was 206.3 million (17.3%). Applying this to the current Indonesian total, the 15 provinces would have about 41 million (perhaps slightly more as their population growth had been slightly above the Indonesian average). So the total current population in the CT is close to 150 million in round figures.

The coastal population has been estimated to be about 65% of the total by (Dahuri 1999) with previous estimates suggesting 70% of people being coastal (Chou 1994). While Dahuri (1999) applies to Indonesia, it is the most recent estimate we have for the Coral Triangle. It should be pointed out that this is probably an underestimate of the actual number of people living in coastal areas. Clearly, in the Melanesia island nations of the Coral Triangle, a much greater percentage of people live coastally. Therefore, the best and probably conservative estimate of the coastal population of the Coral Triangle is about 100 million people, which is close to the conclusions of others (e.g. 126 million people; (TNC 2009d).

ECONOMIC INDICATORS

Gross Domestic Product comparisons between different countries are measured in two different ways: by applying official exchange rates with the US dollar and by measuring it at purchasing power parity (PPP) exchange rates, which is the sum of the values of all goods and services produced in the country valued at prices prevailing in the United States. The concept is complex for a number of reasons, but is preferred by economists when assessing the welfare and living conditions across a nation. The difference between the two measures tends to disappear when conditions between developed and developing countries converge.

Table 3: Economic indicators

	Indonesia	Malaysia	Philippines	Timor-Leste	PNG	Solomons
GDP PPP ($ billion)	932.1	397.5	327.2	2.8	13.4	1.1
GDP per capita (PPP)	$ 3,900	$ 15,700	$ 3,400	$ 2,500	$ 2,300	$ 1,900
GDP official exchange rate ($ bn)	496.8	214.7	168.6	0.5	6.4	0.5
Real annual growth rate	5.9%	5.5%	4.6%	2.5%	6.3%	10.0%
GDP per sector:						
Agriculture	13.5%	9.7%	14.7%	32.2%	32.8%	42.0%
Industry	45.6%	44.6%	31.6%	12.8%	36.5%	11.0%
Services	40.8%	45.7%	53.7%	55.0%	30.6%	47.0%
Labor force (million)	112.0	11.2	36.8	na	3.7	0.3
of which:						
Agriculture	42.1%	13.0%	35.0%	90.0%	85.0%	42.0%
Industry	18.6%	36.0%	15.0%	na	na	11.0%
Services	39.3%	51.0%	50.0%	na	na	47.0%
Unemployment rate	8.2%	3.7%	7.4%	20-40% urban ->	80%	na
Household income or consumption share						
Lowest 10% of households	3.6%	1.4%	2.4%	na	1.7%	na
Highest 10% of households	28.5%	39.2%	31.2%	na	40.5%	na
Inflation (CPI growth)	10.5%	5.8%	9.3%	7.8%	8.8%	6.3%
Oil (million bbl/day)						
Production	1.04	0.75	0.02	0.08	0.04	-
Consumption	1.22	0.50	0.34	na	0.03	0.00
Exports	0.47	0.55	0.04	na	0.04	na
Imports	0.50	0.31	0.36	na	0.02	na
Proven reserves						
Oil (billion bbl)	4.4	4.0	0.1	na	0.1	-
Natural gas (trillion cu m)	2.7	2.4	0.1	0.2	0.2	-

Figures marked in red: Equivalent as shown to distribution of GDP per sector. Agricultural component likely to be higher.

Source: CIA Factbook accessed March 2009.

In fact, it can be observed within a country where a middle class emerges while the bulk of the population remains in traditional village or urban slum conditions. A survey of supermarket prices in Jakarta compared with Australian supermarkets before the Indonesian monetary collapse showed that for people able to go to these outlets, the convergence was actually complete (Hoegh-Guldberg 1997). This moneyed emerging middle class was so detached from the ordinary way of life even in Jakarta (let alone in remote villages) that the average Indonesian person could enjoy (if that is the word) a high purchasing power parity.

The British weekly *The Economist* still publishes its 'Big Mac Index' to illustrate PPP pared to its bones, based on a food item available throughout the world. In February 2009, people in China, Hong Kong, Indonesia, Malaysia, the Philippines, Russia, South Africa, and Thailand paid only about half of what Americans paid, but members of the Euro area paid 24% more, and Danes, Swedes, Norwegians, and Swiss even more. Of course, the Big Mac is only one item and a proper PPP index is based on a representative package of consumer goods.

Malaysia clearly stands out as the most developed country among the six, with a GDP per head in PPP terms of $15,000. Indonesia and the Philippines follow at $3,900 and $3,400, respectively. The differences between these countries and Timor-Leste, PNG and the Solomons would be greater if measured at market rates.

Stage of development also shows up in the distribution of labour force between the three main sectors. The share of agriculture is by far the lowest in Malaysia, with the Philippines and Indonesia again in an intermediate position and the share of agriculture highest in the three eastern nations. It is noted that the labour force distribution in the Solomons is identical with the distribution of GDP per sector, which cannot be right. These official estimates should be ignored. Unemployment shows similar patterns to the labour force distribution of the, with a low percentage in Malaysia, 7-8% in Indonesia and the Philippines, and considerably higher mainly urban unemployment rates in the eastern countries as far as the CIA can tell.

Income distributions appear to favour the relatively rich, especially in Malaysia and PNG and to a lesser extent in the Philippines and Indonesia. There are no data for Timor-Leste and the Solomons.

Inflation rates are high, with Indonesia topping the list and Malaysia lowest.

Indonesia and Malaysia are significant oil producers, in East Kalimantan and along the Malaysian peninsula, respectively. The quantities are small in the three eastern countries, but the 200 million cubic metre gas reserves in Timor-Leste are still potentially important for a tiny country.

ENVIRONMENTALLY RELATED INDICATORS

The World Bank produces an annual 'Little Green Data Book' as part of a collaborative project between its Development Economics Data group and its Environment Department. Table 4 shows recent data. The left-hand column shows comparison with the total East Asia and Pacific region ranging from China and Mongolia in the north to the CT countries in the south and including the Pacific island nations other than Australia and New Zealand. The top panel of Table 4 shows gross income per capita, this time at market rates rather than at purchasing power parity but showing similar patterns with Malaysia at the top at a wide margin, the Philippines and Indonesia following, and Timor-Leste, PNG and the Solomons at the bottom.

Table 4: Environmentally related indicators

	EA & P *	Indonesia	Malaysia	Philippines	Timor-Leste	PNG	Solomons
GNI per capita	$ 1,630	$ 1,280	$ 4,970	$ 1,320	$ 600	$ 500	$ 620
Urban population	41.5%	48.1%	61.3%	62.7%	26.5%	13.4%	17.0%
Urban population growth 1990-2005, pa	3.5%	4.4%	4.3%	3.7%	3.4%	2.5%	4.2%
Total population growth 1990-2005, pa	1.1%	1.4%	2.3%	2.0%	1.8%	2.4%	2.7%
Forest area (% of land area)	28.4%	48.8%	63.6%	24.0%	53.7%	65.0%	77.6%
Deforestation (average % pa 1990-2005)	-0.2%	1.6%	0.4%	2.2%	1.2%	0.4%	1.4%
National protected area (% of land area)	12.1%	14.3%	30.7%	8.2%	12.6%	1.6%	0.1%
Total known bird and mammal species	na	2,271	1,083	811	7	980	320
Of which threatened	na	267	90	120	1	91	41
GEF benefits biodiversity index (max 100)	na	90.0	14.8	33.7	na	na	na
GDP per unit of energy use (2000 PPP $/kg oil equivalent)	4.4	4.1	4.1	7.9	na	na	na
Energy use per capita (kg oil equivalent)	1,124	800	2,279	542	na	na	na
Electric power consumed per capita (kWh)	1,343	478	3,168	597	na	na	na
CO2 emissions							
Per unit GDP (kg/2000 PPP $ GDP)	0.6	0.4	0.7	0.2	na	0.2	0.2
Per capita (metric tons)	2.7	1.4	6.4	1.0	0.2	0.4	0.4
Total growth 1990-2003	40.6%	49.4%	64.7%	43.0%	na	3.4%	6.2%
Access to improved water sources (% of population)							
Total	79%	77%	99%	85%	na	39%	70%
Rural	70%	69%	96%	82%	na	32%	65%
Urban	92%	87%	100%	87%	na	88%	94%
Access to improved sanitation (% of population)							
Total	40%	55%	94%	72%	58%	44%	31%
Rural	51%	36%	93%	59%	56%	41%	18%
Urban	73%	72%	95%	80%	77%	87%	98%

* East Asia and Pacific (American Samoa, Cambodia, China, Fiji, Indonesia, Kiribati, Korea, Laos, Malaysia, Marshall Islands, Micronesia, Mongolia, Myanmar, Palau, Papua New Guinea, Philippines, Samoa, Solomon Islands, Thailand, Timor-Leste, Tonga, Vanuatu, Vietnam).

Source: World Bank, *2007 Little Green Data Book.*

Population growth is lowest in Indonesia (as already established), but urban population growth is high in all these countries except PNG. Urbanization is lowest in the small eastern nations, but except for PNG it is growing rapidly.

Forests cover most of these nations except the Philippines, where the cover is 24%. Deforestation has continued up to the time we have statistics, with the worst declines in the Philippines (with its already low forest cover) followed by Indonesia, the Solomon Islands and Timor-Leste. Malaysia has put the largest proportion of its land area into naturally protected areas (31%), far in excess of Indonesia (14%), Timor-Leste (12%) and the Philippines (8%). There is little activity on this front in PNG and the Solomons despite the fact that a considerable proportion of their bird and mammal species are threatened.

The Philippines appears to be twice as efficient as Malaysia and Indonesia producing energy-efficient GDP; all, however, have large numbers of threatened bird and mammal species. Malaysia, with its newly industrialized status, has far higher energy use and electricity power consumption per head of population compared with Indonesia and the Philippines. Malaysia also emits far more CO_2 than the other two countries and its emissions show the highest rate of growth since 1990.

Access to improved water sources and sanitation also follows income lines with Malaysia in the best position followed by the Philippines and Indonesia. The Solomon Islands seem to score relatively benignly on access to water but not on sanitation.

THE MILLENNIUM DEVELOPMENT GOALS

In the United Nations Millennium Declaration of September 2000, leaders from 189 nations embraced a vision for a world in which developed and developing countries would work in partnership for the betterment of all, particularly the most disadvantaged. To provide a framework by which progress could be measured, this vision was transformed into eight Millennium Development Goals, 18 targets and 48 indicators. In 2007, this monitoring framework was revised to include four new targets agreed to by member states at the 2005 World Summit; additional indicators to track progress towards the new targets were also identified (UN 2008).

The progress towards universal primary education is progressing best in Malaysia followed by Indonesia and the Philippines, with PNG and Timor-Leste lagging. The promotion of gender equality in schools and the literacy of 15-24 year olds have reached high levels in Malaysia and Indonesia with the Philippines lagging slightly behind on literacy. There is no economic pattern in the proportion of women gaining membership in national parliaments: Timor-Leste wins hands down on that score, followed by the Philippines. Indonesian women, already in third position in Table 5, are reported to plan to increase their share of seats in the next elections.

Table 5: Progress towards Millennium Development Goals (excluding Goal 1: Poverty)

Solomon Islands not included	Indonesia	Malaysia	Philippines	Timor-Leste	PNG
Goal 2: Achieve universal primary education					
Net enrolment ratio primary education	98.4%	99.9%	92.0%	68.1%	na
From Grade 1 reaching Grade 5	79.5%	99.4%	79.4%	na	58.2%
Goal 3: Promote gender equality and promote women					
Ratio girls/boys in primary school	1.0	1.0	1.0	0.9	0.8
Literacy rate of 15-24 year olds	98.9%	98.3%	94.4%	na	64.1%
Women in national parliament	11.3%	9.1%	15.3%	25.3%	0.9%
Goal 4: Reduce child mortality					
Mortality rate children < 5 (per 1,000 live births)	34	12	32	55	73
1 year olds immunized against measles	72%	90%	92%	64%	65%
Goal 5: Improve maternal health					
Maternal mortality rate per 100,000 births	420	62	230	380	470
Goal 6: Combat HIV/AIDS, malaria and other diseases					
People living wih HIV, 14-49 year olds	0.2%	0.5%	0.1%	na	1.8%
Tuberculosis per 100,000 people	253	125	432	789	513
Goal 7: Ensure environmental sustainability					
Land covered with forests	48.8%	63.6%	24.0%	53.7%	65.0%
CO2 emissions per capita (metric tons)	1.69	7.05	0.97	0.17	0.41
Access to improved drinking water (% population	80%	99%	93%	62%	40%
Goal 8: Develop global partnerships for development					
Internet users per 100 persons	4.7	54.2	5.9	0.1	1.8
General indicators					
Population (million)	231.6	26.6	88.0	1.2	6.8
Population growth (per annum)	1.3%	1.9%	2.1%	5.3%	2.4%
GDP per capita (PPP US$)	$ 4,130	$ 11,675	$ 5,473	na	$ 2,686
GDP growth (per annum)	5.5%	5.9%	5.4%	-1.6%	3.7%
Inflation rate	11.5%	2.6%	2.7%	12.3%	2.4%
Unemployment rate	10.5%	3.6%	7.3%	na	na
Life expectancy at birth (years)	68.6	73.0	70.3	58.3	56.7
Median age (years)	26.5	24.7	21.8	17.3	19.5

Source: Country fact sheets (http://www.mdgmonitor.org).

Child mortality rates largely follow economic lines with Malaysia lowest and Timor-Leste and PNG highest, but maternal mortality is higher than might have been expected in Indonesia. AIDS/HIV may be less of a issue in most of the countries although the country descriptions mention problem areas – and it is definitely a problem in PNG, especially in remote areas of that country. There is reason for continued vigilance throughout as in the case of tuberculosis (this disease has its highest incidence in Timor-Leste). Malaria is not even part of Table 5 but would flag a problem at least on a par with the two other diseases.

Among the indicators to ensure environmental sustainability, forest cover is highest in PNG and Malaysia and much lower in the Philippines than anywhere else. CO_2 emissions are much higher in Malaysia than anywhere else (four times the level in Indonesia, the next highest observation). Access to improved water sources largely follows economic lines.

Finally, the only indicator of goal 8: develop global partnerships for development, and not a terribly appropriate one, is Internet use. Malaysia has by far the highest value (54.2 users per 1,000 people), whereas only one in 1,000 has access to the Internet in Timor-Leste.

HUMAN DEVELOPMENT AND POVERTY INDICATORS

Tables 6 and 7 ranks the six CT countries in terms of standard indicators where each country is compared with all other countries where it is relevant to make the comparison. This applies to almost all countries for which data are adequate, in Table 6. The United Nations Human Development Index ranks Malaysia 63rd of 179 countries, the Philippines 102nd, Indonesia 109th, the Solomons 134th, PNG 149th, and Timor-Leste 158th (Table 6). However, on individual criteria Indonesia scores relatively well on adult literacy (62nd), Malaysia scores relatively badly on total gross primary, secondary and tertiary education enrolments (104th), the Philippines relatively highly on both adult literacy and total education enrolments, and the Solomon Islands better than might be expected on adult literacy.

Table 6: Human development index (2006)

	Indonesia	Malaysia	Philippines	Timor-Leste	PNG	Solomons
HDI value	0.726	0.823	0.745	0.483	0.516	0.591
Rank (of 179 countries)	109	63	102	158	149	134
Life expectancy at birth (years)	70.1	73.9	71.3	60.2	57.0	63.2
Rank (of 179 countries)	101	57	90	137	146	134
Adult literacy rate (15+)	91.0%	91.5%	93.3%	50.1%	57.3%	76.6%
Rank (of 179 countries)	62	60	49	135	125	100
Total gross education enrolment	68.2%	71.5%	79.6%	63.2%	40.7%	49.7%
Rank (of 179 countries)	116	104	57	126	167	158
GDP per capita (PPP) *	$ 3,455	$ 12,536	$ 3,150	$ 668	$ 1,950	$ 1,586
Rank (of 178 countries)	121	58	122	171	136	145

* Query for Timor-Leste. The CIA statistics in Table 3 suggests that the GDP shown here is at market rates.

Source: United Nations Development Program, Human Development Reports (http://hdr.undp.org/en/statistics/)

There are some discrepancies between Table 6 and previous indicators, including life expectancy at birth in the Solomon Islands. The figure here is the more reliable one.

The related human poverty index (Table 7) shows some clear distinctions between the six countries: Malaysia leads followed by the Philippines and Indonesia, and then not far behind Indonesia the Solomon Islands and much further behind PNG and Timor-Leste. The components of the poverty index are: probability of not surviving 40 years of age, adult illiteracy, lack of access to improved water sources, and the proportion of undernourished children. On each criterion Malaysia scores best, while the picture is more scattered for the other five countries: the Solomon Islands, for instance, has a better rating on undernourished children than either Indonesia or the Philippines.

Table 7: Indicators of human poverty (2006 except where indicated)

	Indonesia	Malaysia	Philippines	Timor-Leste	PNG	Solomons
Human poverty index	18.2	6.4	12.5	41.0	40.1	22.4
Rank (of 135 countries)	69	23	54	122	116	79
Probability of not surviving 40 years	8.7%	4.4%	7.0%	21.2%	20.7%	16.1%
Rank (of 135 countries), 2005	53	17	41	92	89	80
Adult illiteracy rate (15+)	9.0%	8.5%	6.7%	49.9%	42.7%	23.4%
Rank (of 127 countries)	42	41	32	114	104	78
No access to improved water source	20%	0%	7%	38%	60%	30%
Rank (of 123 countries)	73	4	28	98	122	88
Children 0-5 undernourished for age	28%	8%	28%	46%	35%	21%
Rank (of 135 countries)	106	52	105	133	118	92

Source: United Nations Development Program, Human Development Reports (http://hdr.undp.org/en/statistics/)

CARBON DIOXIDE EMISSIONS

The world has increased its emissions by about 2% pa between 1990 and 2004, with the largest percentage increases in China and Korea. In 2004, however, the United States remained the largest emitter, though China is reported to have taken over recently.

Indonesia, the Philippines and especially Malaysia have increased their emissions significantly although the CT countries' share remained at a modest 2.2% in 2004, compared with the fact that the CT countries represent 5.5% of the world population. While emissions per capita from these countries have risen significantly, they remain at about 40% of the world average.

Table 8: Carbon dioxide emissions

	Total emissions (Million tons CO_2)		Annual change	Share of world total		Population share	Emissions per capita (t CO_2)	
	1990	2004	1990-2004	1990	2004	2004	1990	2004
United States	4,818.3	6,045.8	1.8%	21.2%	20.9%	4.6%	19.3	20.6
China	2,398.9	5,007.1	7.8%	10.6%	17.3%	20.2%	2.1	3.8
Russian Federation	1,984.1	1,524.1	-1.9%	8.8%	5.3%	2.2%	13.4	10.6
Korea	241.2	465.4	6.6%	1.1%	1.6%	0.7%	5.6	9.7
Australia	278.5	326.6	1.2%	1.2%	1.1%	0.3%	16.3	16.2
Rest of world**	12,981.5	15,613.7	1.3%	57.2%	53.9%	72.0%	3.5	3.4
World	22,702.5	28,982.7	2.0%	100.0%	100.0%	100.0%	4.3	4.5
Indonesia	213.8	378.0	5.5%	0.9%	1.3%	3.5%	1.2	1.7
Malaysia	55.3	177.5	15.8%	0.2%	0.6%	0.4%	3.0	7.5
Philippines	43.0	80.5	5.9%	0.2%	0.3%	1.3%	0.7	1.0
Timor-Leste	-	0.2	na	-	0.0%	0.0%	-	0.2
Papua New Guinea	2.4	2.4	0.1%	0.0%	0.0%	0.1%	0.7	0.4
Total CT countries* **	314.5	638.6	6.5%	1.4%	2.2%	5.3%	1.2	1.9

* No information for Solomon Islands

** Growth rates inferred. Full data for calculations unavailable.

Source: United Nations Development Program, Human Development Reports (http://hdr.undp.org/en/statistics/)

SPECIAL FOCUS 4: THE PROMISE OF ECOTOURISM: STRATEGIES FOR TRANSLATING CORAL REEF VALUES INTO COMMUNITY WELL-BEING

H.Z. SCHUTTENBERG

Overview

In the Coral Triangle, reef management and conservation efforts cannot be separated from efforts to enhance the well-being of people. Ecotourism promises a direct mechanism for translating the intrinsic value of reef ecosystems into tangible economic opportunities for nearby human communities. Ecotourism is distinct from tourism more broadly in its intentions to protect the environment, maintain local cultures, and increase the environmental awareness of visitors while generating economic benefits. To achieve these goals, efforts to develop or maintain ecotourism must address a number of challenges:

- **Preventing Environmental Harm** - Poorly managed ecotourism is likely to result in environmental degradation. Coral reef ecosystems in particular are vulnerable to overuse by visitors and water pollution caused by constructing and operating tourist facilities. There are many unfortunate examples where inadequate consideration of environmental carrying capacity or the environmental impacts of tourism infrastructure have led to significant damage for the ecosystems at the heart of aspiring ecotourism ventures.

- **Protecting Local Culture & Resource Access** – Introducing tourism can create conflicts between local communities, ecotourism businesses, and visitors. There a number of examples in the region where local governments have granted concessions to tourism businesses that have resulted in local communities being denied access to fishing areas without receiving meaningful benefits from the tourism enterprise. Tourism businesses can also compete with local communities for access to fresh water or property. Local cultural traditions can be displaced by those that are more familiar or desirable to visiting tourists, and conflicts can arise if visiting tourist behaviours or standards of dress are at odds with those that are acceptable within the local culture.

- **Buffering Against Vulnerability to Changing Tourism Markets** – Unexpected changes in economic and political circumstances at global to local scales can have significant implications for tourism markets. Destinations that become overly reliant on income from tourism to support local economies or pay for environmental management are highly vulnerable to these market fluctuations. Diversifying financial sources is a better strategy whenever possible.

Well designed institutional arrangements can overcome the challenges outlined above and deliver the promise of ecotourism. This box highlights case studies that have succeeded in using ecotourism opportunities to improve community well-being and protect ecosystem condition. It also offers recommendations for developing and sustaining ecotourism in the CTI.

SUCCESS STORIES

- **Sharing Benefits, Empowering Communities: Bunaken National Park, Indonesia** – A partnership of government, tourism operators, and local communities in Bunaken National Park has established a system for managing the park that shares the benefits of ecotourism with local communities, has stopped the environmentally destructive practice of fishing by dynamite, and uses marine zoning to separate incompatible fishing and tourism activities. Visiting scuba divers pay a user fee that is locally collected and managed by a multi-stakeholder board that includes representatives for all three partners as well as the local university and environmental groups. Part of the user fee goes to supporting surveillance patrols that are jointly implemented by community members and government park rangers. The fee has also supported activities that directly enhance community well-being, such as scholarships for local school children or improvement to local infrastructure, including roads and schools.

- **Strengthening Environmental Conservation: Sugud Islands Marine Conservation Area (SIMCA), Malaysia** – The establishment of SIMCA through a government concession in 2001 has significantly strengthened environmental protections in this remote, approximately 450 km^2 area of the Sulu-Sulawesi Sea. Unlike typical tourism concessions that are negotiated directly with private business, SIMCA is a concession to an environmental non-profit called Reef Guardians, whose primary goal is marine conservation. Through a collaboration with government enforcement agencies, Reef Guardians has succeeded in reducing illegal activities within the conservation area, notably destructive fishing and poaching of turtle eggs. Reef Guardians funds its conservation and enforcement activities through sub-leases to tourism businesses, which charge visitors a conservation fee, as well as grants from philanthropic foundations. This arrangement has established a successful example of institutional checks and balances which insures that goals for environmental protection do not become secondary to other business priorities. It also diversifies funding options for conservation activities, improving financial stability against fluctuations in tourist visitation patterns.

- Fostering Community Stewardship, Twin Rocks Fish Sanctuary, Philippines – Twin Rocks is a 23 hectare fish sanctuary established by municipal ordinance in 1991. It is also a dive tourism destination, assisted in part by its accessibility from metro Manila. User fees are collected from divers and a portion of this supports community members who have been officially deputized to enforce the sanctuary regulations. This financial incentive is attributed with increasing enforcement which has improved coral cover and fish size. The Philippines MPA Support Network project recognized these accomplishments in 2007 by naming Twin Rocks as a finalist for the country's "most outstanding MPA" award.

RECOMMENDED ACTIONS

Ecotourism offers an enormous promise in the CTI as a way to improve the well-being of local communities and to strengthen protections for coral reef and coastal ecosystems. These benefits are most likely to be realized when stakeholders work together to develop fair and transparent institutional arrangements, avoid over-reliance on tourism income, and plan ahead for climate change related impacts.

1. **Institutional Arrangements** – Embed ecotourism ventures in institutional arrangements that create benefits and responsibilities for governing authorities, ecotourism operators, and other community stakeholders (e.g., fishers). These institutions will need to insure that economic benefits enhance, rather than compete with, sufficient environmental protections and the well-being of local communities. Particular attention should be given to establishing fair and transparent procedures for the way user fees will be collected and spent. Mechanisms such as stakeholder boards or trust funds may provide better administrative mechanisms for keeping money local and re-investing it in community and conservation-relevant projects.

2. **Financial Diversity** – Recognize that tourism visitation may be volatile and try to diversify economic options for local communities. Pursue a diversified portfolio of financial support for environmental management activities by supplementing user fees with annual government funding allocations and project-specific funds from external donors.

3. **Climate Change Planning** - The impacts of climate change on ecosystem condition, tourist visitation patterns, and tourism business viability are increasingly being identified. In 2003, the World Tourism Organization issued its Djerba Declaration on Tourism and Climate Change calling for action to mitigate climate change, assist local destinations with adaptation, and foster more climate-friendly choices by consumers. With climate change, the role ecotourism can play in strengthening environmental protections and raising public awareness become even more important. Identify the potential impacts of climate change in your local area, and, if appropriate, develop a strategy to support the resilience of coastal ecosystems and the human communities that rely on them through ecotourism. Ecotourism businesses should also identify and prepare for the potential impacts climate change may have on their operations.

REFERENCES

Eagles, Paul F.J., McCool, Stephen F. and Haynes, Christopher D.A. (2002). Sustainable Tourism in Protected Areas: Guidelines for Planning and Management. IUCN Gland, Switzerland and Cambridge, UK. xv + 183pp. Available for download (as of 29 March 2009) from: http://app.iucn.org/dbtw-wpd/edocs/PAG-008.pdf

Huttche, C.M., White, A.T., and Flores, M.M. (2003). Sustainable Coastal Tourism Handbook for the Philippines. Coastal Resources Management Project of the Department of Environment and Natural Resources and the Department of Tourism, Cebu City, Philippines, 144pp. Available for download (as of 29 March 2009) from: http://dec.usaid.gov/index.cfm?p=search.getCitation&CFID=4408&CFTOKEN=68197454&rec_no=123050

Schuttenberg, H.Z. and Marshall, P.A. (2007). "Managing for Mass Coral Bleaching: Strategies for Supporting Socio-ecological Resilience" in Status of Caribbean Coral Reefs after Bleaching and Hurricanes in 2005. eds. Wilkinson, C and Souter, D. pp115-127. Available for download (as of 29 March 2009) from: http://www.coris.noaa.gov/activities/caribbean_rpt/

Tapper, R (Ed). (2005). Managing Tourism & Biodiversity: User's Manual on the CBD Guidelines on Biodiversity and Tourism Development. Secretariat of the Convention on Biological Diversity. 122pp. Available for download (as of 29 March 2009) from: http://www.cbd.int/doc/programmes/tourism/tourism-manual-en.pdf

Other References

Erdman, M.V., Merrill, P.R., Mongdong, M., Arsyad, I., Harahap, Z., Pangalila, R., Elverawati, and R., Baworo, P. (2004). Building Effective Co-management Systems for Decentralized Protected Areas Management in Indonesia: Bunaken National Park Case Study. Natural Resource Management Program, Jakarta, Indonesia, 137pp.

Philippines Association of Marine Science. (2008). 2007 Outstanding MPA Awards and Recognition: Promoting MPA Best Practices. MPA Support Network, Marine Environmental & Resources Foundation, Inc. and the Marine Science Institute, University of the Philippines, Diliman, Quezon City, Philippines, 40 pp.

Teh, L.C.L., Teh, L.S.L., and Chung, F.C. (2007). "A private management approach to coral reef conservation in Sabah, Malaysia" in Biodiversity Conservation, 17:3061–3077.

World Tourism Organization. (2003). Djerba Declaration on Tourism and Climate Change. Available for download (as of 29 March 2009) from: http://www.world-tourism.org/sustainable/climate/decdjerba-eng.pdf

Photo 1 Caption: The Sugud Islands Marine Conservation Area is a partnership between government, an environmental NGO, and a tourism enterprise in Malaysia that has strengthened enforcement against illegal fishing. Evidence from the experiment shown here suggests that better enforcement is resulting in larger fish in the conservation area (Photo: James Tan Chun Hong)

Photo 2 Caption: A portion of the user fee collected from divers at the Twin Rocks Fish Sanctuary in the Philippines supports community members who have been officially deputized to enforce the sanctuary regulations. These community rangers are called Bantay Dagat (Photo: Heidi Schuttenberg, CSIRO)

CHAPTER 6
COUNTRY DESCRIPTIONS

In order to build credible scenarios, it is important to understand the context and individual drivers within each of the six Coral Triangle nations. This chapter draws together detailed profiles of each of these nations in preparation for building credible futures for these nations. To achieve a reasonably consistent framework, standard sources of these descriptions include the *CIA Factbook* (CIA 2009), the *United Nations Human Development Reports* and Millennium Development Goal materials. The United Nations Development Program's Fiji office is the source of supplementary material on PNG and the Solomon Islands. These sources are supplemented where possible with the personal knowledge and experience of participating authors. A number of other resources obtained through the Internet are listed in Appendix 3.

The last section of each country description, entitled 'coastal resources and change', deals with selected geographic areas in which coral reefs are important components.

INDONESIA

A. Background and recent history

The country is an archipelago of about 17,500 islands, of which the government estimates that about 920 are permanently inhabited. It straddles the equator and occupies a strategic location along major sea lanes from the Indian to Pacific Oceans. Eastern Indonesia, which contains the Coral Triangle, is described in a separate section below with reference to statistical detail in Appendix 4. It is the world's largest archipelagic state.

After more than 300 years of Dutch rule from the early 17th century, Japan occupied the islands from 1942 to 1945. Indonesia declared its independence after Japan's surrender. It required four years of intermittent negotiations, recurring hostilities, and UN mediation before the Netherlands agreed to transfer sovereignty in 1949. The first president was the charismatic Sukarno, who was the personification of the independence struggle. With time, however, he associated himself with non-aligned leaders such as Egypt's Nasser, India's Nehru, Yugoslavia's Tito and Ghana's Nkrumah. Internally, he replaced a somewhat chaotic democracy with 'guided democracy' in 1957, inspired by the traditional village system of discussion consensus under the leadership of village elders. This system was intended to appease the three main political factions, the army, Islamic groups, and the communists.

The system backfired in 1965 and Sukarno was effectively removed the following year, which also saw a huge bloodbath with between 500,000 and one million alleged communists killed. In 1967, Major General Soeharto took over he full presidency, leading the country into three decades of economic development but also into an era of truly monumental corruption centred on the president and his family. In 1997, the Indonesian economy collapsed during the Asian economic crisis, and Soeharto stepped down the following year.

The free parliamentary election took place after these decades of repressive rule took place in 1999. Indonesia is now the third-largest democracy worldwide, as well as having the world's largest Muslim population. Issues facing Indonesia include alleviating poverty, preventing terrorism, advancing educational standards, consolidating democracy, implementing economic and financial reforms, curtailing corruption, holding the military and police accountable for past human rights violations, addressing climate change, and controlling avian influenza.

In 2005, Indonesia reached an important peace agreement with armed separatists in the northern Sumatran province of Aceh, which led to democratic elections in December 2006. Indonesia continues to confront a low-intensity separatist movement in Papua. However, the only loss of territory through the life of the republic was Timor-Leste, which achieved formal independence in 2002.

Since the economic collapse and Soeharto's fall, when there appeared to be some dangers that the country might disintegrate (Hoegh-Guldberg 1998a,b), Indonesia eventually returned to a higher degree of stability, especially under President Yudhoyono's leadership from 2004.

B. Government

The Republic of Indonesia is governed from the capital Jakarta. It has 33 administrative divisions called provinces (including several new ones created since 2000), of which 15 adjoins the Coral Triangle. These are generally poorer and have different demographic characteristics from the western provinces centred on Java, where more than half the population lives. Following the implementation of decentralization beginning on 1 January 2001, the 465 regencies and municipalities within the provinces have become the key administrative units responsible for providing most government services.

C. Economy

After the major economic setback in 1998, Indonesia, a vast polyglot nation, has made significant economic advances, but currently faces challenges from the global financial crisis and world economic downturn. Indonesia's debt-to-GDP ratio in recent years has declined steadily because of increasingly robust GDP growth and sound fiscal stewardship. The government has introduced significant reforms in the financial sector, including in the areas of capital market supervision, tax and customs, and the use of Treasury bills, and. Indonesia's investment law (passed in March 2007) sought to address some of the concerns of foreign and domestic investors.

Indonesia still struggles with a complex regulatory environment, poverty and unemployment, poor infrastructure, corruption, and unequal resource distribution among regions. The non-bank financial sector, including pension funds and insurance, remains weak, and despite efforts to broaden and deepen capital markets, they remain underdeveloped. Economic difficulties in 2008 centred on high global food and oil prices and their impact on Indonesia's poor and on the budget.

The onset of the global financial crisis dampened inflationary pressures (though the rate remains high according to Table 3 of the previous chapter), but increased risk aversion for emerging market assets resulted in large losses in the stock market, significant depreciation of the rupiah, and a difficult environment for bonds. As global demand has slowed and prices for Indonesia's commodity exports have fallen, Indonesia faces the prospect of growth significantly below the 6% recorded in 2008.

D. Progress towards the Millennium developements goals

Indonesia has made significant progress towards attaining the Millennium Development Goals since the economic crisis and political transformation of 1997-1998. The indicators and development goals of the Medium Term National Plan for 2004-2009 and the National Poverty Reduction Strategy are in line with the MDGs and in some ways are more ambitious than the internationally set targets. Efforts are now under way to mainstream the MDGs into provincial and local development planning and budgeting, and to strengthen the somewhat weak statistical capacity needed to monitor the goals.

But the picture is mixed, with notable challenges. In 2007, 16.6% of the population still lived below the national poverty line. Almost half of the population does not have access to safe water and more than a third lack adequate sanitation. According to the most recent data available from 2004, a maternal mortality rate of 307 per 100,000 women was still among the highest in South-East Asia. Also, despite an apparently low overall incidence, HIV/AIDS is spreading fast among some vulnerable groups and remote regions.

The Government of Indonesia is committed to increase funding for education, poverty alleviation, and health. For example, Indonesia has established the National Community Empowerment Program (PNPM), which seeks to improve rural infrastructure through block grants to sub-districts and create short-term employment for thousands of Indonesians. It was anticipated (before the financial crisis) that by 2009 PNPM will target 5,263 sub-districts in Indonesia with a budget amounting to approximately US$19 billion. In addition to this program, a conditional cash transfer program is also being piloted that will provide cash support for most impoverished to access to health and education services.

However, with an economic slowdown originally driven by high fuel and food prices and now by the global recession originating in the United States, Indonesia's ongoing poverty reduction efforts are being further tested. While the country has benefited somewhat from the hike in commodity prices such as coal and palm oil, being a net oil importer the country has to bear the burden of rising oil prices. As a consequence, the government had to raise the fuel prices by another 29% in May 2008. To offset the impact for the poor, the government is providing direct cash transfers to the poorest households. By early 2009, the Indonesian government reduced fuel price by 25%.

The MDGs may or may not be achieved at the national aggregate level by 2015. The major hurdle that Indonesia faces is how to achieve this across the country. Indonesia's decentralization offers both opportunities and challenges. A greater amount of resources is needed for allocation to address capacity issues at the local level; and greater investments have to be made to improve rural infrastructure, provide employment opportunities, and extend the outreach and upgrade the quality of public services.

E. Eastern Indonesia

The following is a summary of statistics analysed in Appendix 4.
The 15 provinces around the Coral Triangle cover a total area of one million km^2, slightly more than half the total country. But only 17% of the total population live there; at 36 per km^2 in 2000, the population density is only one-fifth of that of the rest of the country (mainly due to Java where the density is approaching 1,000 per km^2). Population growth in Indonesia has been declining, mainly in Western Indonesia, and is now higher than the national average in the provinces around the Coral Triangle.

Child mortality and the total fertility rate of women fell dramatically between 1971 and 1999.

The Indonesian GDP has grown at an accelerating rate in recent years. Indonesian statistics showing 5.1% pa in constant prices between 2003 and 2007 understate the true expansion recorded by the United Nations. However, the annual growth rate is about 1.2 percentage points lower in the Coral Triangle provinces.

Longer series of national statistics show that the economy crashed by 13% in 1998 as the Asian economic crisis hit. It only recovered to pre-crash levels in 2002. In the past several years, however, economic growth has been accelerating until it exceeded 6% in 2007. The current global recession will put a damper on that, whether for Indonesia as a whole or Eastern Indonesia around the Triangle. GDP per head appears to be about 11% lower than the national average in the Coral Triangle provinces, despite East Kalimantan where GDP per head is 2.5 times the national average.

The provinces around the Coral Triangle accounted for 15.5% of the total Indonesian GDP and 18.8% of total construction activity between 2003 and 2007.

Marine fisheries in Indonesia averaged 437,000 tons between 2000 and 2007, of which 80,000 tons was in the Coral Triangle. However, aquaculture production is much higher, averaging 2.1 million tons between 2004 and 2006, of which 1.1 million tons was in the Coral Triangle.

The tourist industry around the Coral Triangle is not well developed except in Bali, which in 2008 accounted for 42,400 of 97,700 rooms in these provinces. Of 46,700 daily visitors to the area, 17,600 were foreign and 16,300 of these came to visit Bali. Domestic visitors were more evenly distributed but even here 9,900 of 29,000 were Bali visitors.

Other eastern provinces with relatively high numbers of visitors were North and South Sulawesi, East and South Kalimantan, and West Nusa Tenggara. But Bali dwarfs them all.

The analysis by Hill et al. (2008) supports our analysis in Appendix 3. Economic activity is centred on Java, but East Kalimantan is the second-most important Indonesian growth centre, after Jakarta. Generally, however, the poorest regions located mainly in Eastern Indonesia have grown only a little more slowly than the national average. No province has shown consistently poor performance over decades.

F. Coastal resources and change

As outlined in previous sections of this report, Indonesia has by far the greatest reef area (50,875 km^2 including Western Indonesia), followed by the Philippines (25,800 km^2) and total Malaysia (4,000 km^2, of which Sabah accounts for three-quarters). In this section, the specific interactions between economic and environmental sectors are explored in the context of coastal resources and climate change. Given that it is impossible to review the entire set of examples available, a number of representative cases were chosen for Indonesia. These include Bali, the island group of Derawan (also known as the Sangalaki group) in the Makassar Strait off the coast of East Kalimantan, three provinces in Sulawesi, East and West Nusa Tenggara, Halmahera in North Maluku, the Aru Islands and other reef areas in Maluku province, and Raya Ampat in West Papua.

BALI

Coral reefs are found mainly along the north and west coast of Bali. The main structures are along the north-western tip of the island, north of Gilimanuk with its short-distance ferry service to Java, in the West Bali National Park and Marine Reserve. The park was originally declared in 1941 to protect the threatened Bali starling and the wild *banteng*, from which Balinese cattle descend. The last starlings still nest in the *Acacia* shrubs on the north coast of Parpat Agung cape on the northwest promontory, within the national park.

Its marine reserves include the cape shores and several sanctuary islands in Gilimanuk Bay which is a refuge for sea birds. But the centre of interest is Menjangan Island 10 km offshore, and the excellent coral reefs surrounding it. The quiet and relatively unspoiled area of easily accessible shallow reefs is described as a diving and snorkelling paradise.

The areas have not been well developed for tourism, and the vast majority of visitors to Bali stay in the south anyway. More than 70% of the local population catch fish for daily consumption and looking for exotic species to sell for exports. Unfortunately they have (or have had) a preference for using sodium or potassium cyanide, which is also lethal for corals because it kills the symbiont zooxanthellae.

This practice led to the formation, in 2002, of the Communication Forum for People Concerned with Coastal Areas (known by its Bahasa Indonesia acronym of FKMPP) in an attempt to resolve the conflict between fishermen, local communities, and tourism and environmental organizations concerned with national park conservation.

One solution to the problem of diversifying livelihoods was devised by a villager who imported seaweed from East Nusa Tenggara. Starting in 2003, he soon raised other people's enthusiasm for planting seaweed. The women process it into food snacks like seaweed chips, cakes, seaweed gelatins, and other products. As the source expressed it: "This business became viable and an effective solution for local people's economy." The seaweed development now covers 15 km along the north coast.

This is an example of changing attitudes after local concerns emerge about the future of a reef area. It is accompanied by activities in nearby Pemuteran, where an artificial reef project started in 2000 assisted by the late Professor Wolf Hilbertz and Dr Thomas Goreau of the Global Coral Reef Alliance. With a total length of 222 metres and situated in an area of two hectares, this is the largest coral reef nursery and restoration project ever attempted. It exceeds the sizes of all other ongoing projects in the Pacific, Caribbean and Indian Ocean combined.

The northwestern coastal area is one of the poorest areas of Bali, with insufficient rainfall for rice growing. The population resorts to fisheries with the expected damage from destructive fishing practices following.

Coral reefs elsewhere include Tulamben on the northwest coast, considered the best in Bali. Attractions there include diving to a famous wreck, the USS Liberty torpedoed by the Japanese during World War II. Tulamben is closer to the other tourist attractions and therefore ought not to be so dependent on subsistence fisheries.

Nevertheless, fishing has involved much use of bombs and cyanide by fishermen, and flood damage in 2002 and irresponsible behavior of people mooring boats and taking underwater photographs have added to the damage. Warming sea temperatures have added further to the damage.

Tulamben village residents have taken action to prevent use of these destructive methods on their reefs, whether by locals or by outsiders. However, the amount of damage is so great that action is urgently needed to restore reef habitat for tourism and fisheries, hence triggering the restoration projects described above.

EAST KALIMANTAN: DERAWAN ISLANDS

"Off the coast of East Kalimantan, the 95-mile Derawan island chain is one of the most biologically rich marine sites in the world, with 460 species of coral and over 700 species of fish. The area is also home to Indonesia's largest population of nesting green sea turtles and four unique species of stingless jellyfish." (TNC 2009a).

Of 31 islands in the Derawan group, two are inhabited: the largest 2,376 ha island, Maratua, is reported to have four villages with a total of 2,700 people, and the small 45 ha island of Derawan has one village of 1,260 inhabitants. Fishing is most important and fishing methods remain controversial. Since the early 1990s, high demand and high prices have spurred the capture of live groupers, napoleon wrasses, and lobsters. The island is considered a world-class dive tourism destination, with three international dive resorts and more being planned.

Problems are listed as:

- Overfishing and overexploitation, including turtle egg collection.
- Destructive fisheries utilizing cyanide and explosives.
- Environmental degradation caused by diving-related activities and unsustainable tourism development, especially around Lake Kakaban (see below).
- Increasing sedimentation due to intensive logging activities in the Berau estuary on the nearby mainland, and in the adjacent watershed areas. This has led to the increased injection of s ediments and nutrients into rivers and creeks that flow into coastal waters, causing major issues for coral reefs.
- Increasing sewage pollution caused by growing human population on small islands and intensive tourism development.

Lake Kakaban is located on the uninhabited 774 ha island of Kakaban. The lake was originally the lagoon of an atoll, formed by corals over a period of two million years. As a result of movements in the earth's crust the coral reef was raised above the sea level, trapping 5 km^2 of seawater within a 50 meter high ridge, effectively creating a landlocked marine lake. The Indonesian Coral Reef Foundation is concerned that an uncontrolled increase in visitor numbers without a code of conduct for sustainable tourism and without a zoning scheme for different lake areas will lead to a fast increase of physical damage to the unique animal and plant communities living in the shallow areas around the lake (Terangi 2006).

According to a recent WWF study, the green turtle nesting population in the Derawan islands complex appears to be declining quite strongly. On Sangalaki Island (15 ha), the average number of nests per month during 2002-2006 was 57.5% of that recorded during 1995-2000. On Derawan Island, the average number of nests per month during 2002-2006 was 25.5% of that recorded during 1985-1990 (Adnyana et al. 2008).

In conclusion, the main problems facing coral habitat in the Derawan island group come down to damage from visitors, as the local population is small and most islands remain uninhabited. The rise in tourism, while still at modest levels, appears to be a growing problem unless properly managed.

SOUTH SULAWESI

In contrast to the reefs off East Kalimantan which have been given a low threat rating in *Reefs at risk*, large reef areas in the provinces of South, Southeast and Central Sulawesi are given a threat rating of high or very high (Burke et al. 2002, p 37). This makes these areas obvious candidates for case studies. All three come up with rather similar conclusions.

According to a study by Hasanuddin University's Coral Reef Research Centre in Makassar, coral reef destruction in South Sulawesi has reached alarming heights and today poses a real threat to the ongoing livelihoods of regional fishermen. With some 70% of the 5,000 km^2 of reefs destroyed, this has also caused great losses to the state via the fishery sector (Hajramurni 2007), reporting to the *Jakarta Post*).

The worst-affected reefs are around Bulukumba regency, with a destruction level of 100% - followed by Pangkajene Islands (Pangkep) at 97%, Sinjai at 86% and Selayar, which encompasses the Taka Bonerate undersea national park, at 70%.

"If the condition persists, the coral reefs would likely disappear and coastal communities would bear the brunt," said the head of the university's maritime study program, Chair Rani.

Several factors have been blamed, but the most disastrous is the long-practised habit of using fishing bombs and poison to catch fish. The reefs were also exploited for exports and building materials.

Natural disasters including earthquakes and strong waves have also caused deterioration in the state of the coral reefs. Fish bombs and poison not only cause serious damage but they decimate coral reefs and marine biota. Coral reefs grow very slowly but fishermen continue to practice illegal fishing, opting for explosives and poison to catch their fish quickly and easily.

The damage would eventually see coastal communities face difficulties in their search for fish. Coral destruction would also cause an increase in coastal abrasion because the coral reefs would no longer break the waves before they hit the beach.

The head of the South Sulawesi Maritime and Fishery Office, Sahrun, generally confirmed the scale of destruction. He said the South Sulawesi administration has launched efforts to prevent further damage to coral reefs and to carry out restoration works. Pangkep and Selayar regencies would receive assistance from the World Bank to help prevent further degradation. Rani said the most effective way to prevent coral reef destruction was by implementing community-based marine management and protection programs. The programs, he said, should directly encourage people to manage and protect their marine resources. He said law enforcement should be strictly implemented (Laporan Tahunan, Annual report 2007).

A number of regulations on the environment and coastal management are in place, but are not fully enforced. And research has shown traditional fishermen are not the only culprits of illegal fishing practices – large companies are also to blame. However, compromised officials often turn a blind eye, and surveillance is not managed properly due to lack of personnel and equipment. The South Sulawesi Maritime and Fishery Office has only 10 personnel and a small speedboat, which is inadequate given the task of regulating such a vast area.

SOUTHEAST SULAWESI

WWF and The Nature Conservancy as part of their worldwide joint reef resilience program have studied the four islands comprising the Wakatobi National Park off the tip of Southeast Sulawesi. Even within one of the world's recognized centres of biological diversity, the area stands out for its coral reef diversity. Throughout Sulawesi, marine and coastal ecosystems are of high ecological and economic importance, including fisheries and commercial uses. For these reasons, 3.4 million acres (13,750 km^2) of islands and waters were declared as the Wakatobi National Park in 1996. The name of Wakatobi is originally from four largest islands in the area i.e. island of Wangi-wangi, Kaledupa, Tomia, and Binongko).

An ecological assessment in 2003 revealed widespread coral damage primarily from fishing pressures, and minimal coral bleaching. The reefs in the area have suffered little from the impacts of coral bleaching. Interestingly, no mass-bleaching events have been documented. The immediate threats to Wakatobi National Park arise from destructive fishing practices (fishers using explosives and cyanide) and overfishing. In addition, coastal development threatens the coral reef and coastal environment of the area.

To address overfishing and destructive fishing practices in Wakatobi, TNC and WWF have been working with the Wakatobi National Park Authority as well as a broad range of stakeholders to redesign the park's management plan. By involving communities, focusing in collaborative management and building firm legal foundations for park zoning and enforcement, conservation action at Wakatobi is intended to become environmentally, socially, and economically sustainable.

TNC reports on lessons learnt (as listed at: www.reefresilience.org/Toolkit_Coral/C8_Wakatobi.html)

- Stakeholder input from forums with the local community, prior to work in the field, ensures that the work is supported by local community and government.
- Extensive work with the local community has enhanced local understanding of the benefits of marine park authorities, and their need for involvement with park management.
- Extensive work with the local government was essential to encourage and advance the shared management regime between the local government and the national park.
- Having a solid team, structured work, clear budget allocations, clear tasks and responsibilities among all team members is necessary for an effective project.
- Extensive monitoring is needed to incorporate comprehensive data analysis with the Marxan software (which is primarily a product of Ian Ball's PhD thesis (Ball 2000) that was supervised by and funded through Professor Hugh Possingham of the University of Queensland) which provides decision support to a range of conservation planning systems, to make sure MPA design and planning align with the biological and ecological characteristics of the area.

CENTRAL SULAWESI

The reefs on both sides of this province, ranging from the Makassar Strait in the west (including the fiord-like Palu Bay) into the Maluku Sea in the east, have almost invariably been marked as under high or very high threat in *Reefs at Risk in Southeast Asia* (Burke et al. 2002). Reefs here lie at the centre of the Coral Triangle are indeed under heavy pressure from human activities – interesting in that the majority of the population is apparently still unaware of the role these key coastal ecosystems play in supporting livelihoods and coastal protection (Moore 2008).

Surveys in the Palu Bay areas have revealed damage from sedimentation to both the seagrass beds (inter-tidal area) and the coral reefs (some almost completely buried below around 9 -10m depth), not surprising in view of the deforestation of the now mainly bare mountains above the site. Impacts on reefs arise from ornamental fish collection using poisons and causing physical damage, coral mining, anchor damage (from stone anchors used by artisanal fishers, severe around 6-10m depth). The most severe recent damage occurred due to an outbreak of the crown-of-thorns starfish (*Acanthaster plancii*), one of several in recent years in Palu Bay.

Populations of commercially valuable fish and invertebrates, as well as those used for subsistence, are very low in the Palu Bay according to recent surveys. The biodiversity of fish and shellfish is also surprisingly low in relation to the coral condition, which still provided much unused habitat. According to experts working in the region, it seems likely that the main cause is chronic overfishing.

Moving east takes us to the Togean Islands, inside the entrance of the Gulf of Tomini. While these islands mainly appear on the Internet as a tourist destination for great dive experiences, they are also the topic of a critical paper on destructive fishing practices (Lowe 1999). She starts: "The fishers of the Togean Islands ... are in a bind. On the one hand, the live reef food fish trade is an attractive source of employment. On the other, wild reef fish, which provide fishers with an income through longstanding markets for salted fish, and which is also an important local food resource, are becoming rare. Due to cyanide use, the live reef food fish trade has quickly proven harmful for the majority of fishers, and to coral reef environments."

Her long paper concludes: “Rather than condemn the industry and its fishers, I have argued we need to understand who participates in the destructive aspects of live fishing, what bureaucratic, social and legal structures facilitate participation, and how and why have they come to exist. By recognizing that the most substantive ecosystem abuses are not organized locally, but rather underwritten by an interconnected bureaucracy and commercial community, we may find a basis for alliance with Togean and other local peoples.”

Whatever the opinion is about the cause of these fishing practices, it is a fact that they are once again seen as central to most problems of sustainability surrounding Indonesian coral reefs. This is reinforced when we reach the last of Central Sulawesi’s highly or very highly threatened coral reef areas: the Banggai Islands. The descriptions here tend to concentrate on the Banggai cardinalfish (*Pterapogon kauderni*), which is being captured for the international aquarium trade in unsustainable numbers. However, the following statements from the website quoted in the reference section show that the problem of destructive fishing practices is also recognized here, as well as the impact of pollution:

- The Banggai cardinalfish is threatened by the loss of habitat caused by destructive fishing practices, including the use of cyanide and dynamite, and increased siltation and pollution runoff from land clearing and poor agricultural practices.
- Significant changes in the health and vigour of coral populations and fish diversity within reef habitats have been observed since 2001. During the March 2007 census, extensive areas of coral reef habitat were found to be covered with algae, a fungus, or bacteria making them unsuitable as habitat for the Banggai cardinalfish and other fish species.

WEST AND EAST NUSA TENGGARA

Nusa Tenggara and Maluku covers a number of islands and ocean, much of which is remote and only connected to the rest of the country by transportation services that are limited and infrequent. This region suffers from high levels of poverty, as well as lacking significant natural resources and major infrastructure.

The areas with 30% or more of the population classified as poor are East Lombok (including the capital Mataram), Sumba, most of West Timor including the capital Kupang, West Flores, and Lembata. (The whole of the province of Maluku also has more than 30% poor, whereas North Maluku around the main island of Halmahera has 10-19% poor.) The poverty rate of the total four Nusa Tenggara and Maluku provinces was given as 26.1% in this source (Arulpragasam and Alatas 2006).

The main agricultural products in West Nusa Tenggara (main islands Lombok and Sumbawa) are coffee, coconut, cashew nuts, cloves and cocoa; in East Nusa Tenggara (Flores, Sumba, West Timor) the same products are listed plus dryland and wetland paddy, maize and soybean. Secondary industries in both provinces include beef processing, fish canning, carrageenan flour (from harvested seaweed), fish flour, frozen fish, integrated coconut, and rattan. The main tertiary export industry is tourism including hotels and restaurants though this has suffered various setbacks over time.

Reefs under a high or very high level of threat according to Burke et al. (2002) include parts of Lombok, Sumbawa, Flores, Sumba and West Timor, and the easternmost island of East Nusa Tenggara, Alor, north of Timor. Most reef areas appear to be under medium risk, and a few are rated low risk. Bugis island, off the north-east coast of Komodo is one of the places in the park where hard coral cover is still very high and the impact of the destructive fishing practices has been low. The latter fact probably can be explained by the low density of fish around this island.

The only reefs rated as low risk in Nusa Tenggara are some small atolls out to sea between north of Sumbawa towards South Sulawesi, and the easternmost group of islands north of Flores. The only low-risk area close to the coast of the larger islands is between Komodo and the western tip of Flores. This is significant in view of the following paragraph.

A description of East Nusa Tenggara places of interest mentions a number of islands and sites between Komodo and Flores. In addition to Bugis, Sebayor Kecil, Tatawa and Tatawa Kecil, Tengah Kecil, Pantai Merah ('red beach'), southern Rinca and Lankoi all appear to have reefs in good condition and recovering well from damage. Batu Bolong between Tatawa and Komodo is one of the top diving locations in the park. "This area is undamaged because the current and topography (steep walls) make it impossible for local fishermen to use their dynamite and cyanide fishing techniques." The following WWF descriptions indicate that the usual problems exist in Nusa Tenggara, including destructive fishing practices.

The area known as 17 Islands National Park in the district of Riung north of central Flores was established in 1996 as a marine protected area. It includes a marine nature reserve (2,000 ha) and a tourism reserve (9,900 ha) and a terrestrial component (about 4,000 ha). WWF has worked in the area as part of its poverty alleviation project to provide technical support to the protected area management authority for a number of issues:

- Surveys and research on the ecological status of reefs, seagrass and mangrove ecosystems
- Rehabilitation of coral and mangrove habitats as part of a collaboration with local communities
- Establishing a pelagic fish aggregation device (FAD) in support of fishers moving from reefs to open waters (doubling as a floating ranger station for enforcement)
- Participatory surveillance against destructive fisheries within the protected area
- Facilitating a multi-stakeholder process and cross-visits for collaborative management
- As a result, the district government has significantly improved its management.

The Alor-Solor region includes the east coast of Flores, the larger islands of Solor, Lembata, Pantar and Alor and some smaller islands and submersed sea-mounts. The area is important for cetaceans as confirmed by scientific expeditions and illustrated by the local communities' long-standing traditional whale hunting activities. The economic conditions in the coastal communities in Alor and Solor are less than optimal and as a result unsustainable harvesting levels and practices have become common. Also, the relatively good status of the ecosystems in this area lures fishers from afar, increasing the pressure on the natural resources even more.

WWF has identified initial steps to work with the local and regional government in support of MPA development and sustainable economic development. WWF also works with local communities to monitor harvest of manta rays and whales.

HALMAHERA

Halmahera is the largest island in the North Maluku province of Indonesia – and also of what was until 1999 the total Maluku province, before North Maluku was split off. Its total area is 17,780 km^2 with more than 160,000 inhabitants. Halmahera's geographic features include several active volcanos, scenic lakes, unexplored caves and plenty of stunning offshore islands. It also boasts Aketajawe-Lolobata National Park, the first in North Maluku, and one of the most pristine and unvisited in Indonesia.

Halmahera, and its two smaller sister islands Ternate and Tidore, formed kingdom long before colonisation, cultivating cloves, nutmeg and other spices in the rich volcanic soils of these islands for hundreds of years (forming the basis of awidespread and lucrative trade). The indigenous population, mostly of Malay stock, engage in subsistence farming, hunting and fishing. The chief products are spices, resin, sago, rice, tobacco, and coconuts. The mountainous island is still largely covered with forests. The coastlines are rimmed with white sand and coral reefs are found in its waters. Offering a beautiful spectacle, Mount Mamuya expels burning lava from time to time, adding to the allure of this island.

People living on Halmahera are mostly farmers, but those living on the small islands surrounding it are fishers. They have great respect for religion, ancestors and nature. The surrounding sea provides great fishing ground for traditional fishers of Halmahera and fishers from outside the area.

Northern Halmahera is an emerging diving destination. Morotai Island, which lies to the north of Halmahera played an important role during World War II as an airbase for the Allies and the Japanese at various points. The wreckage of war can still be seen in this area, where wrecks of aircrafts can be found underwater serving as habitat for coral reefs and marine creatures.

A recent study undertaken by Wildlife Conservation Society's as part of its Indonesia Program discovered an ongoing outbreak of the crown-of-thorns starfish. This particular outbreak stretches of reef up to six miles long, and has resulted in three-quarters of the corals being killed and some of the colonies had been almost completely devoured. The survey results and analysis concluded that starfish had attacked about 20% of the Halmahera reefs and reduced coral coverage in these areas by 95%.

Halmahera possesses an abundance of endemic birds across the Maluku Islands, with over 26 endemic species found there and surrounding islands. There is also a fascinating variety of reptiles - together with with several interesting new species discovered in recent years. This region is also biodiversity hotspot for a range of endemic species of plants, insects, mammals, amphibians, and snails.

After leading an expedition including representatives of WWF, CI and his own organisation, The Nature Conservancy, Rod Salm observed (Salm 2008)): "We have discovered reefs in great condition, supporting exquisite coral gardens and corals ranging in age from youngsters less than a couple of years old to others exceeding 1,000 years in age. We have seen damage – extensive damage – but also vigorous recovery. Yes, they have been hit hard, but they are bouncing back too.

At the outset of the expedition, I was keen to test our hypothesis that Halmahera was a gateway to the Coral Triangle from the Pacific and a key piece of the climate change puzzle. As we suspected, the corals and fishes around Halmahera are extremely diverse. But, more than that, they are showing good reproduction, connectivity and recruitment around much of the island and strong recovery. These are key elements of resilience. But the corals also show a large range in sizes from young to old. This tells us that there is regular good recruitment and excellent prospects for recovery from damage."

"Change is now accelerated by the demands of burgeoning human populations and our influences on natural resources and climate. Addressing the impacts of those changes and adapting the way we manage our reefs and other natural resources is essential now in our rapidly changing world. We start by trying to build the resilience of the areas we manage so that they can absorb and bounce back from the ravages of change.

The convoluted shape of Halmahera, called the 'Spider Island' by some, and the Indonesia Throughflow [the current that flows from the Pacific through the Indonesian archipelago to the Indian Ocean] around the island, generate complex local currents that result in good connectivity, strong recovery, and excellent survival prospects for the coral reef communities there. They may also cause mixing of the water column that helps to keep temperatures fairly stable. This reduces heat stress linked to global warming on the corals and so contributes to their resilience."

This section of the Coral Triangle seems to be less plagued by destructive fishing practices than the others surveyed according to the Wildlife Conservation Society (WCS 2007):

"In December 2007, WCS Indonesia conducted a detailed coral reef survey of the Kayoa Islands in the Halmahera Seascape, in the heart of the Coral Triangle. The area is located 90 km south of Ternate, the capital of Maluku Utara [North Maluku].

Importantly it has existing traditional fishing rules that local fishers follow and it is also one of few conservation areas in Halmahera dedicated to tourism. Local fishers use hand lines, traps and other simple forms of fishing gear, and have placed bans on their communities from using nets on the reefs. Fishers who live outside Kayoa Islands pose the greatest ongoing threat to the 'progressive' local rules set up by local fishers. Prohibitions on net fishing are commonly disregarded by outside fishers and threaten the fisheries management in place that has been established in the absence of formal government management. The rules adopted by the Kayoa fishers are tacit recognition that netting is capable of plundering reef fish and that community support for 'progressive' fishing practices is high.

Alternatives to fishing from tourism may also reduce impacts on reefs, yet our encounters with fishers demonstrated a willingness to continue fishing and adopt fisheries practices that prohibit destructive techniques and limit use of gears that simply harvest too many fish too efficiently."

The Eastern Indonesian map in Reefs at Risk (Burke et al. 2002) rates the reefs around Halmahera at mainly medium risk, with some low observations. One specific threat, however, is from crown-of-thorns starfish which have been observed in concentrations twice as high as what has been considered an 'outbreak'(Hansford 2008). Overfishing of the starfish's natural predators, such as triggerfish and the giant triton mollusk, probably worsened the situation. Survey teams also found evidence of reef blasting, using explosives to stun fish or collect coral as construction material. While such practices don't seem to be as prevalent as elsewhere, they do exist calling for more stringent management.

MALUKU

The picture is mixed in this province.

Known historically as the Spice Islands, Maluku (including the recently created North Maluku province) was for centuries a major source of cloves, mace and nutmeg. These spices have formed a valuable exports, it to gather with coffee and coconut flesh. Other food crops include cassava, yams, taro and sweet potatoes. Maluku's economy also depends in a large measure on fishing, including shrimp, crab, and tuna. Timber production and the mining of manganese, nickel, and oil also provide income. Plywood is exported to Japan, Singapore and Hong Kong.

Most economic activity, including trade, tourism and education, is centred on Ambon, capital of Maluku province. Despite these urban sources of revenue, agriculture is still the key component of Maluku's economy, but fisheries remain relatively important on the many smaller islands.

The Indonesian news agency ANTARA reported in 2007 that at least five of the 17 coral reef zones in the South Maluku district were badly damaged due to the use of fish bombs and toxic substances like potassium cyanide by local fishermen. Six other coral reef zones were slightly damaged according to the head of the environmental affairs section of the Maluku forestry and plantations office. He said this showed local fishermen`s awareness of the impact of the use of potassium cyanide and fish bombs on the environment and marine biota had remained low. Therefore, his office was making intensive efforts to prevent local fishermen from using fish bombs and Sodium cyanide in their work.

Actually this kind of effort is one of the key government policies to sustain coral reef ecosystem through Department of Marine Affairs and Fisheries as well as Department of Forestry. It is fair to say that the government, academics and NGO have put their hands to improve community awareness on the importance of coral reef ecosystems and banning the use of destruction fishing methods including explosive, poison, etc. via Law No 27/2007 (Coastal and Small Islands Management Act), as well as a significant fine or 2-10 years in prison (Ambariyanto pers. comm.)

Another serious problem has been described by B. Fegan (Fegan 2003). It is widely known, he writes, that illegal fishing by foreign-owned trawlers is a major problem for Indonesia. The Minister for Marine Affairs and Fisheries estimated in 2002 that the nation loses some two billion dollars worth of fish every year because of illegal fishing.

These practices have persisted for many years, but after they had been actively discouraged in western Indonesia they have persisted in the east, especially in the Arafura Sea south of Papua. There are positive signs, however, and generally it is important to understand the economic, social and cultural backgrounds of the local communities, described in the case of the Aru Islands in the Arafura Sea by Hidayat (Hidayat 1999). In 2006, the people of the island of Haruku (between Ambon and Seram) rejected a mining company's proposal to explore for a gold mining operation on the grounds that residents had rejected mining activities on their traditional land because, they said, Haruku was a small island with a tiny population and such activities could damage the island's natural ecosystem. It appears that local people have greater opportunity to take such steps after the main authority was transferred from the provinces to the lower levels of government.

While such evidence is anecdotal, it should be taken into account together with the unfavourable evidence from examples of destructive environmental practices.

RAJA AMPAT, WEST PAPUA

The four islands of Waigeo, Batanta, Salawati and Misool are located from north to south off the tip of Papua, with Salawati very close to the Papuan mainland. The name, ‘four kings’, dates back to the 15th century, when the Sultanate of Tidore - one of the Muslim sultanates in the original Maluku west of Halmahera – appointed a local ‘raja’ in each of the four islands. Surrounding the islands is an archipelago of some 1,500 small islands, cays and shoals. The total land and sea area is about 40,000 km^2.

The islands are administratively part of West Papua but differ from the rest of the province. Geographically and when it comes to nature, history and culture, the ‘Ampats’ are in many ways closer to Maluku.

The following paragraphs are an edited description by TNC (TNC 2009c) which has been involved in the area for many years. In 2002, with its partners, it conducted a scientific survey of the islands to collect information on its marine ecosystems, mangroves, and forests. The survey confirmed that Raja Ampat has the highest marine biodiversity on the planet. It brought the total number of confirmed corals to 537 species – an incredible 75% of all known coral species. In addition, 899 fish species were recorded, raising the known total for Raja Ampat to an amazing 1,074. On land, the survey found lush forests, rare plants, limestone outcroppings, and nesting beaches for thousands of sea turtles.

Though human impacts here are less severe than elsewhere in Indonesia, Raja Ampat’s natural resources are endangered by overfishing and destructive fishing, turtle poaching, and unsustainable logging. The Indonesian government recently established Raja Ampat as a separate administrative unit, which will give communities a greater say in managing the natural resources upon which their livelihoods depend. This structure also offers an important opportunity to include conservation in the planning of the newly formed local government.

To address these issues, TNC launched a new project to protect Raja Ampat, working in close partnership with the government and communities to: 1) contribute to a comprehensive conservation action plan to protect Raja Ampat’s reefs and forests; 2) help incorporate marine protected area management into long-term planning and policy; and, 3) establish a network of marine protected areas for Raja Ampat.

The ultimate goal is to protect Raja Ampat’s magnificent reefs while sustaining the livelihoods of local people. The archipelago is part of an area known as the Bird’s Head functional seascape, which also contains Cenderawasih Bay (located to the east, just behind the bird’s head), the largest marine national park in Indonesia.

Notwithstanding these attributes, the *Reefs at Risk* map of Eastern Indonesia appears to rate the threat level for Raja Ampat high to very high (Burke et al. 2000). This seems to be in agreement with the philosophy behind the biodiversity hotspots that defines them as (a) being demonstrably highly diverse and (b) under threat. The totality of the four hotspots making up most of the Coral Triangle have these dual attributes, even though assessed risk levels vary for individual coral reef areas.

MALAYSIA

A. Background and recent history

Great Britain established colonies and protectorates during the 18th and 19th centuries, in the area of current Malaysia. These areas were occupied by Japan from 1942 to 1945. The British-ruled territories on the Malay Peninsula formed the Federation of Malaya in 1948, which moved to become an independent nation in 1957. Malaysia was formed in 1963 when Singapore and the East Malaysian states of Sabah and Sarawak on the northern coast of Borneo joined the Federation.

The first several years of the country's history were marred insurgency of Communist inspired forces. The Indonesian confrontation with Malaysia during the Sukarno presidency, with Philippine claims to Sabah, and Singapore's secession from the Federation occurring in 1965. Malaysia was successful in diversifying its economy from dependence on exports of raw materials to expansion in manufacturing, services, and tourism during the 22-year term (1981-2003) of Prime Minister Mahathir bin Mohamad,.

The country consists of two land areas: peninsular Malaysia with 11 states and including the capital and government centre in Kuala Lumpur, and east Malaysia with the states of Sarawak and Sabah in north Borneo. Sabah is the only Malaysian state included in the Coral Triangle (and the Philippines biodiversity hotspot), but peninsular Malaysia is geographically part of the Sundaland biodiversity hotspot, together with Western Indonesia, Bali, and the waters along eastern Kalimantan.

B. Economy

Malaysia has transformed itself since the 1970s from a producer of raw materials into an emerging multi-sector economy. Prime Minister Abdullah bin Ahmad Badawi, since coming to office in 2003, tried to move the economy farther up the value-added production chain by attracting investments in high technology industries, medical technology, and pharmaceuticals. Exports, particularly of electronics, remain a significant driver of the economy. Abdullah Ahmad Badawi resigned on 2 April 2009 following unfavourable election results in 2008. He was succeeded by his Deputy Prime Minister, Najib Abdul Razak. Abdul Razak grew up in eastern Malaysia as part of the nation's political aristocracy. His father Abdul Razak was Malaysia's second prime minister. The new prime minister vows to implement economic and political reforms, and to assist an ailing economy to achieve more even economic growth by the time of the next elections in 2013.

Malaysia has profited from higher world energy prices as an oil and gas exporter, although the rising cost of domestic gasoline and diesel fuel forced Kuala Lumpur to reduce government subsidies. In 2005 Malaysia 'unpegged' the ringgit from the US dollar and its currency subsequently has appreciated 6% per year against the dollar in 2006-08. Although this has helped to hold down the price of imports, inflationary pressures began to build in 2007 - inflation reached nearly 6% in 2008. In April 2006, the government presented its five-year national development agenda through the Ninth Malaysia Plan, which is a comprehensive blueprint for the allocation of the national budget from 2006-10. The government has unveiled a series of ambitious development schemes for several regions that have had trouble attracting business investment.

Real GDP growth has averaged about 6% per year over recent years, but regions outside of Kuala Lumpur such as the manufacturing hub Penang have not fared so well. The central bank maintains healthy foreign exchange reserves. This regulatory regime has limited Malaysia's exposure to riskier financial instruments and the global financial crisis. Decreasing worldwide demand for consumer goods, however, is expected to hurt economic growth.

C. Progress towards the Millennium development goeals

Malaysia has reached a number of national developmental goals consistent with the essential elements of the Millennium Development Goals since 1970.

The formulation of the New Economic Policy and the National Development Policy that succeeded it in 1991 had been the driving force over the past three decades to reduce and eventually eradicate poverty by raising income levels and increasing employment opportunities among all Malaysians. Its main aim was to reduce the economic disparity between the Chinese minority and the Malay majority, targeting a share of 30% for the latter (not yet reached). The achievements that have been made, and the favourable position of Malaysia in economic and social development, coupled with the policies and strategies envisioned in ten-year Outline Perspective Plans and implemented through Malaysia's national five-year plans, have enabled Malaysia to achieve most of the MDGs.

Although Malaysia's overall achievements have been commendable, the United Nations MDG country team maintains that the challenges include halting the spread of HIV/AIDS, the need to improve spatial and ethnic equity in development outcomes, improve the lives of indigenous peoples, migrants, and the disadvantaged, as well as environmental management. The Ninth Malaysia Plan (2006-2010), released in March 2006, reflected the need to address these development challenges. The National Strategic Plan on HIV/AIDS (2006-2010) provides new policy initiatives on reduction measures to curb the spread of HIV/AIDS.

D. Sabah

The easternmost state of Malaysia, Sabah, covers an area of 76,115 km^2. Sabah's population increased from 654,000 in 1970 to 3.0 million in 2005 (Leete 2008b). As in other Malaysian states, it has shown a rapid trend towards urbanization from 18% in 1970 to 49.5% in 2005.

Sabah's population includes 39 different indigenous communities making up 60% of the total population (the second-largest group is Chinese). Only neighbouring Sarawak has a comparable 'native' component (50%), while the so-called *orang asli* who are the indigenous people in Peninsular Malaysia make up a mere 0.5% of the population (Lasimbang 2002; **Lasimbang 2008**) This puts the western Malaysian people, especially those in Sabah, in a special position compared to the peninsular Malaysians.

The indigenous people in Sabah comprise the native Bornean groups (Dusun/Kadazan, Paitan, Murut, and Dayak) as well as groups originally from the Philippines or Indonesia. Most live in rural areas and maintain a strong bond to their traditional lands. Many are subsistence farmers practicing diversified agriculture - often a form of rotational agriculture combined with wet padi, tapioca, fruits and vegetables, while increasing numbers are cultivating cash crops.

Hunting and collecting is also being practised, using the available resources without depleting them. The amount of food gathered is based on the daily needs: taking the mature and ripe fruits only. The Murut communities have an elaborate system for sharing forest resources - social cohesion has been the key to their survival. Along the coastline and river mouths there are many fishing communities, some of whom also do farming. The vast majority of these farmers grow food for themselves and their families (Lasimbang 2002).

Claudia Lasimbang has been the vice-chair of the Malaysian PACOS Trust (Partners of Community Organisations) since 1987. An indigenous Kadazan, she expresses concern for the future of indigenous Sabah:

“Convincing future indigenous generations that the indigenous way of life is ‘good for you’, in that one only becomes a better human being from the richness of understanding one’s indigenous heritage and spirituality is the actual daunting task ahead of us. For us in PACOS, this has been the core of the organisation’s aims and strategies.” (Lasimbang 2002)

Furthermore: “In Sarawak and Sabah, laws introduced by the British during their colonial rule recognizing the customary land rights and customary law of the indigenous peoples are still in place. However, they are not being properly implemented, and even outright ignored by the government, which gives priority to large-scale resource extraction and plantations of private companies over the rights and interests of the indigenous communities.” (Lasimbang 2008, p 296)

There are other signs of discrimination with indigenous people often being regarded as second-class citizens even by fellow Sabahians.

GDP per capita in 2004 was RM 4,868 at constant 1987 prices, 50% of the Malaysian average of RM 9,746. Its East Malaysian neighbour, Sarawak, was much closer to the national average at RM 9,286. Agriculture accounted for 31.6% of Sabah’s GDP compared with 8.5% for total Malaysia and 14.8% for Sarawak. Manufacturing activity in Sabah accounted for 12.1% compared with 21.2% in Sarawak and a national average of 31.6%.

The proportion of total employment in agriculture has, however, fallen steadily from 56.1% in 1980 to 31.8% in 2004.

The proportion of people aged six and over in 2000 who had never attended school was 21% in Sabah compared with 10% in total Malaysia. However, the literacy rate in Sabah for all persons aged 10 and over increased from 72% in 1991 to 85% in 2000, while the proportion grew from 85% to 92% for the whole of the country. For 15-24 year olds, the Sabah literacy rate increased from 81% to 88% over the period (Malaysia from 94% to 97%). Sabah remains below all other Malaysian states in this respect.

Child mortality (under age 5 deaths per thousand births) was reduced dramatically in Sabah from 21 in 1990 to 3.3 in 2004. Maternal mortality rates are now as good in Sabah as in other Malaysian states.

The proportion of housed covered with safe water supply in Sabah has improved from 81% in 1993 to 95% in 2004, close to the Malaysian average in both years. The number of houses covered with sanitary latrines increased from 75% in 1993 (way below any other state) to 97% in 2004, while the national average increased from 92% to 98%.

In conclusion, Sabah is a relatively poor Malaysian state but has made good progress towards the national average on a number of scores, though the gross regional product per head of population remains only half that of Malaysia's GDP per head. However, the task of ensuring a harmonious transition which as far as possible retains the traditional and allegedly sustainable ways of life will continue to be difficult.

E. Coastal resources and change in Sabah

Sabah's coral reefs are severely threatened according to the state Ministry of Tourism, Culture and Environment. Large tracts of Sabah's coral reefs have been wiped out by destructive fishing methods such as fish bombing and the use of cyanide and dragnets. More than 10% of coral reefs around the state have been destroyed, according to Professor Ridzwan Abdul Rahman from Universiti Malaysia Sabah. The possible contradiction with Lasimbang's information in the previous section caused an inquiry into the locality of indigenous Sabah people. By far the most live in the inland forested areas and only the Dusun/Kadazan come close to being dominant in any coastal area, according to a map shown on the PACOS website (http://www.sabah.net.my/PACOS/people.htm). The main exception is the two peninsulas flanking Marudu Bay in northern Sabah – where the reefs happen to be highly or very highly threatened (Burke et al. 2002). Apart from this, indigenous Sabah people appear to be largely above suspicion for destructive fishing practices on coral reefs.

Professor Rahman says: "It is getting worse. The reefs are continuously being degraded by destructive fishing activities and this will only reduce the fish in the long run. The coral reef ecosystem is the heart of fisheries. Of course there are other ecosystems such as mangroves but the largest source of fish are the coral reefs," he said. Studies have shown that the fish population has, over the years, declined by 75% in the waters off Sabah.

There is some debate over the seriousness of the degradation of Sabah's coral reefs. Sabah Parks Deputy Director Dr Jamili Nais said in 2008: "Based on my own analysis, the coral reefs in Sabah waters are not that badly affected by the human and natural impacts. But the threat is there, particularly those around the islands in Tunku Abdul Rahman Park (surrounding the capital city Kinabalu on the northwestern coast facing the South China Sea) which are the closest to land affected by sediment effluents coming from the rivers," he said. Reefs at Risk shows most of the reefs off Sabah at high to very high risk, including the area around Kinabalu (Burke et al. 2002), which again has a mixed rather than indigenous population.

Nais claimed most of the damaged coral reefs in Sabah recovered positively through the natural process. "The damage to our coral reefs is caused mostly by sedimentation, fish bombing activities as well as fishing trawlers." He also said that the impacts of global warming as well as other major seasonal global phenomenon on the coral reefs and islands in Sabah are still minimal.

Most recently (September 2008), Sabah is reported to be planning to continue to protect its marine parks, using the charismatic sea turtles as flagship species, and by default, protecting the coral reefs the turtles need. To make sure the coral reefs are getting the protection they require, marine parks in Sabah has put together a monitoring program which will use conventional coral check techniques in strategic areas and focus on long-term research.

Sabah's reef fisheries have decreased since reaching a peak in the 1980s (Teh et al. 2005). Destructive fishing methods have been the principal cause of damage to reef habitats throughout Sabah, and have contributed to the decline of reef resources. In response, Sabah Parks proposed the establishment of Tun Mustapha Park in north Sabah n 2001. This marine park includes *Banggi Island*, with the objective of reducing overexploitation of the region's fisheries and helping conserve the rich biodiversity found within its coastal environment.

Banggi is the biggest island in Malaysia, covering a total area of 700 km^2, with a coastline of 420 km. The current population of Banggi is approximately 20,000, mixed rather than with a high percentage of indigenous people. In the past two decades, migrants from the southern Philippines (Palawan) have come to Banggi in search of a marginally better life. Nevertheless, Banggi remains relatively undeveloped, and coastal households are considerably below the Sabah poverty line. These communities continue to depend heavily on marine resources for their livelihood, with fishing accounting for 70% of the island's economic activity. There are 1,195 licensed fishers on Banggi, but this should only be taken as a lower reference point as many local fishers do not own licenses due to lack of Fisheries Department personnel on the island (Teh at al. 2005).

The reef fisheries of Banggi are artisanal, meaning small-scale, using low-technology fishing gear and small fishing vessels operating on fishing grounds close to shore. Banggi's reef fisheries are also open-access; there is no active spatial input or output controls. The only regulation is a ban on bomb fishing which is not always effectively enforced by the Malaysian Marine Police. Hook and line and gillnet are two of the most important fishing methods. The reefs around the island are rated to be at medium risk (Burke et al. 2002).

Banggi's fishers are important in supplying fresh fish to the domestic village market. fishers sell their catch after setting aside fish for family consumption at low prices to one of three local fish buyers. Excess catch and more expensive fish are transported for sale to the local town of Kudat, where the fishing folk have permanent relationships with wholesale fish traders.

The average daily revenue for hook and line and gillnet fishers found in the survey (Teh et al. 2005) reveals that fishers using hook and line are substantially worse off given that they are more susceptible to lost fishing days due to adverse weather conditions. Hook and line, however, requires less capital investment in gear than gillnet, and therefore there may not be as much of a significant difference in net income after fishing costs are deducted.

Anecdotal evidence suggests that the number of fishers has risen markedly in the past 10–15 years, corresponding to a 2-4 times decrease in individual catch. Dynamite and cyanide fishing occur on a regular basis in Banggi. Overfishing in this region has targeted live reef fish trade and resulted in big declines in the abundance of humphead wrasse (*Cheilinus undulatus*) and humpback grouper (*Cromileptes altivelis*) The population of these species, as in many other places, is severely depleted in Banggi.

The coral islands of the *Semporna* district, on the southern shore of Lahad Datu Bay, are reported to represent one of the most biologically diverse coral reef ecosystems in the world, and are considered a priority area for conservation activities. While highly diverse and extraordinarily valuable, these coral reefs are also severely threatened (Burke et al. 2002). Heavy reliance on marine resources for food and livelihoods has resulted in the overexploitation and degradation of many reefs, and the use of dynamite and cyanide fishing practices are endangering the future of these reefs.

Activities to educate local populations to effectively manage, and prosper, from the sustainable use of their resources are essential in this area, but these activities are held back by relative lack of social and economic development with a high proportion of children unable to read or write, without schooling opportunities, and with little or no leisure time or access to reading or creative materials.

Tun Sakaran Marine Park in the Semporna district at the southern entrance to Lahad Datu Bay encompasses eight islands and at 350 km^2 is the largest marine park in Sabah. All but 9.5 km^2 is sea and coral reefs. It was gazetted in 2004. Research shows higher species diversity that at any other site in Malaysia. The main marine conservation and management issues are:

• Serious over-exploitation of fish and other edible species. Few large fish remain.
• Significant habitat destruction caused by blast fishing.
• Localized damage from outbreaks of the crown-of-thorns starfish.
• Coral mortality caused by recent coral bleaching events.
• Threats from land-based pollution from the mainland.
• Poverty and lack of job opportunities drive unsustainable practices.

As marine fisheries decline, the potential for aquaculture is becoming more recognized. Sabah could become the biggest aquaculture area in Malaysia by 2010 according to Sabah's Agriculture and Food Industry Minister Datuk Yahya Hussin. According to the Fisheries Department, 4,914 km^2 in Malaysia is ideal for aquaculture. Of this, 1,823 km^2 (37%) is in Sabah.

The Sabah state fisheries department in 2008 was formulating plans and strategies to become the biggest fish producer in Malaysia, based on expanded aquaculture. Expected production by 2010 includes 33,000 tons of seawater prawns, 30,700 tons of marine fish, 12,700 tons of freshwater fish, 6,000 tons of cockles, and 125,000 tones of seaweed. The total estimated value is $US 1.66 billion, of which marine fish accounts for $US 1.23 billion. The department plans to set up a 633 km^2 aquaculture industrial zone for seaweed cultivation, cultivation of marine fish in cages, molluscs, crustaceans, brackish and freshwater fish cultivation.

To remedy past experience, when exports from Sabah to the European Community apparently ran into some quality problems, all new aquaculture farms in Sabah will be licensed in stages to ensure that the industry is well managed.

While seaweed has the lowest unit value of these products ($6.6 million for 125,000 tons), it is an important alternative for Sabah fishers, especially in the Samporna district. The seaweed contains carrageenan, widely used in the food and other industries as thickening or stabilizing agents. Sabah currently has two seaweed processing mills for semi-refined carrageenan, at Samporna and at Lahad Datu (on the north coast of the Bay). Sabah is looking for the application of technology to produce high-quality seaweed seedlings which feature high gel strength, faster growth and resistance to disease.

THE PHILIPPINES

A. Background and recent history

The Philippine archipelago is made up of over 7,000 islands; it is favourably located in relation to many of Southeast Asia's main water bodies: the South China Sea, Philippine Sea, Sulu Sea, Celebes Sea, and Luzon Strait.

The Philippines was originally a Spanish colony in the 16th century but was ceded to the United States following the Spanish-American War in 1898. the Philippines became a self-governing commonwealth in 1935. The first elected President was Manuel Quezon who was given the task of preparing the country for independence after a 10-year transition period. the islands fell under Japanese occupation during World War II in 1942, and U.S. forces and Filipinos fought during 1944-45 to regain control. The Republic of the Philippines attained its independence on 4 July 1946.

The Philippines had a promising economy in the 1950s and 1960s. Student activism and civil unrest arose in 1960s and early 1970s against the corrupt dictatorship of President Ferdinand Marcos, who declared martial law in 1972. President Marcos's 20-year rule ended in 1986, and he was forced into exile. President Corazon Aquino took command at this point. However, her presidency experienced several coup attempts, which frustrated the return to full political stability and economic development. Fidel Ramos was elected president in 1992. His administration was characterised by good progress on economic reforms and greater stability and progress on economic reforms. The US closed its last military bases on the islands in 1992.

President Joseph Estrada was elected in 1998, but was succeeded in 2001 by his vice-president, Gloria Macapagal-Arroyo, when Estrada had to resign on account of charges of corruption. President Macapagal-Arroyo was elected to a six-year term as president in May 2004.

B. Economy

Economic growth has averaged 5% per annum since President Macapagal-Arroyo took office in 2001. She averted a fiscal crisis by pushing for new revenue measures and, until recently, tightening expenditures. Declining fiscal deficits, tightening debt and debt service ratios, as well as efforts to increase spending on infrastructure and social services heightened optimism over Philippine economic prospects. Although the general macroeconomic outlook has improved significantly, the economy faces several long-term challenges. The Philippines must maintain the reform momentum in order to catch up with regional competitors, improve employment opportunities, and alleviate poverty.

The Philippines will need still higher, sustained growth to make progress in alleviating poverty, given its relatively high population growth and unequal distribution of income.

The economy of the Philippines grew at its fastest pace in three decades in 2007 with real GDP growth increasing above 7%. Growth slowed to 4.5% in late 2008 at the start of the world financial crisis. A number of factors have cushioned the economy from the financial crisis including government spending, a relatively small trade sector, a resilient service sector, and large remittances from the 4-5 million Filipinos, who work abroad.

C. Progress towards the Millennium development goals

The current Medium-Term Philippines Development Plan for 2004-2010 is designed to address the Millennium Development Goals (MDGs) which represents an economic development blueprint to the Philippines. It involves a strategy for economic growth and job creation, energy, social justice and basic needs, education and youth, anticorruption and good governance. Its major objective is to eradicate poverty by establishing lasting prosperity for the Filipino people.

According to a progress report in 2007, the country is highly likely to reach its targets on poverty and dietary energy requirements by 2015. It also looks on track to achieve targets with respect to gender equality, reducing child mortality, combating HIV/AIDS, malaria and other diseases, as well as improving access to safe drinking water and sanitary toilet facilities. More strenuous efforts are required to meet the targets for maternal health, primary education, and access to reproductive health services. The current challenge that the Philippines now face is that of achieving all the MDGs. In this vein, investment priorities, financial requirements, budgeting, and bridging resource gaps have been highlighted to promote inclusive growth.

Challenges and recommendations emphasize the need for good governance to achieve the MDGs in the Philippines. The following key cross-cutting issues and priority actions have also been identified:

- address wide disparities across regions;
- urb high population growth rate;
- improve performance in the agriculture sector;
- accelerate the implementation of basic education and health reforms;
- ensure strict enforcement of laws pertinent to the achievement of the MDGs;
- bridge the financing gap;
- strengthen the capacity of local government units to deliver basic services and manage programs and projects;
- ensure transparency and accountability in government transactions;
- address peace and security issues;
- public-private partnerships;
- improve targeting, database and monitoring.

To squarely address these challenges, the Government has committed substantial funding for priority programs for job generation and poverty reduction. These include agribusiness and upland development, infrastructure spending, microeconomic reforms, hunger mitigation, and social development, mainly in education and health.

The current food and oil crises have come at a critical period in the timeline of the MDGs (as has the global recession). The Philippines will have to demonstrate its resilience in coping with this worldwide phenomenon that is creating a negative impact among the marginalized sectors.

D. Coastal resources and change

"The Philippines is blessed with having one of the most extensive coral reefs found in the heart of the highest diversity region in the marine world. Reef fisheries have been estimated to directly contribute to around 15 to 30% of the total national municipal fisheries [licences issued through local government areas]. Its total reef area covers at least 27,000 km^2. One of the hypotheses for the significance of the high biodiversity in coral reefs concerns the resilience of this ecosystem to various natural stresses, perhaps not including the stresses in relation to fisheries overexploitation. In this region of high diversity, the Filipinos' high dependence on this important life support system is put to a test. In the Philippines nearly 70% of the protein food intake is from fish. The stark contrast between poverty, hunger and deprivation amidst this increasing want is the rapidly declining reef resources. It is no surprise that it is in the Philippines that reefs are in the highest risk from overexploitation, destructive fishing and other human related impacts such as coastal development and sedimentation. To date, over 70% are in a poor state and less than 5% are in excellent condition."

The above slightly edited extract is from an academic paper on the 'challenges and frustrations' of Philippine coral reef fisheries (Aliño 2002). Reef Check Philippines confirms in an up-to-date comment: "Over the past 30 years, coral reefs in the Philippines have been slowly dying. The most productive reef areas in the world are now known as some of the most endangered. Coastal development, sedimentation, dynamite and cyanide fishing, overfishing, pollution and global warming have all contributed to the damage." (http://www.reefcheckphilippines.org/).

"Bleaching combined with overfishing, and the use of dynamite and poison, has left just 5% of the reefs in pristine condition. 'Signature species' such as groupers, the barramundi cod, and the napoleon wrasse -- a protected but highly sought fish -- are difficult to find even in areas far from Philippine coastlines. Between 30 and 40% of the population -- up to 35 million people -- live in coastal areas of the Philippines, described in one US study as the 'centre of the centre' of marine biodiversity, and depend on fishing for a living."

The following three reef descriptions are samples of a larger number of descriptions of Philippine reefs.

Apo Reef Natural Park one of the largest coral reefs reserves in the world. It covers 275 km^2, 158 km^2 of actual reef and 117 km^2 protective buffer zone. It is located west of Mindoro in the northern Philippines. Thirty years ago, the area was one of the world's premier diving destinations. But the 1970s brought dynamite, cyanide, strobe light fishing and *muro-ami* (*muro-ami* uses an encircling net with large stones as pounding devices, literally smashing the coral reef to scare the fish out of their refuges). In 1994, a survey found that coral cover was just 33% of the reef. The park was opened in 1996, but enforcement initially proved lax and illegal fishing methods persisted.

A major blow was experienced by Apo when extremely warm sea temperatures associated with the El Niño conditions of 1998 triggered the massive bleaching episode which resulted in large scale coral mortalities throughout the world. In addition to this, crown-of-thorns starfish outbreaks followed bleaching in many regions including Apo. While the causes are not entirely clear, the outbreak of starfish may be related to the lack of natural predators like the giant triton, napoleon wrasse and harlequin shrimp (WWF officer Gregg Yan).

Despite it all, coral cover increased to 43% by 2003 and to 52% in 2006. Finally, all extractive activities such as fishing, collection and harvesting of any life form was banned from the Natural Park: the whole of Apo Reef became a no-take area, leading to revival of the fish stock both inside and outside the protected area.

Alternative sources for fishing are being developed and installed. Giant fish aggregation devices or fish-attracting cages, locally termed payaw, have been installed a few km from the coast. The crude but effective devices are composed of a buoy, a counterweight, and 10 to 15 giant coconut fronds. Algae growing on the decomposing fronds attract herbivores such as surgeon fish (Acanthurus) and rabbitfish (Siganus), which then draw in larger predators. Only about one in 10 fishermen have been protesting the park's closure to fishing.

Tubbataha Reefs Natural Park lies in the middle of the Sulu Sea and falls under the political jurisdiction of Cagayancillo, an island municipality situated 130 km to the north. The park is around 150km southeast of Puerto Princesa City, capital of the province of Palawan, the usual jump-off point for visitors and dive boats going to Tubbataha.

Tubbataha is well known to fishermen of the southern Philippines but until the late 1970s, Cagayanons were the primary users of the reefs' resources. During the summer, they would make fishing trips to Tubbataha in fleets of traditional wooden sailboats.

Tubbataha's isolation and its susceptibility to harsh weather once protected it from overexploitation. But by the 1980s, fishermen from other parts of the Philippines started exploiting Tubbataha in motor boats, many using destructive fishing techniques to maximize their catch.

In 1988, in response to a vigorous campaign by Philippine scuba divers and environmentalists, President Corazon Aquino declared Tubbataha a National Marine Park. This park includes much of the biodiversity associated with the Coral Triangle and contains roughly 100 km^2 of coral reefs.

In 2007, the University of the Philippines in the Visayas conducted a study on the distribution and dispersal of fish larvae in the Sulu Sea. The study revealed that Tubbataha is a source of coral and fish larvae, seeding the greater Sulu Sea. This is of huge significance, since the Philippines, the second largest archipelago in the world, relies heavily on its marine resources for livelihood and food.

The Turtle Islands (*Tawi-Tawi*) are found near the south-western tip of the Philippines, which is right at the edge of the international treaty limits separating the Philippines and Malaysia. The six small islands are located south of Palawan and Northeast of Sabah. Locally the islands are known as the 'Tawi-Tawi islands'. The total land surface of the Turtle Islands is not much more than 318 hectares.

Together with the three Turtle islands in neighbouring Malaysia and the surrounding coral waters, are the only living area of the Green Sea Turtles in Asia and worldwide. The islands have been declared Protected Area (further described below) since 1996, which appears the only way to ensure the existence of the green sea turtles and their nesting sites.

The Turtle Islands Heritage Protected Area (TIHPA) was established in 1996 Inian effort to save the decreasing population. Along the border of Malaysia and the Philippines, TIHPA is the world's first trans-border marine protected area for sea turtles. Three of the nine islands in the TIHPA, are on the Malaysian side and six in Philippine territory. The latter are Taganak, Boan, Bakkungan, Lihiman, Langaan and Baguan. These six islands comprised of a total land area of 308 hectares, with the exception of Baguan remaining uninhabited after it was declared a marine turtle sanctuary in 1982. The TIHPA remains Southeast Asia's largest nesting site for green turtles (Chelonia mydas), with 80% of turtle nestings in the Philippines. 98,000 completed nests were documented between 1984 and 1998 on Baguan.

TIMOR-LESTE

A. Background and recent history

Portuguese trade with Timor began in the early 16th century and it was colonized mid-century. Skirmishes began Dutch in the region, eventually resulting in a treaty in 1859. The Portuguese ceded the western portion of the island at that point. Japan occupied Portuguese Timor from 1942 - 1945, but Portugal regained colonial authority after World War II.

East Timor declared independent from Portugal on 28 November 1975, but was invaded by Indonesia nine days later. At this point, it was incorporated into Indonesia in July 1976 as Timor Timur ('East Timor') province. A unsuccessful campaign of pacification followed over the next 20 years. During this time, an estimated 100,000 - 250,000 individuals lost their lives.

An overwhelming majority of the people of Timor-Leste voted for independence from Indonesia in a UN-supervised popular referendum on 30 August 1999. In the time between the referendum and the arrival of a multinational peacekeeping force in late September 1999, anti-independence Timorese militias, supported and organised by the Indonesian military, embarked on a large-scale, scorched-earth campaign of retribution. The militias killed some 1,400 Timorese and forcibly pushed 300,000 people into western Timor as refugees. The majority of the country's infrastructure, including homes, irrigation systems, water supply systems, and schools, and nearly 100% of the country's electrical grid were destroyed. On 20 September 1999 Australian-led peacekeeping troops brought the violence to an end.

Timor-Leste was recognized as an independent state on 20 May 2002 by the international community. Internal tensions in late April 2006 threatened the security of the new nation - with a military strike leading to violence and a near breakdown of law and order in the capital Dili., an Australian-led international stabilization force deployed to Timor-Leste in late May - invited to do so by the fledgeling Timorese government. The UN Security Council established a mission in Timor-Leste which included an authorized police presence of over 1,600 personnel in August. The combined missions restored stability, and allowed Timor Leste to to hold presidential and parliamentary elections in 2007 in a largely peaceful atmosphere.

A rebel group staged an unsuccessful attack against the president and prime minister In February 2008. While injuries were sustained by the President José Ramos-Horta, he survived. The ringleader of the attack was killed and the majority of the rebels surrendered to the government in April 2008.

B. Economy

In late 1999, about 70% of the economic infrastructure of Timor-Leste was laid waste during the conflict, with 300,000 people fleeing westward. Over the next three years a massive international program, manned by 5,000 peacekeepers (8,000 at peak) and 1,300 police officers, led to substantial reconstruction in both urban and rural areas.

Refugees from the conflict had returned or had settled in Indonesia by the end of 2005. At present, the key challenges for Timor Leste are those associated with strengthening the civil administration, rebuilding its infrastructure, and generating jobs for young people entering the work force. Oil and gas resources developed in offshore waters have begun to supplement government revenues ahead of schedule and above expectations. The technology-intensive industry, nonetheless, has done little to create jobs for unemployed people due to the lack of production facilities in Timor. A large amount of the gas from the Timor Leste fields is piped to Australia.

In June 2005, the National Parliament of Timor Leste unanimously voted in favour of the creation of a Petroleum Fund which currently serves as a repository for all petroleum revenues. Its intention is to preserve a large portion of Timor-Leste's petroleum wealth for future generations. The Fund was holding assets of US$3.9 billion in October 2008, and the economy is still recovering from the mid-2006 outbreak of violence and civil unrest. In 2008, the government repatriated tens of thousands of an estimated 100,000 internally displaced persons from the conflict. The principal challenge that Timor Leste currently faces is how to best deploy oil-and-gas wealth to lift its non-oil economy onto higher economic growth to reduce poverty.

C. Progress towards the Millennium development goals

The first National Development Plan, which served as the primary guiding document for development, was established against the backdrop of the MDGs. The government plans to allocate more than 30% annually of its state budget to education, health, and water and sanitation to bring the country closer to the MDG targets.

Progress towards achieving Timor Leste's twin objectives of economic growth and poverty reduction have been limited because of current problems in budget execution. Socioeconomic indicators indicate low life expectancy, high rates of illiteracy, as well as widespread food insecurity and limited access to basic services. Timor-Leste currently scores lower on the human development index of all the member states of the Association of Southeast Asian Nations.

D. Coastal resources and change

Timor Leste is among the 50 least developed countries in the world. Since independence in 2002, it has continued to juggle a sudden influx of income from natural energy resources and persistent widespread poverty, whilst until recently, neglecting marine and coastal resource management and science (Penny 2008). Set back by conflict both before and after independence in 2002, information about the reefs and general directions has been slow to emerge.

The economy of Timor-Leste is dominated by the agricultural sector which contributes about one-third of GDP and employs about 80% of the working population in production for consumption and trade. Traditional agricultural production systems commonly used by farmers include swidden (slash-and-burn) cultivation of rain-fed crops, mainly maize, lowland cultivation of rice, household gardens with rain-fed crops of maize, cassava, and beans and small livestock such as chickens, goats, and pigs, production of Bali cattle and buffalo, and harvesting forest products such as tamarind, candlenut, firewood and stand-by foods such as yams. In addition to these production systems, certain areas have extensive tree crops such as coconuts in the low lands and coffee in the highlands (da Costa 2003) .

Timor-Leste has a large fishery potential with many valuable species. Among these are tuna, skipjack, snapper and prawns (da Costa 2003). Approximately 10,000 families depend completely or partly on fishing, with about half live around Dili or on Ataúro Island to the north. An UNDP study in 2001 concluded that the country's marine ecosystem, if used in a planned and non-destructive manner, has considerable potential to support economic development and sustain the population.

A SWOT analysis (Piggin 2003) identified the following directions for future development of fisheries in Timor-Leste:
establishment of agreed national offshore fishing boundaries

- development of inventories for fish resources
- development of management plans and policies for sustainable utilization of fish stocks
- development of appropriate fishing facilities and technologies
- development of appropriate on-shore aquaculture technologies.

Current weaknesses are lack of capital and expertise, low institutional capacity, lack of coordination, a limited and simple fishing fleet, and a limited sense of ownership of equipment. The main external threats were illegal immigration, depleted resources, and illegal fishing by others.

Timor-Leste's reefs are along the northern and eastern coasts of the country, as well as around Ataúro Island. Coastal villages rely heavily on seafood from the nearby coral reefs for protein and as a source of material for construction and curios. Timor-Leste is known by a small number of divers for its relatively pristine and readily accessible coral reefs. The first surveys by the new Timorese Reef Check team show no indication of obvious anthropogenic damage, bleaching or disease to the corals. However, their data do indicate a lack of large predatory fish and macro invertebrates such as giant clams and crayfish (Penny 2008).

PAPUA NEW GUINEA

A. Background and recent history

The eastern half of the island of New Guinea is the second largest in the world and was originally divided between Germany (north) and the UK (south) in 1885. The northern area was transferred to Australia in 1902, which continued to administer the combined areas until independence in 1975. A 9-year revolt by secessionist on the eastern island of Bougainville ended in 1997 after claiming some 20,000 lives, though conflicts remained at least until 2005.

B. Economy

Papua New Guinea has abundant natural resources although extraction has been hampered by rugged terrain and costly infrastructure development. Agriculture supports subsistence livelihoods for 85% of the population, while mineral deposits (including copper, gold, and oil) account for nearly two-thirds of export earnings. Papua New Guinea is a very poor country despite its natural and mineral wealth, and poverty impacts on the daily lives of almost all of the population. Poverty is exacerbated by extreme rural isolation, high rates of crime and ethnic and gender-based violence, and a growing HIV/AIDS epidemic. Other challenges could upend the economy including chronic law and order and land tenure issues. Australia supplied more than $300 million in aid in the financial year 2007-08, which accounts for nearly 20% of the national budget.

The development challenges for the people of Papua New Guinea are daunting: Only about 40% enrol in school, 5.5% of babies born will die before they are two years old and the average life expectancy is just 57 years at birth. 37% percent of PNG's population lives below the national poverty line. UNDP's poverty reduction program is geared towards providing strategic support to the government in its formulation and implementation of national development plans and strategies so that it can achieve the Millennium Target of halving poverty by 2015.

The government of Papua New Guinea, as with many developing countries, needs to overcome low levels of training and skill development among its staff, insufficient transparency, corruption, , and limited or low-quality delivery of public services. These issues need to be tackled in order for a Papua New Guinea to fulfil its own aspiration of becoming more democratic, more focused on human rights, , more efficient, and more accountable, so that it can deliver better services and succeed in overcoming underdevelopment and poverty.

Papua New Guinea has suffered from the painful and protracted conflict in Bougainville, which ended in 2005 when Bougainville became an autonomous region. An important part of the peace process involves reconciliation and nation building, as well as taking measures to ensure violence decreases, such as eliminating dangerous weapons from the community. UNDP also assists the government to enhance its ability to prevent and better respond to a wide range of natural disasters. Gender-based violence and political exclusion of women represent significant problems and challenges in PNG.

C. Progress towards the Millennium development goals

Papua New Guinea has made some progress since the 2000 Millennium Declaration, though much remains to be done. In collaboration with the United Nations, the Government produced its initial National Millennium Development Goals Progress Report in 2004, and more recently established a National MDG Road Map and announced its 15 national MDG targets and 67 indicators.

Lack of availability of data to prepare an accurate, statistical baseline report remains an obstacle. Accordingly, the Government has adopted the UN database system, and is conducting other statistical surveys into health and household income and expenditure.

D. Coastal resources and change

Papua New Guinea is a major coral reef nations with 40,000 km^2 of reefs, seagrass beds, and mangrove forests within its borders. Like many places in the Indo-Pacific region, however, coral reefs and the local communities and businesses that depend on them are trapped in the middle of a struggle between development and the need to protect the reefs for future generations.

One specific effort is through the Coral Reef Alliance (CORAL, in partnership with other organizations such as WWF), whose main goal in the species-rich waters of PNG is to establish the Madang Conservation Corridor on the north coast of Madang Province as the principal coral reef sustainable destination effort. By consulting with local stakeholders and conducting sustainable marine recreation workshops, Coral Reef Alliance has identified the principal threats to the coastal reef and is developing plans to address them, including mooring buoy installations to reduce help anchor damage to the reefs, as well as educational efforts to build awareness of environmentally responsible business practices, and a user fee system to bring financial sustainability to local communities. In addition, CORAL has also assisted in the development and capacity building of the Madang Lagoon Association, an organization which is composed of more than 250 community members representing villages and clans from the broader lagoon area.

Pollution, sewage, population, pollution, and a burgeoning coastal population are among the real factors challenging ecological diversity in the Madang Lagoon. Like most developing nations with valuable resources, PNG has to make difficult choices between large-scale extractive industries such as terrestrial and seabed mining, commercial fishing, and the reef cutting necessary to allow shipping traffic and sustainable economic development. In its work to reduce destructive fishing practices, CORAL is operating along the following lines:

- Preventing overfishing catch and destructive techniques like blast fishing with dynamite.
- Financing for marine parks, assessing the needs for and facilitating dialogue about a comprehensive user fee system for Madang Lagoon, and supporting the development of financial management capabilities for the Madang Lagoon Association.
- Raising awareness by educating local businesses and the community about sustainable tourism, threats to the reef, and coral reef ecology. Ongoing awareness efforts involve the development of locally-driven, CORAL-funded projects that address reef threats.
- Providing alternatives to destructive fishing by developing training and best-practice materials to be used by marine recreation providers, educational institutions, and people interested in marine recreation careers. CORAL is also exploring a partnership with PNG's tourism authority to produce a similar guidebook to increase the reach of this project.

These efforts must be seen against the socioeconomic characteristics of the country, and the influence of these characteristics on programs like the one just described. The majority of coastal communities throughout PNG, and other countries like Indonesia and Fiji, rely heavily upon marine resources for sustenance and income. As coastal populations are rapidly expanding, and move towards more efficient and damaging fishing methods, many reefs in the Asia-Pacific region are facing threats of destruction and overexploitation.

This in turn is affecting the livelihoods of the communities that are so heavily dependent upon the marine environment. Achieving marine conservation in the region always requires finding a balance between conserving biological wealth and maintaining the livelihoods of the communities dependent upon the marine environments.

The most important threats facing coral reefs in this region are exploitation of fishery stocks, destructive fishing practices, and coral bleaching some stress. The generally long life spans of targeted reef species, in addition to the low productivity of reef ecosystems, destine coral reef fishery stocks particularly susceptible to overfishing. Furthermore, destructive fishing methods such as dynamite and cyanide fishing and the use of monofilament nets, not only deplete fisheries stocks at an alarming rate, but also damage or destroy essential reef structures and habitats. The bleaching of corals from high sea temperatures is also leading to significant decline in corals and humans significantly changing reef habitats.

In 2006, The Nature Conservancy and partners designed the world's first network of marine protected areas (MPAs) that was specifically designed to be resilient to the threat of climate change (Green et al. 2007). The design formed the basis for working with local communities and other stakeholders to refine and implement the design over time. Since local communities are the marine resource owners and decision makers in Kimbe Bay, final decisions regarding the MPA network design will be at their discretion. To date two large areas have been declared as locally managed marine areas (LMMAS), reinforced by local level legislation, with plans to establish LMMAs in various stages of negotiation in six other areas. It is expected that it will take five years to implement the design.

SOLOMON ISLANDS

A. Background and recent history

Solomon Islands represent an archipelago made up of six main islands, with numerous smaller islands scattered over an Exclusive Economic Zone of 1.3 million km^2 in the Pacific Ocean. The population reported in the 1999 census was 409,000 people, of which young people under 15 years of age accounted for 41.5%. Although the majority of the population live in rural areas (84.4%), there has been a significant drift towards the capital of Honiara on Guadalcanal since independence in 1978. The resulting pressure on land and jobs in the urban centre led to the outbreak of conflict in 1998 primarily between the people of Guadalcanal and those from Malaita, the most populous of the Solomon Islands which made up the majority of the domestic migrants.

The United Kingdom established a protectorate over the Solomon Islands in the 1890s. Some of the bitterest fighting of World War II occurred here. The Solomon Islands self-governance in 1976 with independence two years later. Problems associated with violence and government malfeasance have undermined stability and civil society. This led to widespread violence and unrest, resulting in an Australian-led multinational force arriving to restore peace at the Solomon Islands prime minister June 2003.

An undersea earthquake measuring 8.1 on the Richter scale occurred on 2 April 2007, 345 km WNW of the capital Honiara (Guadalcanal). This triggered a tsunami which devastated coastal areas and resulted in dozens of deaths and thousands dislocated. The provincial capital of Ghizo was especially impacted by this natural disaster.

B. Economy

Most people in the Solomon Islands depend on agriculture, forestry and fishing for part or all of their livelihoods. The Solomon Islands important most petroleum products and manufactured goods. The islands being rich in undeveloped reserves of mineral resources (e.g. lead, zinc, nickel, and gold). Despite these riches and prior to the arrival of RAMSI (the Australian led peacekeeping force), the country was beset with severe ethnic violence, the closing of key businesses, and an empty government treasury. This culminated in economic collapse. The moment of opportunity provid ed by RAMSI allowed the Government to establish a framework for economic recovery and a platform for medium- to long-term economic development and growth. It also enabled donor partners, including UNDP, to refocus their development assistance from short-term humanitarian assistance to more long term development initiatives.

However, the success of the government and the donor community in creating a platform for long-term sustainable peace in the country depends on how the issues of economic and governance reform are managed. Structural weaknesses in the economy, government system, and public service are recognized as major problems that need to be addressed but how to reach agreement from all parties as to how is yet to be settled. There are still many challenges in the area of governments and policy structures. In this regard, poor standards of governance and high levels of corruption have been seen as major underlying reasons for the renewed ethnic tensions in 2006. A comparative ranking placed Solomon Islands in 206th place out of 209 countries on government effectiveness (quality of public service delivery and competence of the bureaucracy), 187th out of 208 countries on rule of law, and 193rd out of 204 countries on control of corruption.

Health represents a major development challenge for Solomon Islands, with problems such as Malaria being endemic. In this regard, Solomon Islands has the highest incidence of the disease in the Pacific. Forestry from hardwood tropical trees is one of the main resources of the Solomon Islands, but has been exploited at an unsustainable rate with a reforestation either not been done or not producing the original biodiversity.

The infrastructure for schooling in the Solomon Islands is in adequate to keep up with the increasing population, and many children miss out. Opportunities are less for women and girls, with fewer employment opportunities and access to health services, particularly in rural areas and outer islands. The state of this situation is evidenced by the fact that there were no women were up elected from the 60 female candidates in the 2006 general election. Women also fall victim to widespread gender-based violence. The lack of control of resources plus the inequities have contributed significantly to the complex scene within the Solomon Islands over the past decade. The widely scattered rural population structure and mountainous island geography contribute to low levels of household access to either improved water supplies (29.8% in 1999) or improved sanitation facilities (22.4% in 1999). The lack of access to basic essentials such as water is a significant factor contributing to high levels of hardship and poverty in Solomon Islands.

C. Securing Millennium development gains

The Solomon Islands were not included in the formal review by the United Nations Millennium Development project which was an important information source for the other countries. The following is mainly from the UNDP Fiji office.

In July 2006, World Vision released a report which concluded that the Pacific region generally is struggling to achieve the MDGs, and that many countries in the Pacific are not on track to achieve several MDG goals. According to this report, the Solomon Islands is off-track to achieve at least four MDG goals. These four goals are those relating to poverty and hunger, gender equality in education, reducing child mortality and reducing maternal mortality. Continuing tensions exacerbate these already difficult circumstances – and renewed efforts are anticipated and are being planned to bridge the gaps in both income poverty and human deprivation.

Helping build social resilience among communities is essential for maintaining the gains that have been achieved so far in the Solomon Islands. Preventing conflict through poverty reduction strategies, as well as fostering employment creation with emphasis on creating opportunities for youth, and addressing rural/urban migration with its associated challenges are necessary steps towards sustainable gains. Improving governance and the effective functioning of public institutions is another pre-requisite to improving human development and making progress towards the MDGs. It is self-evident that corruption erodes human development and promotes poverty, because the poor bear the brunt of kickbacks and bribes. Many consider that this is where progress must be made if the Solomon Islands is to make significant advances in equitable access to basic economic and social services in the next ten years. Undoubtedly Solomon Islands faces a difficult period of rebuilding and recovery but the MDGs nevertheless provide a clear focus and a set of priorities for sustainable development efforts. The ethnic tensions of recent years have had significant adverse impacts across all sectors and have led to a significant increase in hardship and poverty, especially for those who were displaced. But many others have also suffered as the quality and delivery of essential services has deteriorated.

D. Coastal resources and change

Coral reefs are widespread throughout the Solomon Islands, and include wide areas still largely unaffected by direct human activities, although there are also areas where such pressures are large and growing. The islands have one of the fastest population growth rates in the world, and 86% of the people are rural. Dependence on coral reefs for protein remains high and subsistence fishing is wide-spread. In the more populous areas this is leading to overfishing and in certain parts, such as the Lau Lagoon off north Malaita, many of the preferred edible species have been lost. Fishing methods can also be destructive, whether trampling and damaging the reefs with nets, or poison fishing including traditional methods that use coastal plant species to provide the poison. This poison is unselective, killing a number of non-targeted species and damaging corals.

Traditional management systems are still of considerable importance in the Solomon Islands, as customary marine tenure is widely held and all reefs are 'owned' by particular groups who have fishing rights. Traditional kastom men, Christians or villagers themselves regularly place taboos on particular reefs, usually for a restricted period of time. More complete protection is provided in some areas by other beliefs. Examples include those around Onogou (Ramos) Island, where it is believed to house the spirits of the dead and can only be visited after following strict protocols.

Commercial fishing has had far-reaching effects across the islands, notably on selected target fish and invertebrates. The export of trochus and related gastropod molluscs brought in excess of US$1 million in 1999, with sea cucumbers, shark fins, live fish and spiny lobster also bringing in substantial amounts. Both stew cucumbers and trochus are already over- exploited and have declined rapidly across most areas.

A giant clam fishery reached maximum production in 1983, but overexploitation has also depleted these stocks in all areas. These problems have been exacerbated by illegal poaching by foreign vessels, with the concerned that if these different fisheries collapse, exploitation of other species invertebrate and fish species such as those used in the live fish trade will increase.

Efforts to establish giant clam mariculture have been ongoing for about ten years. While this has been interrupted by violence on Guadalcanal, a smaller operation continues near Ghizo. Pearl exports have traditionally been an important industry in the Solomons, and with the export of wild-caught stocks prohibited there are now ongoing efforts to establish a farm near Ghizo. The aquarium trade has been increasing relatively rapidly, much of it around Nggela in the Florida Islands, where there have been reports of extensive damage. Coral pieces are broken off for collection, damaging methods such as cyanide are used to capture reef fish, and reefs are trampled during capture, resulting in coral breakage.

Although many of the Solomon Islands retain considerable tracts of forested areas, logging is ongoing in many areas with few efforts to control sediment runoff. There is also no sewage treatment in any of the urban centres in the Solomon Islands, and as populations grow this will increasingly threaten the health of both humans and reefs. Tourism remains a minor industry, despite there being many facilities and hotels that cater for divers. The establishment of protected areas within Solomon Island law is complicated by the customary tenure of all reefs. As a result, several island sanctuaries have recently been repealed, with negotiations over the ownership of at least one of these being ongoing. There is evidence that a number of villages have been using the confusion to rapidly deplete the surrounding reef resources.

There are several success stories such as that told by Spalding et al. (2002). “The most successful marine protected area is the Arnavon marine conservation area. First established in 1975 there have been a number of disputes and problems, but in 1992 the site was revived and a community-based management committee established. The eastern third of Rennell Island was declared a World Heritage Site in 1998, with boundaries extending seawards for three nautical miles.

Civil unrest in the Solomon Islands is largely confined to the island of Guadalcanal, but general instability is causing considerable disruption, not only to the small tourism industry, but also to development activities, including mariculture. In particular the closure of the Coastal Aquaculture Centre near Honiara in late 1999 has set back aquaculture research considerably. A new Institute of Marine Resources run by the University of the South Pacific has also been abandoned.”

In 2004, The Nature Conservancy, Solomon Island National and Provincial Governments, and other NGOs, conducted the Solomon Islands Marine Assessment – the first broad scale survey of marine resources in the Solomon Islands (Green et al 2006). The survey covered seven of the nine provinces in the Solomon Islands, and provided an assessment of the biodiversity and status of coral reefs, seagrass beds, oceanic cetaceans, reef food fish, commercial invertebrates and associated habitats, and recommendations for their conservation and management.

The Marine Assessment demonstrated that the Solomon Islands is an area of high conservation value where marine diversity is exceptionally high, marine habitats are in good condition, and current threats are low (Green et al 2006). However, there is some concern regarding increasing threats to marine habitats, particularly from fishing and poor land use practices in some locations.

INTRODUCTION

Global and regional climate has varied in the past on a range of timescales and due to a variety of internal and external causes. Global and regional climate is now changing rapidly as a result of human activities since the Industrial Revolution increasing the atmospheric concentrations of greenhouse gases and resulting in a significant positive radiative forcing of global climate (Forster et al., 2007). The atmospheric concentration of the main greenhouse gas, carbon dioxide (CO_2), increased from ~280 ppm in 1750 to 384 ppm in 2008 (http://cdiac.ornl.gov/), a 37% increase and the highest concentration of the last 800,000 years (Petit et al. 1999)and probably last 20 million years (Pearson and Palmer 2000; Augustin et al. 2004). The rate of increase in atmospheric CO_2 is also accelerating from 1.5 ppm yr-1 from 1990-1999 to 2.0 ppm yr-1 for 2000-2007 (Canadell et al. 2007; GCP 2007). These rates exceed anything seen over the past 720,000 years at least (Hoegh-Guldberg et al. 2007).

As a consequence of this increase in greenhouse gases, average global temperatures have significantly warmed by ~0.7oC over the period of reliable instrumental records, 1906-2005 (Trenberth et al. 2007). The rate of warming has also increased from 0.07oC per decade over the past 100 years to 0.12oC per decade for the most recent 50 years (Figure 1a). The magnitude of warming of global climate is greater over land areas than the oceans and at higher compared to lower latitudes – this does not, however, mean that the changes in tropical ocean regions (Figure 1b), such as the Coral Triangle, are insignificant. The observed global warming is associated with observed changes in the global climate system such as more intense rainfall and more frequent droughts (Trenberth et al. 2007).

Projections of how climate will continue to change in a rapidly warming world, and specifically for a region such as the Coral Triangle, depend upon a number of factors (Meehl et al. 2007). First is the trajectory of further increases in greenhouse gas concentrations which depends upon human responses to the current global warming challenge (Table 1); indeed it has recently been suggested that our target for global climate stabilization should be at 350ppm CO_2, i.e. well below our current level (Hansen et al. 2008a). The second consideration is that even if all greenhouse gas emissions could be immediately stabilized we have a substantial commitment to ongoing warming, sea-level rise and regional climate changes (e.g. (Meehl et al. 2005; Wigley 2005) (Solomon et al. 2009). Finally, there are questions about the ability of the current generation of global climate models to realistically model current and future climate conditions. No single climate model appears able to do this as yet so with the most recent IPCC assessment in 2007, use was made of multi-model averages. There are also limits to the ability to provide sufficient regional-scale detail (downscaling) for specific regions. For the Coral Triangle region, current global climate models still have difficulties in realistically modelling current climate conditions especially in the tropical western Pacific (e.g. (Neale and Slingo 2003) – this makes any efforts at “downscaling” difficult (Shukla et al. 2009). Donner et al. 2005, however, used several methods to evaluate bleaching occurrence based on General Circulation Model (GCM) resolution sea surface temperature (SST). The absolute error (predicted-observed) in SST downscaled from the HadCM3 resolution was less than 0.25°C in 73% of the grid cells and less than 0.5°C in 96% of the 36kmgrid cells for both the warmest and second warmest years (Donner et al. 2005a). The results were similar for SSTs downscaled from the Parallel Climate Model (PCM) resolution as well.

CURRENT CLIMATE OF THE CORAL TRIANGLE

The Coral Triangle lies at the heart of the "Maritime Continent" (Ramage 1968) with a complex distribution of islands and shallow seas and some of the warmest sea surface temperatures (SSTs) in the world (Figure 2) and a relatively small annual SST range (Figure 3). The latter may well be important in terms of responses to climate change as evidence is emerging that tropical organisms may be more sensitive to the relatively smaller magnitude warming predicted than their higher-latitude counterparts, as the latter are adapted to much larger ranges of temperatures.

This "boiler box" of the tropics is an area of intense tropical convection, which is a dominant heat source for the global atmospheric circulation (McGregor and Nieuwolt 1998). It contains complex ocean current systems that link the Pacific and Indian Oceans (Figure 4) and is intermediate between the Asian monsoon to the north and the Australian monsoon to the south. Principal atmospheric circulation features are the Intertropical Convergence Zone (ITCZ) separating the Northern and Southern Hemisphere circulations and its extension, the South Pacific Convergence Zone (SPCZ) in the southeast of the Coral Triangle. The ITCZ lies south of the Coral Triangle in January and to the north in July. The region has a monsoonal climate with seasonal reversal of wind fields and much of its rainfall arises from intense, localized thunderstorms. The main rainfall season north of ~10oN is from July-October and south of 5oS from January-April (Chang et al. 2005) with more even distribution of rainfall throughout the year close to the equator (see left panel of Figure 5). Annual rainfall totals are high, between ~ 1,500-3,000 mm and significantly modulated locally by the complex topography of islands and seas and characterised by marked diurnal cycles.

Major sources of disturbance (strong winds, high rainfall, storm waves and surges) to coastal *environments are tropical cyclones. These do not form within ~10o of the equator and are*, therefore, significant weather phenomena primarily affecting the northern parts of the CT (Figure 6). Climate of the CT is also significantly modulated by the major source of interannual global climate variability, El Niño-Southern Oscillation (ENSO) events (McPhaden et al. 2006).

OBSERVED CLIMATE CHANGES IN THE CORAL TRIANGLE

A. Sea surface temperature

Climate change is not a future event for the CT, significant warming of the surface ocean of the region has already occurred. Rotated factor analysis of annual SSTs (1950-2007) over the wider area of the western tropical Pacific (114.5o-162.5oE, 18.5oN-12.5oS) shows that SSTs within the CT co-vary in three main regions: 1) CT-SST Region 1 encompassing EcoRegions 1, 2, 6 and the north-eastern part of 3, 2) CT-SST Region 2 encompassing Ecoregions 4, 5, 7 and the south-western part of 3, and 3) CT-SST Region 3 encompassing Ecoregions 8, 9, 10 and 11. Subsequent analyses of SST variations are based on averages for these three regions and average statistics are presented in Table 2.

Annual, annual maximum and annual minimum SSTs have all significantly warmed in all three regions over the period 1950-2008. The rate of warming has been greatest for CT-SST Regions 1 and 3 and is comparable to the rate for global average land and sea temperatures. The observed rate of warming for CT-SST Region 2 is lower and more comparable to that of average tropical SSTs (Table3, Figures 7-9). Annual maximum SSTs have warmed more than annual minimum SSTs in CT-SST Regions 2 and 3, whereas annual minimum SSTs have warmed more in CT-SST Region 1. This observed warming is also associated with increases in the thermal stress that causes coral bleaching (as measured by the o-month index;(Lough 2000); Figures 7-9).

A key issue for SST responses in the CT to continued global warming is not just how much SSTs warm but how much can they warm. The region lies just to the west of the Western Pacific Warm Pool which encompasses the world's warmest SSTs. Feedback mechanisms, the "ocean thermostat" or "thermal cap", have been suggested to operate to maintain maximum tropical SSTs at ~30-31oC (Newell 1979; Clement et al. 2005). A recent study (Kleypas and Lough 2008) found evidence to support lower rates of warming and less reports of coral bleaching (relative to the tropical oceans as a whole) in Micronesia and Melanesia just east of the Coral Triangle. A subsequent study (van Hooidonk and Huber 2009) has, however, questioned these conclusions and suggest that the evidence for such a thermal cap is "equivocal". Analyses of the SST distribution within specified ranges for the three CT-SST regions (Figures 7-9) indicate that for all three regions there has been a marked decrease (between the periods 1950-1969 and 1989-2008) in the percentage area with SSTs within the 28-29oC range and increase in the percentage area with SSTs in the range 29-30oC but relatively small changes in the percentage area with SSTs between 30-31oC. These asymmetric changes in SST distributions are suggestive, though not proof, that the "ocean thermostat" may be operating to restrain SSTs at or below 30-31oC.

It should be noted at this stage that the concept of thermal cap is not supported by the literature or by global models - all climate models show a warm Pool warming of 2-4°C for CO_2 doubling (IPCC 2007). Additionally, the fact that less bleaching is reported is not a good indication of less thermal stress because bleaching data are extremely sparse in the CT region and many sites lack data due to lack of capacity to monitor/record bleaching and remoteness of sites.

EVIDENCE FROM HIGH-RESOLUTION SATELLITE OBSERVATIONS

The NOAA Pathfinder dataset provides high-resolution (4 – 50 km) AVHRR satellite products starting from 1985, giving greater detail of recent SST changes for the tropical oceans and the CT region (e.g. Eakin et al., 2009). Warming is evident throughout most of the CT region and with a similar spatial pattern (Figure 10, (Peñaflor et al. 2009) with a rate greater during the last 22 years than observed from the coarser SST data back to 1950. This provides further support for global indications of recent acceleration in rates of warming (Trenberth et al. 2007).

Degree Heating Weeks (DHW) indices, which are relevant for assessing conditions conducive to coral bleaching (Strong et al. 2006), suggest that the CT region has witnessed little increase in potential bleaching stress between 1985-1995 and 1996-2006 (Figure 11). This analysis also indicates that some areas may be more prone to bleaching-level stress (e.g. south-eastern Papua New Guinea) and some areas have seen little to no bleaching stress in the past 21 years (e.g. the interior seas of Indonesia). Also, in a global context, the CT region has not witnessed the high levels of potential bleaching stress of other coral reef regions (Figure 12). This is consistent with results in Kleypas et al. (2008) that show a relatively low number of ReefBase bleaching reports in Southeast Asia, which includes the Coral Triangle (www.reefbase.org). We must also be mindful that lower reports is reported is not a good indication of less thermal stress (as discussed above) given many sites lack data due to their remoteness of lack of local scientific groups.

B. Rainfall

Although there is evidence globally for changes in rainfall with downward trends dominating the tropics since the 1970s, determination of regionally significant trends is hampered by the greater inter-annual and decadal variability of rainfall in countries bordering the Pacific (Wang and Ding 2006; Trenberth et al. 2007) and the CT and equatorial Pacific are regions of high inter-annual rainfall variability (Smith et al. 2008). Analyses of annual rainfall anomalies (1950-2006) for latitudinal bands from 17.5oN to 12.5oS (Figure 5) illustrates this high inter-annual and decadal variability in the monsoonal rainfall of the CT. None of these series shows significant trends to either wetter or drier conditions.

C. EL NIÑO-Southern oscillation modulation of CT climate

ENSO events are the major source of interannual tropical climate variability with the two phases, El Niño and La Niña, resulting in significant and different climate anomalies throughout much of the tropics. ENSO events typically evolve over 12-18 months. Averaging over several events can provide an indication of the typical climate anomalies associated with each phase. Typical monthly SST anomalies for the three CT-SST regions show that the major effects are associated with the El Niño phase (Figure 13a-c). Cooler-than normal SSTs characterise the first year of the event (e.g. 1982 of the 1982-83 event) with some warmer-than-normal occurring the following year in the northeast and southwest CT regions. SST anomalies associated with La Niña events are less marked and appear primarily to appear in the southwest CT region where warming tends to occur along the South Pacific Convergence Zone. This is associated with an increase risk of conditions conducive to coral bleaching in this region during La Niña events compared to the risk being higher for most tropical coral reefs during El Niño events (Eakin et al. 2009).

ENSO events also affect rainfall within the CT, but again, the main effects are associated with El Niño rather than La Niña events (Figure 5). Unusually dry conditions typically occur through the CT from 12.5oN to 12.5oS during El Niño events, with less consistent rainfall anomalies associated with La Niña phases.

ENSO events also modulate tropical cyclone activity in the Philippines, the main part of the CT affected by these destructive weather events. Tropical cyclone activity tends to be greater during northern summer of El Niño events (which could partly account for the higher rainfalls observed at 17.5on and 12.5oN; Figure 5). Tropical cyclone activity tends to be suppressed during La Niña events (Lyon and Camargo 2009).

PROJECTED FUTURE CLIMATES OF THE CORAL TRIANGLE

"many aspects of tropical climatic responses remain uncertain."

Christensen et al. (2007)

Climate change is one of the central challenges facing nations everywhere, and understanding how conditions will change in the Coral Triangle is central to the objectives of this report. As noted in the Introduction to this chapter, projecting future climates for a region such as the Coral Triangle depends upon a number of factors. Of particular relevance, however, is that future projections are tempered by substantial inter-model differences in representing current monsoon and, especially western tropical Pacific, climates and ENSO (Neale and Slingo 2003; Christensen et al. 2007). Additionally, poorly constrained circulation in the Indonesian through-flow brings projections of SST in this region into question.

These limitations severely curtail the confidence with which we can suggest what future climates of the region might be like. Another key issue is that, for the foreseeable future, climate will be changing. This is important to recognize as it means that it is not simply a change to a new climate regime to which organisms can adapt. A final key issue is the rapid rate with which climate currently is changing and there are various lines of evidence that suggest that both the rate of recently observed changes is accelerating and that we are currently exceeding the higher end of the IPCC SRES scenarios, even after these were modified upward in the 4th Assessment Report in 2007.

In general, with continued warming of the tropical ocean regions, the hydrological cycle is likely to intensify (Meehl et al. 2007). This will result in rainfall increasing in tropical areas which already experience high rainfall and decreasing in the subtropics. There are also likely to be more intense rainfall events in the tropics. Current climate models do not provide consistent indications as to what may happen to the frequency and/or intensity of ENSO events. Modelled warming is, however, greater in the eastern than in the western Pacific which suggests a tendency to more El Niño-like conditions, although there is considerable debate over ENSO dynamics and considerable uncertainty around this projection. This would be associated with a weaker tropical circulation and eastward shift of the rainfall maximum. Despite this uncertainty, it is reasonable to assume that ENSO events are likely to continue as a source of interannual climate variability.

Modelling of future changes in tropical cyclone activity is limited by the current relatively coarse spatial resolution of global climate models. Embedding finer resolution models within these coarser grids suggests, however, that the distribution of tropical cyclone occurrence is likely to remain similar to present (see Figure 6), that there may indeed be fewer tropical cyclones but those that do occur are likely to be more intense. For every 1oC warming of tropical SSTs, rainfall rates with tropical cyclones have been suggested to increase by 6-18% and surface wind speeds by 1-8% (Karl et al. 2008). For the northern part of the CT region affected by tropical cyclones, an increase in intensity will also increase the magnitude of associated storm surges and coastal erosion which will be exacerbated by higher sea levels.

A. Temperature

Examples of surface temperature changes for a low-emissions (B1) and a high-emissions (A2, slightly lower than A1FI) scenario for the CT region show very similar temperature changes in the short term but substantial differences by the end of this century (Figure 14). These spatial projections can be compared to those estimated for the end of this century based on recent relationships between CT-SST Regional trends and global average temperatures (Table 4). Aside from showing greater warming over land than the oceans, the surface temperature projections show very little spatial detail across the western Pacific Ocean in terms of the magnitude of warming. This contrasts with the differences in already observed warming between the three CT-SST regions (Figures 7-9) and maps of linear annual SST trends, 1950-2007 (Figure 15) and 1985-2006 (Figure 10). Also, as discussed in the preceding section it is, as yet, unclear whether the “thermal cap” at 30-31oC is fixed or whether it will change with continued global warming. If the former case holds true, temperature increases under the high-emissions scenarios are likely to be less than projected in the Coral Triangle region.

B. Rainfall

Similar examples of seasonal rainfall projections (Figure 16) expose the current limitations of global climate models in the vicinity of the CT region. Grey areas indicate either no model agreement or no significant change from current conditions. Projected changes for the short term are for slight increases (5-10%) in southern Papua New Guinea. These slight increases become slightly more extensive by the end of this century. It is, however, likely that rainfall events will be more extreme and that the intensity of droughts will be exacerbated by higher temperatures. The frequency of such droughts would also increase if ENSO shifted to a more El Niño like state (e.g. typical rainfall anomalies in Figure 5).

C. Sea level

Average global sea level has significantly risen by ~20cm since the 19th century with most of the warming observed to date due to thermal expansion of the oceans and a lesser contribution from melting of land ice (Bindoff et al. 2007). The rate of increase in sea level averaged 1.7 mm yr-1 over the 20th century and this rate appears to have accelerated recently to ~3 mm.yr-1 over the period 1993-2003 (Church and White 2006b). There are also mounting concerns that the projections of sea-level rise (Table 1) are likely to be underestimates due to increased and accelerating contributions from melting of land ice. The 4th assessment report of IPCC (IPCC 2007) recognises the possibility of scaled-up ice sheet discharges from melting of the large land-based ice sheets in Antarctica and Greenland, which would lead to sea level rises in the order of +4m to +6m. However, because of uncertainties associated with the possible timing of such events these much higher estimates are not directly included in predictions for 2100. Sea-level in the tropical oceans is modulated on interannual time scales by ENSO events and detecting current trends is hampered by the short time span of observational networks. Analyses of available data suggest that sea-level rise in the CT region, 1950-2001, has been similar to the global average for that period of ~2 mm.yr-1 (Church et al. 2006)) and there is no reason to expect the rate of future rise to be different from the global average.

D. Ocean Chemistry

A more insidious effect of increasing greenhouse gases is that about 30% of the main greenhouse gas, CO_2, which humans have injected into the atmosphere, has been absorbed by the surface oceans (Sabine et al. 2004). Without this, global temperatures would have warmed more than observed to date. This increase in CO_2 is altering the ocean chemistry with a 0.1 drop in pH already observed to date and projected falls of 0.3-0.4 pH units by the end of this century (Feely et al. 2004; Sabine et al. 2004). The rate of current and future carbon dioxide increase is estimated to be ~100 times faster than at any time over the past 650,000 years. Increasing the amount of carbon dioxide dissolved by the oceans lowers the pH and decreases the availability of carbonate ions in the water and thus lowers the saturation state of the major shell-forming carbonate minerals making it harder for marine calcifying organisms to form their skeletons and shells (Kleypas and Langdon 2006). Not only do these changes in ocean chemistry reduce calcification by corals, they also decrease important secondary cementation of reef materials and may increase erosion. The result is slower reef growth or net erosion, and weakening of reef frameworks (Manzello et al. 2008). Projections of how the aragonite saturation state of the surface ocean will change in the Coral Triangle are severely hampered by the lack of observational data for the region (see Figure 1 in (Guinotte and Fabry 2008)). and the limited number of corals for which these impacts have been tested (Langdon and Atkinson 2005). Comparisons with surrounding ocean regions suggest, however, that changing ocean chemistry due to the absorption of atmospheric CO_2 will cause the waters of the CT to be “marginal” for coral reef calcification and the maintenance of carbonate reef structures by as early as 2020-2050 (Hoegh-Guldberg et al. 2007) See figure 2 in the next chapter for how these conditions are likely to change relative to ecosystems like the coral reefs.

SUMMARY

Observed and projected global warming is greater at high than low latitudes and greater on land than in the oceans. The Coral Triangle, despite lying in the warmest ocean region on earth, will not be immune to significant warming nor to other changes in its physical environment, with significant consequences for its tropical coral reefs and associated ecosystems. Projecting how climate will change both globally and for the CT depends on several factors, particularly global and local responses that are taken in the short and long term to curb and stabilise greenhouse gas emissions. In addition, there are still difficulties in applying global climate models to correctly model current climate of the Maritime Continent, which makes future projections more speculative for this region than in other parts of the world. Putting the necessary work in to fill these important gaps in our understanding of how climate change will affect the Coral Triangle environments should be a priority.

Changes in the following physical environmental variables will be of consequence for the CT's coral reef ecosystems:

- **Sea surface temperatures:** Annual, maximum and minimum SSTs in the CT have already significantly warmed and are projected to be between 1-4oC warmer by the end of this century.

- **Ocean acidification:** pH of the global oceans has already decreased by ~0.1 units due to absorption by the surface oceans of ~30% of the extra carbon dioxide injected into the atmosphere from fossil fuel burning and other human activities. Projections indicate that the aragonite saturation state and hence coral calcification will become "marginal" for coral reefs of the CT within the period 2020-2050.

- **Rainfall and river flow:** There are some indications that equatorial Pacific rainfall, especially in the vicinity of the ITCZ, will increase but there are conflicting scenarios from different climate models. Even without changes in average rainfall, it seems likely that rainfall events will become more extreme and that inter-annual variability of monsoon rainfall will increase. Importantly, the intensity of drought associated with a given rainfall deficit will be greater in a warmer world.

- **Sea level:** Global sea level has already increased and current projections suggest a further ~30-60cm rise by 2100 but this is regarded as a very conservative estimate due to underestimation of the contribution of melting of land ice.

- **Tropical cyclones:** There is no clear consensus amongst global climate models as to whether the location or frequency of tropical cyclones will change in a warming world but there is agreement that they will become more intense (with greater maximum wind speeds and heavier rainfall), and there is some evidence that this is already occurring.

- **El Niño-Southern Oscillation events:** ENSO, particularly El Niños, significantly modulate SSTs and rainfall in the CT. There is no clear consensus as to how the frequency and intensity of ENSO events will change in a warming world, though the Pacific may become more "El Niño like". This phenomenon is likely to continue as a significant source of inter-annual climate variability in the CT region.

- **Ocean circulation patterns:** There is little information currently available about what may happen to the complex ocean circulation patterns of the CT as the world warms.

In summary, although some aspects of future climate projections for the CT region are not well constrained at present, SSTs will continue to warm, sea-level will continue to rise, the surface ocean aragonite saturation levels will become progressively less hospitable for coral reef development and extreme events, which are a source of localised destruction for coral reefs (e.g. floods and drought, tropical cyclones), will become more intense. A key issue is the unprecedented rate at which these changes are occurring. Another important issue is that, for the foreseeable future, the physical climate and environment of the CT will be changing and we do not, at present, know what the end point will be (i.e. it is not simply a change to a new stable climate regime to which coral reef organisms can adapt).

SPECIAL FOCUS 5: CLIMATE CHANGE AND COASTAL COMMUNITIES IN THE SOUTH PACIFIC

Francis Areki

South Pacific island nations and their peoples are amongst the world's most vulnerable to the impacts of climate change. The irony of the situation is that despite their combined absolute emissions accounting for less than 1 percent of global green house gas (GHG) emissions, each of these nations is expected to face the full brunt of negative impacts brought about by sea level rise and climate change. With a global prediction of 18-59cm sea level rise and temperature increase of 1.1 - 6.4^{o} C by 2100 (IPCC 2007), much of the region is expected to face changes such inundation and erosion of low lying coastal areas, decline in fishery productivity due to coral bleaching and ecosystem change, variability in rainfall patterns and dependent water and agricultural systems and intensified cyclone and storm surges. The situation per nation across the region is varied, where some low lying atoll nations such as Tuvalu and Kiribati are faced with the bleak and dramatic reality in possibly having to relocate its populations in future, whereas other larger nations such as those in Melanesia face issues dealing with heightened poverty and the widening inability to cope and implement adaptive measures, due to limitations in its financial and natural resources.

WWF's Climate Witness Programme in the Fiji Islands indicates that many of the communities it works with are already experiencing the adverse impacts of climate change. Community vulnerability assessments found that a recurrent concern identified by communities were coastal inundation and flooding, water shortage and declining food security. An example from its community project site Kabara, a raised limestone island in eastern Fiji, indicate longer dry season and diminished crop productivity. As over 80% of villages in Fiji are located along the coast, communities have also reported the encroachment of the sea into village boundaries and ancestral burial grounds due to increased coastal erosion and there is common reporting of coral bleaching events, apparent non recovery and declining productivity within community fishing grounds. Fiji despite being a high island and more economically developed is supposedly better equipped to cope with Climate Change impacts, say in comparison to its low lying neighbor Tuvalu. However this is not so, despite its larger land mass, only 20% of its land is viable for agriculture and development, again most of it being located in low lying coastal areas. To lose significant proportions of these coastal areas over time would have profound impacts on the country's infrastructure, economy and ability to produce food. This is however, not an isolated case unique to Fiji as similar observations and impacts have been documented from many other communities throughout the Pacific.

Unfortunately, it should be noted that Pacific Island nations also have the least capacity to adapt to the adverse impacts of climate change, due to variables such as remoteness, scarce resources and lack of access to appropriate information and technology.

In an attempt to redress this and part of mainstreaming climate change into its ongoing conservation efforts within the region WWF South Pacific has since 2004 strived to build the capacity of local communities it works with, to not only understand how climate change threatens their ways of life and but to also work towards building their resilience against such threats. This process has involved assisting communities identify and develop their adaptation strategies and assisting them in implementing them with support from government departments and donor agencies. Some of the major adaptive strategies that WWF South Pacific advocates for with the communities and project partners it works with include:

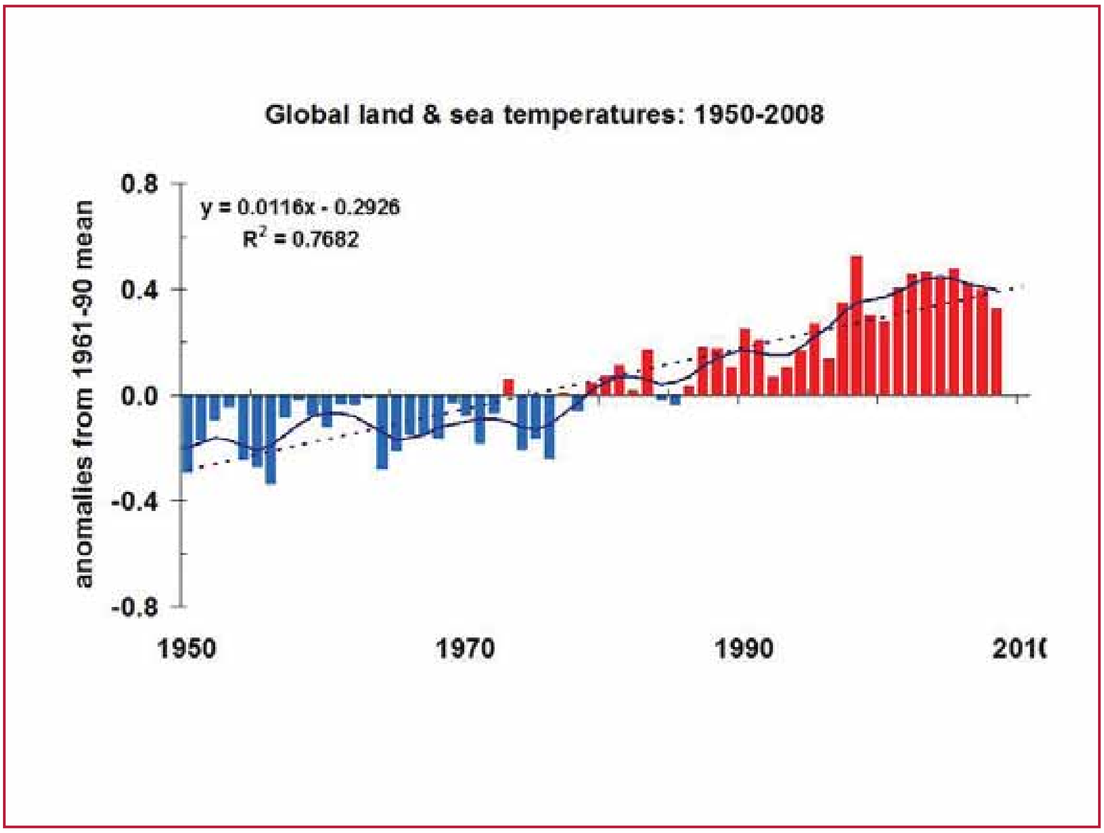
1. Application of Ecosystem Based Management approaches, that include the rehabilitation, protection and sustainable management of natural sea defences and fish nurseries, such as mangroves and coral reefs

2. Applied watershed management, to sustain agricultural productivity, quality of water resources and minimizing upland impacts such as sedimentation into coastal fishing grounds

3. Improved community water management systems, through water harvesting and storage capacity; and

4. Encouraging renewable energy such as solar power to meet community needs.

The context of applying integrated ecosystem based and watershed management, not only provides a means for biodiversity perpetuation, it also enables food security through healthier fisheries and better land management and also builds coastal community resilience against storm surge and cyclonic events. As South Pacific island nations are non oil producing nations, this makes them heavily dependent on petroleum imports to meet national energy demands. In turn this situation makes them especially susceptible to escalating global fuel prices with the resulting outcome that sustainable development may not ideally be achieved. This heavy dependence on imported fuel is an identified conduit for facilitating the unsustainable exploitation of natural resources and biodiversity loss and with it the ability for communities to effectively apply adaptive measures. Countries in the Pacific such as Fiji need to be aggressive in regard to the pursuance of renewable energy sources not only for the long term benefit of their national economies and effectively eradicating poverty but also to highlight a consolidated global effort taken even by communities in Pacific to reduce their carbon emissions.



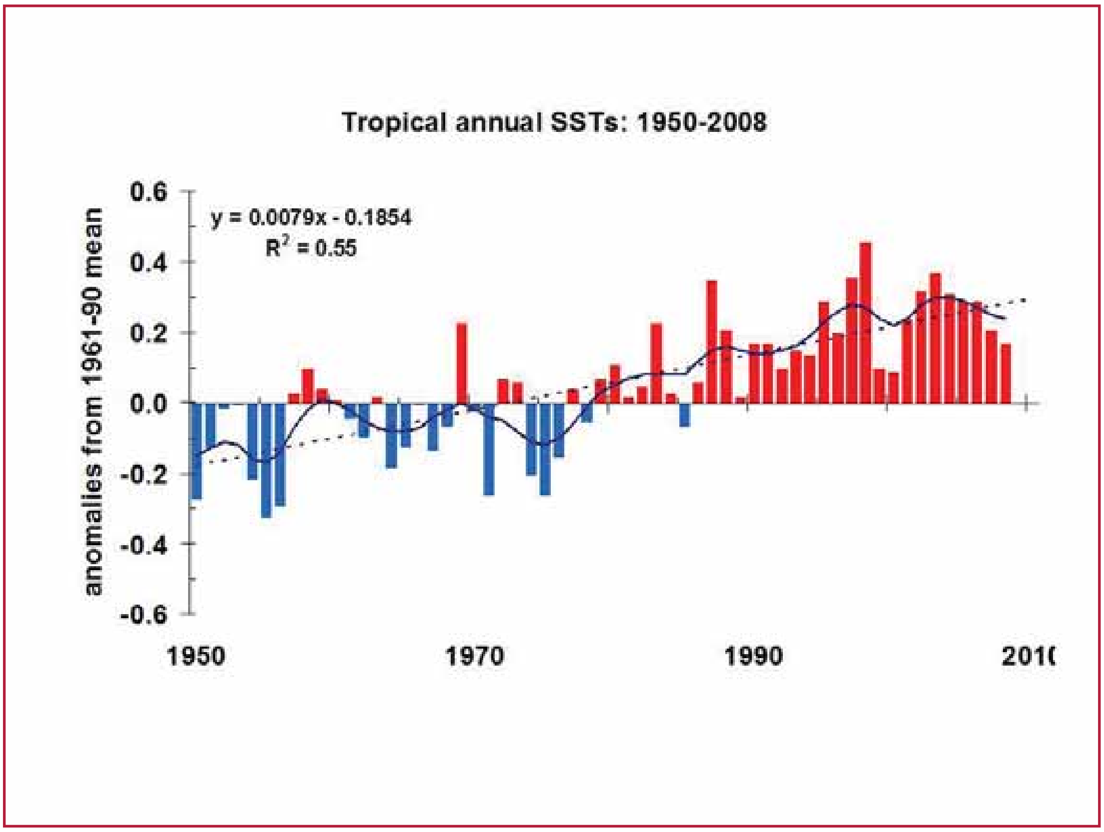


Figure 1: a) Global land and sea temperatures and b) tropical SSTs (bottom), 1950-2008 (data source: CRU, HadlSST; references)

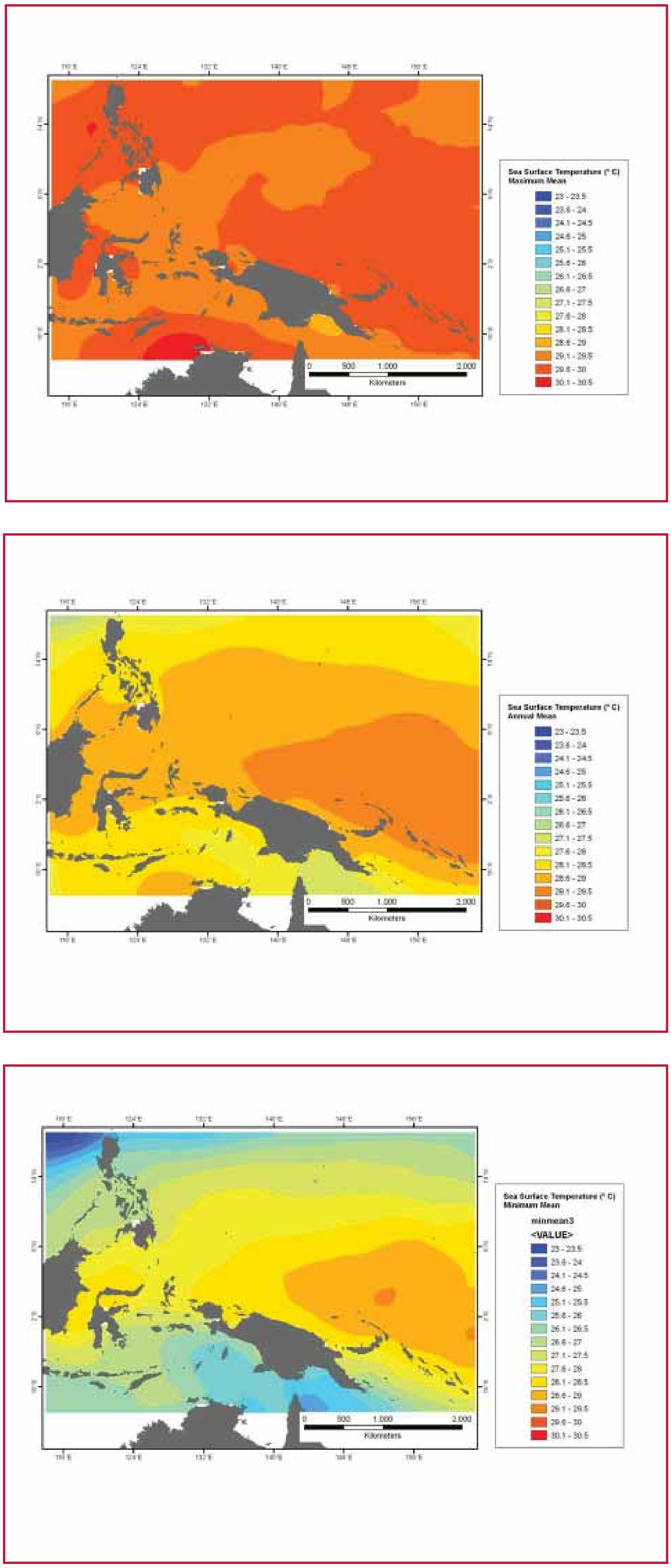


Figure 2: Average annual, annual maximum and annual minimum SSTs, 1950-2007 (data source HadISST, (Rayner et al. 2003) http://badc.nerc.ac.uk/data/hadisst/)

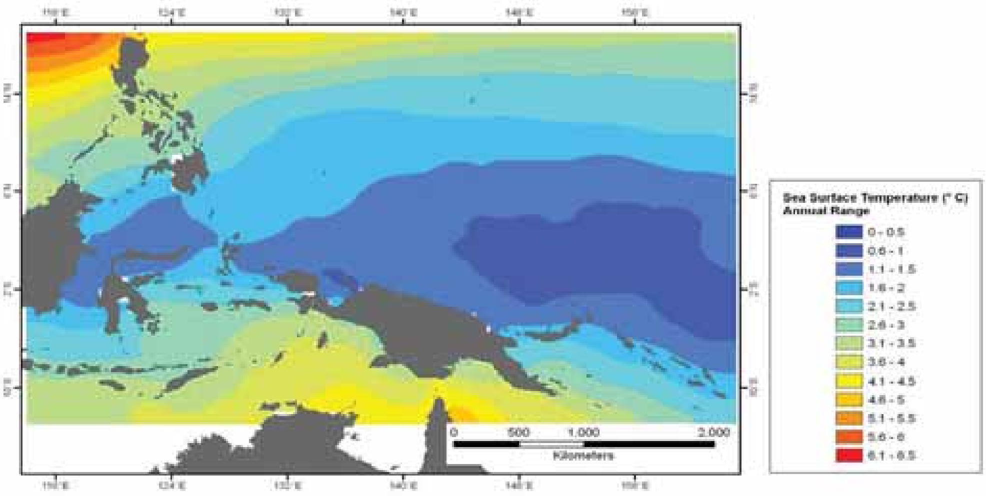


Figure 3: Annual range of sea surface temperatures for the Coral Triangle area. (data source HadISST, Rayner et al. 2003, http://badc.nerc.ac.uk/data/hadisst/)

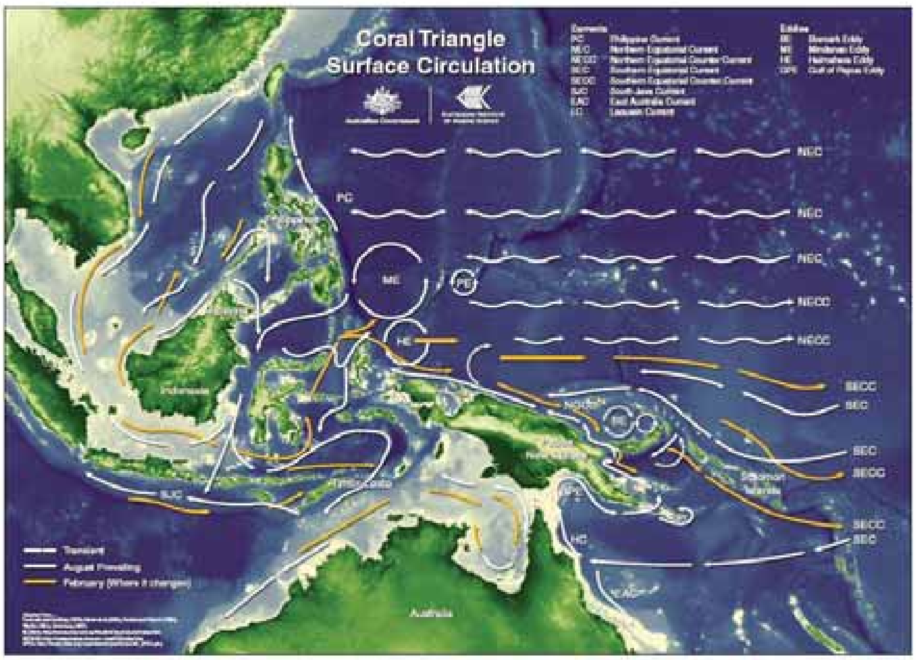


Figure 4: Surface ocean circulation in vicinity of Coral Triangle (Craig Steinberg, AIMS).

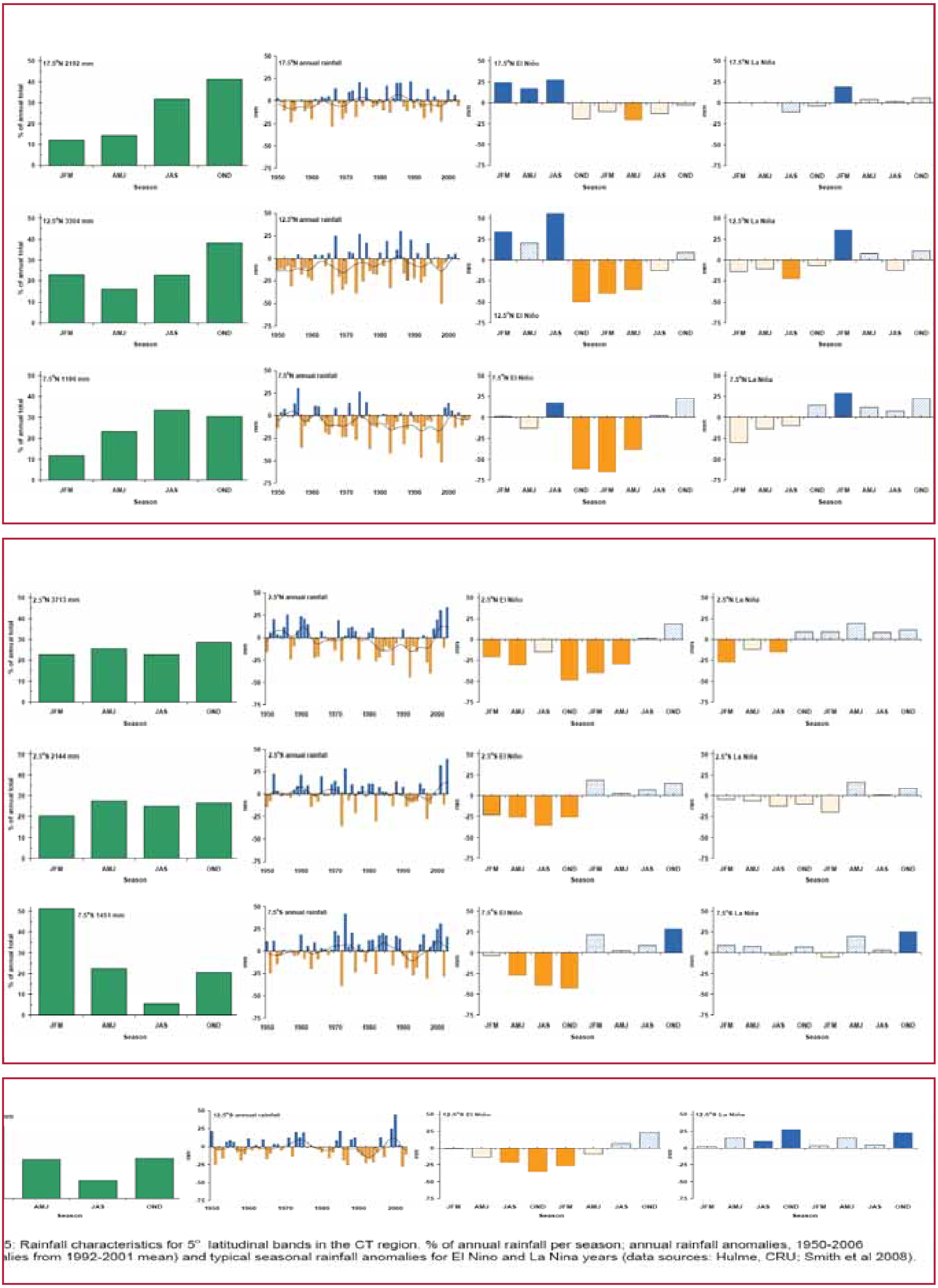


Figure 5: Rainfall characteristics for 5o latitudinal bands in the CT region. % of annual rainfall per season; annual rainfall anomalies, 1950-2006 (anomalies from 1992-2001 mean) and typical seasonal rainfall anomalies for El Nino and La Nina years (data sources: Hulme, CRU; Smith et al 2008).

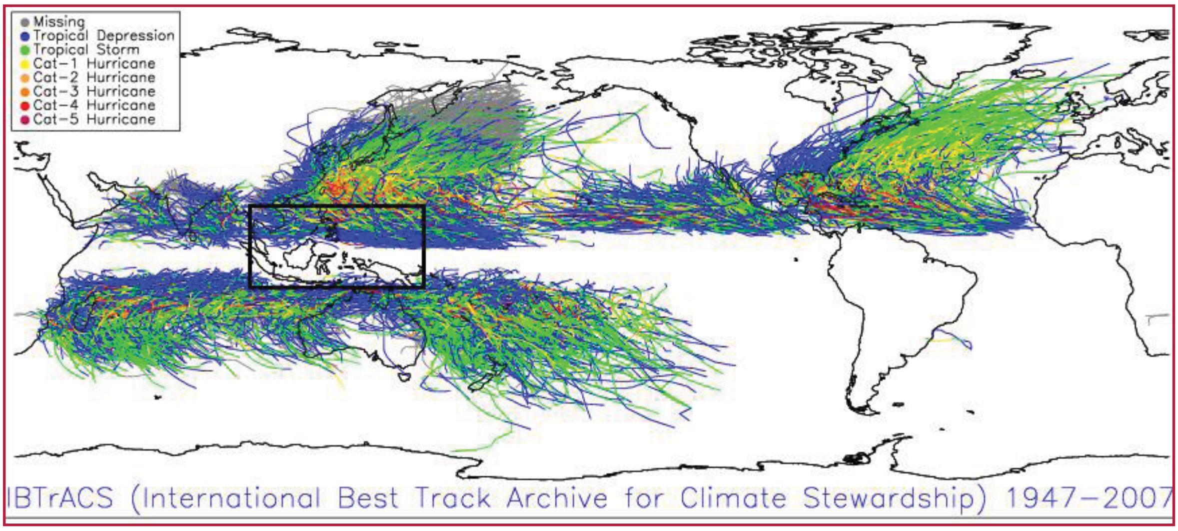


Figure 6: Map of all tropical storm and tropical cyclones tracks, 1947-2007 (http://www.ncdc.noaa.gov/oa/ibtracs/)

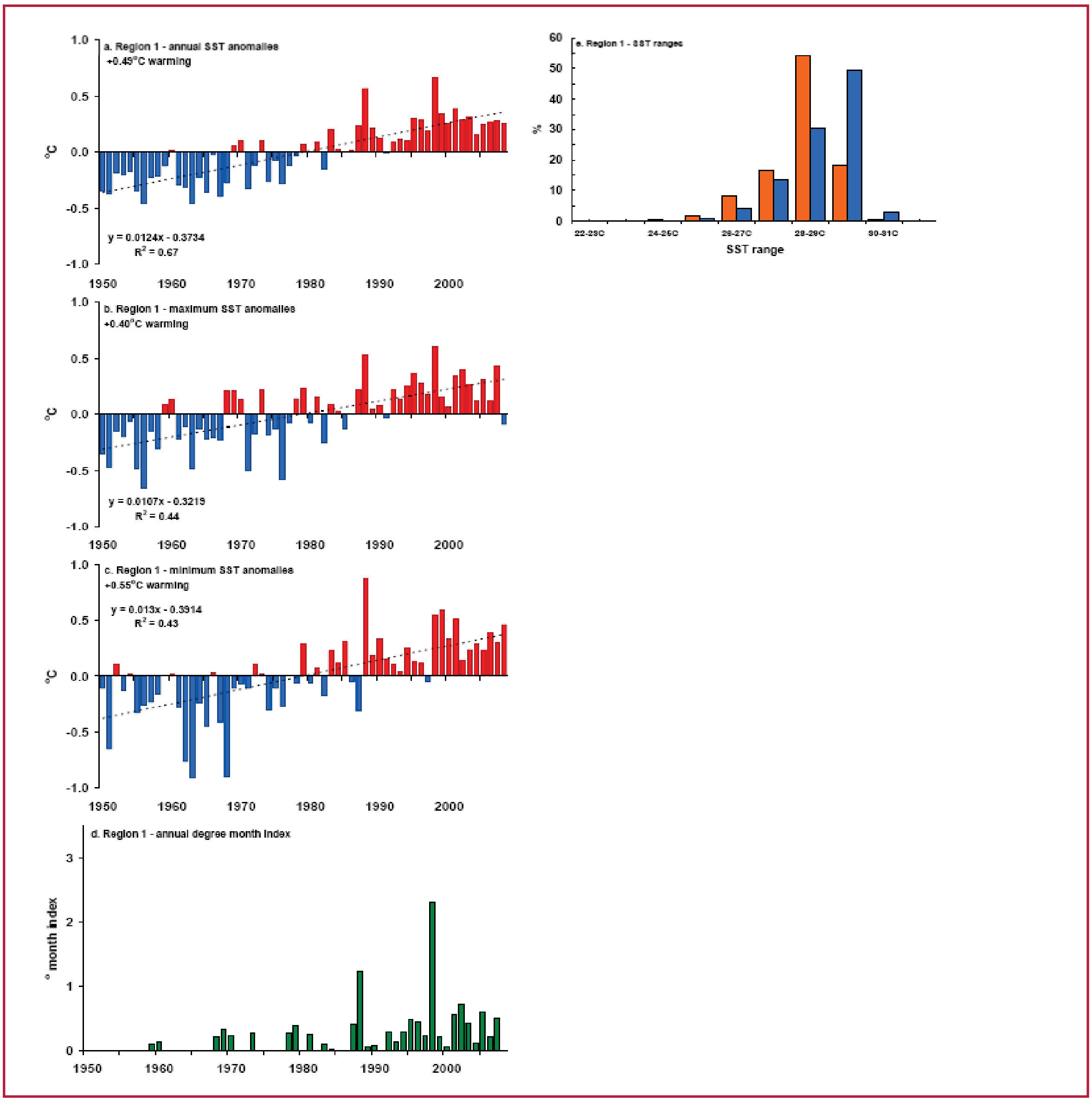


Figure 7: CT-SST region 1: annual, annual maximum, annual minimum, degree month index & SST changes, 1950-2008 (data source HadISST, Rayner et al. 2003, http://badc.nerc.ac.uk/data/hadisst/)

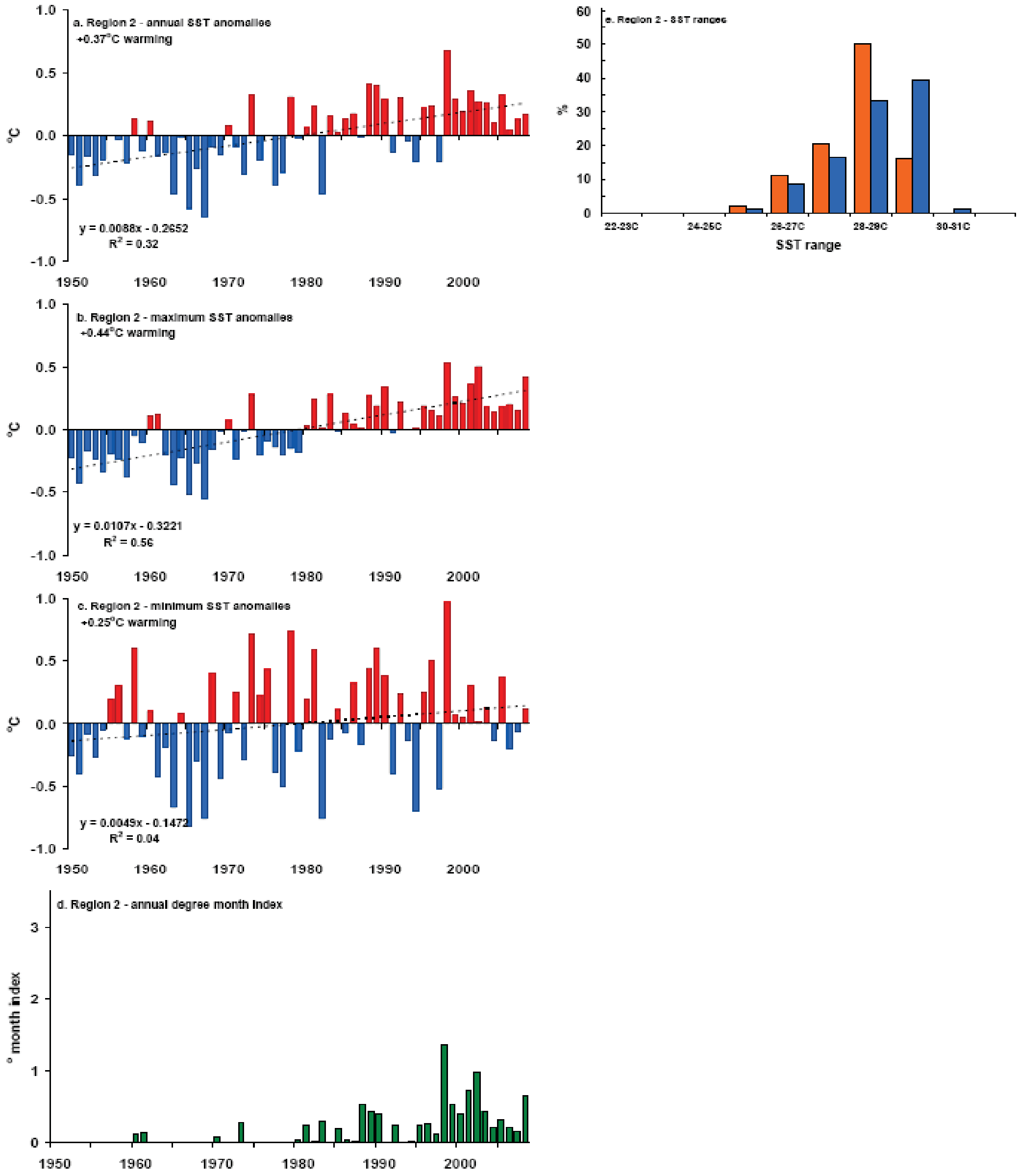


Figure 8: CT-SST region 2: annual, annual maximum, annual minimum, degree month index & SST changes, 1950-2008

Figure 8: CT-SST region 2: annual, annual maximum, annual minimum, degree month index & SST changes, 1950-2008 (data source HadISST, Rayner et al. 2003, http://badc.nerc.ac.uk/data/hadisst/)

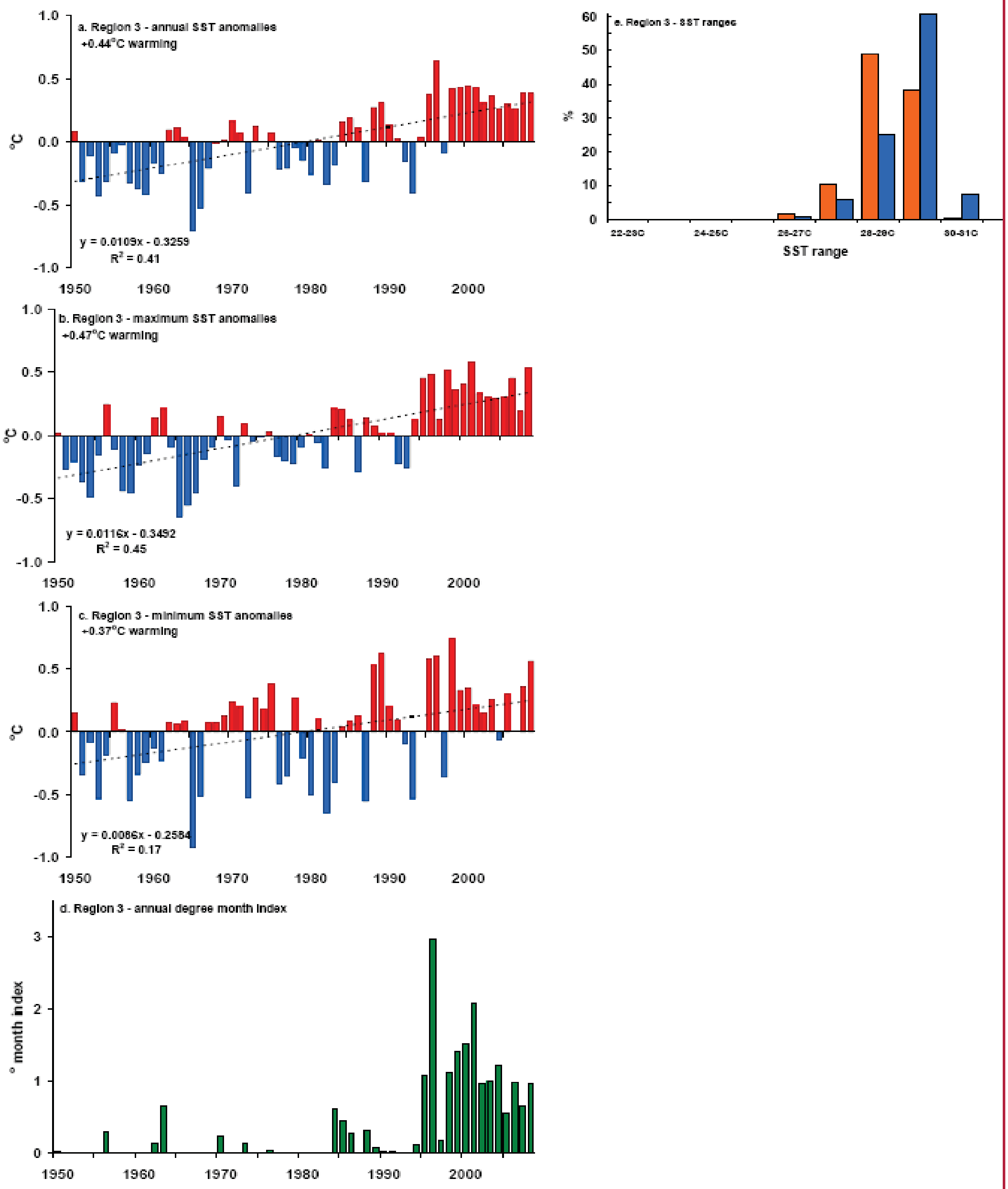


Figure 9: CT-SST region 3: annual, annual maximum, annual minimum, degree month index & SST changes, 1950-2008

Figure 9: CT-SST region 3: annual, annual maximum, annual minimum, degree month index & SST changes, 1950-2008 (data source HadISST, Rayner et al. 2003, http://badc.nerc.ac.uk/data/hadisst/)

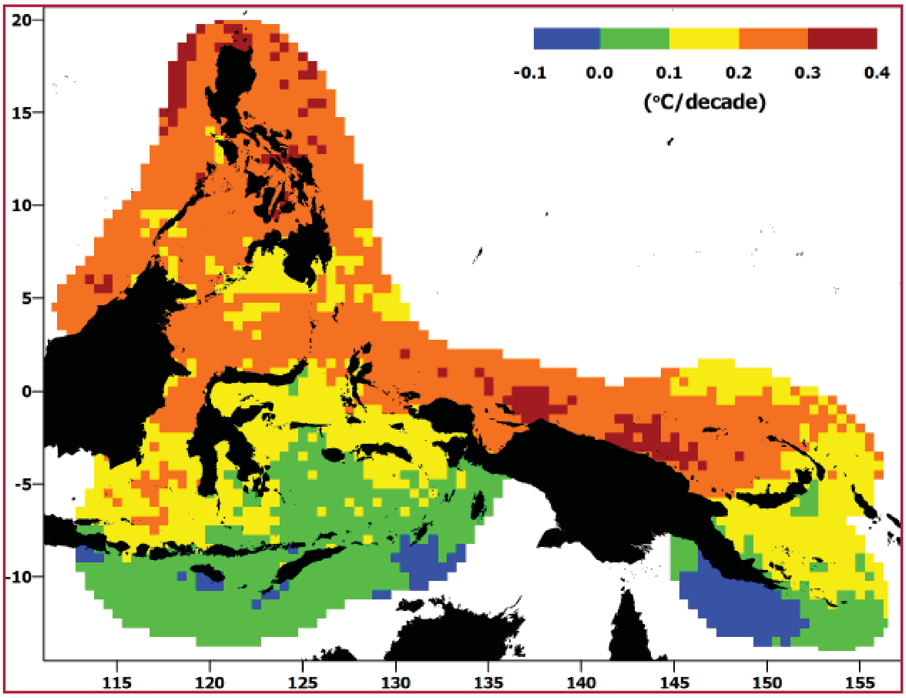


Figure 10: Linear trends in 0.5o bi-weekly AVHRR SSTs, calculated from gap-filled Pathfinder 4km satellite data, over the period 1985-2006 (Peñaflor et al., Coral Reefs in press; with kind permission of Springer Science and Business Media).

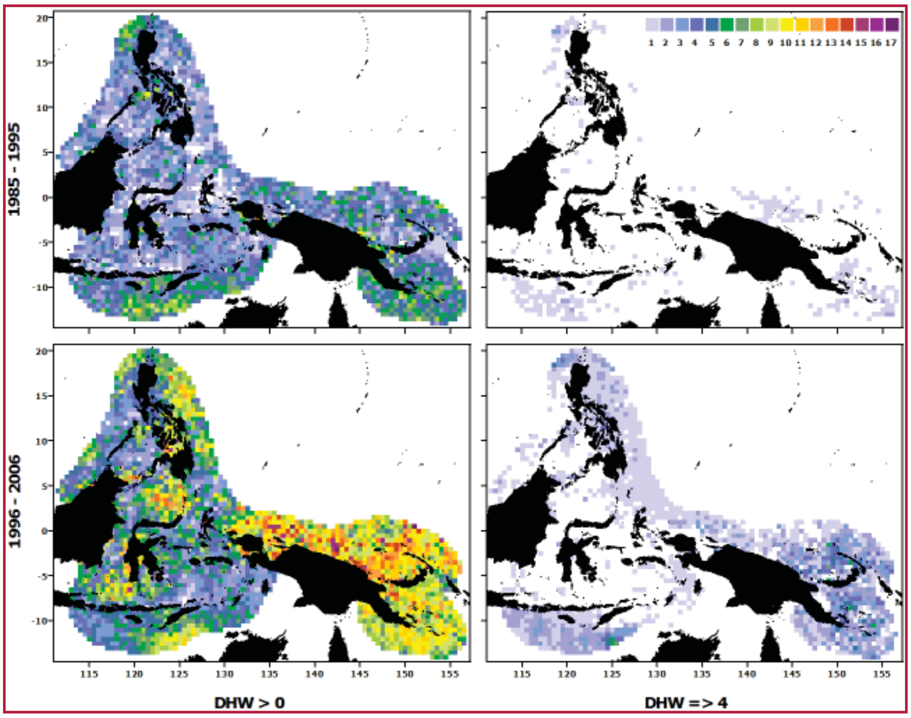
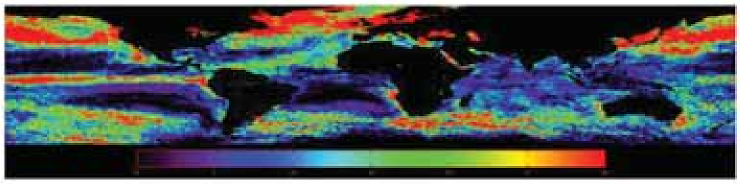


Figure 11: Number of years with Degree Heating Weeks (DHW) from AVHRR satellite data greater than 0 (left panels) and greater than 4 (right panels) for the periods 1985-1995 (top panels) and 1996-2006 (lower panels). DHWs were calculated at 0.5o resolution, from gap-filled Pathfinder 4km satellite data (Peñaflor et al., Coral Reefs in press; with kind permission of Springer Science and Business Media).



New Figure 12

Figure 12: Global map of number of years with DHW greater than 4 from weekly 4km gap-filled AVHRR Pathfinder satellite data, over the period 1985-2005.

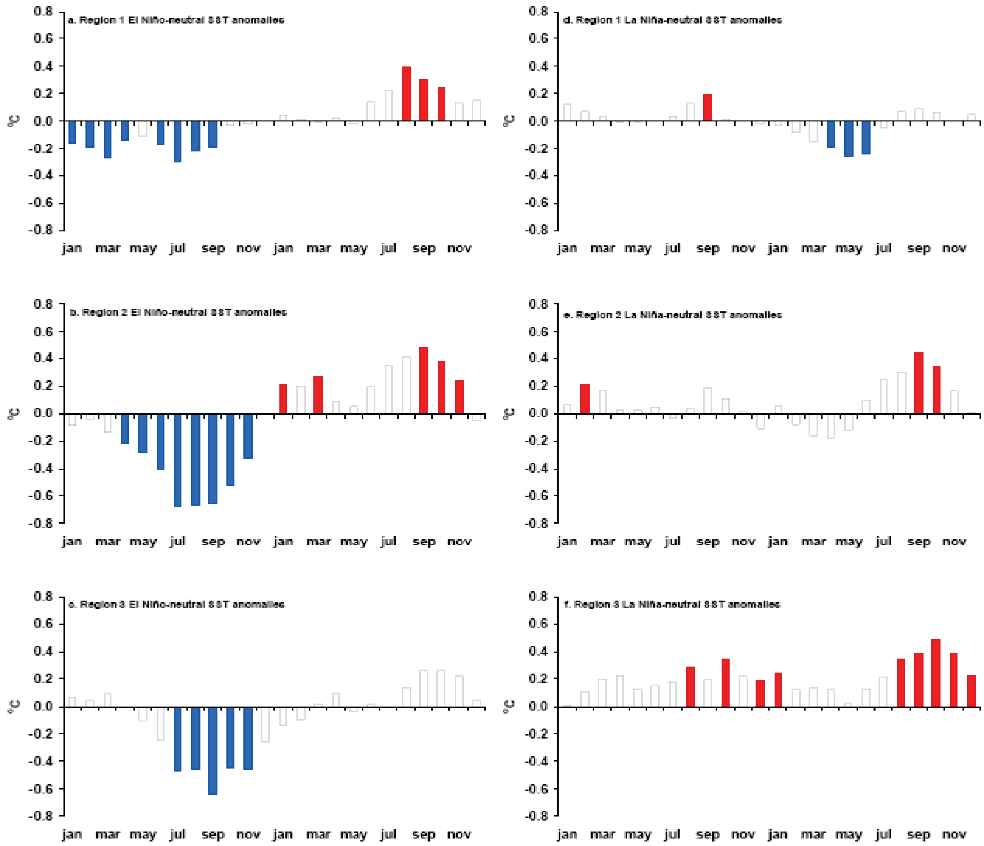


Figure 10: Typical monthly SST anomalies during El Niño and La Niña events (24 months from eg 1982-1983 etc). Filled bars are months when the average SST anomalies are significantly different (5% level) from ENSO-neutral conditions for CT-SST regions 1-3

Figure 13: Typical monthly SST anomalies during El Niño and La Niña events (24 months from e.g. 1982-1983 etc). Filled bars are months when the average SST anomalies are significantly different (5% level) from ENSO-neutral conditions for CT-SST regions 1-3

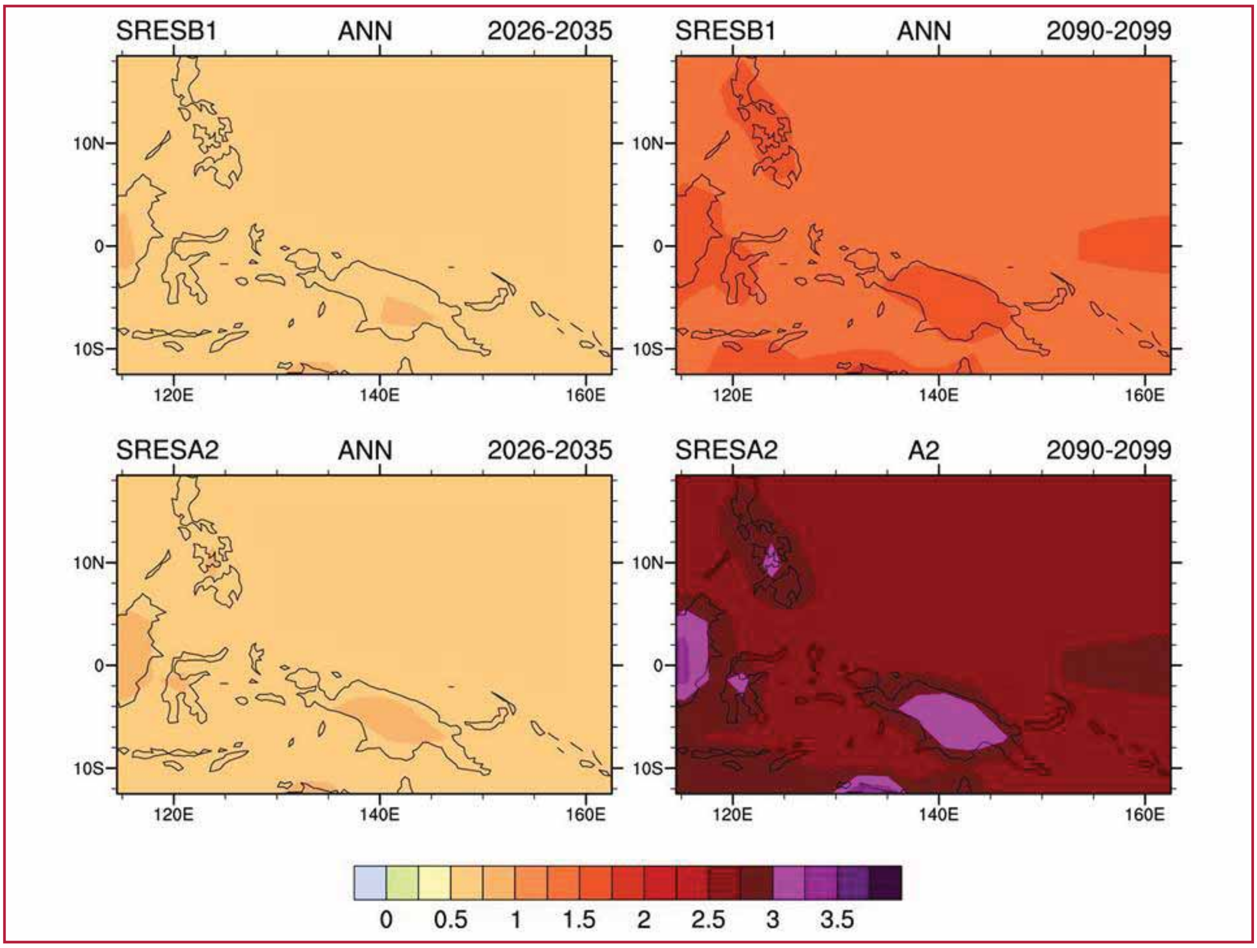


Figure 14: Multi-model annual mean surface temperature differences (C°) for a) low emission scenario B1, 2026-2035 minus 1980-1999; b) same as (a) except for 2090-2099 minus 1980-1999; c) same as (a) except for the high emission scenario A2; d) same as (b) except for the high emission scenario A2 (SRESA2) (Data provided by Julie Arblaster based on Meehl et al., 2007).

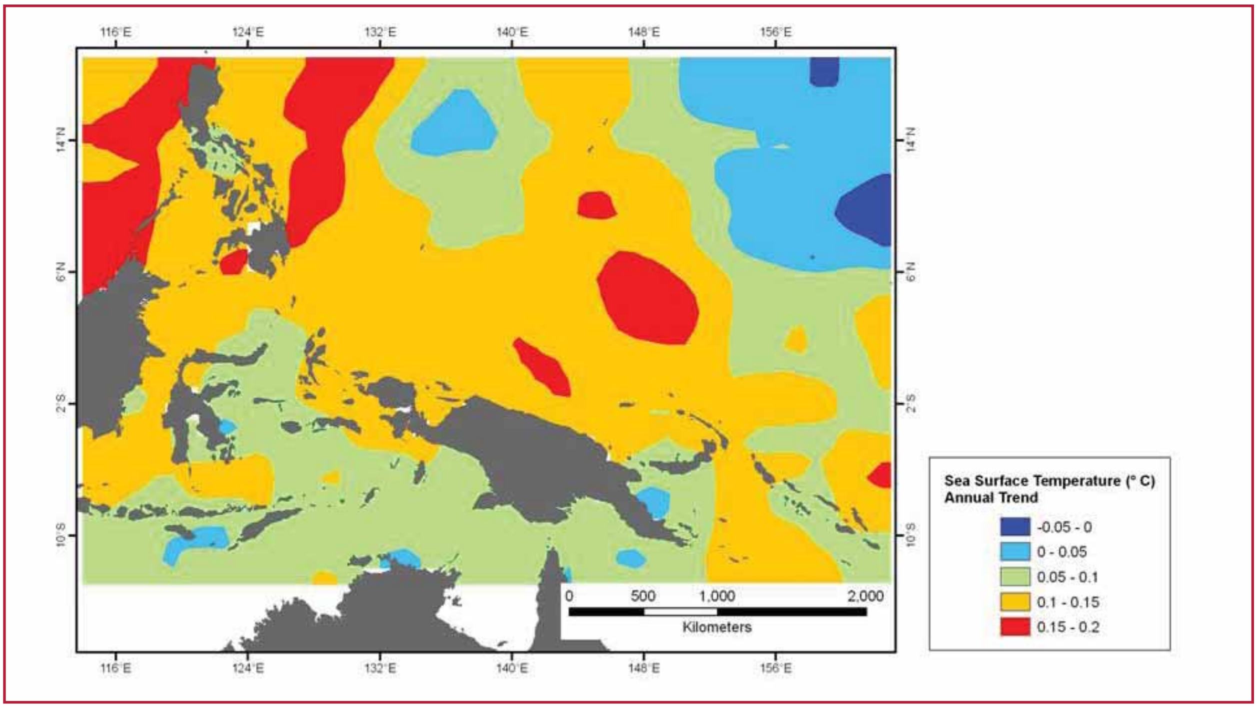


Figure 15: Linear trend (oC/decade) of annual SSTs, 1950-2007.

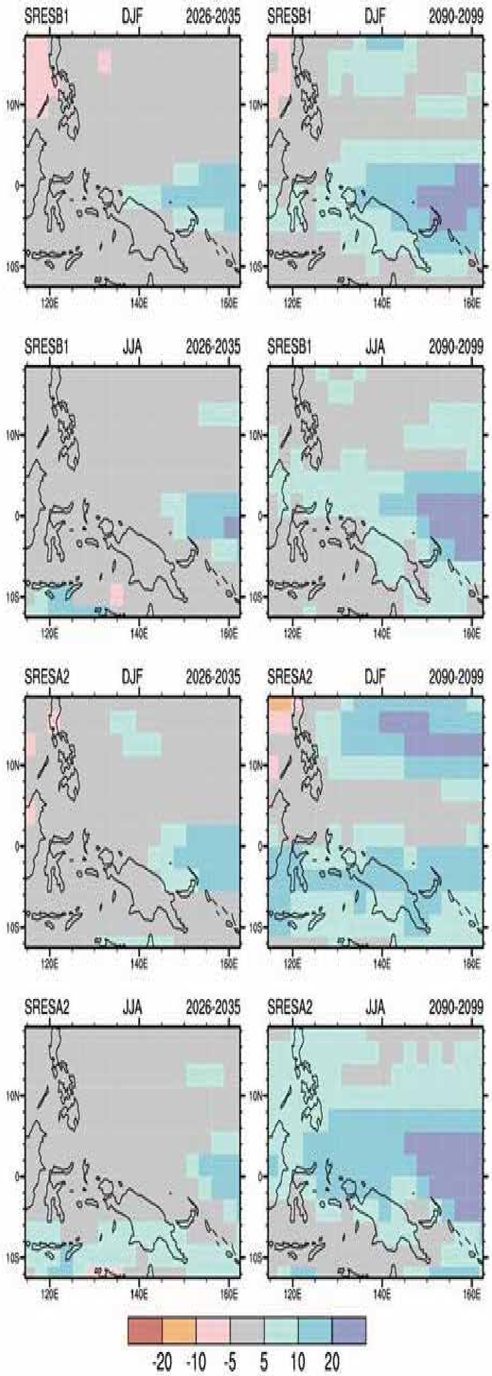


Figure 16: Multi-model seasonal precipitation differences (%) for a) DJF (low emission scenario B1, 2026-2035 minus 1980-1999; b) same as (a) except for 2090-2099 minus 1980-1999; c) same as (a) except for JJA; d) same as (c) except for JJA; e) same as (a) except for the high emission scenario A2; f) same as (b) except for the high emission scenario A2; g) same as (c) except for the high emission scenario A2; h) same as (d) except for the high emission scenario A2. Key: DJF; Dec-Jan-Feb. JJA: Jun-Jul-Aug.

Table 1: Projected global temperature changes, sea-level rise (relative to 1980-99) and CO_2 concentrations for various SRES scenarios (Bindoff et al., 2007; Meehl et al., 2007)

Scenario	**Temperature**	**Sea level rise**	**CO_2**
B1	+1.8 (1.1-2.9) oC	0.18-0.38 m	450-500 ppm
A2	+3.4 (2.0-5.4) oC	0.23-0.51 m	750-800 ppm
A1FI	+4.0 (2.4-6.4) oC	0.26-0.59 m	950-1000 ppm

Table 2: SST statistics for 3 CT regions, 1950-2008 (mean ± sd)

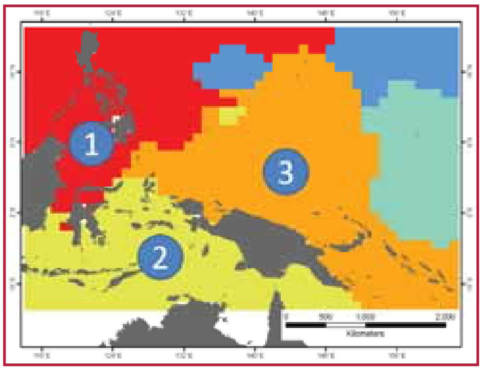
	Annual	**Maximum**	**Minimum**	**Range**	**Month of maximum**	**Month of minimum**
CTRegion 1	28.55±0.26 oC	29.49±0.28 oC	27.25±0.34 oC	2.24±0.28 oC	May-June	February
CTRegion 2	28.36±0.27 oC	29.34±0.25 oC	26.88±0.40 oC	2.46±0.36 oC	December	August
CTRegion 3	28.95±0.29 oC	29.44±0.30 oC	28.28±0.36 oC	1.16±0.26 oC	December	August

Table 3: Linear trend, 1950-2008 and temperature difference (1989-2008)-(1950-1969) for 3 CT regions and global land and sea temperatures and tropical SSTs (all values significant at 5% level).

	Global Land & Sea	**Tropical SST**	**CTRegion 1**	**CTRegion 2**	**CTRegion 3**
Trend	0.12 oC/decade	0.08 oC/decade	0.12 oC/decade	0.09 oC/decade	0.11 oC/decade
Difference	0.45 oC	0.29 oC	0.49 oC	0.37 oC	0.44 oC

Table 4: Projected temperature changes (and ranges) by 2090-99 from 1980-99 mean for global surface temperatures and SST estimates for 3 CT regions based on recent (1950-2008) relationships between CT trends and global land and sea temperatures (Table 2), i.e. assuming current relative changes are continued into the future (Global temperature changes from Meehl et al. (2007)) and observed SST average, 1980-99 and projected for 2090-99. The map insert shows the approximate location of the CT-SST regions.

Scenario	Global temperatures	CTRegion 1 (100%)	**CT Region 2 (75%)**	**CTRegion 3 (92%)**
B1	1.8 (1.1-2.9) oC	1.8 (1.1-2.9) oC	1.4 (0.8-2.2) oC	1.7 (1.0-2.7) oC
A2	3.4 (2.0-5.4) oC	3.4 (2.0-5.4) oC	2.6 (1.5-4.1) oC	3.1 (1.8-5.0) oC
A1F1	4.0 (2.4-6.4) oC	4.0 (2.4-6.4) oC	3.0 (1.8-4.8) oC	3.7 (2.2-5.9) oC
SST 1980-99		28.7 oC	28.5 oC	29.0 oC
SST 2090-99 B1		30.5 oC	29.9 oC	30.7 oC
SST 2090-99 A2		32.1 oC	31.1 oC	32.1 oC
SST 2090-99 A1F1		32.7 oC	31.5 oC	32.7 oC



CHAPTER 8

IMPACTS OF CLIMATE CHANGE ON COASTAL ECOSYSTEMS AND PEOPLE

One of the consequences of the rapidly growing global population and associated energy demand has been a soaring rise in the burning of fossil fuels. As was outlined in the previous chapter, this will substantially change the physical and chemical conditions associated with most regions of the world including the Coral Triangle. As was recognized at the United Nations climate change conference held in Bali, Indonesia (December 2007), as well as the IPCC scenarios, developing countries like those in Southeast Asia are among the most vulnerable to the impact of climate change yet have the least capacity to adapt to the consequences. This also holds for the poorer sections of national economies including areas adjacent to coral reefs in eastern Indonesia and Sabah, relative to the rest of the countries to which they belong.

In this section, the general impacts of climate change is considered before delving down into how the coastal ecosystems (coral reefs, mangroves and seagrass) and dependent coastal populations within the Coral Reef Triangle will be affected. In undertaking this analysis, much of the insight into how global climate change is likely to affect these ecosystems is drawn from examples from within and outside the Coral Triangle; mainly on account of the inherent likelihood this of these systems to act in similar fashion is across tropical regions globally.

GENERAL VULNERABILITY OF CORAL TRIANGLE TO CLIMATE CHANGE

There is a growing literature on the vulnerability of Southeast Asian countries to the impact of rapid anthropogenic climate change. While a complete review of this literature goes beyond the intentions of this report, resources such as the IPCC 4th assessment Report provide an assessment on how climate change is likely to generally affect the South-East Asian region. This, plus the climate change hazard maps produced by Yusuf and Francesco (2009) provide the background important for understanding how climate change is likely to impact the six Coral Triangle countries.

According to the Fourth Assessment Report, there climate change has affected many sectors in Asia already. Rising temperatures and extreme weather events have affected human infrastructure and agricultural yields. These changes are expected to continue to affect agriculture, with 2.5-10% decreases in crop yields projected for many parts of the region by the 2020, with further decreases from 5-30% by 2050 (as compared to 1990 levels). Ultimately these will increase the risk of hunger and water shortages. The same trends also hold for Asia in general, with an estimated 120 million to 1.2 billion people experiencing water stress by 2020. These problems will be exacerbated in coastal areas by increased flooding and storm surge impacts along with the loss of groundwater supplies as they are inundated seawater as sea levels rise (Cruz et al. 2007).

Yusuf and Francisco (2009) followed the assessment framework of the United Nations Intergovernmental Panel on Climate Change (IPCC) to identify the most vulnerable regions within South-East Asia to climate change impacts, using spatial distribution data on various climate related hazards in 530 areas in Southeast Asia, including areas from Indonesia, Philippines and Malaysia (Yusuf and Francisco 2009). The methodology used to investigate the vulnerability recognized the component parts exposure (rates of change in key physical and chemical parameters), sensitivity (the degree to which a system is affected adversely or beneficiary by climate related changes), and adaptive capacity (the ability to adjust to the variability and extremes of climate change in order to reduce its effects or take advantage of its opportunities). This analysis led to the climate change vulnerability map for Southeast Asia shown in figure 1A.

According to the analysis of Yusuf and Francisco (2009), the Philippines, Indonesia (particularly Sumatra, Java and West Papua) and Malaysia (Sabah) are among the most vulnerable countries to climate change within the South-East Asian region. The vulnerability is a consequence of a high exposure to increasing frequencies of droughts (Sabah, Malaysia and parts of the Philippines), as well as cyclones, landslides and floods in other parts of the Philippines and Indonesia. Much of these changes are driven by the changes in temperature and precipitation described in chapter 7.

The ability of these countries to respond to the challenges of climate change was calculated as a function of many of the parameters explored in chapter 5 and 6 (in particular, education, poverty, income inequality, infrastructure and longevity). While Timor Leste, Solomon Islands and Papua New Guinea were not analysed by Yusuf and Francisco (2009), the broad principles of the methodology used would almost certainly place these countries in a lower category of vulnerability. Papua New Guinea is expected to have a moderate exposure to floods, droughts and landslides, but greater adaptability given lower population densities and relatively more natural resources. Coastal flooding from rising sea levels and change precipitation patterns is also be a problem in Papua New Guinea and some regions of the Solomon Islands. The relative adaptability of different regions of the Coral Triangle to climate change as assessed by Yusuf and Francisco (2009) is shown in Figure 1b.

These perspectives on the climate vulnerability of the six countries in the Coral Triangle, lead naturally into a consideration of how this vulnerability that has been considered in terms of natural disasters, water availability, and agricultural productivity is influenced by the impacts of climate change on coastal ecosystems. While this aspect does receive attention within the IPCC Fourth Assessment Report, the details are broad at best and the added vulnerability remains largely unassessed until now. The next section reviews our current understanding of how climate change will affect coastal ecosystems in preparation for climate change scenarios involving changes to coastal ecosystems and human communities over the next few decades and century.

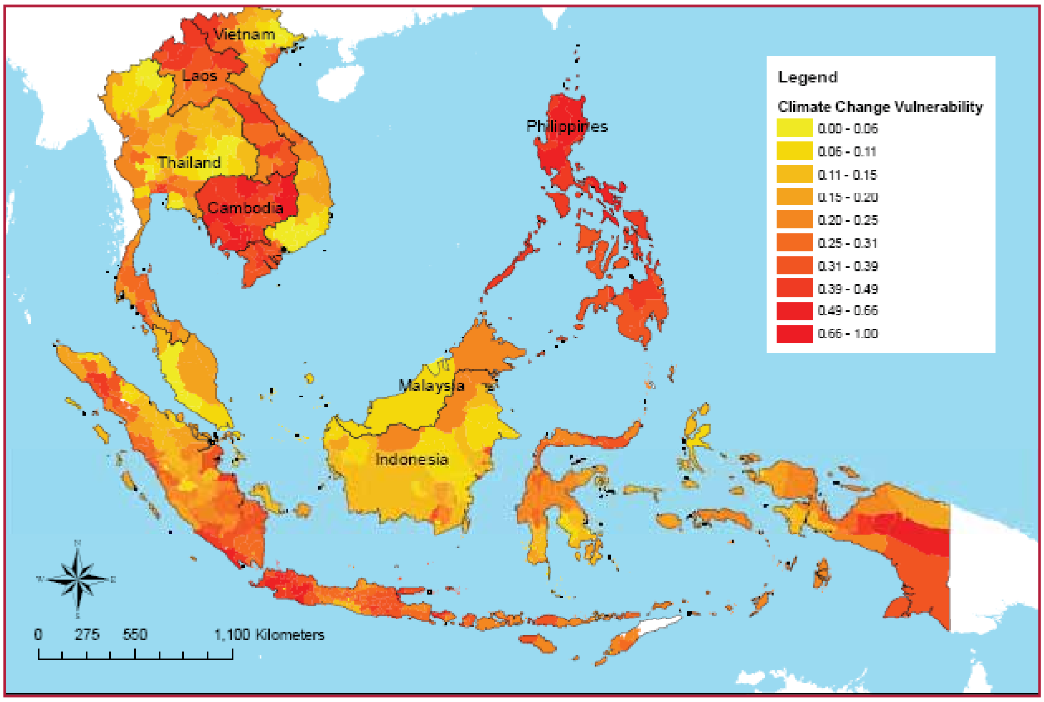
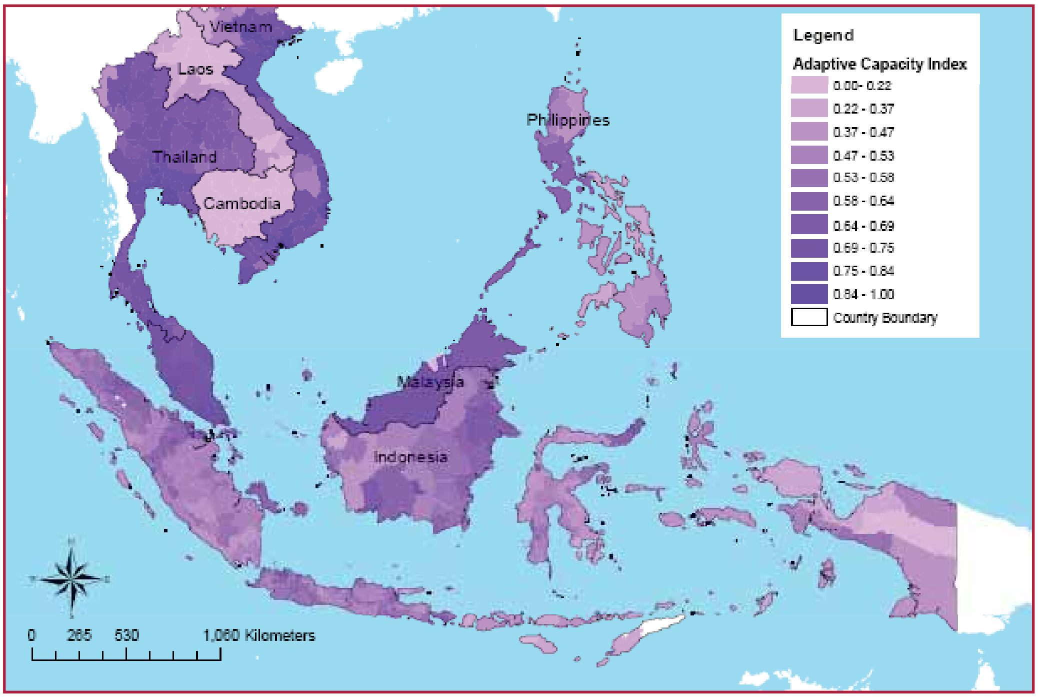


Figure 1. Vulnerability (A) and adaptive capacity (B) of Coral Triangle region to climate change as assessed by Yusuf and Francisco (2009, reprinted with permission).



CORAL REEF ECOSYSTEMS

Coral reef ecosystems are among the most sensitive marine ecosystems, with an estimated 40-50% having been lost over the past 40 years and the South-East Asian and Western Pacific regions (Bruno and Selig 2007). These losses appear to have a global component as they are occurring in well-managed (e.g. Great Barrier Reef) as well as poorly managed areas of the world (many parts of SE Asia). Corals in themselves appear to also show an elevated risk of extinction. In this regard, (Carpenter et al. 2008) recently assessed the conservation status of 845 coral species using IUCN Red List Criteria, and found that 33% faced an elevated risk of extinction, with alarming decreases in abundance associated with bleaching and diseases driven by elevated sea surface temperatures, and exacerbated by local-scale anthropogenic disturbances. Interestingly, the Coral Triangle had the highest proportion of species in all categories of elevated extinction risk.

In this section, we outline the current state of knowledge of how the current changing climate and acidifying oceans will impact upon coral reef, mangrove and seagrass ecosystems. This will be done by considering the impact of key changes that already are occurring and are expected to occur to tropical coastal environments on coral reefs, mangroves, salt marshes and seagrasses. This will establish the basis for considering how the future will unfold for these important coastal ecosystems within the Coral Triangle when we integrate these changes with the climate change scenarios developed in the next chapter.

A. Mass coral belaching and increasing sea temperatures

Tropical sea temperatures have increased steadily over the past 50 years in concert with the rise in atmospheric carbon dioxide and global temperature (IPCC 2007). These changes when combined with the natural variability in sea temperature have periodically pushed communities of corals beyond their upper thermal threshold (Hoegh-Guldberg 1999). Thermal stress leads at first to a breakdown of the mutualistic symbiosis that corals maintain with dinoflagellate microalgae from the genus, *Symbiodinium*. When the corals eject the brown microalgae, the coral host appears bleached as their now translucent coral tissues reveal the underlying calcium carbonate skeleton.

Mass coral bleaching, where often hundreds of square kilometres of coral reefs are affected simultaneously, was first reported in the early 1980s. There are no scientific reports of coral bleaching on this scale prior to 1980 (Hoegh-Guldberg 1999).

Mass coral bleaching occurs when sea temperatures increase to 1°C or more above the long-term "summer" sea temperature maxima. This relationship has been extensively verified experimentally and through field observations, and is highly reliable given that measurements of sea surface temperature anomalies by passing satellites can accurately predict the advent of bleaching (Strong et al. 1996). Solar irradiance is a contributing factor that exacerbates the effect of thermal stress. In this particular case, warm conditions under cloudy skies may result in reduced impacts from the same level of thermal stress (Mumby et al. 2001). Similar observations have been made with respect to water motion (Nakamura and van Woesik 2001), with corals being more susceptible in still conditions than when ventilated by strong currents. While these secondary factors may influence the outcome of thermal stress, they do not generally cause mass bleaching on their own.

Corals that bleached are deprived of their principal energy source, leading to starvation, and increased rates of disease and mortality. Numerous mass bleaching events have taken place since the early 1980s. In each of these widespread events, entire coasts, regions and sometimes oceans have been affected. While communities of corals have recovered from mass bleaching events, major coral mortalities have occurred on broad geographical scales, often with the loss of over 95% of the corals on many reefs within a region. In 1998, most coral reefs across the world bleached when ocean temperatures increased above long-term averages. In many cases, a large proportion of bleached corals largely recovered (Brown and Suharsono 1990; Suharsono 1998; Wilkinson 2008). But in others, such as the Western Indian Ocean, Palau, and Okinawa, reefs experienced major mortalities within their shallow water coral communities. For example, by the end of 1998, approximately 46% of all corals surveyed in the Western Indian Ocean region had died after the elevated sea temperatures and bleaching impacts.

Climate projections indicate that bleaching and mortality will increase sharply over the coming decades unless corals are able to rapidly adapt to increased sea temperatures (Hoegh-Guldberg 1999; Done et al. 2003; Donner et al. 2005b; Hoegh-Guldberg et al. 2007). So far, evidence for the rapid adaptation of corals is scant, and most evidence suggests that the threshold of corals and their communities for thermal stress will not change at the rate required to keep pace with rising sea temperatures.

B. Reduced reef accretion and ocean acidification

Approximately 34% of the carbon dioxide emitted to the atmosphere has been absorbed by the global ocean (Sabine et al. 2004). On entering the ocean, carbon dioxide reacts with water molecules to produce carbonic acid, which produces a proton that subsequently reacts with carbonate ions and converts them into bicarbonate ions. The increase of atmospheric carbon dioxide from 280 ppm in the preindustrial period to 384 ppm in 2008 has shifted the pH of shallow water oceans down from 8.179 to 8.104 (Orr et al. 2005). This seemingly small change in pH has resulted in an overall drop in the carbonate ion concentration of around 30 µmol per kg seawater. When atmospheric carbon dioxide exceeds 480-500 ppm, the carbonate ion concentration will have dropped below 200 µmol per kg seawater for most parts of the global ocean. It is important to note that carbonate coral reefs (i.e. those that produce extensive calcium carbonate reef structures) do not grow today in conditions where carbonate ion concentrations are less than 200 µmol per kg seawater (Figure 2).

The impact of ocean acidification on corals and the reefs they build (Kleypas et al. 1999b) has been extensively supported by experimental studies done in laboratory and mesocosm settings (Kleypas and Langdon 2006). There is also growing evidence from field studies that show a significant impact on coral growth and reef accretion. Recent studies (Cooper et al. 2008; De'ath et al. 2009) have demonstrated that corals on the Great Barrier Reef are calcifying at rates which are 14% slower than those measured before 1990, a sudden downward trend that is unprecedented in the 400 years of record examined by the scientists. Similar decreases have been observed for Thai reefs (Tanzil et al. 2009). While it is impossible to attribute these decreases in calcification to ocean acidification directly as many factors have changed over this time, it is very clear that some combination of stresses involving increased temperatures and acidity have taken a toll on the ability of coral reefs to form the extensive calcium carbonate structure which is so important to reef ecosystems.

Aragonite is the form of calcium carbonate that corals and many other coral reef organisms deposit into their skeletons. The aragonite saturation of seawater is a measure of the calcium and carbonate ion concentrations as a function of the precipitation point of aragonite. Looking across reefs today, carbonate coral reefs do not form in waters where aragonite saturation decreases below 3.3 (Cao et al. 2007). This is backed up by experimental evidence as discussed above. Recent modelling of how aragonite saturation will change as atmospheric carbon dioxide increases (Figure 1) suggests that conditions suitable for carbonate coral reefs will rapidly contract to equatorial western-boundary current regions by the time atmospheric carbon dioxide climbs to 450 ppm (Hoegh-Guldberg et al. 2007; see Figure 2). Interestingly, conditions within the Coral Triangle may be among the last in the world that will support carbonate coral reef ecosystems, although models are unreliable in this region and should be the focus of future research. Atmospheric carbon dioxide concentrations that exceed 500 ppm, however, will rapidly extinguish even these last potential havens for carbonate coral reefs.

C. Sea level rise

Global sea level is currently increasing at the rate of 3.3 mm per year (Church and White 2006a; IPCC 2007), although the amount varies geographically. The estimates of sea level rise accepted by the 4th Assessment Report of the Intergovernmental Panel on Climate Change range between 11 and 77 cm by the end of the century. There are considerable uncertainties around this estimate, particularly given the sudden and precipitous loss of summer Arctic Ice over the past five years (which exceeds even in the worst case scenarios of the IPCC) (Cressey 2007; Meier et al. 2007; Zhang et al. 2008). Recent evidence that this is being accompanied by rapid melting and breakdown of the Greenland (Witze 2008) and Antarctic (Steig et al. 1998 ; Steig et al. 2009) ice sheets suggests that scenarios of how sea level will change will need revision, especially given the observation that icesheet melting now dominates sea level rise (Meier et al. 2007). The potential for several metres of sea level rise this century is growing and our ability to estimate this change is improving, as glaciologists understand more about ice dynamics and conclude that abrupt climate change can happen in a few years (Steffensen 2008). The relative impact of coastal areas within the Coral Triangle of a 1 m and 5m sea level rise are depicted in Figure 3.

Current rates of coral growth and reef accretion appear to be able to keep up with the present rate of sea level rise. If sea level rise continues to accelerate, this situation may change, especially if coral growth and calcification has been compromised by the impacts of thermal stress and ocean acidification. For example, if the increase in sea level accelerates to several metres per century, even healthy coral communities and reefs will have difficulty in keeping up. Add to this, the expectation that coral growth may be minimal if atmospheric carbon dioxide increases above 500 ppm, and the spectre of drowned coral reefs as sea levels rise is an even greater possibility.

Crucially, there is growing evidence of coral reefs being left behind by rapid sea level rise in the recent past (Grigg and Epp 1989; Blanchon and Shaw 1995). In the latter case, timing of a sudden shift in the positioning of coral reefs along shorelines ('back-stepping') such as that which happened 121,000 years ago suggested that corals had trouble with sea level changes that exceeded 30 mm per year (Blanchon et al. 2009).

D. Changing weather patterns and storm intensity

Changing weather patterns can have significant effects on coastal ecosystems such as coral reefs. In this respect, changes to rainfall and storm intensity can have significant influences on coastal water quality. For example, long periods of drought driven by changing rainfall patterns may lead to the loss of coastal vegetation and the destabilisation of soils within river catchments that flow out into coastal environments. These problems can be aggravated by increasing storm intensities that would lead to huge amounts of water suddenly becoming available within these catchments, leading to the extensive efflux of nutrients and sediments into coastal waters. Warmer seas are likely to drive more intense storms (Emanuel 2005 ; IPCC 2007) with the prospect that the extent to which coral reefs experience physical damage may increase, both in intensity and frequency. These types of changes along coastlines may lead to a number of insidious effects on the health of coastal ecosystems. It is important to note, however, that cyclonic storms do not occur in the heart of the Coral Triangle (see Figure 6, chapter 7), and therefore these impacts are more likely to affect the Philippines and Solomon Islands as opposed to other countries.

E. Ramifications of coral loss for ecosystem components and services

The loss of coral-dominated communities has major implications for the biodiversity and productivity of tropical reef systems (Hoegh-Guldberg et al. 2007), especially given the central role that reef-building corals have in providing the three-dimensional topology that forms the habitat for hundreds of thousands of species. Our understanding of these changes is growing, but remains restricted to a handful of organisms such as fish. In the latter case, the decline of coral dominated reef structures is associated with the loss of approximately 25-50% of fish species. Species that depend on corals for recruitment, food and shelter represent the most sensitive species to the loss of coral communities, while others such as herbivores may actually increase in number over time (Graham et al. 2007a; Pratchett et al. 2008; Wilson et al. 2008a; Wilson et al. 2008b). Our understanding of how other organisms such as invertebrates and marine algae will change as coral communities continue to decline is limited (Poloczanska et al. 2007; Przeslawski et al. 2008). However, given the tight ecological relationships between corals and many other species, it is highly likely that the loss of corals will be accompanied by disappearance of many other species.

It is important to realise that the reefs that are currently coral dominated will not disappear, and will be ultimately replaced by other organisms. These other organisms may have different physiological and ecological properties, leading to fast changes in the quantity and quality of species suitable for harvesting by coastal people. There is also the prospect that issues such as poisoning from toxins such as ciguatera could rise significantly as benthic communities change from coral dominated systems to cyanobacteria and other types of organisms. In this regard, the study by Hales and co-workers is particularly insightful in this respect. These authors have shown a steady increase in the number of cases of ciguatera in the Pacific over the past several decades, a trend that is at least loosely associated with the loss of coral dominated reef systems (Hales et al. 1999). Given that our limited understanding of the types of interactions that are likely to arise as corals are lost from reef ecosystems, the potential for surprises like that illustrated by the rise in ciguatera is considerable.

Reducing the structure and diversity of coral reefs will also have implications for tourism within the Coral Triangle. Clearly, as argued for ecosystems such as the Great Barrier Reef (Hoegh-Guldberg and Hoegh-Guldberg 2004), a loss of structure and diversity from coral reefs will reduce their appeal for international tourism, resulting in potential losses as international tourists no longer choose to travel the extra distance to see coral reefs which are no longer exceptionally spectacular as they are today in the Coral Triangle.

F. Interaction and synergies between factors

What are the key uncertainties within our understanding of how local and global factors will affect coral reef ecosystems lies in the synergies and interactions between factors. At the global level, considerable evidence is accumulating that suggests that global warming and ocean acidification are likely to interact in a number of ways. (Anthony et al. 2008) recently demonstrated that increasing seawater acidity lowers a coral's thermal bleaching threshold. This interaction is so strong that corals will bleach without being exposed to elevated sea temperatures when the pH drops to 7.6. This suggests that projections of the impacts of rising temperatures on corals are likely to be optimistic (Hoegh-Guldberg 1999; Done et al. 2003; Donner et al. 2005b; Hoegh-Guldberg et al. 2007). Similar interactions are likely to occur with respect to sea level rise, which may not be a problem as long as corals are healthy and growing vigorously. However, the combination of rapidly rising sea temperatures plus slower coral growth, raises the spectre of reefs that no longer keep pace with the surface of the ocean, and run the risk of becoming drowned (Blanchon and Shaw 1995; Blanchon et al. 2009).

Similar interactions have been noted between local and global factors. For example, (Hughes et al. 2007) found that reducing the number of herbivorous fish on the coral reef reduced the recovery rate of coral communities from mass coral bleaching by a factor of three. These interactions between global and local factors also point to a number of adaptive strategies, which arise from the fact that increasing the resilience of coral reefs to global disturbances may be most effectively done by reducing local stresses such as poor water quality and the overexploitation of key functional groups such as herbivores (Hughes et al. 2003; Hoegh-Guldberg et al. 2007). This issue will be a major theme when the policy recommendations for responding to the impacts of climate change are considered later in this report.

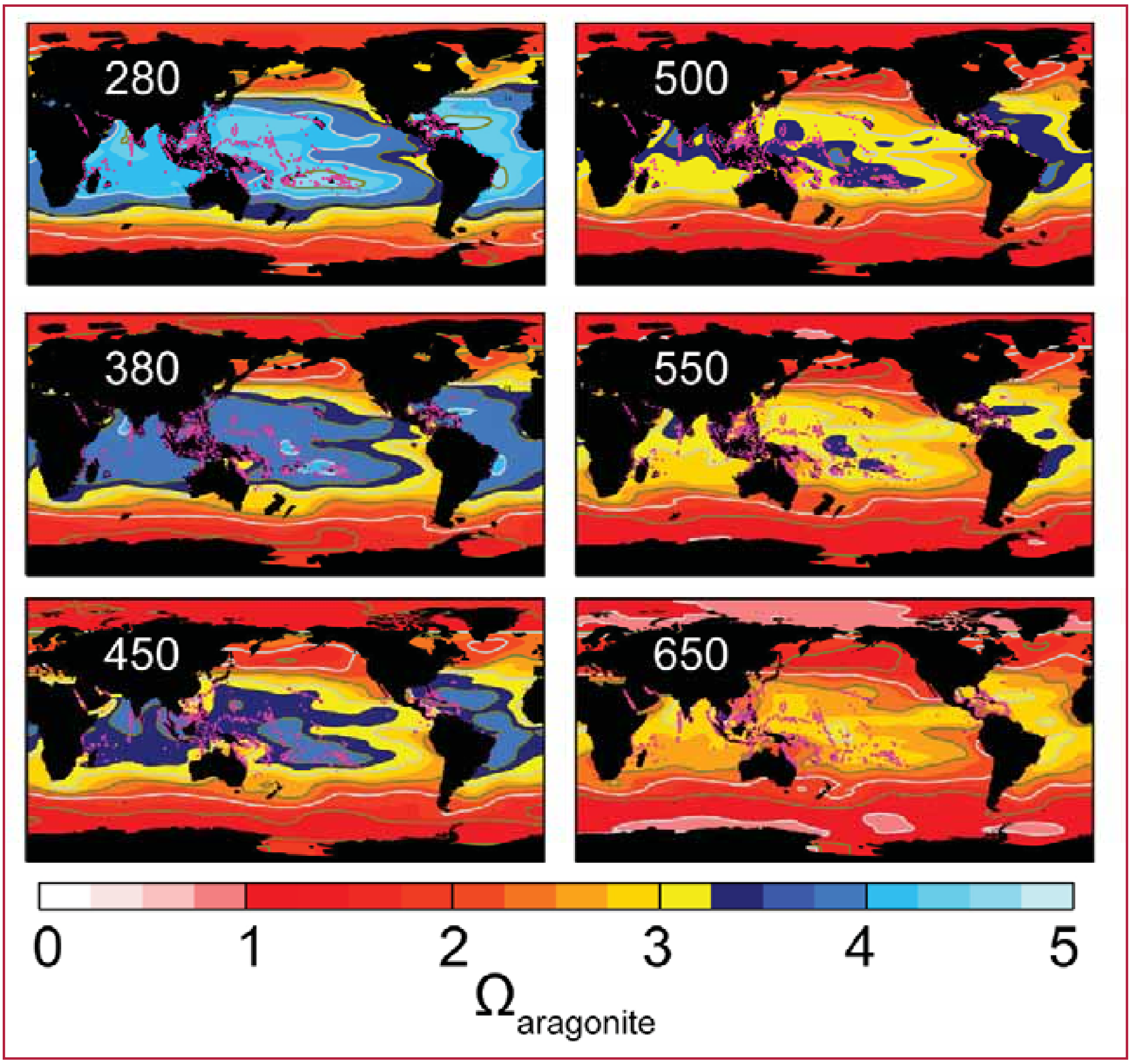


Figure 2. Distribution of carbonate coral reefs (pink dots) relative to the aragonite saturation (□aragonite = [Ca 2+]. [CO3 2−]/Ksp aragonite) calculated for different atmospheric concentrations of carbon dioxide (white number in each box). The aragonite saturation is a measure of the concentration of calcium and carbonate ions relative to solubility of aragonite (the chief form of calcium carbonate deposited by corals and other marine calcifiers).

The distribution of today's coral reefs relative to the current aragonite saturation is shown in the panel labelled 380, revealing the association of carbonate coral reefs with waters that have an aragonite saturation of more than 3.3 (blue areas). As atmospheric carbon dioxide increases, the distribution of these waters contracts to the equator and more or less disappears when concentrations of atmospheric carbon dioxide rise above 550 ppm. Importantly, some of the last waters to contain enough calcium and carbonate ions to sustain reefs at 500 ppm lie in the region of the Coral Triangle.

MANGROVES

Several aspects of climate change are likely to affect mangroves. These include changes in sea level, atmospheric carbon dioxide concentration, temperature, storm intensity, ocean circulation, and inundation events (Gilman 2004; Gilman et al. 2008). Compared to other anthropogenic activities such as the removal of mangroves to facilitate aquaculture and urban expansion, climate change has been seen as a smaller and longer term threat (Alongi 2002a; Duke et al. 2007). Growing evidence, however, suggest that climate change already has, and will continue to, cause reductions in mangrove area (Nicholls et al. 1999; Gilman et al. 2007; Gilman et al. 2008).

Increases in sea level represent the greatest threat to mangroves, especially when the rate of change exceeds the rate of change in the surface elevation of mangrove sediments (Gilman et al. 2008). Under this situation, mangroves will expand in the landward direction as seedling recruitment and vegetative reproduction capitalise on the new habitat becoming available through erosion and inundation of coastal areas by seawater (Semeniuk 1994). Under natural settings, the rate at which colonisation of these new habitats occurs depends on the slope of coastal areas and the presence or absence of obstacles to be landward migration. Increasingly, however, the modification of coastal areas immediately adjacent to mangroves has prevented the landward migration and has exacerbated the loss of mangroves and sea levels of change (Saintilan and Wilton 2001; Wilton 2002; Gilman et al. 2007).

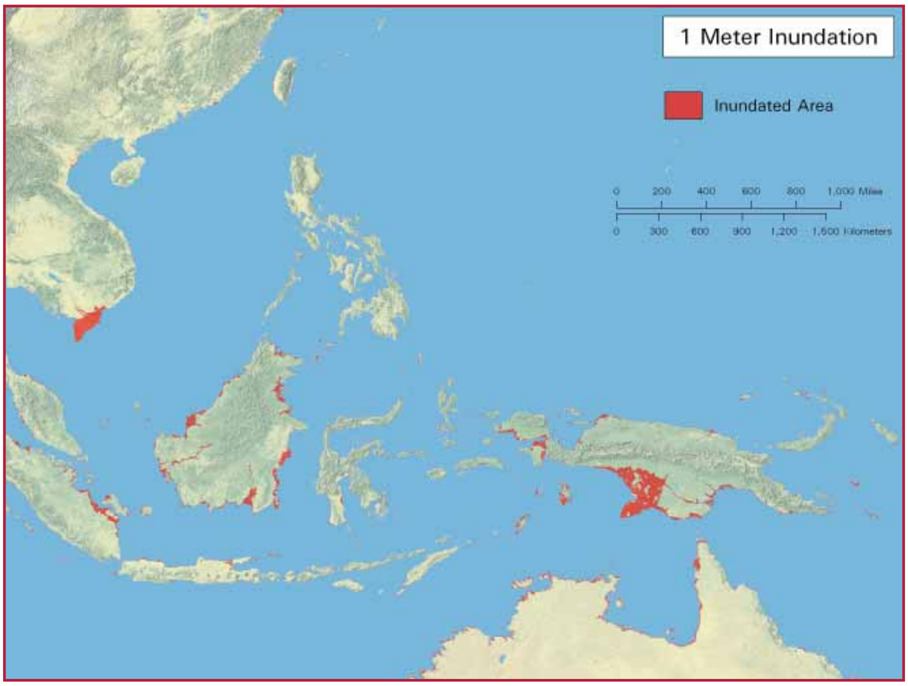
The relative threat from a 1 m versus a 5 m sea level change is illustrated in Figure 3. The most severely impacted regions include the West Coast of Sumatra, East Coast of Kalimantan and extensive regions within Western Papua. These patterns of inundation intensify further sea level rise to 5 m, and are essentially regions of high vulnerability from storm surge, ecological change as well as inundation of groundwater. All of these changes represent environmental challenges to existing mangrove forests and other ecosystems, and will directly impact on the ecological functions of these particular areas within the coral Triangle.

Other components of climate change are expected to influence mangrove health and resilience. Changes in the strength of tropical storms coupled with sea level rise are expected to increase the damage to mangroves through defoliation and mortality, as well as altering mangrove sediment elevations via soil erosion, deposition, or compression (Smith et al. 1994; Woodroffe and Grime 1999; Baldwin et al. 2001; Sherman et al. 2001; Woodroffe 2002; Cahoon et al. 2003b; Piou et al. 2006). Changes in precipitation driven by climate change will also influence mangrove health, through longer droughts, as well as more intense periods of inundation. The decrease in precipitation will deliver less water to groundwater increasing soil salinity and reducing mangrove productivity (Field 1995). Increased salinity will also alter the availability of sulphate, which will drive and aerobic decomposition of organic matter in the soil, increasing mangroves vulnerability to rising sea levels through declining soil oxygen contents (Snedaker 1995). Shifting rainfall patterns may also lead to areas receiving greater amounts of water, which may lead to increased mangrove growth rates and productivity. This may lead to taller and more diverse forests that expand into landward wetland areas (Field 1995; Duke et al. 1998; Duke et al. 2007).

Changing air and sea temperatures are also likely to affect mangroves by changing species composition, timing of flowering and fruiting, productivity, and the distribution of mangroves latitudinally (Ellison and Farnsworth 1997; Ellison 2008). In the latter case, the reduction in days it decreases below 16°C may result in mangrove species extending their range to higher latitudes. On the other hand, the increased risk of heat mortality events will increase, leading to a contraction of some species at lower latitudes (Gilman et al. 2008).

Increased carbon dioxide may have direct effects on some mangrove species by increasing productivity in situations where it is limited by evaporative demand at the leaf surface (Field 1995; Ball et al. 1997; Komiyama et al. 2008), although this area is still poorly understood and outcomes debatable.

Other impacts on mangroves can occur due to changing ocean circulation patterns (Gregory et al. 2005) which may affect dispersal of propagules and, hence, the genetic structure of mangroves. These changes are largely speculative but are likely to occur if major changes to the ocean circulation and currents occur. Like coral reefs, the influence of many factors may be enhanced by synergies and interactions with other climate change and non-climate change associated factors.



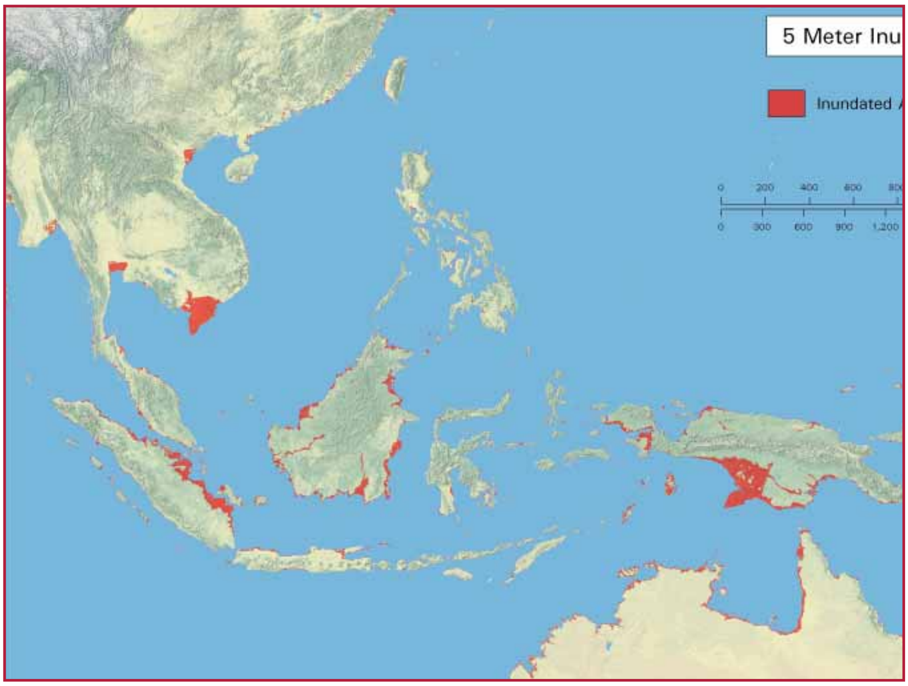


Figure 3. Inundation of coastal areas within the Coral Triangle as a result of 1m and 5m sea level rise (Information provided by the Centre for Remote Sensing of Ice Sheets (CReSIS), website www.cresis.ku.edu.).

SEAGRASS COMMUNITIES

Seagrass communities also face a series of threats from global climate change that include increasing temperature, sea level, storm intensity and the direct effects of elevated atmospheric carbon dioxide (Short and Neckles 1999).

Increasing temperature is likely to affect photosynthesis and restoration of seagrasses, and hence their primary productivity. The precise direction will depend on species involved and their respective thermal tolerances (Zimmerman et al. 1989). This in turn may result in changes to the distribution an abundance of seagrass species (McMillan 1984; Walker 1991). Changes to temperature are likely to also affect reproductive behavior such as the timing of flowering, and survival of recruits. The competition between seagrasses and the suite of epiphytic macroalgal species that inhabit their leaves is also temperature dependent, with high temperatures favouring the algae and leading to overgrowth of seagrass blades (Neckles et al. 1993). Accelerated algal growth under the influence of temperature and eutrophication (i.e. too many nutrients) could accelerate the loss of seagrass habitats in shallow and strong environments.

The primary effect of increased sea levels will be to modify the location of the maximum depth limit for seagrass growth, leading to a similar situation to that seen with mangroves, the movement of seagrass species landward as new habitats open up. As with mangroves, the slope and the existence (or not) of barriers to shoreward growth will be crucial to how seagrass communities respond. Water movement may also result from sea level induced changes to tidal range, leading to scouring and settlement in different locations. Coupled with intensified storms, these changes may result in shifting distributions of seagrass as sea level changes. Other impacts of sea level will be felt through the impacts of increased penetration of salt water and tidal systems (Titus et al. 1991; Dyer 1995). The increasing salinization of soils may have impacts on mature communities through influences on growth, recruitment, primary productivity and interspecific competition. Increased salinity intrusion is also likely to influence the establishment of plants by affecting sexual reproduction and vegetative propagation. These impacts are not well understood.

The impact of more intense storms on seagrass meadows may be felt through greater rates of erosion by the wave action, shading through increased turbidity and smothering of seagrass beds through sediment movement. The increased frequency of intense storms could potentially overwhelm the much longer time interval required for recovery of seagrass beds following disturbance (Short and Neckles 1999).

Increasing atmospheric carbon dioxide is predicted to have direct effects on global vegetation, including those of aquatic plant communities. In the case of seagrasses, increased atmospheric carbon dioxide will lead to increased dissolved inorganic carbon (DIC) and dissolved CO_2, which in turn can lead to increases in growth and biomass (Thom 1996; Zimmerman et al. 1997). These effects are large enough to offset decreases in light availability as sea level rises (Zimmerman et al. 1997). These potential offsets though significant are unlikely to keep up with sea level increases at the upper end of the potential scenarios.

SPECIFIC THREATS TO INDUSTRY (FISHERIES)

Climate change is likely to have five main impacts on fisheries and fishing communities (Allison et al. 2005; Allison et al. 2009), Daw et al. unpublished data). These include: 1) changes to fish yields; 2) changes to fish distribution; 3) damage to the infrastructure; 4) impacts on human health and safety; and 5) changes to climate-driven policies that regulate the fishing industry more tightly.

CHANGING FISHERIES YIELDS

Climate change is likely to impact overall yields and increase the variability in catches. This may be a result of: a) declining abundance of target species. Examples include declines in pelagic species as a result of changes to key oceanographic processes such as currents and upwelling zones, changes to reproductive patterns as a result of changing temperatures, or a decline in coral reef fish after a severe bleaching event); b) changed distribution of fish (as a result of changes to fish migration routes, discussed below), and c) an increase in the number of potential non-fishing days as a result of predicted increases in wind speed and frequency of storms (Allison et al. 2005). These changes will not always be negative and in some instances, local yields may increase. For example, Allison et al. (2005) project increased landings in the flood plain areas of Asia during floods.

One of the main mechanisms that climate change is likely to impact coral reef-related fisheries is expected to be through coral bleaching. However, to date, no studies have actually shown that total catch, catch composition, or value of fisheries have been affected by severe mass bleaching events (McClanahan et al. 2002) (Grandcourt and Cesar 2003). This is in part because the confounding effects of overfishing in many locations outweigh any effects that coral mortality may have on fisheries yields. For example, after the 1998 bleaching event in Kenya, catches of rabbitfish (Siganidae) overall were reduced by 8% and fishermen's daily catch decreased 20-30% for rabbit-fish and parrotfish (Siganidae and Scaridae), but most of this change was attributed to a 17% rise in fishing effort between 1994-2001 (McClanahan et al. 2002). Failure to detect significant effects of climate-induced coral bleaching on coral-reef fisheries may also be because fishes that directly depend on live coral for feeding or settlement comprise <6% of artisanal reef fisheries (Cinner et al. 2009a; Cinner et al. 2009b). However, the majority of catch for most fishing gears came from fishes that were dependent on the reef structure for habitat. Recent studies suggest there may be a lag effect of >7 years between when a bleaching event occurs and the structural complexity of the reef collapses, which would cause a longer-term decline in those fish species which rely on the reef for habitat (Graham et al. 2007b).

CHANGING DISTRIBUTION OF FISH STOCKS

Climate change is likely to result in a redistribution of certain fish stocks (Glantz and Feingold 1992; Stenseth et al. 2002). For example, western Pacific tuna stocks are expected to shift east in response to projected changes in ocean temperatures (Aaheim and Sygna 2000), which would have profound effects on household livelihoods and national-level revenuesn especially in the eastern regions of the Coral Triangle.

Infrastructure- Increased sea level rise, cyclonic activity, and storm surge associated with climate change is likely to cause increased damage to coastal villages and fisheries infrastructure (e.g. wharfs, ship yards, roads and transportation networks). The increased frequency of extreme events may also result in increasing loss of or damage to gear such as nets, traps, and long-lines (Allison et al. 2005).

HUMAN HEALTH AND SAFETY

Climate change will impact human health and safety for fishers and coastal communities. For example, more variable weather patterns may increase the danger associated with fishing activities. The health and safety of coastal communities may also be impacted by changes in disease outbreaks such as malaria and cholera, and also by increased incidents of seafood poisoning resulting from temperature dependant phytoplankton blooms (Allison et al. 2005).

CLIMATE CHANGE-DRIVEN POLICIES

In the shorter term, the biggest climate-related changes that fishers and coastal communities will have to cope with are likely to come from policies that aim to protect marine resources against the impacts of climate change. For example, in 2004, the Great Barrier Reef Marine Park authority expanded the amount of fisheries closures from ~5% of the Great Barrier Reef to 33%. This considerable increase in the amount of reef closed to fishing was largely a climate change-driven policy. Fishers in the region are likely to increasingly be confronted with climate-driven policies such as an increased proportion of fishing grounds being designated as no-take areas.

INTERACTIONS BETWEEN ECOSYSTEM COMPONENTS

Coastal environments such as coral reefs, seagrass beds and mangroves are strongly interlinked (e.g. (Mumby et al. 2004). Impacts on one ecosystem (e.g. coral reefs) can have major knock-on effects for other ecosystems such as mangroves and seagrass. Given this and the complexity of climate change, it becomes clear that small changes in the conditions that dictate the health of one or more components within this ecological in linked system can have far-reaching effects across coastal biological systems. These and other issues will be discussed in subsequent chapters where the important linkages between climate change, coastal ecosystems and human livelihoods are discussed.

HUMAN DIMENSIONS OF CHANGE

In outlining the potential changes that might occur in response to rapid global climate change, it becomes increasingly important to understand how ecosystem components will impact on human livelihoods and communities. In this respect, it is important to consider climate change in the context of the flexibility and resilience of human communities. The following issues represent an attempt to define the types of changes and complexities that are likely to impact human livelihoods and communities.

A. Social resilience in coastal communities

From the preceding discussion, changes in the intensity and frequency of local and global impact on natural ecosystems will ultimately impact human populations living within the Coral Triangle. Understanding these changes, however, depends on other factors such as the ability of the human community to absorb or resist change. In this respect, the term social resilience has been used to describe the ability of groups or communities to cope with external stresses that arise as a result of social, political and environmental change (Adger 2000). The linkages between ecological resilience, social and economic resilience are also key components of any attempt to project how climate change is likely to influence human systems.

Social resilience, like ecological resilience can be examined within the context of how vulnerability coastal communities are to change. It is useful to define and explore the concept of social resilience in preparation for an examination of a series of credible futures for the people of the Coral Triangle. The impacts of climate change are likely to vary from place to place, and for different people within society. These impacts are largely determined by differing levels of vulnerability, which is a critical component of social resilience. Vulnerability in this context is the level of susceptibility to harm from events such as coral bleaching, cyclones, and sea level rise. Vulnerability is often perceived as having distinct components, which include exposure, sensitivity and adaptive capacity (Figure 3).

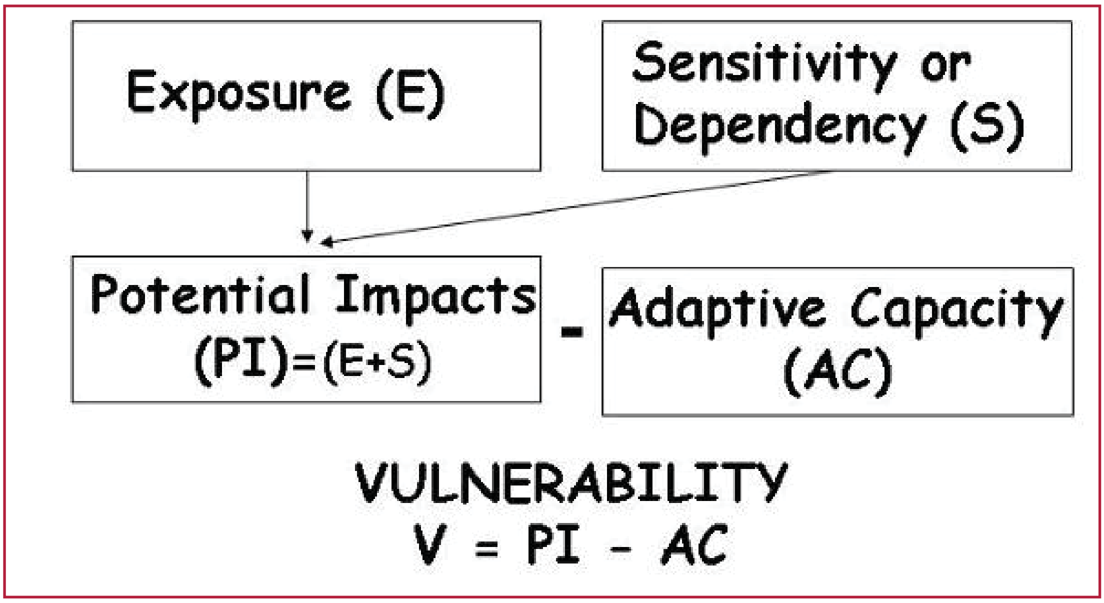


Figure 3. Vulnerability is comprised of exposure and sensitivity (which capture the potential impacts) and adaptive capacity (which captures peoples' ability to cope with or adapt to change).

Exposure is the degree to which a system is stressed by climate change. Exposure is characterized by the magnitude, frequency, and duration of a climatic event such as coral bleaching or a cyclone. Exposure varies for different locations based on oceanographic conditions, prevailing winds, and/or latitude, which can cause some areas to have a higher likelihood of being impacted by events such as cyclones or coral bleaching. There are limited adaptations societies can undertake to minimize exposure, which often rely on engineering solutions (e.g. levees, sea walls).

Sensitivity is the degree to which events such as coral bleaching or cyclones actually modifies or affects a system. Sensitivity may be affected by conditions such as the level of dependence on marine resources. For example, low dependence on marine resources may mean that climatic events such as coral bleaching have a lesser impact on coastal communities. Sensitivity to climatic events can be lowered by adaptations such as early warning systems for cyclones or alternative livelihood programs to reduce dependence on marine resources.

Adaptive capacity refers to the conditions that enable people to cope with or adapt to change. The four key components of adaptive capacity are: 1) the flexibility of individuals and institutions; 2) access to assets and infrastructure; 3) the quality and strength of social organization; and 4) the capacity to learn about change (Cinner et al. in press). People or societies with low adaptive capacity may not be able to adapt to changes in the flow of ecosystem goods and services brought about by climate change. Those with low adaptive capacity will also have trouble coping with changes to climate-related policies (such as no-take areas) and will unlikely be able to take advantage of the opportunities created by change.

One way to develop adaptive responses to climate change that consider vulnerability is to plot exposure against adaptive capacity. This reveals four domains or quadrants where differing conservation and policy may be required: protect and preserve; capacity building; relief and reorganization; and adapt and transform (Figure 4). Climate-related strategies to protect ecosystem such as no-take areas are likely to be most effective and useful in sites with high social adaptive capacity because local communities can readily adapt to changes in access and take advantage of new opportunities, such as increased tourism.

Communities with low adaptive capacity are poorly equipped to cope with even short-term restrictions on resource use imposed by no-take areas. As a result, these communities may be unwilling or unable to comply with no-take measures. These regions first require building social resilience through investments in poverty alleviation, infrastructure, social capital, and alternative incomes. Once local capacity is enhanced, these regions are more likely to be able to take advantage of the opportunities arising from conservation and successfully implement management strategies. Differentiation in exposure may help inform the type of management required in an area. Regions with high exposure are going to be most impacted by climate change. Strategies such as no-take areas may be an important strategy to conserve marine resource in these regions, but will require a different management approach than areas of low exposure. For example, they should not depend on tourism revenue for funding, since tourists are unlikely to visit these areas after major bleaching events and funding may fluctuate considerably. This would argue for effective economic and social safety nets to help poor, vulnerable communities withstand/cope with periodic acute impacts until their capacity to deal with climate change impacts on a more regular basis—their resilience—is built up. Social safety nets will help societies make a transition to more diversified income generating ctivities, including and some initially high risk strategies (changing agricultural crops, cultivation patterns, fishing, aquaculture, etc.).

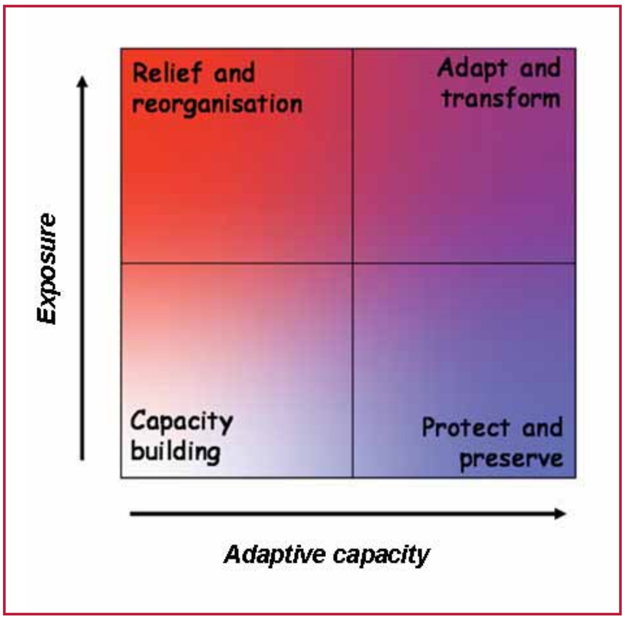


Figure 4. Theoretical model indicating gradients of social adaptive capacity against vulnerability to produce four quadrants of differing conservation priorities.
Source: (McClanahan et al. 2008).

The above framework can be used to examine vulnerability in four CTI countries under two different emission scenarios (A1FI, Figure 5a; B1, Fig. 5b) (Solomon Islands and Timor Leste were data deficient) (Allison et al. 2009). For all four CTI countries, adaptive capacity is low to moderate, suggesting that under any emissions scenario, building adaptive capacity is going to be a critical strategy in the region. Under the low emissions scenario (Fig. 5b), most countries have low exposure to climate change, but relatively low levels of adaptive capacity (except for Malaysia, which is edging into the moderate adaptive capacity range). Building adaptive capacity will be a high priority for donors, governments, and conservation groups. Until this capacity is built, management measures with lower social costs will be required- these might include managing fishing gears that specifically target reef fishes that are considered key to recovery after a bleaching event (Figure 6).

Indonesia, and the Philippines are also edge into the quadrant with high vulnerability and low adaptive capacity, where communities will be severely affected by climate change, but do not currently have the resources or ability to adapt. These regions are a primary concern for human development and require government or donor assistance to ameliorate disaster risk, strengthen social safety nets, diversify sources of livelihoods, and reduce dependence on local natural resources.

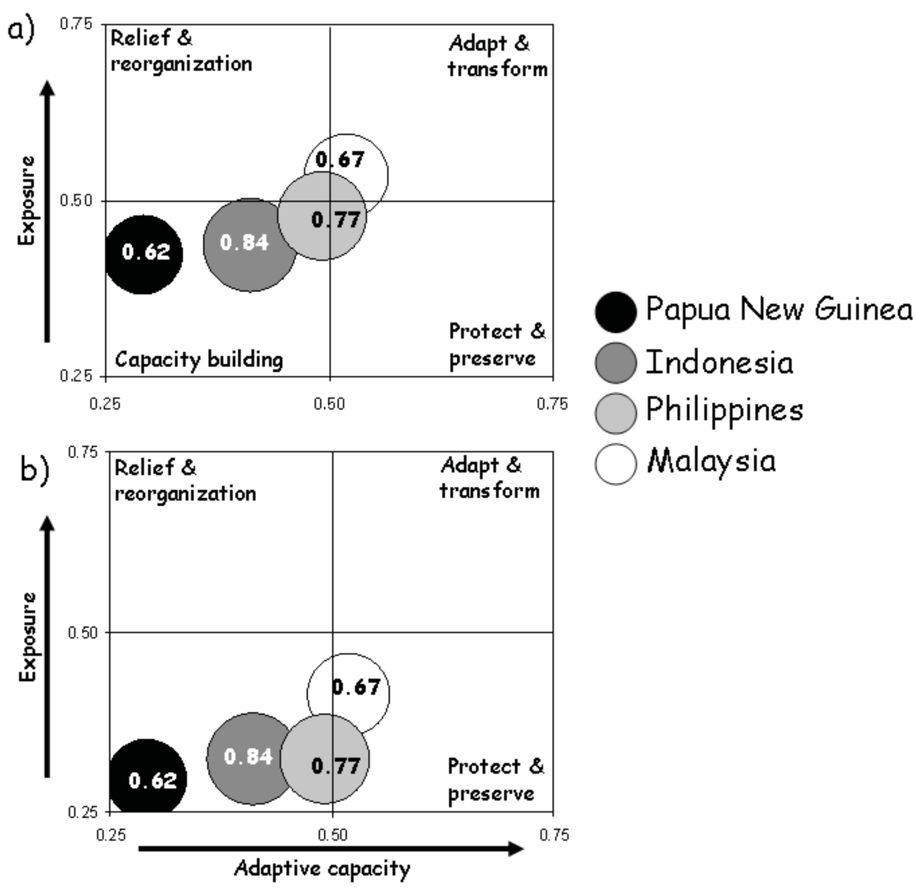


Figure 5. Comparison of the response of CT countries with respect to exposure versus adaptive capacity with respect to climate change.

Under the high emissions scenario, exposure for all countries is increased dramatically if not unsustainably, and Malaysia and the Philippines edge into the 'adapt and transform' quadrant, where profound societal transformations may be required to navigate the impacts of climate change. Although the exposure is slightly lower in Indonesia, the sensitivity is higher, which suggests that the impacts of climate change will be felt more by Indonesia. It is important to remember that country-level analyses such as this ignore the heterogeneity of capacity, exposure, and sensitivity within a country. Community-level studies of vulnerability have been conducted for other regions, but have not yet been developed for the CTI region. This is a critical research priority.

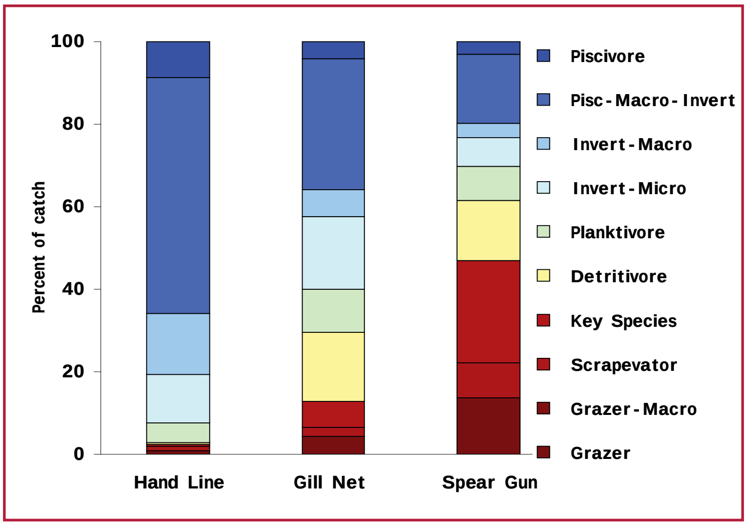


Figure 6. Shows catch data from the PNG artisanal fishery. Fish species are broken down by functional group. Groups in red represent groups or species that have feeding habits (e.g. herbivores) that may play a key role in the recovery of coral reefs. Banning gears such as spear guns may help the recovery of coral reefs after a bleaching event, but have a smaller socioeconomic impact on fishing communities than a fisheries closure. Source: (Cinner et al. 2009a).

B. Local versus regional issues

Although biologically diverse ecosystems can be highly resilient to human disturbances certain ecosystems are at particular risk of sudden collapse for example coral reefs and freshwater systems (Tompkins et al. 2005). The consequence is that people that depend on these ecosystems may find themselves deprived of essential goods and services in a relatively short time span and unable to cope or adapt. The object is to reduce the decline in our current ecosystems to allow enough time for cultural, social and physical adaption to the impacts of climate change to take place.

For countries in the Coral Triangle there are two types of potential climate change impacts. The first and the most compelling in terms of political action is the sudden onset and extreme hazard such as cyclones, heat waves etc. The second and the one most likely to be put off into the future is that of the slow-onset hazards and slowly changing conditions such as sea level rise, coral reef degradations. Both types of impacts require different responses.

All countries in the Coral Triangle have in place management plans, laws and regulations relating to coastal zone management, environmental impact assessment (EIA) and strategic environmental assessment (SEA). However in many cases these are not implemented or enforced. Nor do many of these legal obligations refer directly to impacts of development on climate change. In many cases coastal managers do not have access to local or regional climate change impact assessment that utilise local topography and coral reef structures. In order to assist managers and planners it would be advantageous for managers and planers to have detailed information on the likely level of inundation that can be expected from sea level rise, the risk of salt inundation to agriculture lands, the role local reefs play in physical protection from waves and the likelihood for the need to construct coastal protection units. In some instances, these impacts may be assessed in relation to future develops through the EIA and SEA processes. In this respect, obtaining donor assistance to profile these in a risk probability map format is really central to understanding the entire range of issues.

The primary international models for management of climate change namely the Kyoto Protocol and the United Nations Framework Convention on Climate Change are uncertain and in jeopardy of failure due to both developed and developing states assessing the treaty and the possibility that some states may not meet benchmark emissions goals (Caleb 2008). Alternative methods for coping with climate change, such as EIAs provide valuable secondary tools which immediately advance the issue and work towards the establishment of a primary international mechanism.

In addition to this, many countries already have in place legislation on coastal management and the use of Strategic Environmental Assessment (SEA) mechanisms that support the present and future management of the local environments. EIA is already an established mechanism, which does not require lengthy debates and can be enacted using existing laws in most countries. EIAs work to familiarize decision-makers and private interests with the practical local decisions, which will help to implement a multi-faceted global approach (Caleb 2008). EIAs and SEAs may prove effective in linking global goals with municipal action to reduce the decline in the coastal and ocean ecosystems and allow for more time for adaptation. Donor agencies could facilitate adaption mainstreaming by screening their project portfolios for potential climate change impacts. For example the Development Assistance Committee OECD has researched ways of integrating adaptation into EIA and strategic environmental assessment, the World Bank Assessment and Design for Adaptation to Climate Change tool or ADAPT (IGES 2008).

SUMMARY

Rapid increases in carbon dioxide and other greenhouse gases are driving rapid rate of change in the physical and chemical characteristics of coastal environments in coral triangle. Under the worst-case scenario, warming and acidifying oceans may eliminate coral dominated reefs, decimate mangrove systems and eliminate seagrass beds. These changes will dramatically reduce the productivity, structure and function of these important ecosystems, with ramifications for hundreds of thousands of species and tens of millions of human dependants. Under the worst-case scenario, sealevel could increase by as much as 4-6 m by the end of the century, essentially disrupting all natural and man-made systems within the coastal zone. These changes, in turn, will drive further losses of coastal ecosystems. Under the worst-case scenario, coastal ecosystems such as coral reefs, mangroves and seagrass beds will largely be eliminated by these extremely rapid changes.

Under the best case scenario, in which effective international collaboration between nations leads to a decline in emissions and stabilisation of atmospheric carbon dioxide at or below 450 ppm, coastal ecosystems will experience severe challenges but will not completely disappear. Under these circumstances, productivity and hence fisheries production along these coastlines is likely to fall by at least 50% of what it is today (NB: this is a consequence of multiplying the current decline in yield by 41 years without taking into account climate change so it is ultimately conservative), with consequences for coastal dwelling people and societies. Steady sea level rise under these scenarios will cause severe challenges for coastal infrastructure, with the best case scenarios suggesting that sealevel may increase by at least 1 m by the end of this century. This will put extreme pressure on coastal people throughout the Coral Triangle, and will lead to a reduction in the ability of coastal ecosystems to provide food for artisanal fishing communities.

Understanding the linkages between social systems and the health of coastal ecosystems is extremely important if the implications of rapid global change to be understood. In this respect, some societies within the Coral Triangle are inherently more socially resilience to change than others, with differing levels of exposure and sensitivity to climate change driving overall vulnerability. The more resourced CT countries (Philippines and Malaysia) show a greater adaptive capacity than Papua New Guinea and Indonesia, and far greater than the Solomon Islands and Timor Leste. This analysis highlights the complexity of generating an understanding of how Coral Triangle countries will fare under a rapidly transforming environmental setting. Equally important, is the fact that not all coastal communities will be impacted at the same level within a particular CT country.

Highly exposed and impoverished coastal populations will be clearly at risk of issues arising from food security, storm surge and changes to income arising from the loss of commercial opportunities such as tourism and fishing. In this regard, some countries in the coral triangle will be better resourced to respond to these challenges, and will have a greater history of environmental regulations to accommodate and respond to the challenges being posed by regional and national change in the circumstances of people's livelihoods and incomes.

SPECIAL FOCUS 6: AGGRAVATED TIDAL FLOODING IN SEMARANG, CENTRAL JAVA

Dr Ambariyanto

Sea level has been increasing over the past 100 years, and threatens to inundate large areas within the Coral Triangle. This outcome of rapid climate change looks set to dramatically change the lives of potentially millions in the coastal areas lining the Coral Triangle countries. The question becomes, how will countries respond to the increased inundation of coastal agriculture, dwellings and water supplies as the seas rise? To answer this question, it is instructive to investigate the experience of several locations within South-East Asia that have already experienced the aggravated impacts from rising seas due to subsiding coastal areas.

One such case exists with parts of Semarang, which is the capital of Central Java Province, Indonesia, where geographically is located at 6o58'S 110o25'E / 6.967oS 110.417oE approximately 540 km to the east of the capital Jakarta. While just outside the boundaries of the Coral Triangle, this example illustrates some of the issues that Coral Triangle communities are, and are likely to face, with rapid changes in sea level. This coastal city covers an area of approximately 374 km^2 and has a total population which has grown from 1.3 to 1.47 million in the period 1991 and 2006. This city is unique in having a hilly area in its southern area, and a low land coastal area to the north which lies within 0 - 3.49 m of sea level (Pratiwo, 2004).

As a coastal city with 25 km coastal line, Semarang has been facing a problem with respect to flooding since Dutch colonization (Pratiwo, 2004). Interestingly, flooding is even part of the lyrics of one of the most iconic traditional songs about Semarang.

BRIEF HISTORY & CAUSES

Tidal flood (locally known as banjir rob) is one of three types of flooding in Semarang and the other two are local flood inundation and river flood. The last two are mainly due to heavy rainfall combined with insufficient and malfunction drainage systems, as well as improper waste disposal. While, tidal flood is mainly due to high tidal wave overflowing coastal area combined with land subsidence (9 cm/year mainly due to excessive groundwater extraction, Hartoko et al., 2008), as well as sea level rise (3.3 mm/year). While sea level is unlikely to rise at this rate, the issues and responses going back many decades instructive about the types of problems and responses that governments and their coastal managers might have to sea level rise that may occur over longer periods.

According to Pratiwo (2004) the Dutch government built two canals i.e. Banjir Kanal Timur (Eastern Flood Canal) located at the eastern part of Semarang, and Banjir Kanal Barat (Western Flood Canal) located at the western part of the city. During the Dutch colonial period, it seems that these canals were used as flood outlets, so that the seawater would flow into these water courses thereby avoiding flooding.

However, at the present time, the sedimentation rate within these two canals has led to clogging and water flow is reduced during high tide. This sedimentation is mainly due to land use change upstream, which is mainly associated with the development of residential areas in the hills of Semarang, as well as improper waste disposal by communities who live along the canals.

The worse tidal flooding usually occurs during rainy season and west monsoon between October and January when tidal height of Semarang waters reach up to 1.8 m combined with 2 m height of ocean wave. This aggravated by the rainy season which occurs between November-February, when the water runoff from upstream is bigger.

According to Wirasatriya (2005) approximately 2.418 ha of coastal area now suffers from tidal floods that are exacerbated by sea level rise. This has had a direct effect on the people of the region, particularly those from the villages of Trimulyo, Terboyo Wetan, Terboyo Kulon, Tambak Rejo, Kemijen, Tanjung Mas, Bandarharjo, Kuningan dan Panggung Lor.

IMPACTS

Tidal floods are an everyday event in many parts of coastal Semarang. Several interviews with the coastal community has revealed that the height of water inundation and the area affected has increased considerably over the past decades. The flooded area is not only coastal villages (most of 17 coastal villages suffer from the flood with different degree of inundation), but also several important streets, city infrastructure, as well as public facilities. See Table 1 and photo 1.

Table 1. Villagers currently suffering from regular tidal flood in Semarang (Marfai, 2003).

Villages	Streets	Public Facilities	Others
Mangunharjo	Siliwangi St	Tawang Train Station	Tanah Mas Resedential Area
Mangkang Wetan	Kaligawe St	Terboyo Bus Station	
Tambak Lorok	Ronggowarsito St	Tanjung Mas Sea Port	Governement and Private Offices
Genuk, Bandarharjo	Raden Saleh St	Johar Market	

The impacts of tidal flooding can be divided into two broad aspects; physical losses and social economics. Physical losses involved direct damage from water to city infrastructure and dwellings. Social economic looses mainly occur in the form of lost working time, reduced productivity of offices, shops, traffic jams, as well as increasing illness. Tidal flood obviously influences daily activities including at schools and offices which have to stop or started late. Public services can not be conducted normally such as disruption of roads, as well as schedules changes of train and bus, etc. While physical looses including degrading streets, damage houses, damage belongings such as furniture, motorcycles, etc.

PROGRAMS

Local governments in Semarang have been taking a number of measures to reduce the impact of flooding, including:

PERSUADING PEOPLE TO MOVE FROM INUNDATED AREAS

This does not work well for a number of reasons. Not only that they have been living there for years, but also they do not want to sell their houses for much lower compared with when they bought the house. However, some houses and office were abandoned especially at the most affected area (Figure 2).

IMPROVING DRAINAGE SYSTEMS

In order to solve sedimentation problems, Semarang city government has been conducting regular sediment removal programs that have included dredging canals and rivers, as well renovating the system of dikes. These steps now appear to be overwhelmed, given that they have not been able to reduce flooding problems.

PROVIDING PUMPING STATIONS

A pumping system has also been introduced and the government has provided pumping stations, including at polder area. See photo 3. This program is also carried out by local community especially in resident area such as Tanah Mas.

ELEVATING STREETS AND PUBLIC FACILITIES

Several streets including Kaligawe streets have been elevated to avoid water inundation. For example, at the moment the government elevating Tawang Train station yard. See photo 4.

BUILDING POLDERS (A FORM OF DYKE)

Local government of Semarang built polder in front of Tawang train station which finished in 2001 with 10.000 m3 capacity was aimed to minimized water inundation at Tawang train station and its adjacent area. See photo 5.

IMPROVING COASTAL AREA

This program mainly aims to improve the condition of coastal areas in the region through several programs run by the government including mangrove rehabilitation. At the moment according to Office of Fisheries and Marine Affairs Semarang, there only 15 ha mangrove with only 4 ha in a good condition.

COMMUNITY ADAPTATION

The community has been adapted to this regular type of flood. Most of them are not willing to move to other places with some reasons. For example, there is no place where they can move to, they do not have enough financial support, and their original place has family historical value.

Several responses taken by the community varies, among others are:

- Do nothing, because they believe that flooding will be temporary only.
- Putting their valuables (e.g. furniture, television sets, radios, motorcycle, etc) to higher places to avoid water inundation
- Moving out from their original houses, usually for those who can not stand with all the difficulties and problems due to tidal flood, by selling their houses and buy a new one with no risk f flooding
- Elevated their house floor and house yard above water level. However, when the government elevates the streets level, the water will, again, flowing into their houses.
- Building high dike and small dam surrounding their house to avoid water entering into their house.

WHAT NEEDS TO BE DONE

There are a range of programs need to be developed by government and community organizations. Government should continue their existing programs such that focused on improving drainage systems, polder systems, and other aspects. They should also improve the infrastructure such as establishing integrated drainage system which all aspects related to tidal flood. There are a few plans to deal with the aggravation of coastal flooding by climate change, which is a situation that needs to be addressed. It is also clear that there should be greater enforcement of government restrictions on waste disposal, development of upstream communities, ground water extraction and other aspects like limiting the tonnage of trucks in order to produce drainage problems and sedimentation.

REFERENCES

Hartoko, A., Wirasatria, A., Helmi, M., and Rochaddi, B. 2008. Geomatic technology application for land subsidence mapping at Semarang coastal area. Ilmu Kelautan. Indonesian Journal of Marine Sciences. 13(1): 13-18.

Marfai, M.A. 2003. GIS Modelling river and tidal flood hazard in waterfrontcity. Case study: Semarang City, Central Java, Indonesia. Mac Thesis. International Institute for Geo-Information Science and Earth Observation Enschede, The Netherlands

Pratiwo. 2004. The City Planning of Semarang 1900-1970. The 1st International Urban Conference, Surabaya, 23rd-25th 2004

Wirasatria, A. 2005. Study on sea level rise for tidal flood problem solving at Semarang coastal area. MSc Thesis. Coastal Management Program. Diponegoro University, Semarang, Indonesia.

Photo 1 and 2. Tidal flood at northern road and the sea port of Semarang

Photo 1 and 2. Tidal flood at northern road and the sea port of Semarang

SPECIAL FOCUS 7: INVOLVING LOCAL COMMUNITIES IN COASTAL MANAGEMENT: 'TOP-DOWN/BOTTOM-UP' APPROACHES

Melanie King & Geoff Dews

Historically coastal and marine ecosystems services have been an integral part of small island communities and coastal settlements. The coastal and near-shore marine ecosystems have provided a vast array of ecosystem goods and services to contemporary communities. However, humans have not easily or intuitively related to marine ecosystems and the scales of space and time underlying them (Kenchington 2003: 42). Human activities and environmental impacts on the coastal areas and in-shore waters are becoming increasingly complex as marine resources become depleted through overfishing, pollution, the destruction of habitats and climate change impacts.

Adding to this management complexity is the increasing number of varying levels of engagement of stakeholders, all focusing on utilising the natural and cultural resources found in the coastal areas to their personal advantage. Furthermore, these personal objectives change with time and circumstances, and can be seasonal or annual variations due to externalities of the economy. The scale and processes of the ecosystems, their linkages to the land and intertwined interests of sectors and jurisdictions raise the need for effective mechanisms of coordination or integration of policy and management for human activities and impacts (Kenchington 2003: 42).

With over 70% of the human population of the Coral Triangle living within 50km of the coastline (Chou, 1994), the need to integrate the needs and resources of a range of stakeholders including local communities, Governments and other organisations, is becoming critical to the success in managing coastal and marine resources. Currently, many coastal and marine resource management projects approach the issue either through a 'top-down' approach through national governments or donors – or a 'bottom-up' approach through the mobilisation of communities by Non-governmental organisations (NGOs). These strategies implemented in isolation, can be problematic as the approach is exacerbated by a focus upon a specific sector or issue whereas many issues facing the countries in the Coral Triangle, particularly the Pacific require a cross-sectoral approach at all levels of government, civic organisations and local community.

With the prospects of increasing pressure on the coastal and marine resources, it is now becoming increasingly evident that there is a need for the adoption of mechanisms which consider an integrated approach such as a co-management or "nested collaboration" (Margerum, 2007) style of arrangement with coastal resources responsibilities being shared between national and local governments, civic organisations and local communities (Leach et al, 1999). Co-management through a 'nested collaboration' approach would bring together 'top-down' and 'bottom-up' approaches into a coordinated and synergistic operation for implementing ecosystem-based management.

In many nations marine matters are a responsibility of national or federal government, whilst management of land may be the responsibility of local or state government (Kenchington, 2003: 44). Approaches to coastal management in Asia and the Pacific region are diverse but at local levels there still exists a range of traditional customs and sometime sea tenure system that governs access to coastal resources which have shown remarkable resilience over time (Minura 2008). Through a co-management approach, the empowerment of various stakeholders including local governments and communities to have a greater input into decision-making processes will increase the community's capacity to consider and propose new and alternative strategies for development (Desai & Potter 2006), thereby maximising the capacity of the strategy to be successful in working against these threats.

The move towards utilising a co-management approach with a focus on community-based management, will become more important and ultimately predominate, particularly as a device in overcoming constraints of environmental protection and economic development (Minura 2008). Local organisation institutions are becoming more effective but require skills and resources to compensate for the complex issues they face.

The case-study of the Kahua Association in the Solomon Islands reflects this change in awareness by local communities of their marine and coastal resources, and also reflects how local communities can come together and conserve their environment with minimal or no support from national governments.

In Kahua, an isolated region in eastern Makira-Ulawa Province of the Solomon Islands, local communities recently registered a grass roots charitable organisation called the Kahua Association. The organisation came about through a growing awareness of the need to conserve their coastal and marine resources and a desire to learn more about how they could be protected from human impacts. The organisation is led by a team of four executives and an extended network of subordinate bodies (council of chiefs, women, youth, ecumenical, conservation and biodiversity, and the Kahua development corporation) (Diagram 1). The organisation is governed by the Kahua Association Council made up of the chairpersons of the subordinate bodies and is ideally set up for promoting participatory development for a number of reasons. First, it has been set-up to assist communities to make uniform or better informed decisions but is not a ruling authority, and the right to make final decisions remains with individual communities. Second, it is democratic with members elected every two years and supreme authority held by the annual general meeting which gives power to participants to veto council decisions. Third, it has a flat hierarchical structure and appears to be unique in the Solomon Islands in that the chiefs are maintained at the same level of decision-making as the chairs of the other subordinate bodies. Fourth, it has demonstrated a high commitment to professionalism, accountability, and the provision of equal opportunities.

The Kahua association has achieved consensus on their future development and have refused permission for logging in the district and declined approaches by mineral exploration companies to establish leases. These decisions mean the communities have forfeited short-term income and infrastructure opportunities but have preserved their environment. One of the next priorities for the Kahua Association is to establish marine managed areas. The recently ratified Solomon Island Fisheries regulations sets in place a legal framework for communities to establish marine managed areas that are enforceable. This recent development of partnership between community groups such as the Kahua Association and the Government will allow for more strategic planning of resource use particularly in remote areas.

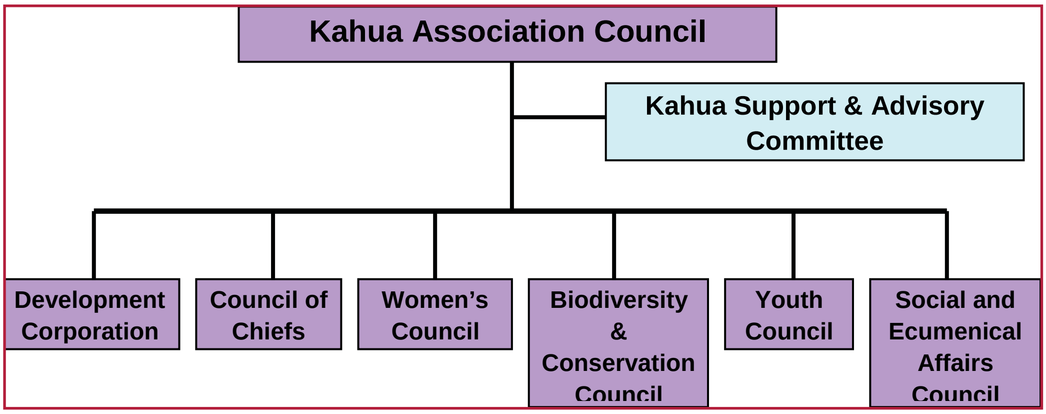


Diagram 1: Structure of the Kahua Association

This example, which reflects a new strategy in the Small Island States of the Pacific, reiterates the need to acknowledge not only formal organisations such as governments and NGOs, but the role of formal and informal institutions including traditional leadership, family ties, church and other community membership structures. Faced with increasing pressures, what then is the appropriate approach? If integrated coastal management is the major concept, then we must understand both the past and ongoing phenomena through observations, monitoring, and scientific studies. On the basis of this we establish responses that include management policies, institutional arrangements and applicable technology; then they need to be implemented and evaluated for effectiveness. To promote these steps we must form a scientific consensus which will need to be interpreted to foster practical polices and actions (Minura 2008)

References

1. Aitaro, Joseph et al. 2006. 20 Lessons for future environmental initiatives in the Pacific: Summary of lessons from the IWP National Coordinators. International Waters Program: USA.

2. Asian Development Bank. 2004. Pacific Region Environmental Strategy 2005-2009: Volume 1: Strategy Document. Pacific Studies Series. Manila: Asian Development Bank.

3. Desai, Vandana and Robert B. Potter. 2002. The Companion to Development Studies. Hodder Arnold: London.

4. Devine, Joe. 2006. 'Community-based organizations – new fad or old hat?' Community Development Journal 41 (4): 521-527

5. Hassall, Graham and Feue Tipu. 2008. 'Local Government in the South Pacific Islands'. Commonwealth Journal of Local Governance (1): 1-24. Available from http://epress.lib.uts.edu.au/ojs/index.php/cjlg.

6. Hegarty, Aileen. 1997. 'Start with what the people know: a community based approach to ntegrated coastal zone management'. Ocean & Coastal Management 36 (1-3): 167-203.

7. Hildebrand, Lawrence P. 1997. 'Introduction to the special issue on community-based coastal management'. Ocean & Coastal Management 36 (1-3): 1-9.

8. Kenchington, R.A. 2003. 'Managing marine environments: an introduction to issues of sustainability, conservation, planning and implementation' in Conserving marine environments. Out of sight out of mind, Hutchings, Pat and David Lunney (eds). Royal Zoological Society of New South Wales: Mosman, NSW.

9. Leach, Melissa, Robin Mearns, and Ian Scoones. 1999. 'Environmental Entitlements: Dynamics and Institutions in Community-based Natural Resource Management'. World Development 27 (2): 225-247.

10. Margerum, Richard D. 2007. 'Overcoming Locally Based Collaboration Constraints'. Society and Natural Resources 20: 135-152.

11. Minura, N., Ed. (2008). Asia -Pacific coasts and their management. Dordrecht, Springer.

12. SPREP, 1999. Island Life: Celebrating Pacific Island biodiversity: Case studies of island life. Secretariat of the Pacific Regional Environment Programme (SPREP): Apia, Samoa.

13. Veitayaki, Joeli. 1997. Traditional marine resource management practices used in the Pacific Islands: an agenda for change. Ocean & Coastal Management 37 (1): 123-136.

SPECIAL FOCUS 8: MANAGING THE IMPACTS OF CLIMATE CHANGE

Heidi Schuttenberg and Ove Hoegh+Guldberg

Ultimately, the way people in the Coral Triangle experience climate change will depend on the severity of its impacts minus the extent to which they are able to cope with or adapt to these changes. In the language of the Intergovernmental Panel on Climate Change (IPCC), which has been adopted in this report, these relationships are estimated as:

Vulnerability = Potential Impacts – Adaptive Capacity

where Potential Impacts are considered to be the sum of Exposure and Sensitivity to stress. The preceding chapters on biophysical and socioeconomic conditions, predicted environmental changes, and the anticipated impacts of these environmental changes establish the basis for developing future climate scenarios.

Here, we add an assessment of the ability of local management actions to reduce vulnerability to climate change by making a difference in either its potential impacts or the adaptive capacity of people to respond to these impacts.

The ability to reduce vulnerability to climate change through local management actions is at the heart of a CTI response to this global threat. This report identifies four significant mechanisms, or threats, by which climate change will impact Coral Triangle coral reefs and the people who depend on them: sea-level rise, increased cyclone intensity, ocean acidification and mass coral bleaching. We briefly review management options for the first three of these four threats, and then turn our attention to a framework for responding to mass coral bleaching, which has had the largest impact on reef ecosystems to date. This analysis demonstrates that both decisive actions to mitigate climate change as well as effective local management actions are required to achieve best case scenarios for the region. The final section outlines an agenda for management action based on all four threats.

MANAGEMENT RESPONSES FOR SEA-LEVEL RISE, INCREASED STORM INTENSITY, AND OCEAN ACIDIFICATION

Of the four threats identified in this report, management responses to sea-level rise and increased storm intensity are the most established. The IPCC report (IPCC 2007) on “Impacts, Adaptation and Vulnerability” traces the evolution of adaptation practices (see Chapter 6, “Coastal systems and low-lying areas) from the three recommendations of the first IPCC assessment report—protect, accommodate or retreat—to current best practice. The authors conclude that integrated coastal zone management (ICZM) “is widely recognized and promoted as the most appropriate process to deal with climate change, sea-level rise and other current and long-term coastal challenges” specifically noting its advantages over, “reactive and standalone efforts to reduce climate-related risks to coastal systems” (p340). ICZM is a widely known and established global practice, and its requirements are discussed further below.

In contrast to responses to sea-level rise, effective management actions to reduce the impacts of changes in ocean chemistry are, to date, minimal. Possible responses focus on preventing damage to the coral skeleton (reducing damage from anchoring, blast fishing), since acidification reduces calcification and hence the ability to ‘repair’ these types of damage. Actions to minimize damage from anchors, tourism, and fishing will be useful. Additionally, bioerosion of coral skeletons is greater in poor water quality, so maintaining or enhancing good condition will help.

These limited response options inevitably lead to the conclusion that ocean acidification is poised to have significant impacts on the viability of coral reef ecosystems with very little room for reducing their vulnerability once thresholds of concern have been exceeded. Ocean acidification is therefore an unmoving reminder of the urgent need for reduction of greenhouse gases to prevent crossing thresholds that will disrupt the calcification of corals.

A FRAMEWORK FOR RESPONDING TO MASS CORAL BLEACHING

Efforts to identify meaningful management actions for responding to mass coral bleaching began in earnest after the global 1997-98 mass bleaching event wiped out 16% of the world's coral reefs (Hoegh-Guldberg 1999). A decade later, a number of pressure points for reducing the vulnerability to bleaching have been identified, and are summarized in Figure 1. This response is part of an integrated strategy for responding to mass coral bleaching discussed in detail by Marshall and Schuttenberg (Marshall and Schuttenberg 2007). The scientific rationale and broad goals of the strategy are summarised here.

There are four inherent processes that are involved during and after the stress arising from global warming. These are illustrated in Figure 1, and involve (1) the ability of corals to resist thermal stress; (2) the ability of corals to survive bleaching events; (3) the ability of coral reefs to recover after significant mortality, and (4) the ability of human users to maintain their well-being despite the loss of coral reef ecosystems. At each of these stages, there are factors, or pressure points, that determine whether the system will move toward recovery—to the upper, right corner of the figure—or whether a tipping point will be crossed and a further decline will occur, illustrated as a slide toward the lower left part of the diagram. These pressure points are briefly described here.

TAKING ADVANTAGE OF NATURAL RESISTANCE TO THERMAL STRESS

A combination of environmental and intrinsic factors determines whether corals will resist bleaching or succumb to it. Some areas are naturally cooler or more shaded than other areas, leading to a local advantage in terms of resisting the impacts of high temperature. The Nature Conservancy's Reef Resilience Toolkit provides guidance for identifying such inherently "lucky" areas so they can given priority protection, e.g., in no-take areas (Salm et al. 2000; Salm et al. 2006). While some authors have explored manipulating the environment around corals to reduce the impact of bleaching (e.g. shading corals to reduce bleaching), deploying these techniques would be impossible or prohibitively expensive to scale up to that of entire coral reefs or regions.

BOOSTING THE ABILITY OF CORALS TO SURVIVE BLEACHING

When corals lose their symbionts and bleach, they are not dead. Many corals will regain their symbionts if conditions do not remain too warm too long. While they have survived, these corals are usually in a weakened state, with compromised growth, reproduction and a greater susceptibility to disease. In this respect, management strategies which reduce the impact of other stresses on coral communities can increase the ability of corals to survive and grow after the thermal stress event. Equally, corals that are treated well beforehand (i.e. protected from other local stresses) will have a greater chance of surviving a mass coral bleaching event.

PROMOTING THE RECOVERY OF CORAL REEFS AFTER MASS MORTALITY

Management actions become more influential in determining the future quality of reef ecosystems at the recovery phase. Reefs will spend more time in recovery mode even under best-case climate scenarios, so implementing strategies that facilitate their natural ability to regenerate is essential. There are now several studies demonstrating that maintenance of grazing fishes promotes more rapid recovery of reefs that have experienced mass mortality due to bleaching (Hughes et al. 2007; Ledlie et al. 2007). Maintaining good water quality along coastlines is also a critical factor for helping corals recover. Equally important is access to a good supply of coral recruits, which is often a function of the proximity of healthy coral populations to the impacted reef. Protecting biological diversity gives coral reef ecosystems more flexibility in reorganizing, yet maintaining coral dominance after high mortality.

SUPPORTING HUMAN ADAPTIVE CAPACITY

While the previous three pressure points aim to minimize environmental damage, this final steps is focused on supporting human communities in coping with or adapting to instances of unavoidable ecosystem loss. This aspect is of major importance in the Coral Triangle, considering the vast numbers of people that are closely dependent on the ecological health of their coastal ecosystems. Understanding these components will require multidisciplinary approaches which consider the full spectrum of potential responses.

THREE TARGETS FOR REDUCING VULNERABILITY TO MASS BLEACHING

Taken together, the framework outlined for responding to mass bleaching leads to three targets for managers aiming to reduce vulnerability to mass coral bleaching (Marshall and Schuttenberg 2007):

1. Identify and protect areas that are naturally resistant to climate stresses.
2. Maintain grazing fishes, water quality, connectivity, and biological diversity to strengthen coral survival and reef recovery
3. Support adaptive capacity for diversifying incomes and food sources, where possible reducing dependence on the ecosystem services being contributed by coastal ecosystems.

RESPONDING TO CLIMATE CHANGE: AN AGENDA FOR ACTION

In the complex arena of designing national and regional strategies through which to address climate change impacts, a systematic consideration of the options available is essential. Table 1 presents a synthesis of management options for reducing the potential impacts of climate change on coastal ecosystems and people. Priority actions include:

1. **Marine Protected Area Networks** – MPA networks are a critical tool for reducing coral reef ecosystem vulnerability to climate change. The anticipated impacts of mass coral bleaching suggest a range of new considerations for MPA design, which are presented in TNC's excellent Reef Resilience Toolkit (www.reefresilience.org). A new report by CTI partners describes the strengths and weaknesses of various approaches to implementing MPA networks in practice using country-appropriate strategies (Green et al. 2008). For example, the Philippines with its history of community-based management is "scaling-up" by networking proximate community fish sanctuaries together.

In Kimbe Bay, PNG, the opposite approach has been taken of using best available science to identify an ecologically ideal blueprint and then working with interested communities to establish a network of no-take areas in desired locations. Given the significant differences in CTI country management institutions, varying approaches will be required to achieve MPA networks; the goal, however, should be to achieve a legitimate and effective network that protects a spatial area which is adequate for supporting reef recovery.

2. **Renewed importance for Integrated Coastal Zone Management and Land-use Planning** – As recognized by the IPCC, Integrated Coastal Zone Management is particularly suited to addressing climate related impacts from sea-level rise and increased storm intensity. Additionally, it can be successful in improving and maintaining water quality, a key requirement for boosting coral reef ecosystem resilience to climate change. ICZM has a 30 year history and there is a great deal of consensus about the processes and tools involved in its implementation (Sorensen 2000). Effective implementation, however, requires management, technical, and financial capacities that will need to be strengthened in the CTI.

3. **Implications for Fisheries Management** – Fisheries management measures are needed to complement marine protected areas in efforts to support coral reef ecosystem resilience and sustainable fisheries. A shift away from management for fisheries production toward ecosystem-based fisheries management is particularly warranted given the feedbacks, many still unknown, between climate change and fish population structures. A new emphasis on protecting populations of grazing fishes, in addition to more valued target species, will assist in facilitating coral reef recovery from climate change-related damage.

4. **Contingency Planning** – The climate change impacts outlined here will occur both as slow change and acute events. Contingency planning to respond to emergency events, such as cyclones or mass bleaching, is essential. Disaster response is typically part of ICZM programs, but disaster response plans also need to be developed where ICZM is not currently in place, particularly in areas that are vulnerable to cyclones recognizing typical storm paths may change under new climate regimes. Bleaching response plans are also valuable tools for preparing resource managers to understand, communicate, and respond to these events (Marshall and Schuttenberg 2007).

5. **Building Adaptive Capacity** – Chapter 17 of the IPCC report (IPCC 2007) on "Impacts, Adaptation and Vulnerability" reviews the current literature on adaptive capacity and identifies its elements and constraints. Additionally, a large literature on ICZM, protected areas, and coral reef management consistently recognizes capacity limitations as a major barrier to effective resource management. The last decade has seen this discussion shift from calls for technical skills toward development of learning networks; although, the requirement for financial resources has remained unchanged. Support for adaptive capacity is needed at the levels of resource users, resource managers, and higher-level government policy. Investments in adaptive capacity are essential to enable the success of other recommendations for protected area networks, ICZM, fisheries management, and disaster response.

6. **Mitigating Climate Change** – For some potential impacts, such as weakened coral skeletons due to acidification and ecosystem destruction resulting from increased cyclone intensity, there is little scope for local management response. Additionally, the ability for local management actions to provide relief from climate change impacts is limited beyond a certain thresholds of change. These circumstances emphasize the critical importance of reducing greenhouse gas emissions at levels that prevent change beyond the thresholds identified in this report; specifically, 2°C and atmospheric carbon dioxide levels of 450 ppm.

REFERENCES

Green S, Meneses A, White A, Kilarski S, Christie P (2008) MPA Networks in the Coral Triangle: Development and Lessons., TNC, WWF, CI, WCS and the United States Agency for International Development, Cebu City, Philippines. 106 p.

Hoegh-Guldberg O (1999) Climate change, coral bleaching and the future of the world's coral reefs. Mar Freshw Res 50:839-866

Hughes TP, Rodrigues MJ, Bellwood DR, et al. (2007) Phase shifts, herbivory, and the resilience of coral reefs to climate change. Curr Biol 2007 Feb 20;17(4):360-5 Epub 2007 Feb 8

IPCC (2007) Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson, Eds., Cambridge University Press, Cambridge, UK, 976pp.

Ledlie M, Graham N, Bythell J, et al. (2007) Phase shifts and the role of herbivory in the resilience of coral reefs. Coral Reefs 26:641-653

Marshall P, Schuttenberg H (2007) Reef Manager's Guide to Coral Bleaching

Salm R, Clark J, Siirila E (2000) Marine and coastal protected areas: a guide for planners and managers. The World Conservation Union (IUCN)

Salm RV, Done T, McLeod E (2006) Marine protected area planning in a changing climate

Sorensen J (2000) Baseline 2000 background report: The status of integrated coastal management as an international practice. Harbor and Coastal Center, University of Massachusetts, Boston Available online at http://www uhi umb edu/b2k/baseline.

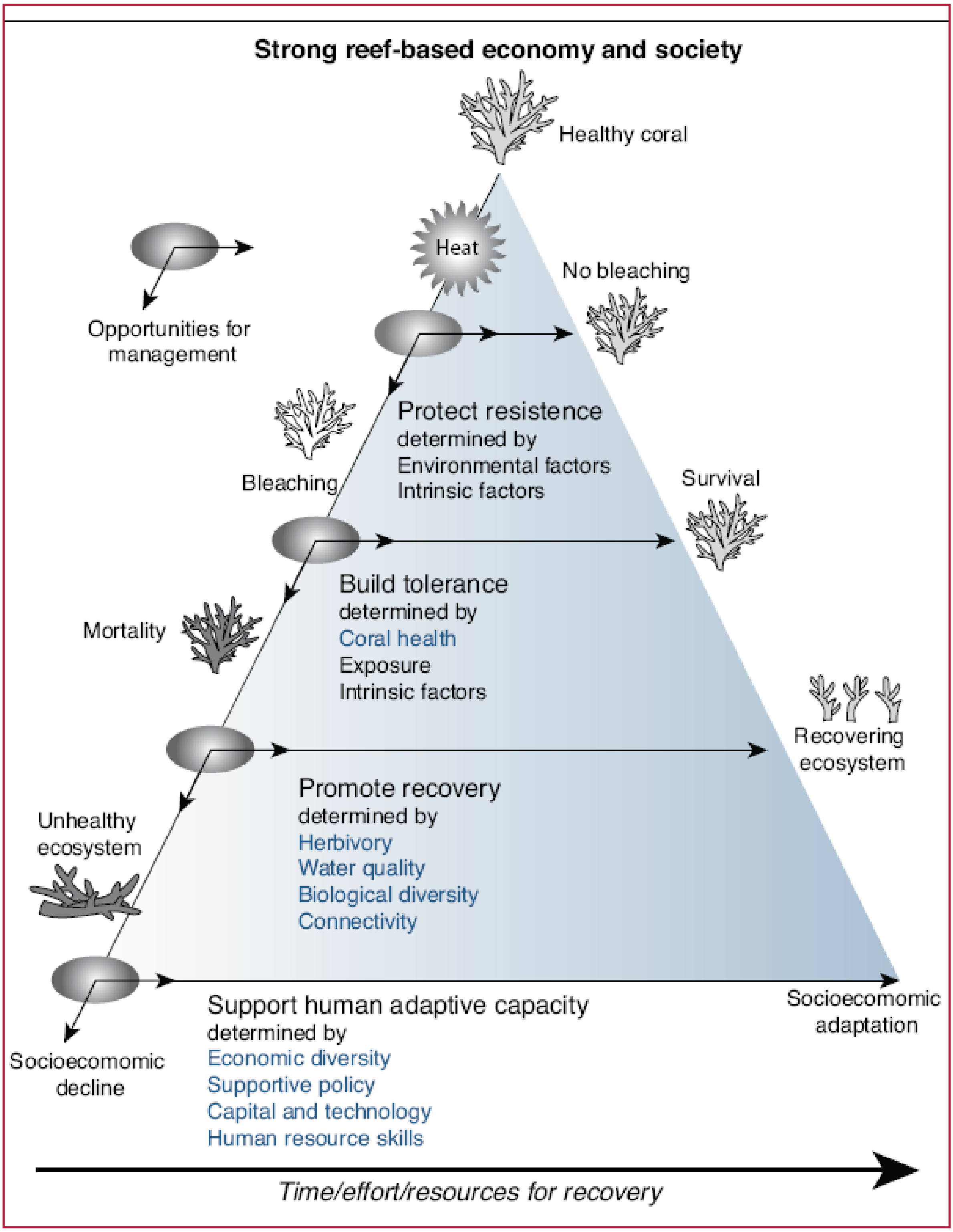


Figure 1. Framework for reducing the vulnerability of coral reefs to damage from thermal stress From Marshall and Schuttenberg 2006).

Table 1. Management Options for reducing the potential impacts (rows) of climate change on coral reef ecosystems (1st Order Outcomes) and people (2nd Order Outcomes) in the CTI. The management goals for reducing vulnerability to climate change are shown as columns and recommended actions that can be used to achieve them are in the boxes. The first column refers to mitigation rather than adaptation.

Management Goals Rows = Potential impacts Columns = Management targets for reducing vulnerability to climate change		*Reduce exposure*	Increase protection of priority coral reef areas	Protect/improve water quality	Protect herbivorous fish	Maintain connectivity between reef areas & protect biodiversity	Improve ability of mangroves to move and adapt to changing conditions	Protect infrastructure	Improve food security	Diversify economic base
1st Order Impacts on Ecosystem Condition	Weaker coral skeletons due to acidification	*Reduce CO2 emissions*	Education and co-management with tourism operators	Integrated coastal management						
	Increased coral reef destruction from cyclones	*Reduce CO2 emissions*	Identify and protect areas that receive the least impacts from	Encourage reef regeneration through integrated coastal management, protected area networks and fisheries management						
	Increased coral bleaching due to increased exposure to unusually hot sea temperatures	*Reduce CO2 emissions*	Identify and protect naturally resistant areas by implementing zoning recommendations (e.g. Reef Resilience							
	Reduced ability for corals to survive bleaching due to stressed condition at start of event			Reduce nutrients, sediments, and pesticides by improving coastal land-use and practicing integrated coastal management	Marine protected areas; other fisheries regulations such as restrictions on gear types and catch (species, quota)					
	Shift from coral reefs to algal reefs after devestating events, such as mass bleaching or cyclones					Develop networks of marine protected areas to protect				
	Reduced mangrove area due to lack of room to move and sea-level rise	*Reduce CO2 emissions*					Land-use plans and integrated coastal			
2nd Order Impacts on Human Well-being	Reduced food security and fisheries income as coral reef, mangrove, and seagrass habitats are lost with flow-on effects for fisheries		Minimize impacts by protecting condition of coastal ecosystems						Diversify food sources and develop contingency plans/capacity to	Build adaptive capacity and alternative livelihoods through training, financing, providing information, etc
	Reduced income from coastal resources (e.g. tourism) as a results of the way reef degradation reduces amenity values, water clarity, and white									
	Increased damage to coastal infrastructure as cyclone intensity increases and buffering by mangroves and reefs decreases							Integrated coastal zone management and appropriate engineering designs		Improve access to emergency funds (National, Regional, International) during storm and coastal

The original global scenario storylines behind the Third Assessment Report of the IPCC (*Special Report on Emissions Scenarios*), remained qualitatively plausible, but the expected impact of a given set of global climate change conditions has changed since the scenarios were written in the 1990s (Nakicenovic and Swart 2000).

The four scenario stories were originally constructed along two dimensions: 'global' versus 'regional' (horizontal axis in the diagram below, reproduced from the SRES report), and 'economic' versus 'environmental' (vertical axis). So, for example, 'A1' is largely driven by global and largely short-term economic forces whereas 'B2' is more environmentally driven and portrays a more regionalized world. The drivers of each scenario are shown in the roots of the 'tree'.

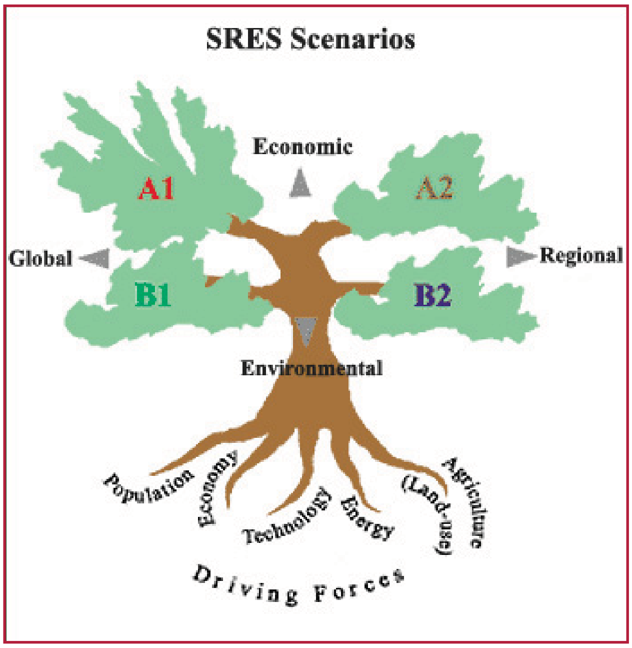


Figure 1. Schematic representation of the four major SRES scenarios (source IPCC 2001). Different worlds represent different combinations of global/regional and economic/environmental drivers, and arise from a range of driving forces (represented as roots to the tree). A1 and B1 are global scenarios dominated to different extents by economic (A1) versus environmental (B1) motivations. It is important to note that economic and environmental goals may not necessarily oppose each other and certainly synergise in many circumstances (e.g. Triple Bottom Line).

In principle scenario drivers can be any socio-cultural/demographic, technological, economic, ecological and political forces that are considered relevant. There are three main elements behind this shift from the 1990s.

First, a growing body of evidence that shows that the projected levels of greenhouse gases in the atmosphere resulting from a given scenario exceed most tolerance levels for human communities and the ecosystems on which we depend (green column in Table 1). Scientists attending the recent climate science meetings in Copenhagen in March 2009 presented a large amount of new science that indicates that climate change occurring at much faster rates than projected by the fourth assessment of the IPCC report in 2007. Indeed, many leading climatologists like James Hansen of NASA have concluded that even the current atmospheric level of about 387 ppm CO_2 may be too high to avoid irreversible and dangerous climate change (Hansen et al. 2008b) – even if other greenhouse gases such as methane remain under relative control. In fact, the atmospheric level of methane has resumed growing at a time when Arctic permafrost appears to be thawing much faster than predicted only a few years ago (Pearce 2009). There is growing scientific consensus that the emissions of CO_2 (and other greenhouse gases) must be reduced to almost zero as soon as possible.

Where science-based policy once called for reductions in emissions of 50% of 1990 levels by 2050, it is now becoming widely accepted that reductions in emissions of 80% or more will be needed to avoid catastrophic changes in the earth's atmosphere and biological systems. This obviously makes climate change policy advancement even more demanding.

Table 1: IPCC scenarios: likelihood that each will stabilize at particular increases

Scenario	Temperature change (°C) Best estimate	Temperature change (°C) Likely range	CO_2 ppm abundance in 2100	Likelihood that temperature change will be in range (crude measure based on IPCC 2007) 1-1.99°C	2-2.99°C	3-3.99°C	4-4.99°C	5°C+
B1	1.8	1.1 - 2.9	545	50%	50%			
A1T	2.4	1.7 - 3.8	578	14%	48%	38%		
B2	2.4	1.7 - 3.8	616	14%	48%	38%		
A1B	2.8	1.7 - 4.4	710	11%	37%	37%	15%	
A2	3.4	2.0 - 5.4	846		29%	29%	29%	12%
A1FI	4.0	2.4 - 6.4	964		15%	25%	25%	35%

Source: Based on IPCC 2007 Synthesis Report, Table 3.1.
Notes:
These estimates are from various sources including a large number of Atmosphere-Ocean General Circulation Models (A)GCMs). They do not take account any deterioration of climate change prospects after IPCC 2007 was finalized. The estimates are therefore conservative.

Temperature changes are expressed as the increase from 1980-1999 to 2090-99. To express the change relative to the period 1850-1899 add 0.5oC.

The three A1 scenarios are A1T (non-fossil energy resources), A1FI (fossil-intensive), and A1B (balance across all energy resources). A1 and A2 are driven by economics, globally and regionalized, respectively. B1 and B2 put more emphasis on protecting environmental resources, again either in a global context or in a world with many regions working independently.

Secondly, our understanding of possible positive feedback effects is now much better, due to improved climate models as well as actual observation. Highly visible aspects include the melting of Arctic (and now Antarctic) ice and snow, acidification of the global ocean, accelerating sea level rise, and rapid thawing of permafrost, mentioned above. These changes are increasingly nonlinear and synchronistic, pushing global circulation models to their limit.

Thirdly, no scenario can be expected to result in an exact impact on temperature (and other impacts of climate change) – there is always a range of variant models and probabilities that the actual result will stray from the best estimate, as shown in Table 1. If and when this happens, there is an increasing risk, according to many climate scientists, that large-scale events will be triggered or accelerated. These effects could start at a stabilization level of +30C or lower. The latest IPCC report (IPCC 2007) noted that to prevent the global temperature from rising above 20C by 2100 requires starting to reduce annual greenhouse gas emissions as early as 2015, only six years away as we write.

THE BEST AND THE WORST CASE SCENARIOS

The best-case scenario presented here is an updated interpretation of B1, with its global cooperation and environmentally friendly policy framework. The worst case is what is becoming recognized as a potentially disastrously, short-term-economics-driven, fossil-fuel intensive IPCC scenario, A1FI (the extreme variant of A1 among the IPCC scenarios). The intermediate case is the A1B variant where fossil and alternative fuels are used in what the IPCC called a 'balanced mix'. The three scenario stories are sketched below.

Preparing scenario principles for a 5th IPCC Assessment Report, Moss and colleagues have proposed two different scenario horizons (Moss et al. 2008): ‘near-term’ for the next 25 years or so, and ‘long-term’ to the end of the century and beyond. The latter would help set the dangers, risks and uncertainties due to global climate change, and then focus on the Coral Triangle in a century-long perspective. The ‘near-term’ scenarios would then be developed in as much useful detail as possible, with an eye on possible mitigation and adaptation strategies.

A final note on scenario planning: it is generally agreed that all scenarios should be interpreted as being equally credible and equally likely to happen (or unlikely to happen since no story is expected to come through in detail – the purpose of the scenarios is to set the boundaries for what is plausibly going to happen). Also, the story is told omitting any deliberate steps to modify future climate change policy. Having constructed the various long-term scenarios, the next question becomes how the worst cases can be avoided and the ‘best case’ (or even better) can be achieved.

In the context proposed by Moss et al. (2008), the long-term scenarios could be interpreted as demonstrating the consequences of not taking any further direct policy steps to climate change as things start to go astray, as they almost certainly would, especially under a scenario like A1FI. So the long look into the future would provide a basis for assessing the risk of crossing identifiable thresholds in both physical change and impacts on biological and human systems. The 25-year ‘near-term’ scenarios would then help identify measures of adaptation and mitigation to avoid or modify what would otherwise happen.

This doesn’t mean that we deny the reality of current climate change policy, with governments having already adopted direct policies, agreed on international conventions such as the Kyoto Protocol, are in the process of introducing carbon-trading schemes, and appointing ministers not focused on the environment and climate change. The approach is legitimate because powerful forces resisting these policies still exist. The global scenarios to a large extent outline who wins in the short term, say over the coming decade, and the consequences thereof over the century.

IMPLICATIONS OF ALTERNATIVE SCENARIOS FOR COASTAL ECOSYSTEMS

We cannot precisely project the changes occurring in the complete set of coastal ecosystems within the Coral Triangle. Coral reefs, on the other hand, provide a well-defined ecosystem response to rapid changes in local and global factors such as global warming and ocean acidification, with established thresholds and triggers. This response might be seen as indicative of how other ecosystems like mangroves and seagrasses might change in response to global and local stresses. Each ecosystem will have its own characteristic response and pattern of change. For example, coral reefs are expected to decline because of increasing mass coral bleaching arising from thermal stress and ocean acidification, whereas mangroves are expected to decline due to rapid sea level rise.

CORAL COVER

Three reference scenarios to help us understand how coral cover might change over the coming decades and centuries. Given the linkages between coastal productivity and biodiversity to coral cover, projecting how coral cover changes within these projected scenarios provides an overall insight into how conditions might change under the best and the worst case scenarios.

The following sections describe each scenario sequentially, starting globally then focusing on the Coral Triangle. Coral reefs, however, are the central theme within the Coral Triangle, in particular the extent to which they are affected by given CO_2 stabilization levels, and how these outcomes might be affected by reducing local stresses or not.

Figure 1 illustrates the outcomes for coral cover of three alternative stabilization levels of atmospheric CO_2.

STABILIZATION ABOVE 700 PPM

The first scenario, stabilization at an atmospheric CO_2 of 750 ppm (the most optimistic stabilization point within the 'A' family of IPCC scenarios) would result in sea temperatures of between 1.5 and 6.4°C (Table 4, chapter 8). Anything above 2°C (which is more than 80% likely if atmospheric carbon dioxide levels rise to 750 ppm or more) will result in coral dominated communities in the region vanishing due to thermal stress related mass bleaching and mortality. The few remaining remnant corals would exhibit slow growth due to reduced pH and carbonate ion concentration. Reef calcification would drop well below biological and physical erosion. Thus, coral reefs as three-dimensional habitats for coral reef organisms coastal protection would crumble and disappear (Hoegh-Guldberg et al. 2007). The conditions under this scenario are so severe that no amount of attention to reducing the impact of local stresses would have any effect on the outcome (hence the common trajectory of the red and green lines as atmospheric carbon dioxide increases in the atmosphere). Basically, coral reefs as functional ecosystems are doomed under this scenario, and hundreds of thousands of marine species will become rare or go extinct. The high rates of sea level rise that are almost certain under this scenario would result in the health and abundance of mangrove systems dwindling to very low levels, with an equal likelihood that these systems would also largely disappear as functional ecosystems.

STABILIZATION AT JUST BELOW 450 PPM

The second scenario involves atmospheric CO_2 increasing over the next few decades until it stabilises just below 450 ppm. This would involve decisive and quite challenging changes to CO_2 emissions, with decreases needing to begin by 2020 or earlier. These changes would bring coral reefs very close to the point where they are no longer viable as complex carbonate reef systems. Mass coral bleaching events, often exceeding the impacts of 1998 by several fold, would occur every two to three years on coral reefs in the Coral Triangle, with the steady loss of coral cover over time. The decrease in pH and carbonate ion concentration associated with coral calcification would see slowing of coral growth and calcification, with the implication that coral dominated reefs steadily replaced by non-coral reef communities, with a loss of biodiversity and productivity (Graham et al. 2007a; Pratchett et al. 2008; Wilson et al. 2008b). Many coral species and other organisms would persist, but at much lower levels than they do today. Given the lag time in response between temperature and carbon dioxide, coral reefs would continue to decline at the rate of about 2% a year as is happening now (Bruno and Selig 2007) until atmospheric levels of carbon dioxide have stabilized.

It would be reasonable to expect that under these conditions, coral cover on reefs in the Coral Triangle would dwindle to a low point of around 25% of what it is today. The community composition of these coral reefs would change substantially towards species that were more resilient to increasing temperatures and declining pH and carbonate ion concentrations. Some areas would have next to no coral cover, while other areas may have substantially higher amounts of coral than this average amount.

At this point, with the slowing of climate change as stabilization occurred, corals and other organisms would redistribute themselves according to the new conditions (with equatorial species moving in a pole ward direction) with the prospect that coral cover may start to slowly increase in the early part of next century. Time would exist for slow evolutionary changes to catch up with the previously rapid changes in climate.

These ecosystems will be relatively fragile compared to their relative resilience today, and will be less able to cope with local stresses such as poor water quality, overfishing, and pollution. For this reason, there will be considerable differences between the trajectories of reefs where the impacts of local stresses have been reduced versus reefs where local factors have not received effective attention. Under this scenario, the climate would continue to change until it stabilizes at the end of this century. In situations where reefs were impacted by both local and global factors, coral cover would be lost at an even greater rate. Equally, as coral cover began to increase due to the stabilization of climate conditions, reefs that were heavily impacted by local pressures such as overfishing, pollution and poor water quality, would recover at a much slower rates than those reefs where these impacts were reduced.

STABILIZATION AT 400 PPM

In the third scenario, stabilization at 400 ppm, aggressive and immediate action on CO_2 emissions would rapidly slow the increase in atmospheric CO_2, and would stabilize temperature relatively quickly. This may come about as a result of the cuts in emissions combined with the implementation of successful technologies to absorb CO_2. In this case, atmospheric CO_2 would continue to increase until around 2060, and coral cover would continue to fall until well into the 22nd century without effective management. It is realistic, however, to expect coral cover in a regime of effectively managed marine parks to remain above 50% of current levels, and to start a trend towards full recovery to current levels later this century. As with the second scenario, the management of local stresses would play a major role in determining the extent to which coral cover decreases, and how quickly and substantially it recovers following stabilization of CO_2 and sea temperature. This is, obviously, the best case scenario, involving a world where political leaders take immediate and effective action on carbon dioxide emissions, and in which effective action is taken to dramatically reduce the impact of local pressures on coral reefs in the Coral Triangle. It is also the scenario which would require a radical approach to eliminating CO_2 emissions. To date, no model or a technological/ policy pathway exists for totally eliminating CO_2 emissions so quickly.

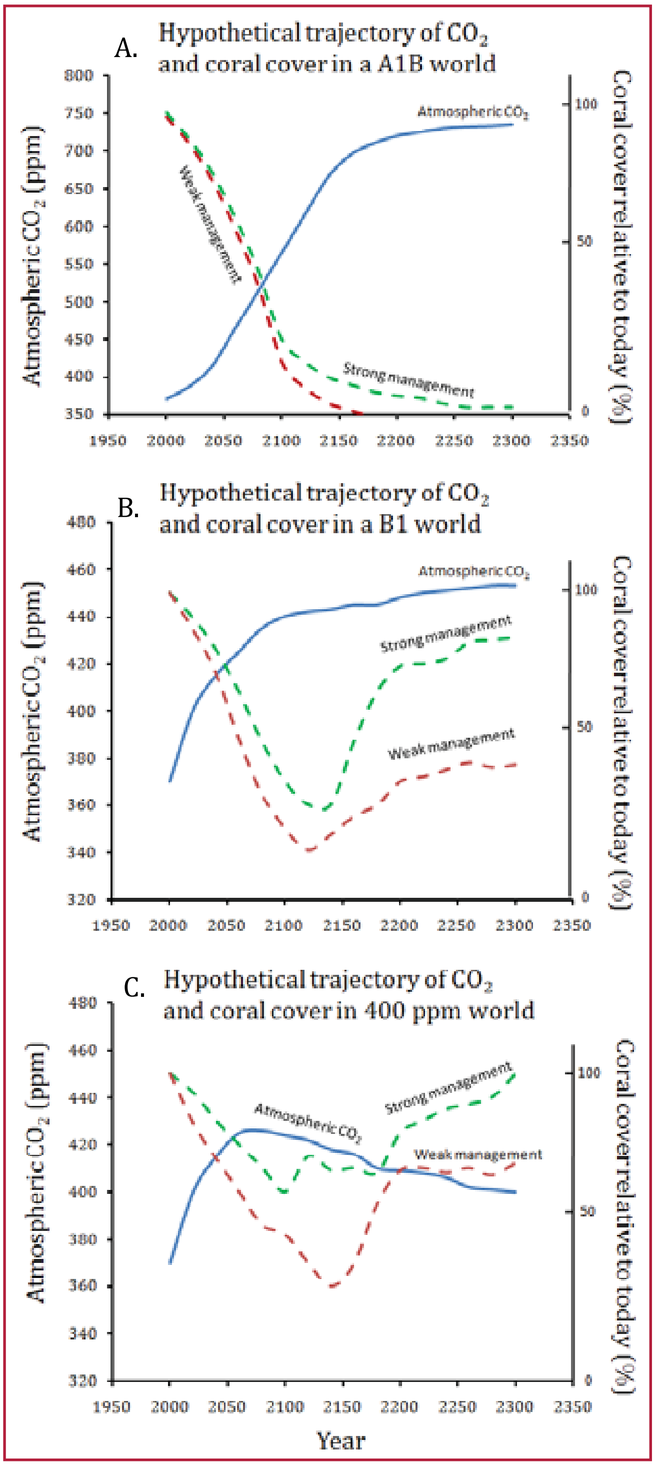


Figure 1 Coral cover over the next three centuries in a world in which strong cuts in CO_2 emissions occur (A. Stabilisation 750 ppm), a world that adopts deep cuts in CO_2 emissions over the next few decades (B. Stabilisation at 450 ppm), and a world that adopts immediate and deep cuts to CO_2 emissions (C. Stabilisation at 400 ppm). The red lines indicate worlds in which local threats to coral reefs are not managed, while the green lines are worlds in which strong policies and actions to manage and reduce local threats are implemented.

A1: GLOBALIZATION AND ECONOMIC GROWTH

Approach to scenario building

The global IPCC scenario descriptions describe, in very general terms, the kind of world that will develop under different drivers and assumptions. To get into that world rather than having to recreate the complete scenario story, we need to postulate a near-term path, say, to 2020, and tell its story. We also need to review whether the general storyline still holds water. Hence, the sequence is: (1) the path over the next decade, (2) the world assumed to develop over the 21st century as depicted by the original IPCC stories, and (3) a brief evaluation ten years after the original storyline was published in the Third Assessment Report. Having taken these three steps, we can then (4) zoom in on the Coral Triangle.

A storyline for the A 2010S, with a fork in the road

Despite increasing attention to climate change in the lead-up to the December conference in Copenhagen in 2009 climate change sceptics as well as enormous vested interests including big businesses in the leading western countries and emerging giant economies in China and India, and other economies (Russia, Brazil, Mexico, South Africa, Malaysia and others on the rise). Massive globalization dominates our world. Despite a sense of mutual dependence, climate change is given second priority to current business interests, always with reference to ‘sacrosanct’ shareholder interests and the financial bottom line.

Barack Obama enters the US presidency vested with high hopes that he would lead a determined and effective set of actions to combat climate change, but he gets bogged down in the crisis in the global economy, which despite massive injections of taxpayers’ money remains in the doldrums into 2011. The crisis deprives the world of fresh American leadership against climate change and while much changes compared with the previous administration (notably the introduction of a universal public health scheme and much improved education system for all Americans), resistance from Congress crippled the Administration’s bold moves to address the issue of climate change and provides international leadership in matters such as effective carbon cap-and-trade schemes and assistance to developing countries to reduce the rise in greenhouse gas emissions.

In many other ways, the US economy is highly progressive, and as the decade moves ahead and the economy resumed its growth pattern, the impact of a more informed education policy starts to benefit the energy sector. Other first-world nations also resume their growth; many developing countries benefit from the technologically orientated interconnected global pattern and graduate into newly industrialized status.

In 2016, scenario planners become aware of a ‘fork in the road ahead’, relative to where they sat in their own high-growth, global economic community. No one can say which fork will be taken, because the future remains essentially unknown and unpredictable. But according to these scenario planners, one path would, in the fullness of time, prove fatal for our global civilization, as we have come to know it, while the other would prove more viable though still full of uncertainties.

The fork in the road concerns energy. While it is too late to take effective control of climate change (a path offered during the Copenhagen conference in 2009), several years later, two plausible futures emerged:

- The first sees the exploitation of all possible fossil fuel resources, including marginal resources such as shale oil, deep sea and polar sources, plus natural gas and the still abundant coal reserves. Scenario planners keep the name of this path as A1FI, originally given to the prototype economic-growth orientated fossil-fuel intensive scenario devised for the IPCC Third Assessment Report. It sought to perpetuate the fossil-fuel world of the past century, and the globalization that snow-balled in the 1990s and early 2000s.

- The second realizes that conventional petroleum resources are likely to run out within a few decades, and that environmental considerations need to brought back from the backburner (where they have been since the collapse of the Copenhagen conference and subsequent climate change meetings). The plan is to use the formidable technological capacity that is emerging to develop a range of economically viable energy sources, both renewable and new technologies designed to make fossil fuel use environmentally safe (e.g. carbon sequestration). This scenario is A1B, for economic-growth orientated balanced-energy use.

The THE IPCC storyline

The A1 storyline is a case of rapid and successful economic development, in which regional average income per capita converge - current distinctions between ‘poor’ and ‘rich’ countries eventually dissolve. The primary dynamics are:

- Strong commitment to market-based solutions.
- High savings and commitment to education at the household level.
- High rates of investment and innovation in education, technology, and institutions at the national and international levels.
- International mobility of people, ideas, and technology.

The transition to economic convergence results from advances in transport and communication technology shifts in national policies on immigration and education, and international cooperation in the development of national and international institutions that enhance productivity growth and technology diffusion.

In the A1 scenario family, demographic and economic trends are closely linked, as affluence is correlated with long life and small families (low mortality and low fertility). Global population grows to some nine billion by 2050 and declines to about seven billion by 2100. Average age increases, with the needs of retired people met mainly through their accumulated savings in private pension systems.

According to the original storyline (IPCC 2001), “the global economy expands at an average annual rate of almost 3% to 2100, reaching around US$550 trillion (in 1990 dollars). This is approximately the same as average global growth since 1850, although the conditions that lead to this global growth in productivity and per capita incomes in the scenario are unparalleled in history. Global average income per capita reaches about US$21,000 by 2050. While the high average level of income per capita contributes to a great improvement in the overall health and social conditions of the majority of people, this world is not necessarily devoid of problems. In particular, many communities could face some of the problems of social exclusion encountered in the wealthiest countries during the 20th century, and in many places income growth increases pressure on the global commons.

Energy and mineral resources are abundant in this scenario family because of rapid technical progress, which both reduces the resources needed to produce a given level of output and increases the economically recoverable reserves. Final energy intensity (energy use per unit of GDP) decreases at an average annual rate of 1.3%. Environmental amenities are valued and rapid technological progress 'frees' natural resources currently devoted to provision of human needs for other purposes. The concept of environmental quality changes in this storyline from the current emphasis on 'conservation' of nature to active 'management' of natural and environmental services, which increases ecological resilience.

With the rapid increase in income, dietary patterns shift initially towards increased consumption of meat and dairy products, but may decrease subsequently with increasing emphasis on the health of an aging society. High incomes also translate into high car ownership, sprawling suburbia, and dense transport networks, nationally and internationally.

Several scenario groups considered in the A1 scenario family reflect uncertainty in the development of energy sources and conversion technologies in this rapidly changing world. Some scenario groups evolve along the carbon-intensive energy path consistent with the current development strategy of countries with abundant domestic coal resources. Other scenario groups intensify the dependence on unconventional oil and, in the longer run, natural-gas resources. (The 'coal' and 'oil-and-gas' groups were subsequently combined in one group, named fossil-intensive or A1FI.)" (IPCC 2001).

A third group envisages a stronger shift toward renewable energy sources and conceivably also toward nuclear energy [A1T]. If aggressively pursued, this scenario would probably not differ too much from the explicitly environmentally friendly scenario called B1, which was in fact chosen as the best case.

A fourth group included the A1B marker scenario, adopted for this study as the intermediate scenario case. It assumes a balanced mix of technologies and supply sources, with technology improvements and resource assumptions such that no single source of energy is overly dominant.

As the SRES report itself notes, the implications of these alternative development paths for future greenhouse gas emissions are challenging: the emissions vary from the carbon-intensive to decarbonised paths by at least as much as the variation of all the other driving forces across the other SRES scenarios.

Implications of the alternative A1 scenarios

There is no objection to the story as such. However, ten years after the scenarios were written and the implied indicators were measured, problems arise. Table 1 assists in showing how.

The fossil-intensive scenario, A1FI, as its best-estimate stabilization rate records +40C compared with 1980-99. At this rate, there are already grave risks that major feedbacks will have been triggered, such as Siberian methane released from thawing permafrost, and massive sea-level rise from melting polar areas. Table 1 furthermore shows that there is a 35% chance that global temperatures will be 50C or higher by 2100, and 25% chance that they will reach between 4 and 4.90C. At these rates it is unlikely that economic growth can be maintained; in fact, some authors think civilization, as we know it, will have collapsed in these conditions.

The Fourth Assessment Report has a graph showing CO_2 levels for A1FI increasing from about 360 ppm in 2000 through 410 ppm in 2020, 450 ppm in 2040, 615 ppm in 2060, 775 ppm in 2080, before reaching 964 ppm in 2100. This world would become increasingly dysfunctional and unliveable for most people, from about 2060. Moreover, the levels of atmospheric CO_2 shown in the green column of Table 1 are increasingly considered as being unsustainable, even the level for the best-case B1 scenario discussed in the next section.

The middle-ranking A1B scenario has a best estimate temperature increase of 2.80C over the century, but even it shows a 15% risk of entering a 40C world. It is 37% likely to end up within a 3.0 to 3.90C range, so it can no longer be described as even a reasonably safe world, even if this was thought to be so in the late 1990s when the scenarios stories were first written.

The A1B scenario ends up according to Table 1 with 710 ppm CO_2 in 2100, a path from 360 ppm in 2000 through about 410 in 2020, 430 in 2040, 550 in 2060, and 630 in 2080. To prevent the rises in the second half of the century, strong action would have to be taken from at least the 2030s.

Population projections

Both the A1 and B1 scenarios project a world population of 8.7 billion by 2050, followed by a reduction towards 7 billion by 2100. The United Nations (2007) in its medium projection expects 9.2 billion in 2050 (UN 2007), by which time the world population will be increasing at low rates and might well be compatible with a reduction in the second half of the century. However, other evidence tells a different story, as discussed below. Since these projections show individual countries, we have at least an approximation of how population growth may turn out in each of the six Coral Triangle countries (Table 2).

Table 2: World population projections to 2050

	Million persons				2050	Annual growth	
	2007	2015	2025	2050	over 2007	2005-10	2045-50
World	6,671.2	7,295.1	8,010.5	9,191.3	138%	1.17%	0.36%
Indonesia	231.6	251.6	271.2	296.9	128%	1.16%	0.10%
Malaysia	26.6	30.0	33.8	39.6	149%	1.69%	0.41%
Philippines	88.0	101.1	115.9	140.5	160%	1.90%	0.50%
Timor-Leste	1.2	1.5	2.0	3.5	292%	3.50%	1.84%
PNG	6.3	7.3	8.6	11.2	178%	2.00%	0.77%
Solomons	0.5	0.6	0.7	1.0	200%	2.33%	0.89%

Note: These projections are largely compatible with world projections for A1 and B1 scenarios.

Source: United Nations (2007).

The world population was thus expected to be 30% higher in 2050 than in 2007, based on IPCC, while United Nations (2007 (UNDP 2007)) has a 38% increase as shown by Table 2. If all 2050 projections were reduced to fit the global IPCC projection, Indonesia's population would be 281 million (21% higher than in 2007), compared with 37.5 million in Malaysia (+41%), Philippines 133 million (+51%), Timor-Leste 3.3 million (+175%), PNG 10.6 million (+68%), and the Solomon Islands 950,000 (+90%). The small and relatively less developed countries to the east are therefore projected to have the highest growth rates, led by Timor-Leste. Of the larger countries, Indonesia's population is currently growing at the world average but is expected to fall below it by 2050, showing hardly any growth between 2045 and 2050. Malaysia will come back to the world average growth rate by 2050, and the Philippines will remain above average. Growth rates are expected to fall in all six nations, though it would appear that Timor-Leste's population would continue to increase into the second half of the century, and perhaps the same will apply to PNG and the Solomons despite reductions in the world population.

Table 3: World population in 2050 (2008 estimates)

	Million persons			
	Low	Medium	High	Constant*
World	7,958.8	9,150.0	10,461.1	11,030.3
Indonesia	248.2	288.1	332.1	317.9
Malaysia	34.3	39.7	45.4	47.1
Philippines	126.3	146.2	167.8	181.6
Timor-Leste	2.9	3.2	3.6	5.1
PNG	11.2	12.9	14.7	17.9
Solomons	0.9	1.0	1.4	1.4

* Constant fertility at 2000-05 levels.

Source: United Nations (2008)

The most recent population estimates are from 2008 (Table 3). They show a range from low through medium to high projections, and also what the population would grow to by 2050 if fertility rates remain constant since 2000-05. The medium world population estimate is below the estimate in Table 2. So are the projections for Indonesia and Timor-Leste, whereas those for the Philippines and PNG are higher.

None of these projections, however, reflect the pattern of the A1 and B1 IPCC scenarios, with the global population peaking in 2050 at 8.7 billion, and then falling towards 7 billion by 2100. The only projections going beyond 2050 are some very long ones all the way to 2300 (UN 2004); the medium projection for the world population is 8.919 billion for 2050 and 9.064 billion for 2100. The projection for Indonesia is for a fall from 293.8 million to 272.8 million, for Malaysia 39.6 million for both years, for the Philippines a marginal increase from 127.0 to 128.8 million, for PNG an increase from 11.1 to 12.4 million, and for the Solomons from 1.07 to 1.19 million. The estimates for Timor-Leste in UN (2004) are incompatible with the estimates in the two subsequent UN publications.

Basically, the projected reduction in the global population according to the IPCC would have been based on detailed population models where mortality, fertility and birth rates are built in to produce consistent results. We don't know what these assumptions were and therefore cannot reproduce the model in an updated form, nor get compatible country detail. The basic information from Tables 2 and 3 must suffice even though it takes us only to 2050.

We can assume in a general way that the growth rates shown in Table 2 will continue to reduce for the six nations, most for Indonesia (going into negative growth), least for Timor-Leste. These assumptions can then be overlayed with estimates of when projections become unrealistic, as in the worst case scenarios after about 2060, and maybe later in the century for the medium-range scenario.

A note on economic growth

The A1 scenario family is a particularly high-growth scenario. Apart from the possibility that global warming, sea-level rises and storm surges may limit and reverse further economic growth because much of the world will become increasingly unliveable, two other aspects need to be recorded too:

- As the world becomes increasingly exposed to environmental damage, a greater portion of GDP will be used for remedial infrastructure, insurance premiums will go up, and other impacts will limit the part that is available for consumption of conventional goods and services. So lifestyle is by no means the same as GDP per capita.

- Particularly relevant for the Coral Triangle study, inequalities will become even more prominent between rich and poor parts of a country. National GDP growth may not translate into growth for all; negative growth may result in areas as they become further disadvantaged.

Implications of the A1 scenario for the Coral Triangle

A basic outcome of the climate change scenarios is that poorer countries and poorer people within each country bear the brunt of the burden. Within the Coral Triangle, this *a priori* places the Solomon Islands, Papua New Guinea and Timor-Leste in the most vulnerable category (Howes et al. 2006), especially in the economically orientated A1 scenarios, and especially as global temperatures rise beyond 30C .

All six countries are classified as developing. However, Malaysia in particular, and Indonesia and the Philippines following, may be on their way to newly industrialized status, which may be accelerated during the first two or three decades of the A1 scenario in a strong global economic growth scenario, before growth slows as the many problems associated with climate change grow in size and impact. The main coral reef areas in Malaysia surround the poorest state, Sabah, and Eastern Indonesia is also significantly poorer than the rest of the country, especially the islands east of Bali (Nusa Tenggara), Maluku, and Papua. While Bali and East Kalimantan are notable exceptions to the rule, many areas adjacent to the Coral Triangle are relatively poor, and hence the same may not apply to the coral areas near these islands. Coral reefs are found mainly on Bali's north coast which does not benefit from the lush rice growing of the south, and does not attract a fraction of the tourists that come to Kuta, Legian, Sanur, Nusa Dua, Ubud and other Balinese tourist meccas. Tourism to the Derawan islands east of Kalimantan also remains at modest levels. These differences translate into inequalities across the full spectrum of income, health and education.

Rapidly changing climate associated with the A1 storyline leads to major impacts on the Coral Triangle through changing precipitation and soaring temperatures by 2050. The Philippines, Sabah and parts of Indonesia are hit hard by increasingly intense rainfall events which are broken by severe droughts that last for years, as well as by episodic and catastrophic cyclones in the Philippines. Rising seas steadily inundate coastal communities across Indonesia, further exacerbating the impacts of the increases in rainfall and storm activity.

These impacts cause major dislocation of people and communities through flooding and storm damage, which hit with increased scale and frequency. Foreign aid to alleviate human distress dwindles as richer nations face their own problems with climate change, and as the regularity and scale of these events expands. Tens of millions of people have to move from rural and coastal settings due to the loss of homes and income, putting pressure on expanding urban centres and on surrounding developed nations such as Australia and New Zealand.

Coastal areas within the Coral Triangle remain relatively poor. In Timor-Leste, PNG and the Solomons coral reefs are a major source of income, from fisheries rather than tourism. Sabah and the Indonesian provinces next to the Coral Triangle also tend to be poor relative to the rest of their nations, and the same largely applies to the main coral reef areas in the Philippines.

Initially, each of the three large countries benefits from general economic growth and is converging towards the economics of first-world countries. Some of this growth benefits the poorer areas next to the coral reefs. Tourism, however, never becomes the major income generator it has proven to be in Bali (in a non-coral setting) and elsewhere like the Great Barrier Reef. Past top dive areas in the Philippines have faded due to insufficient park management in the past. The pristine coral reefs in Papua and Maluku are generally too remote to attract significant tourism, especially as long-distance travel becomes less frequent due to constantly rising aviation fuel prices. After two decades of relative prosperity in all three countries, the less benign aspects of rapid economic growth begin to emerge more decisively. The following snapshot is based on a '2050 perspective', referring to the 'balanced-energy' A1B scenario heading towards a 2.80C increase by 2010 (see concluding note for the fossil-intensive worst-case scenario):

- Most Indonesian provinces, Sabah, and reef areas adjacent to the Philippines, as well as the three small eastern island states, have stopped growing beyond a constant GDP per head, due to loss of resources associated with climate change. Looking ahead from 2050, there is some risk that real incomes per head in these areas will actually decline over the next decade and beyond.

- Artisanal fishing has declined strongly, causing major social disruption. Traditional fishers looking for work in cities leave their wives and families behind and live in poor conditions. Whole families move to other rural areas causing land conflict. Traditions, heritage and other cultural values are lost. Traditional management skills become superfluous.

- Commercial fisheries take over from the traditional fishing activities. They employ young un-married males, who join socially unstable groups and whose incomes are out of proportion with the income of the locals, causing further social disruption, income inequities, and potential health problems. The young males stay for a while but eventually disappear again to be replaced by others.

- The commercial fisheries put further pressure on regional communities, including the activities of illegal and unreported fisheries of pelagic fishes, which by 2050 have been declining in numbers and average size for decades. Regional communities suffer from lack of protein not affordable from alternative sources, from poor health, and the infant mortality rate has once again been rising.

- Meanwhile, sea levels have been increasing rapidly, much above what had been originally predicted by science back in the early 21st century. Sea level increases of at least 1 m have occurred, with possible excursions well beyond that as predicted by sealevel experts such as Stefan Rahmstorf (Potsdam University) and others in 2009. The impact is compounded by an increase in the intensity of storms and inundation events, leading to increased physical damage from storm surges, and increase inland salinity problems (loss of water supplies due to salinization of groundwater in coastal regions).

- The land lost to the sea and exacerbated by the surges is a contributing factor adding to the competition for scarce coastal land, pushing up prices of an increasingly scarce resource. This has ripple effects for adjacent agricultural land values, causing further disruption to what had been traditional communities. At the same time, agricultural yields continue to decline due to climate change. Agricultural resources in some areas have been spiralling downwards.

- The Solomon Islands and many islands off PNG are particularly vulnerable to declining fisheries, whether these are due to climate change or overfishing, or both.

- The cohesion of the Coral Triangle countries is now fragmented, driven by the difficulties, dwindling resources and opportunities. Their common bond over coral reefs and coastal resources disintegrates as the health of these systems has declines.

- This extends internationally. There has always been a strong reliance on overseas aid, especially in the Solomons, PNG and Timor-Leste. More than a moral prerogative, such aid has been given with a view to develop these countries into stronger trading partners. But now the incentive has weakened, together with reluctance on the part of the international insurance industry to increase its own exposure. While more funds might be available for disaster relief with rapid global economic growth, the richer world may no longer have the incentive to make these funds available for what might be seen increasingly as an unproductive use of funds.

- Private remittances, however, continue as a strong economic force. Unfortunately, these benefit the three poor eastern nations only to a very limited extent. The main beneficiary remains the Philippines, with Indonesia in second place. Malaysia, meanwhile, appears to have taken off successfully as the new ‘Korea’ of Southeast Asia, and is in less need of remittance income from abroad (Sabah, however, remains a relatively poor state compared with the rest of Malaysia).

ENDNOTE ON THE WORST-CASE SCENARIO

The above description is about the global economic growth scenario with balanced renewable and fossil fuel development. It shows that even if the world will be advancing at least until the late 21st century, provided that the global temperature average growth stays at 2.80C, the areas adjacent to the Coral Triangle may not share in the prosperity of that world.

This situation is many times worse if the fossil-intensive scenario prevails. At an average 40C growth, there is a 60% risk according to Table 1 that the actual rise will exceed 40C. This makes the A1FI world unliveable from about 2060, as previously explained. The economies around the Coral Triangle will collapse as well, and it is a question how long it will take before the remaining human beings are evacuated to cooler regions of the planet.

B1: GLOBAL ENVIRONMENTAL FOCUS

A possible path over the 2010S

The election of Barack Obama restores the United States to a position of unrivalled progressive leadership, including a determined approach to climate change policy previously led by Europe. President Obama's inaugural speech showed that he would assume that mantle. The new administration initially focuses on the economic crisis, but as 2009 progresses it is able to take advantage of the situation to restructure and rebuild industries with both the economy and climate change in mind. The massive bail-out of the auto industry under the previous administration becomes progressively more loaded with conditions to develop alternatives to internal combustion engines – a development reinforced by competition from Japanese, Korean and European car makers who are moving rapidly into hybrid and other technologies.

Massive lobbying from the petroleum industry and others puts a damper on such developments, aggravated by a temporary fall in the price of crude oil through 2009. The temporary collapse in business expectations and share prices leads to the postponement of some major projects. Several solar firms cut back severely in late 2008 as demand threatens to plummet. Low prices could mean that the developing world gets greater access to solar power, or that investors are attracted to flagging companies.

During 2009, powerful political forces, led by the Obama administration, accept the realism of the idea of killing two birds with one stone: the economic crisis and climate change. The United Nations Secretary-General and the heads of state hosting the 2007-09 climate change conferences advocated this in November 2008: "The answer is to find common solutions to the grave challenges facing us. And when it comes to two of the most serious – the financial crisis and climate change – that answer is the green economy. Scientists agree: To address climate change, we need an energy revolution, a wholesale change in how we power our societies. Economists agree as well: The hottest growth industry in the world is renewable energy." (Ban Ki-moon , Susilo Bambang Yudhoyono, Donald Tusk and Anders Fogh Rasmussen 2008)

True to his pre-election program, President Obama plays a leading role at the climate change conference in Copenhagen in December 2009 (COP-15), based on preceding diplomatic work to achieve effective international agreement about the urgency of the problem. The Obama administration has some success in bringing a wavering Europe back in the climate change fold, including Germany where lobbyists were successful in 2008 in watering down plans for carbon emissions trading in a new EU energy package, thereby endangering the achievement of targets to cut emissions unilaterally by 20% by 2020.

Despite qualified support of most developed countries, and China (which increasingly realizes the risk involved in its massive power industry program without adequate clean-coal technologies), other countries (notably India and Russia) are less cooperative. As a result, the EU, and countries like Australia, do not offer to increase their targets for emissions cuts beyond their initial unilateral offers, despite original promises to do so if other developed countries follow suit. The key decisions needed for a 20C target for the century do not emerge from COP-15 (though some steps are taken and goodwill among countries increases), and attempts to secure a peak in greenhouse gas emissions by 2015 (only six years ahead) are in trouble.

After a relatively cool 2009, the global warming path resumes and from the middle of the year onwards 2010 is clearly on track to become the hottest year on record according to midyear weather forecasts (pushing the extreme El Niño year of 1998 into second position). This triggers a number of worldwide events, which combines to create the circumstances for a global resolve to deal with climate change.

Catastrophic fires affect California, south-eastern Australia and large parts of Europe, resulting in large-scale loss of life and infrastructure. The start of the monsoon season results in a massive increase in precipitation, resulting widespread flooding in India and loss of thousands of lives. Other parts of Asia experience the consequences of the increased melting through record flooding. As well as damaging the livelihood of vast numbers of people there are fears of renewed threats from water- and insect-borne diseases such as cholera, hepatitis and malaria. Summer ice in the Arctic dwindles to a mere 5%, and further Antarctic ice is lost from the Larsen C ice shelf. In tropical areas of the planet, mass coral bleaching due to soaring ocean temperatures again strikes the world’s coral reefs, this time with major impacts on the Great Barrier Reef, where 40% of its corals die over six months. Most regions of the world experience worrying losses, with the Solomon Islands and Philippines experiencing losses of more than 80% on most of their coral reefs.

These events underscore what the expert community has been telling policymakers; that serious damage has occurred to the climate system and that potentially catastrophic nonlinear climate change is in progress. Thus ‘encouraged’ by Mother Nature, politicians build on the initial goodwill summoned through the Copenhagen meeting; countries like Australia reconsider their original plans to cut emissions unconditionally by only 5% by 2020 and set higher target of around 25%. Britain and the European Community continue to develop strong positions in this respect, and an effective international agreement much broader than the Kyoto Protocol is finally put in place in 2012 which firmly commits nations to cooperate towards an 80% reductions in greenhouse gas emissions by 2050.

Carbon cap-and-trade schemes with a binding rate of significant reduction of the cap over five years help encourage the competitive position of renewable fuels to a point where they can take off in their own right; a combination of international agreements also serve to encourage and fund developing countries to leapfrog into the new technologies. An understanding develops between the US and China which greatly encourages both countries to cooperate on technologies from ‘clean coal’ to efficient building standards. India comes on-board as well though it insists on going down the nuclear path too. So do countries like Russia as technological developments favour a major switch to renewable energy sources.

As the decade moves towards its close in 2020, several additional extreme events serve to remind the world of the urgency of the climate change problem – including an increasing number of Category 5 tornados and hurricanes, shrinking glaciers and sea ice, and rapid sea level rise.

The iconic Coral Triangle and Great Barrier Reef, among others, in 2017 become victims of warm seas associated with El Niño events riding on top of already warmer seas. While not as catastrophic as the 1998 or 2010 events, these events remind leaders that reefs have a vest ecological as well as economic value, and must be saved by all possible means.

In 2018, the upward movement in global greenhouse gas emissions finally ceases, and a sustained fall begins. It happens a little later than the ideal time, and it will be difficult to avoid an increase to perhaps as high as 450 ppm atmospheric CO_2 by 2100 (though there is some hope for less), not to mention a rise in methane levels which is attributed to thawing permafrost in 2009.

This scenario can be extended further into the future, but basically the world develops into the IPCC storyline described below. In brief, the storyline is only possible with (a) strong and early political leadership personified here in a new American president, and (b) a number of triggers that succeed in shocking the world beyond both complacency and the impact of vested corporate and political interests.

The level at which CO_2 and other greenhouse gases stabilize also depends on the speed at which the current scenario merges into the ‘B1 future’ described below. The assumption here is that this will essentially happen by 2020, due to a capitalistic system in which environmentally sustainable technologies finally become competitive, supported by international organizations and national government policies.

The IPCC storyline

The central elements of the B1 future are a high level of environmental and social consciousness combined with a globally coherent approach to a more sustainable development. Heightened environmental consciousness can emerge from clear evidence that impacts of natural resource use, such as deforestation, soil depletion, overfishing, and global and regional pollution, pose a serious threat to the continuation of human life on Earth. In the B1 storyline, governments, businesses, the media, and the public pay increased attention to the environmental and social aspects of development. Technological change also plays an important role.

According to the original storyline (IPCC 2001), “Economic development in B1 is balanced, and efforts to achieve equitable income distribution are effective. As in A1, the B1 storyline describes a fast-changing and convergent world, but priorities differ. Whereas the A1 world invests its gains from increased productivity and know-how primarily in further economic growth, the B1 world invests a large part of its gains into improved efficiency of resource use, equity, social institutions, and environmental protection.

A strong welfare net prevents social exclusion on the basis of poverty. However, counter-currents may develop and in some places people may not conform to the main social and environmental intentions of the mainstream. Income redistribution and high taxation levels may adversely affect the economic efficiency and functioning of world markets.

Particular effort is focused on increases in resource efficiency to achieve the goals stated above. Incentive systems, combined with advances in international institutions, permit rapid diffusion of cleaner technology. To this end, R&D is also enhanced, together with education and capacity building for clean and equitable development. Organizational measures are adopted to reduce material wastage by maximizing reuse and recycling. The combination of technical and organizational change yields high levels of material and energy saving, as well as reductions in pollution. Labor productivity also improves as a by-product of these efforts.

The demographic transition to low mortality and fertility occurs at the same rate as in A1, but for different reasons, as it is motivated to a greater extent by social and environmental concerns. Global population reaches nine billion by 2050 and declines to about seven billion by 2100. This is a world with high levels of economic activity (growing at 2.5% per annum to a global GDP of around US$350 trillion by 2100) and significant and deliberate progress toward international and national income equality. Global income per capita in 2050 averages US$13,000, one-third lower than in A1." IPCC (2001).

A higher proportion of this income is spent on services rather than on material goods, and on quality rather than quantity, because the emphasis on material goods is less and also resource prices are increased by environmental taxation [taxing carbon either directly or through cap-and-trade schemes encouraging efficient and innovative producers would be part of this in an updated B1 scenario].

The original B1 storyline continues, "The B1 storyline predicts a relatively smooth transition to alternative energy systems as conventional oil and gas resources decline. There is extensive use of conventional and unconventional gas as the cleanest fossil resource during the transition, but the major push is toward post-fossil technologies, driven in large part by environmental concerns.

Given the elevated environmental consciousness and institutional effectiveness of the B1 storyline, environmental quality is high, as most potentially negative environmental aspects of rapid development are anticipated and effectively dealt with locally, nationally, and internationally. Land use is managed carefully to counteract the impacts of activities potentially damaging to the environment. Cities are compact and designed for public and non-motorized transport, with suburban developments tightly controlled. Strong incentives for low-input, low-impact agriculture, along with maintenance of large areas of wilderness, contribute to high food prices with much lower levels of meat consumption than those in A1. These proactive local and regional environmental measures and policies also lead to relatively low greenhouse gas emissions, even if not explicitly designed to mitigate climate change."

The B1 story and changes in assumptions since 2001

There is little criticism to level against the general B1 storyline, with the possible qualification that a similar world described today might show a more enforced transition from fossil to renewable energy. This might be caused by the oil tipping point (the point at which reserves are expended, oil supply decreases and the resulting price increases make its use unsustainable economically) being reached sooner rather than later, and/or deliberate direction of technological change and policies towards the development of competitively priced alternative energy. The scenario, after all, embodies 'a globally coherent approach to a more sustainable environment.' In other words, B1 written today would reflect an increased urgency to replace fossil fuels with renewable energy.

Referring to Table 1, the stabilization level for scenario B1 was 1.80C above late 19th century levels when estimated in 2007, with a 50% risk that the global temperature might stabilize between 2 and 30C higher. Subsequent research and observed impacts of climate change suggests that the risk and uncertainties are increasing further.

The target of 545 ppm atmospheric CO_2 in 2100 is no longer acceptable according to the latest science, nor is the path towards that target: about 405 ppm in 2020, 425 in 2040, 490 in 2060, and 535 in 2080 (these numbers are from a graph in the Fourth IPCC Assessment Report). This reality puts increasing pressures on countries to adopt policies that reduce emissions, from at least 2015 onward. The challenge of staying within sustainable levels of atmospheric greenhouse gases, by reducing emissions by 80% by 2050 remains a formidable one.

The path towards sustainable development should now enable a reduction in emissions by 80% by 2050 despite global population's increasing by almost three billion in the next 40 years. The implications of this scenario are a best estimate of +2.20C by 2100, and in the previous scenario-building framework captured by Table 1 a likely range between +1.5 and 3.30C.

These factors change the probability pattern compared with Table 1. The implication is that even under the B1 scenario, there is now a finite possibility (17%) that the global average temperature will increase beyond 30C where the risk of major positive feedback effects are considered to rise rapidly, while the chance of staying below 20C has been reduced to 28%. The remaining 55% refers to the probability of a rise between 2 and 30C.

The previous scenario descriptions (A1) had a section on population growth that is also relevant to this scenario, which uses the same global population projections. Basically it identifies a range of projections from Indonesia going into negative population growth after 2050, to Timor-Leste likely to maintain relatively high growth to the end of the 21st century, given sufficient capacity.

Implications of the B1 scenario for the Coral Triangle

By 2050, available food from coastal ecosystems in the Coral Triangle has been reduced to 50% of present levels and sea levels have increased by as much as 50 cm, or as much as the worse-case (A1B) scenario related in the previous section. This may look like a pessimistic assumption, but it is interesting to review this for a world still expected to sustain itself through the century and beyond – and a world in which countries like Malaysia, Indonesia and the Philippines are becoming increasingly important economic players in a way a country like South Korea has succeeded today.

One of the assumptions that underpins this projection that communities remain reasonably soundly based, as in the general B1 scenario, is that they can cope with fairly severe hardships including the impact of a gradual 50 cm sea level rise on coastal fishing, agricultural and urban communities.

Setting that sort of condition for a world we expect to absorb some major controversies and hardships (some of which we cannot hope to predict) encourages faith in the basic economic, social and cultural resilience without which our civilizations probably couldn't survive.

While of course there are great differences as the impact of climate change has intensified and major new economic and social patterns have emerged, this has happened in an reasonably gentle fashion so that a basic connection remains with the world developing during the 2010s, which started – albeit it with some hesitation – with a successful commitment of practically all developed and developing nations to a ‘Copenhagen Protocol’ in 2012. Having set the basic parameters at the time, the main feature in 2050 is less of a radical change of the past and more of a continuing adaptation process.

Basically, this world is no longer going to run into a brick wall due to galloping atmospheric CO_2 content. It will continue to find solutions to keep this content under strict control internationally by known technologies. Sufficient food remains available to enable the Coral Triangle communities to survive despite the loss of half their consumption of fish protein. Pockets of scarce food supplies have been filled in this interconnected and significantly richer world, in which the Coral Triangle countries share, especially the three larger ones.

One problem that at some stage appeared to be intractable was the different time horizons of human communities and the democratic political systems that remained in charge as the 2050 world took shape. The main weakness that may be alleged about democratic systems is that their idea of time is truncated unless visionary forces emerge to convince politicians to look further ahead, or sufficient evidence has helped to build up evidence that can no longer be ignored (as appeared to be happening with climate change as the first decade of the 21st century drew to an end).

It was always acknowledged that it would be difficult to see any actual differences for twenty or thirty years in the outcomes of adopting environmentally sensitive global policies versus a full-speed-ahead economic growth regime. This highlights the difference between what amounts to something approaching a generation of human life, and the normal three-to-five year electoral cycle of political systems that places a premium on short-term political gain. The political conundrum of the two time horizons began to be solved when the politicians and their electors themselves realized that it existed, sometime during the early years of the 21st century.

Perhaps the most powerful lever to overcome the conundrum was a shortening of the time horizon. Climate change became a problem not just affecting some unborn descendants of ours but the much more urgent one affecting our children – or even ourselves during our lifetimes. Another helpful factor was the realization that we could do something about it within our interconnected international system.

There was another growing insight which again amounted to a sea change in perception. It had to do with the use of our resources. For two centuries, industrialists had grabbed irreplaceable natural resources such as minerals and ecosystems and used them to produce ever-increasing levels of human consumption objects. This consumption was simply recorded as economic growth without accounting for any depletion of our non-renewable natural wealth.

The added damage caused by sending our greenhouse gases into the atmosphere remained equally unpaid in our economic accounts, until Lord Nicholas Stern in 2006 branded them as the greatest market failure ever encountered in our capitalistic economic system. A market failure which humankind now pays for dearly as a result of the atmospheric and other pollution caused by a small but powerful number of industries.

Meanwhile, other forms of economic capital had been recognized in the form of physical infrastructure, human skills, and cultural assets – capital which was belatedly seen to be able to help develop substitutes for at least some of our irreplaceable natural capital.

The world in 2050 benefits crucially from this realization by relying on a strong physical, human and cultural capital base while acting increasingly gently in the use of precious ecosystems and other natural resources, especially the atmosphere. This is particularly beneficial to human communities in what had been the developing world in the 20th century but have emerged as economically viable partners in the world of the 21st.

This doesn't mean that all areas become equal. Coastal areas next to the Coral Triangle countries in many cases remain relatively poor in economic terms in 2050. But the communities are sustainable and the access to assistance through international and national organizations and NGOs, as developed since the mid 20th century, remains strong.

The following snapshot is based on a '2050 perspective', refers to the 'Global environmental focus" B1 scenario heading towards a 2.20C increase by 2100:

- The countries of the Coral Triangle experience a moderate rate of growth in GDP per head, despite the impacts of climate change on resources, and the impact of a growing population. Average income has increased, as have life expectancy and literacy in the poorer nations. Sabah and other mainly inland parts of countries along the Coral Triangle have succeeded in combining traditional values and increased prosperity in a greening environment.

- The ability of coastal people to feed themselves from artisanal fishing has declined due to the reduced productivity of coastal regions. Communities here have been disrupted by steady sea level rise that has interrupted water supplies and led to the inundation of their homes and businesses. Migration towards cities has increased although it is much less than in the A1 story. Maintenance of coastal resources allows many cultures to thrive and play a major role in communities in the region. This leads to local management of marine protected areas in much of the coastal regions of the Coral Triangle, with an estimated 30% of all regions under some form of protection.

- Small-scale fisheries decline, although the implementation of marine protected areas reduces this decline significantly, albeit at about 50% of where they were in 2009. There is a steady increase in aquaculture, which occurs under the watchful eye of local communities and governments, who are now looking out for long-term sustainable yields as opposed to quick financial returns.

- Commercial fishing expands up until 2020 when, due to sharp decreases in fish stocks or species such as tuna, a region-wide agreement is struck with respect to the fisheries of the Coral Triangle. This leads to sustainable harvesting through an adaptive management cycle and regulation of stocks at lower but sustainable levels across the Coral Triangle. Region-wide cooperation on fisheries also discourages undocumented harvesting through the aquarium fish and live fish trades, with agreement struck up with richer Asian neighbours such as China and Singapore to reduce demand for unsustainable seafood.

- Sea levels rise by 50 cm by 2050 and cause inundation of coastal areas, with moderate loss of coastal infrastructure and water supplies. In addition to sea level rise, warmer and more acidic seas impact coral reefs, mangrove and seagrass ecosystems. These problems are as significant by

2050 as they were in the A1 storyline, but will be significantly lower by 2100 due to the measures used to stabilise atmospheric carbon dioxide at or below 450 ppm. By the end of the century, the stabilisation of carbon dioxide lead to the expansion of some ecosystems such as coral reefs and mangroves back into many areas.

- While increasing numbers of people move towards urban centres by 2050 (as in the A1 storyline), timely interventions by governments in the region reduce the extent of this movement and associated problems. Continued advances in birth control lead to lower rates of growth of human populations in the coastal zone. The pressure on urban centres is also reduced by the implementation of more locally-based and sustainable management of coastal resources. This leads to a slower decline in coastal productivity, and the maintenance of many of the benefits associated with coastal ecosystems well into the middle of the century.

- This regional and local effort to value and sustain coastal resources avoids some of the worst problems that were looming in the Solomon Islands and areas of PNG. Implementation of adaptive fisheries management, new technologies such as fish attraction devices, marine protected areas and the growth of sustainable aquaculture help maintain food security within these regions.

- The regional pressures placed on Coral Triangle countries leads to a number of commitments and accords which bind nations which otherwise have different histories and cultures together. The enthusiasm for cooperation and collaboration from richer countries such as Australia, the US and New Zealand leads to effective regional agreements and activities that eliminate many of the challenges that existed in 2009. The more benign climate change scenario associated with B1 ensures that countries that are rich today still retain resources to assist in the development of the Coral Triangle region.

- The role of the Coral Triangle in protecting tropical biodiversity increases as a result of the regional cooperation, and the binding international partnerships. As a result of the stern action on local factors through regional and national conservation programs, the loss of biodiversity has been contained to 30% - meaning that 70% of the rich biodiversity of the Coral Triangle remains in 2050.

FINAL NOTE ON SUSTAINING ECONOMIC GROWTH INTO THE FUTURE

The IPCC scenarios were all based on assumptions that incomes would increase through the 21st century, especially the economics-driven global A1 scenarios which also assumed a convergence in incomes per capita between developed and developing countries. Income growth was assumed to be less, but still substantial, in the global environmentally-orientated scenario, B1, which in updated form is our best case.

As climate change prospects have deteriorated, grave doubts have arisen about the sustainability of the A1 scenarios much beyond the next few decades. The fossil-intensive version could run into a brick wall by 2060 and the balanced A1B version later in the century. Long before that happened, economic growth could decline and turn negative. The best case for sustained growth is B1, as modified for this project.

The generally lower-income coral reef regions in the three major countries (Sabah, eastern Indonesia, and south-western Philippines) should be able to benefit from higher incomes in the nation to which they belong to and receive support. This would depend on convincing the respective national governments of the importance of preserving (a) the ecosystems and (b) threatened coastal communities.

While growth rates have been apparently strong for some of the small countries in the east, their prospects could be fragile. International aid would be needed to help them, in view of their least-developed status among developing countries.

SUMMARY

In exploring these scenarios, it becomes increasingly apparent that doing nothing will have direct impact on the lives of tens of millions of coastal dwelling people within the Coral Triangle, not to mention the rest of the world. Even if the worst of the worst scenarios, assuming rapid economic growth with a continued reliance on fossil fuels, doesn't eventuate, millions will remain impoverished, disadvantaged and highly vulnerable to the impacts of climate change. Those people who will be hit hardest by climate change will be least capable of counteracting its effects. Rising sea levels will destroy coastal infrastructure through elevated storm surges while the inundation of salt water into coastal aquifers will put extreme pressure on water resources in the region. Changing rainfall patterns will mean more expensive and destructive deluges in some parts, and extreme water shortages in other parts of the Coral Triangle.

Global climate change will also continue to imperil natural ecosystems such as coral reefs and mangroves, which underpin the food security of millions of people in the Coral Triangle. Coupled with increasing local threats such as overfishing, pollution and declining water quality, rapidly warming and acidifying oceans will continue to accelerate the loss of these crucial resources. At the current rate of loss (1-2% per year, Bruno and Selig 2007), less than 30% of these ecosystems will remain functional in 2050. This will have serious implications for the food and resources of the descendants of the current 150 million people in the Coral Triangle. With the widespread destruction of their homes, food sources and employment, tens of millions of people will drift towards already crowded cities in the region. This will put further pressure on social systems, and in the 'business-as-usual' scenario which is largely reflected in the 'A1' case will eventually lead to chronic poverty and disease on a scale that this region has not seen.

There is one very clear message from this study, and that is that current growth of atmospheric carbon dioxide is unsustainable and risks the lives of tens of millions of people in the Coral Triangle by the latter part of the century, and many more worldwide. To avoid this, the international community must commit to a complete restructuring in the way energy is generated, how we undertake agriculture and protect the forests.

The second message from the study is that important time can be bought if we begin to deal with the slew of other more local factors that are bringing about the demise of critically important coastal ecosystems like coral reefs. As has been outlined in previous parts of this report, there is overwhelming evidence that reducing local pressures on coastal ecosystems such as coral reefs and mangroves will retain the resilient abilities of these ecosystems to bounce back from the impacts of a changing climate. Without these steps to deal with local factors, the ability of coastal ecosystems to survive climate change and re-flourish in the decades and centuries beyond today will be severely compromised.

CHAPTER 10
POLICY IMPLICATIONS

In this section based on the key vulnerabilities identified in previous sections of this report, we will describe appropriate local, national, regional and international adaptation responses, as well as the policy actions that are urgently needed at the national, regional and international scales.

TAKING ACTION NOW TO AVOID CALAMITY LATER

In the previous chapters, one gets a strong sense of the urgent situation we are in today regarding the effects of climate change in the Coral Triangle. When confronted with challenges like these it is often preferable to avoid making a decision, or ignore the problem and shift attention to more traditional concerns. Unfortunately the issue of climate change will not resolve itself and avoiding the problem will only allow it to become more onerous.

Examination of the key vulnerabilities in the Coral Triangle leads us to propose two main strategies: mitigation and adaptation. Mitigation is reducing the cause of climate change by reducing greenhouse gas emissions and adaptation is limiting the effects of climate change. With both strategies we must remember that we are not powerless to act on climate change, regardless of our position on the planet or role in governance. There are mitigation and adaptation opportunities for everyone.

Planning for adaptation to climate change can be thought of in terms of the various response options to these key vulnerabilities. However, no plan should be created for a single vulnerability in a single location, rather effective planning requires that the various responses we can imagine be woven together into a fabric that is composed of actions that work together to provide the greatest adaptive benefit for the greatest number of vulnerabilities or the highest priority vulnerabilities.

ADAPTATION RESPONSES

Adaptation planning can begin by considering three questions:

1. What are the key vulnerabilities to the Coral Triangle? These need to be broken down into exposure; sensitivity of communities and ecosystems to increased CO_2 concentrations; and ability to respond to the anticipated impacts.

2. How could we respond to these vulnerabilities to reduce them? Or if they are imminent impacts, how can society prepare for them? Can we increase resilience of CT ecosystems and societies to future impacts by taking actions today?

3. What types of actions should start being implemented today to facilitate these responses at the local, national, regional and international levels? What are the no regrets actions we can take today which will improve ecosystem health and productivity in the near term while enhancing resilience to future impacts and which are least cost solutions to the problems we are trying to address?

4. As described in the previous chapters of this report, the key climate change vulnerabilities, or priority issues, for the Coral Triangle include environmental and human livelihood challenges (Box 1).

Box 1: Key Climate Change Vulnerabilities for the Coral Triangle

Environmental challenges
- Increasing sea temperatures
- Ocean acidification
- Sea level rise
- Longer and more intense floods and droughts
- More intense cyclones and other storms
- Loss of mangroves, seagrasses and coral reefs
- Interaction among these factors and with other traditional stresses (such as destructive fishing, overexploitation, deforestation, infilling and water quality/pollution/sewage)

Human livelihood challenges
- Increased vulnerability of coastal communities,
- Reduced food security,
- Changes in fish yields and distribution of fish stocks,
- Social disruption,
- Damage to infrastructure
- Impacts to human health and safety
- Deteriorating regional security

To limit these vulnerabilities there needs to be a combination of local and regional adaptation action, and local, regional and global policy efforts to support both adaptation and mitigation. To begin, there are some international priority actions that apply globally:

- Peak emissions before 2020. In order to limit global warming to less than 2˚C above pre-industrial temperatures to avoid more dangerous climate change, global emissions should peak well before 2020 and be reduced by more than 90% below 1990 levels by 2050.

- Push for an aggregate group reduction target for developed countries of 40% below 1990 levels by 2020, and for developing countries a reduction from business as usual of at least 30% by 2020.

- Support and fund adaptation. Create an adaptation and risk prevention framework for the most vulnerable with an operational and adequately resourced Adaptation Fund. This should also include an insurance mechanism to cover the damages or responses to unavoidable and catastrophic effects.

- Give countries in the region a greater say in identifying the interventions and targeting the financing according to their own priorities for adaptation.

There are also some national and regional priority actions that that will apply to all countries in the Coral Triangle and are part of the solutions for all of the key vulnerabilities:

- Limit the rate and extent of sea level rise by implementing national climate change mitigation policy to stabilize atmospheric CO_2 concentrations at levels not higher than 430-450 ppm by the end of this century.

- Reassess conservation and development strategies to determine their vulnerability to climate change and redesign them as necessary. Mainstream adaptation planning and climate resilience into economic development planning over the near, medium and long term –taking into particular account investments in infrastructure and energy stocks.

- Develop multi-sectoral national and regional adaptation strategies balancing conservation and development plans to maximize sustainability in the face of climate change.

- Develop stakeholder and community engagement processes with respect to adaptation. Affected parties need to be part of the creation and implementation of adaptation solutions in order for them to be equitable and effective. Fundamentally, it will be local knowledge that generates the innovative adaptation strategies that may prove most successful.

- Extend and strengthen regional networks of representative large-scale marine protected areas and community managed areas in places that demonstrated increased potential for resistance and resilience to climate change. These sites should include a range of marine and coastal habitats. They can act as stepping stones for species movement in response to climate change and simultaneously support human responses to climate change.

- Employ ecosystem-based management of the region's seas and coastal areas to protect vital ecosystem services which will be essential to coping with an uncertain and challenging future. Protect marine biodiversity and implement more sustainable fisheries management as no-regrets actions to address current declines in productivity and adapt to future challenges of climate change.

There are also actions to specifically address each of the key vulnerabilities. In many cases can be taken at the local level by resource manager and communities, while in others they will require national, regional or international support to implement. Here we explore each of the vulnerabilities and offer a number of examples of the types of actions that could be taken to address each. These lists are not intended to be prescriptive or exhaustive. Rather, these lists aim to stimulate local thinking and catalyze action to address these challenges. Real adaptation plans will require holistically thinking that considers all of the relevant vulnerabilities in a given location and the combination of actions that can address them.

ENVIRONMENTAL IMPACTS

PRIORITY ISSUE: INCREASING SEA TEMPERATURE

Adaptation Concepts

- Develop risk management responses to bleaching responses in regions of high value (e.g. shading, close access)
- Reduce local non-climate stresses and thereby increase ecological resilience to effects of warming
- More radical efforts to decrease temperature (e.g. upwelling tubes)
- Increase protection of more resilient reefs or refuge reefs (e.g. those in regions of high flow, naturally cooler or other ameliorating conditions)

PRIORITY ISSUE: OCEAN ACIDIFICATION

Adaptation Concepts

- Use information about ocean acidification as an additional lever to expedite significant CO_2 emissions reductions. This can be through appeals by resource managers and resource users (fishers, dive operators) to policy makers regarding how impossible their tasks become in light of this new challenge.
- Reduce other non-climate stresses and ameliorate other climate stresses to increase resilience to early pH shifts

National/Regional Actions

- Significant and rapid implementation of national greenhouse gas emissions reductions in order to quickly limit additional acidification.

PRIORITY ISSUE: SEA LEVEL RISE

Adaptation Concepts

- Protect coastal features that protect shoreline including mangroves and reefs
- Plan new coastal protection and development with sea level rise projections in mind
- Prepare contingency plans for exiting protection (parks, reserves, environmental regulations) and development in light of climate change
- Plan for inland movement of natural and built communities

PRIORITY ISSUE: LONGER AND MORE INTENSE FLOODS AND DROUGHTS

Adaptation Concepts

- Map vulnerability and model changes in precipitation patterns according to best available data
- Prepare water use plans, coastal management plans and development plans to include this range of uncertainty

National/Regional Actions

- Development of regional emergency monitoring systems and response plans, including early warning systems
- Creation of regional disaster plans for people and the environment

PRIORITY ISSUE: MORE INTENSE CYCLONES AND SEVERE STORMS

Adaptation Concepts

- Protect attributes that protect shoreline including mangroves and reefs
- Protect replicate systems to share risk
- Develop infrastructure for this greater threat

National/Regional Actions

- Development of regional emergency monitoring systems and response plans
- Creation of regional disaster plans for people and the environment

PRIORITY ISSUE: INTERACTIONS AMONG CLIMATE PRIORITY ISSUES

Adaptation Concepts

- Develop adaptation planning in a multi-sectoral manner to avoid missing interactions between vulnerabilities and leverage solutions to solve multiple challenges in a unified manner
- Implement and monitor adaptation along multi-sectoral lines to avoid or decrease unintended consequences.
- Carry out cost-benefit analysis of different options and of consequences of delaying action to help prioritize and sequence interventions

National/Regional Actions

- Regional strategies and agreements to reduce transboundary stressors and increase regional resilience

PRIORITY ISSUE: INTERACTIONS BETWEEN CLIMATE CHANGE AND NON-CLIMATE STRESSORS

Adaptation Concepts

- Stricter actions and regulations to reduce non-climate stressors (coastal deforestation, infilling, declining water quality, pollution, sewage, destructive fishing, overexploitation of marine life)
- Planning for reduction of any of these stressors should explicitly include the vulnerability and exacerbating effects of climate change.

National/Regional Actions

- National regulations to address non-climate stressors that include additional pressure from climate change exacerbating impacts
- Regional strategies and agreements to reduce transboundary stressors and increase regional resilience.

PRIORITY ISSUE: MANGROVE FOREST VULNERABILITY

Adaptation Concepts

- "Restore" mangroves using more robust species
- Protect land behind current mangroves for migration inland of mangrove systems, working with local communities

National/Regional Actions

- Stop non-climate related mangrove damage (harvest, clearing)
- Support mangrove restoration actions
- Create and maintain adequate protected/buffer zones to allow for inland migration of mangroves with sea level rise
- Create regional plans to prepare for or facilitate mangrove species range shifts or compositional changes due to climate change

PRIORITY ISSUE: SEAGRASS COMMUNITY VULNERABILITY

Adaptation Concepts
- "Restore" seagrass beds with an eye toward emerging conditions (plant appropriate species in appropriate locations), working with local communities
- Reduce damage to seagrass communities
- Incorporate sea grass protection into coastal zone management

National/Regional Actions
- Stop non-climate related damage to sea grass and mangroves
- Support mangrove restoration actions
- Develop methods to regenerate sea grass
- Create regional plans to prepare for or facilitate seagrass species range shifts or compositional changes due to climate change

HUMAN LIVELIHOOD IMPACTS

PRIORITY ISSUE: INCREASING VULNERABILITY OF COASTAL COMMUNITIES

Adaptation Concepts
- Protect coastal buffers (mangroves, reefs)
- Provide technical and financial support for communities to plan and redesign for greater resilience
- If unavoidable, communities should consider relocation early rather than later, especially of most vulnerable communities, in order to avoid chaos and loss of life

PRIORITY ISSUE: REDUCED FOOD SECURITY

Adaptation Concepts
- Provide technical and financial support for communities to develop alternative livelihoods, begin shifting resource use prior to crisis
- Limit all non-climate stressors to maximize food resource protection and prolong access to food for communities
- Increase household resilience by diversifying sources of income and creating community safety nets

Related Issue
Change in fish yields and distributions of fish stocks

Adaptation Concepts
- Improve rotational management to maximize sustainability of yields
- Consider fisheries or reef closures, such as those employed in managed areas such as the Great Barrier Reef
- Early development of alternative livelihoods and food sources, especially protein
- If needed, preparation for movement of human populations in search of new food resources

National/Regional Actions
- Regional agreements to manage fisheries, including life history stages, to maintain fisheries as long as possible under a changing climate (includes protection of early life stages, locally managing catch limits as part of large schemes)

PRIORITY ISSUE: SOCIAL DISRUPTION

Adaptation Concepts

- Develop alternative livelihoods
- Proactive contingency planning developed by affected parties, not third parties, prior to crises
- Design social safety nets to help most vulnerable members of the community
- Funding mechanisms created in advance of crises

National/Regional Actions

- Regional disaster plans
- Intergovernmental, transboundary agreements to facilitate changes in communities as they follow the resources they require to sustain life, or avoid the damages wrought by climate change.

PRIORITY ISSUE: DAMAGE TO INFRASTRUCTURE

Adaptation Concepts

- Prepare funding mechanism for repair, relocation or reconsideration of vulnerable and damaged infrastructure
- Encourage development of less vulnerable infrastructure

National/Regional Actions

- Develop national and regional infrastructure guidelines and development plans to reduce vulnerability to and risk from climate change in all new investments.

PRIORITY ISSUE: IMPACTS TO HUMAN HEALTH AND SAFETY

Adaptation Concepts

- Review existing health and safety plans and revise if not appropriate for potential effects of climate change. If no plans exist, create them with climate change implicit in the thinking.
- Prepare public health and safety plans in preparation for emergencies, including disease outbreak, extreme weather events and famine.

National/Regional Actions

- Regional public health planning to manage disease and vectors.
- Regional support and funding apparatus to support neighbors in times of crisis and manage regional conditions cooperatively.

PRIORITY ISSUE: DETERIORATING REGIONAL SECURITY

Adaptation Concepts

- Proactive planning

National/Regional Actions

- Creation of safety nets that foster cooperation and mutual benefit between countries, regions and sectors, rather than animosity.
- Planning for human migration and resource shortages.

URGENT ACTIONS

With the worsening of impacts in real time as a result of climate change, we need to take real action now. First we must prioritize significant CO_2 emissions reductions in order to reduce the severity of the effects we can expect; keeping us on a track with the best case scenario rather than a worst case scenario. This is essential as even the best case scenario is rife with challenges and potential losses to both human communities and natural resources in the region. Delaying action on mitigation will result in insurmountable change. Second, we cannot plan for adaptation after we finish mitigation agreements. Delaying action on adaptation will result in missed opportunities, reduced options and a more daunting task with less chance of success.

1. **Create a binding international agreement to reduce the rate and extent of climate change**. To do this, emissions should peak no later than 2020, and global warming limited to less than 2°C above pre-industrial temperatures (i.e. atmospheric $CO_2 < 450$ ppm) by 2100. This will require steep global cuts in emissions that are 80% below 1990 levels by 2050. Inherent to this recommendation is the creation of an aggregate group reduction target for developed countries of 40% below 1990 levels by 2020, and a reduction from business-as-usual emission levels for developing countries of at least 30% by 2020.

2. **Take immediate action to establish national targets and plans to meet these commitments such that the international agreement can be achieved.** This report shows that nations in the Coral Triangle region have a great deal at stake if climate change continues unchecked. They must become part of the solution and must do this expeditiously. Lag-times and non-linear responses in the climate system mean that every day we wait to take action, the problem becomes dramatically more difficult and costly to address successfully.

3. **Pursue the establishment of integrated coastal zone management across the region** to reverse the decline of the health of coastal ecosystems. This should include implementation of policies that eliminate deforestation of coastal areas and river catchments, reduce pollution, expand marine protected areas, regulate fishing pressures and abolish destructive practices. It is important that these actions not aim to restore or protect ecosystems for past conditions, rather they must prepare for conditions under a changing climate.

4. **Support the establishment of a global fund to meet the adaptation needs of developing countries.** While some of the cost of adapting to climate change can be met by redirecting current resources that are being used in a manner that is vulnerable to climate change, the growing challenge of climate change will result in new and increasing costs. Funds will be required to meet these costs given the nature of the problem and that the disproportionate brunt of the hardship caused by the problem is borne by developing countries. International funds will be necessary to meet these needs.

5. **Build adjustable financial mechanisms into national budgeting to help cover the increasing costs of adaptation to climate change.** Climate change will require not only new funds, but also a reassessment of current spending so that funds are not spent in ways that are not 'climate-smart', in other words on efforts that are not resilient to climate change. Every effort should be made to avoid spending funds and taking actions that exacerbate the problem of climate change

6. **Establish governance structures that integrate resource and development management to provide robust protection of both in the face of climate change.** Adaptation plans cannot be developed on a sector-by-sector basis. Doing so risks creating problems such as adaptation being effective against one issue but maladaptive against another. It will be important to plan holistically and create governance structures that can support, implement and monitor these efforts.

7. **Build the socio-ecological resilience of coastal ecosystems and develop stakeholder and community engagement processes for communities to improve their ability to survive climate change impacts.** Involving coastal people and communities in planning provides greater stability and efficacy for solutions to social and ecological systems within the Coral Triangle. Fundamentally, it will be local knowledge that generates innovative adaptation strategies which may prove most successful. Reducing the influence of local stress factors on coastal ecosystems makes them able to better survive climate change impacts. Protecting the diversity of components (communities, populations, and species) under the guidance and actions of local people strengthens the resolve of these systems in the face of climate change.

8. **Critically review and revise conservation and development efforts at the local, national and regional levels for their robustness in the face of climate change.** Business-as-usual conservation and development will not achieve success. The new mode of action requires integration between conservation and development, and the realisation that many past approaches are no longer effective due to the impacts of climate change.

9. **Build capacity to engage in planning for climate change.** Climate change planning, both mitigation and adaptation, will require that we educate current and future practitioners, as well as the concerned constituencies. Mechanisms must be created to develop current resource managers and planners so that they can immediately implement these new approaches. As the problem of climate change is not one that we will be solving in this generation, planning and responses to climate change will be iterative as the target continues to move over the coming centuries. Therefore, it will also be necessary to develop training for future capacity through education in academic settings. Informed stakeholder and community engagement is at the core of successful adaptation, so in addition to professionals and students, civil society must be given access to the information they need to understand and respond to climate change.

10. **Focus adaptation on playing a role in economic stimulus, especially in job creation and financial mobilisation.** Private-public sector incentive schemes, regional/international arrangements and investment partnerships (e.g. national insurance reform and special-access loan schemes) need to better incorporate risk management and adaptation strategies to reduce investment risk and maintain positive financial conditions.

REFERENCES

Aaheim A, Sygna L (2000) Economic impacts of climate change on tuna fisheries in Fiji Islands and Kiribati. Cicero

Adger WN (2000) Social and Ecological resilience: are they related? Progress in Human Geography 24:347-364

Adnyana W, Pet-Soede L, Gearheart G, Halim M (2008) 'Status of green turtle, Chelonia mydas, nesting and foraging populations of Berau, East Kalimantan, Indonesia, including results from tagging and telemetry'. Indian Ocean Turtle Newsletter 7:2-11. January. http://www.seaturtle.org/iotn/iotn7_1.html

Alcala A, Gomez E (1987) Dynamiting coral reefs for fish: a resource-destructive fishing method Human impacts on coral reefs: Facts and recommendations, ed B Salvat (pp 51–60) Moorea French Polynesia: Antenne Museum Ecole Pralique des Haute Etudes, pp51-60

Alcala A, Russ G (2002) Status of Philippine coral reef fisheries. Asian Fisheries Science 15:177-192

Alcala A, Russ G, Maypa A, Calumpong H (2005) A long-term, spatially replicated experimental test of the effect of marine reserves on local fish yields. Canadian Journal of Fisheries and Aquatic Sciences 62:98-108

Alcala AC (2008) Proceedings of the Conference on the Results of the Philippines-Vietnam Oceanographic and Marine Scientific Research Expedition in the South China Sea (JOMSRE-SCS I to IV), 26-29; Alcala, AC (editor) Halong City, Oceanfriends Foundation, Silliman University Press, 195 pp.

Aliño P, M. (2002) Philippine Coral Reef Fisheries – Challenges and Frustrations. http://www.unuftp.is/pdf/Philippine%20Coral%20Reef%20Fisheries.pdf

Allen AP, Gillooly JF (2006) Assessing latitudinal gradients in speciation rates and biodiversity at the global scale. Ecology Letters 9:947-954

Allen GR (2008) Conservation hotspots of biodiversity and endemism for Indo-Pacific coral reef fishes. Aquat Conserv Mar Freshw Ecosyst 18:541-556

Allison E, Adger W, Badjeck M, et al. (2005) Effects of climate change on the sustainability of capture and enhancement fisheries important to the poor: analysis of the vulnerability and adaptability of fisherfolk living in poverty. Fisheries Management Science Programme London, Department for International Development Final Technical Report Project:167

Allison E, Perry A, Badjeck M, et al. (2009) Vulnerability of national economies to the impacts of climate change on fisheries. Fish and Fisheries 9999

Alongi D (2002a) Present state and future of the world's mangrove forests. Environmental Conservation 29:331-349

Alongi DM (2002b) Present state and future of the world's mangrove forests. Environmental Conservation 29:331-349

Alongi DM (2008) Mangrove forests: Resilience, protection from tsunamis, and responses to global climate change. Estuarine, Coastal and Shelf Science 76:1-13

Anthony KR, Kline DI, Diaz-Pulido G, Dove S, Hoegh-Guldberg O (2008) Ocean acidification causes bleaching and productivity loss in coral reef builders. Proc Natl Acad Sci U S A 105:17442-17446

Arulpragasam J, Alatas V (2006) Making the New Indonesia Work for the Poor. World Bank Office Jakarta and World Bank. http://indopov.org

Augustin L, Barbante C, Barnes P, R., F., et al. (2004) Eight glacial cycles from an Antarctic ice core. Nature 429:623-628.

Baldwin A, Egnotovich M, Ford M, Platt W (2001) Regeneration in fringe mangrove forests damaged by Hurricane Andrew. Plant Ecology 157:151-164

Ball IR (2000) The Dynamics of Tree Hollows and the Design of Nature Reserves. PhD Thesis, University of Adelaide. http://www.ecology.uq.edu.au/docs/theses/Ball-MathematicalApplicationsforConsEcology.pdf

Ball M, Cochrane M, Rawson H (1997) Growth and water use of the mangroves Rhizophora apiculata and R. stylosa in response to salinity and humidity under ambient and elevated concentrations of atmospheric CO_2. Plant, Cell & Environment 20:1158-1166

Bandaranayake W (1998) Traditional and medicinal uses of mangroves. Mangroves and Salt Marshes 2:133-148

Baran E, Hambrey J (1998) Mangrove conservation and coastal management in southeast Asia: What impact on fishery resources? Mar Pollut Bull 37:431-440

Bartholomew JG, Clark WE, Grimshaw PH (1911) Atlas of Zoogeography. Bartholomew, Edinburgh

Bell J, Kronen M, Vunisea A, et al. (2009) Planning the use of fish for food security in the Pacific. Marine Policy 33:64-76

Bindoff NL, Willebrand J, Artale V, et al. (2007) Observations: oceanic climate change and sea level. In Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Solomon S, Qin D, Manning M, Chen Z, Marquis M, Averyt KB, Tignor M, Miller HL PY - eds)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp 387-432

Bjork M, Short E, McLeod E, Beer S (2008) Managing seagrasses for resilience to climate change. IUCN Resilience Science Group Working Paper Series - No. 3. Gland, Switzerland. 56pp.

Blanchon P, Shaw J (1995) Reef drowning during the last deglaciation; evidence for catastrophic sea-level rise and ice-sheet collapse. Geology 23:4-8

Blanchon P, Eisenhauer A, Fietzke J, Liebetrau V (2009) Rapid sea-level rise and reef back-stepping at the close of the last interglacial highstand. Nature 458:881-884

Briggs JC (1984) Centers of biogeography University of Leeds

Briggs JC (2005) The marine East Indies: Diversity and speciation. J Biogeogr 32:1517-1522

Brodie J, Fabricius K, De'ath G, Okaji K (2005a) Are increased nutrient inputs responsible for more outbreaks of crown-of-thorns starfish? An appraisal of the evidence. Marine Pollution Bulletin 51:266-278

Brodie J, Fabricius K, De'ath G, Okaji K (2005b) Are increased nutrient inputs responsible for more outbreaks of crown-of-thorns starfish? An appraisal of the evidence. Marine Pollution Bulletin 51:266-278

Brower K (1989) State of the Reef. . Audubon 3:57-81

Brown B, Suharsono (1990) Damage and recovery of coral reefs affected by El Nino related seawater warming in the Thousand Islands, Indonesia. Coral Reefs 8:163-170

Bruno JF, Selig ER (2007) Regional decline of coral cover in the indo-pacific: timing, extent, and subregional comparisons. PLoS ONE 2:e711

Burke L, Selig L, Spalding M (2002) Reefs at Risk in Southeast Asia. World Resources Institute, Washington DC

Cahoon D, Hensel P, Rybczyk J, Perez B (2003a) Hurricane Mitch: Impacts on Mangrove Sediment Elevation Dynamics and Long-Term Mangrove Sustainability. US Geological Survey Open File Report:03-184

Cahoon D, Hensel P, Rybczyk J, et al. (2003b) Mass tree mortality leads to mangrove peat collapse at Bay Islands, Honduras after Hurricane Mitch. Journal of Ecology 91:1093-1105

Cairns SD (2007) Deep-water corals: An overview with special reference to diversity and distribution of deep-water scleractinian corals. Bulletin of Marine Science 81:311-322

Caleb C (2008) The use of EIA in addressing climate change

Canadell JG, Le Quere C, Raupach MR, et al. (2007) Contributions to accelerating atmospheric CO_2 growth from economic activity, carbon intensity, and efficiency of natural sinks. Proceedings of the National Academy of Sciences of the United States of America 104:18866-18870

Cao L, Caldeira K, Jain AK (2007) Effects of carbon dioxide and climate change on ocean acidification and carbonate mineral saturation. Geophys Res Lett 34:5

Capone DG (2001) Marine nitrogen fixation: what's the fuss? Current Opinion in Microbiology 4:341-348

Carpenter K, Abrar M, Aeby G, et al. (2008) One-Third of Reef-Building Corals Face Elevated Extinction Risk from Climate Change and Local Impacts. Science 321:560

Carpenter KE, Springer VG (2005) The center of the center of marine shore fish biodiversity: the Philippine Islands. Environmental Biology of Fishes 72:467-480

Cesar H, Burke L, Pet-Soede L (2003) The economics of worldwide coral reef degradation. Cesar Environmental Economics Consulting (CEEC)

Cesar H, Lundin CG, Bettencourt S, Dixon J (1997) Indonesian Coral Reefs: An Economic Analysis of a Precious but Threatened Resource. Ambio 26:345-350

Cesar H, Warren K, Sadovy Y, et al. (2000) Marine Market Transformation of the Live Reef Fish Food Trade in Southeast Asia. Collected Essays on the Economics of Coral Reefs:137-157

Chang CP, Wang Z, McBride J, Liu CH (2005) Annual cycle of southeast Asia – maritime continent rainfall and the asymmetric monsoon transition. Journal of Climate 18:287-301

Chou LM (1994) Marine environmental-issues of southeast-asia - state and development. Hydrobiologia 285:139-150

Christensen JH, Hewitson B, Busuioc A, et al. (2007) Regional climate projections. In Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Solomon S, Qin D, Manning M, Chen Z, Marquis M, Averyt KB, Tignor M, Miller HL PY - eds)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp 847-940

Church J, White N (2006a) A 20th century acceleration in global sea-level rise. Geophysical Research Letters 33

Church JA, White NJ (2006b) A 20th century acceleration in global sea-level rise. Geophysical Research Letters 33, L01602, doi: 101029/2005GL024826

Church JA, White NJ, Hunter JR (2006) Sea-level rise at tropical Pacific and Indian Ocean islands. Global and Planetary Change 53: 155-168

CI (2008) Economic Values of Coral Reefs, Mangroves, and Seagrasses. A Global Compilation
CI (2009) Biodiversity Hotspots; www.biodiversityhotspots.org Conservation International Foundation; Arlington, VA. Accessed February 23, 2009

CIA (2008) CIA Fact Book Central Intelligence Agency, Washington, DC

CIA (2009) CIA Fact Book. Central Intelligence Agency, Washington, DC. Accessed March 2009
Cinner J, Daw T, McClanahan T (2009a) Socioeconomic Factors that Affect Artisanal Fishers' Readiness to Exit a Declining Fishery. Conservation biology 23:124-130

Cinner J, McClanahan T, Daw T, et al. (2009b) Linking Social and Ecological Systems to Sustain Coral Reef Fisheries. Current Biology 19:206-212

Clarke A (1992) Is there a latitudinal species diversity cline in the sea? Trends in Ecology and Evolution 7:286-287

Clement AC, Seager R, Murtugudde R (2005) Why are there tropical warm pools. Journal of Climate 18: 5294-5311

Cooper TF, De 'Ath G, Fabricius KE, Lough JM (2008) Declining coral calcification in massive Porites in two nearshore regions of the northern Great Barrier Reef. Glob Change Biol 14:529-538

Copland J, Lucas J (1988) Giant Clams in Asia and the Pacific. ACIAR Monograph Series No. 9:274

Coudray J, Montaggioni L (1982) Coraux et recifs coralliens de la province Indo-Pacifique: repartitiongeographique et altitudinale en relation avec la tectonique globale. . Bull Soc Geol Fr 24:981-993

Coutrier P (1988) Living on an Oil Highway. Ambio 17:186-188

Cressey D (2007) Arctic melt opens Northwest passage. Nature 449:267-267

Cruz R, Harasawa H, Lal M, et al. (2007) Asia. Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, ML Parry, OF Canziani, JP Palutikof, PJ van der Linden and CE Hanson, Eds. Cambridge University Press, Cambridge, UK

da Costa H (2003) 'The evolution of agricultural policies in East Timor'. http://www.gov.east-timor.org/MAFF/ta100/ta108.pdf

Dahdouh-Guebas F, Jayatissa L, Di Nitto D, et al. (2005) How effective were mangroves as a defence against the recent tsunami? Current Biology 15:443-447

Dahuri R (1999) Coastal zone management in Indonesia: issues and approaches. In Rais, J, Dutton, IM, Pantimena, L, Plouffe, J, Dahuri, R (eds) Integrated Coastal and Marine Resource Management Proc Inter Symp Malang, 1998, 60-72

Dana JD (1853) On an isothermal oceanic chart illustrating the geographical distribution of marine animals. Am J Sci 16:314-327

Darwin C (1859) The origin of species by means of natural selection, or the preservation of favoured races in the struggle for life. John Murray

De'ath G, Lough JM, Fabricius KE (2009) Declining Coral Calcification on the Great Barrier Reef. Science 323:116-119

de la Moriniere C, Pollux B, Nagelkerken I, et al. (2003) Ontogenetic dietary changes of coral reef fishes in the mangrove-seagrass-reef continuum: stable isotopes and gut-content analysis. Marine Ecology Progress Series 246:279-289

DFID Fisheries and livelihoods FMSP Policy Brief 4. http://www.mrag.co.uk/Documents/PolicyBrief4_Livelihoods.pdf

Done T, Whetton P, Jones R, et al. (2003) Global Climate Change and Coral Bleaching on the Great Barrier Reef. In: Department of Natural Resources QG (ed) Final Report to the State of Queensland Greenhouse Taskforce through the Department of Natural Resources and Mining, Donnelly R, Neville D, Mous P (2003) Report on a rapid ecological assessment of the Raja Ampat Islands, Papua, Eastern Indonesia held October 30-November 22, 2002. The Nature Conservancy-Southeast Asia Center for Marine Protected Areas, Sanur, Bali, Indonesia

Donner SD, Skirving WJ, Little CM, Oppenheimer M, Hoegh-Guldberg O (2005a) Global assessment of coral bleaching and required rates of adaptation under climate change. Glob Change Biol 11:2251-2265

Donner SD, Skirving WJ, Little CM, Oppenheimer M, Hoegh-Guldberg OVE (2005b) Global assessment of coral bleaching and required rates of adaptation under climate change

Duarte C, Cebrian J (1996) The fate of marine autotrophic production. Limnology and Oceanography 41:1758-1766

Duke N, Ball M, Ellison J (1998) Factors influencing biodiversity and distributional gradients in mangroves. Global Ecology and Biogeography Letters 7:27-47

Duke N, Bell A, Pederson D, Roelfsema C, Bengtson Nash S (2005) Herbicides implicated as the cause of severe mangrove dieback in the Mackay region, NE Australia: consequences for marine plant habitats of the GBR World Heritage Area. Marine Pollution Bulletin 51:308-324

Duke N, Meynecke J, Dittmann S, et al. (2007) A World Without Mangroves? Science 317:41-42

Dulvy N, Freckleton R, Polunin N (2004) Coral reef cascades and the indirect effects of predator removal by exploitation. Ecology Letters 7:410-416

Dyer K (1995) Response of estuaries to climate change. In: Eisma D (ed) Climate change: Impact on coastal habitation. CRC Press, Boca Raton, pp85-110

Eakin CM, Lough JM, Heron SF (2009) Climate, weather and coral bleaching. Chapter 4 in: Coral Bleaching. Patterns, Processes, Causes and Consequences, van Oppen MJH, Lough JM PY - eds), Springer-Verlag Ecological Studies, Vol. 205, pp. 41-67

Ehler C, Cicin-Sain B, Knecht R, South R, Weiher R (1997) Guidelines to assist policy makers and managers of coastal areas in the integration of coastal management programs and national climate-change action plans. Ocean and Coastal Management 37:7-27

Ekman S (1935) Tiergeographie des Meeres. . Akademische Verlagsgesellschaft, Leipzig

Ellison AM, Farnsworth EJ (1997) Simulated sea level change alters anatomy, physiology, growth, and reproduction of red mangrove (Rhizophora mangle L.). Oecologia 112:435-446

Ellison J (2008) Long-term retrospection on mangrove development using sediment cores and pollen analysis: A review. Aquatic Botany 89:93-104

Emanuel K (2005) Increasing destructiveness of tropical cyclones over the past 30 years. Nature 436:686-688

Epstein N, Bak R, Rinkevich B (2000) Toxicity of Third Generation Dispersants and Dispersed Egyptian Crude Oil on Red Sea Coral Larvae. Marine Pollution Bulletin 40:497-503

FAO (2009) “Fishery and Aquaculture Country Profile.” [Accessed 6 April 2009.] Fisheries and Aquaculture Department, Food and Agriculture Organization of the United Nations. Available at: <http://www.fao.org/fishery/countrysector/FI-CP_MY/en>

FAO/SEAFDEC (2005) Proceedings of the FAO/SEAFDEC Regional Workshop on the Improvement of Fishery Data and Information Collection Systems. Bali, Indonesia, 15-18 February 2005. Volume 1: Report of the Workshop

Faunce CHSJE (2006) Mangroves as fish habitat: 50 years of field studies. Mar Ecol Prog Ser 318:1-18

Faunce CHSJE (2008) Growth and secondary production of an eventual reef fish during mangrove residency. Estuar Coast Shelf Sci 79:93-100

Feely RA, Sabine CL, Lee K, et al. (2004) Impact of anthropogenic CO_2 on the CaCO3 system in the oceans. Science 305: 362-366

Fegan B (2003) 'Plundering the sea'. Inside Indonesia 73, Jan-Mar

Field C (1995) Impact of expected climate change on mangroves. Hydrobiologia 295:75-81

Forbes E (1856) Map of the distribution of marine life, Edinburgh

Fortes M (1995) Seagrasses of East Asia: Environmental and management perspectives. RCU/EAS Technical Report Series No. 6. UNEP, Bangkok.

GCP (2007) Global Carbon Project 2007, http://www.globalcarbonproject.org/carbontrends/index.htm, (accessed April 7, 2009)

George W (1964) Biologist philosopher: a study of the life and writings of Alfred Russel Wallace. Abelard-Schuman, London

George W (1981) Wallace and his line. In Whitmore, T.C. Wallace's Line and plate tectonics. Clarendon Press, Oxford

Gillett R, Lightfoot C (2001) The contribution of fisheries to the economics of Pacific Island Countries. A report prepared for the Asian Development Bank, the Forum Fisheries Agency, and the World Bank, 217 pp.

Gilman E (2004)... and managing coastal ecosystem response to projected relative sea-level rise and climate change. Prepared for the International Research Foundation for , 2004 ;0(0):0

Gilman E, Ellison J, Coleman R (2007) Assessment of Mangrove Response to Projected Relative Sea-Level Rise And Recent Historical Reconstruction of Shoreline Position. Environmental Monitoring and Assessment 124:105-130

Gilman EL, Ellison J, Duke NC, Field C (2008) Threats to mangroves from climate change and adaptation options. Aquatic Botany 89:237-250

Glantz M, Feingold L (1992) Climate variability, climate change, and fisheries: a summary. Climate Variability, Climate Change and Fisheries

Gomez E (1988) Overview of Environmental Problems in the East Asian Seas Region. Ambio 17:166-169

Gomez E, Mingoa-Licuanan S (2006) Achievements and lessons learned in restocking giant clams in the Philippines. Fisheries Research 80:46-52

Gordon A, Fine R (1996a) Pathways of water between the Pacific and Indian Oceans in the Indonesian seas. Nature 379:146-149

Gordon A, Dwi Susanto R, Ffield A (1999) Throughflow within Makassar Strait. Geophysical Research Letters 26:3325-3328
Gordon AL, Fine RA (1996b) Pathways of water between the Pacific and Indian oceans in the Indonesian seas. Nature 379:146-149

Graham NA, Wilson SK, Jennings S, et al. (2007a) Lag effects in the impacts of mass coral bleaching on coral reef fish, fisheries, and ecosystems. Conserv Biol 2007 Oct;21(5):1291-300

Graham NA, Wilson SK, Jennings S, et al. (2007b) Lag effects in the impacts of mass coral bleaching on coral reef fish, fisheries, and ecosystems. Conservation biology 21:1291-1300

Grandcourt E, Cesar H (2003) The bio-economic impact of mass coral mortality on the coastal reef fisheries of the Seychelles. Fisheries Research 60:539-550

Grave dS (2001) Biogeography of Indo-Pacific Pontoniinae shrimps (Crustacea: Decapoda): a PAE analysis J Biogeog 28:1239-1253

Green A, Lokani P, Atu W, et al. (2006) Solomon Islands Marine Assessment: Technical report of survey conducted May 13 to June 17, 2004. TNC Pacific Island Countries Report

Green A, Lokani P, Sheppard S, et al. (2007) Scientific design of a resilient network of marine protected areas. Kimbe bay, West New Britain, Papua New Guinea. TNC Pacific Island Countries Report No. 2/07. ISBN 9980-9964-7-1 http://conserveonline.org/workspaces/pacific.island.countries.publications/kimbebaycontents/kimbe

Green AL, Mous PJ (2008) Delineating the Coral Triangle, its Ecoregions and Functional Seascapes. Version 5.0. TNC Coral Triangle Program Report 1/08. 44 pp.

Green E, Short F (2003) World Atlas of Seagrasses. Prepared by the UNEP World Conservation Monitoring Centre. University of California Press, Berkeley. USA). 298pp

Gregory J, Dixon K, Stouffer R, et al. (2005) A model intercomparison of changes in the Atlantic thermohaline circulation in response to increasing atmospheric CO 2 concentration. Geophys Res Lett 32

Grigg R, Epp D (1989) Critical Depth for the Survival of Coral Islands: Effects on the Hawaiian Archipelago. Science 243:638-641

Groombridge B, Jenkins M (2002) World atlas of biodiversity. University of California Press London

Guinotte JM, Fabry VJ (2008) Ocean Acidification and Its Potential Effects on Marine Ecosystems. Annals of the New York Academy of Sciences 1134:320-342

Hajramurni A (2007) 'More than half of South Sulawesi coral reefs damaged: Report'. The Jakarta Post, Makassar. 24 August

Hales S, Weinstein P, Woodward A (1999) Ciguatera (fish poisoning), El Niño, and Pacific sea surface temperatures. Ecosystem Health 5:20-25

Hall C (1994) Tourism in the Pacific Rim: development, impacts, and markets. Addison-Wesley Longman Ltd, Melbourne, Australia

Halpern BS, Walbridge S, Selkoe KA, et al. (2008) A global map of human impact on marine ecosystems. Science 319:948-952

Hansen J, Sato M, Kharecha P, et al. (2008a) Target atmospheric CO_2: where should humanity aim? The Open Atmospheric. Science Journal 2: 217-231

Hansen J, Sato M, Kharecha P, et al. (2008b) Target atmospheric CO_2: Where should humanity aim? Atmospheric and Oceanic Physics eprint arXiv:0804.1126

Hansford D (2008) 'Starfish Swarm Devouring Corals in Indonesia'. National Geographic News. 17 January

Hargreaves-Allen V (2004) Estimating the Total Economic Value of Coral Reefs for Residents of Sampela, a Bajau Community in Wakatobi Marine National, Sulawesi: A Case Study. MSc Thesis, Facility of Life Sciences, Imperial College of Science, Technology and Medicine, London. Online at: <http://www.iccs.org.uk/thesis/Hargraves-AllenMSc%20Thesis.pdf>

Hidayat H (1999) Economic, social and cultural activities of the Aru Island in Southeast Maluku, Indonesia. http://www.iges.or.jp/en/fc/phase1/ir99/2-1-hida.pdf

Hoegh-Guldberg H (1997) 'Supermarket Price Survey' Attached to Indonesia Outlook Quarterly Update, February. <http://economicstrategies.files.wordpress.com/2009/04/supermarket-survey-for-web.pdf>

Hoegh-Guldberg H (1998a) Indonesia Outlook: Four Scenarios to 2008: The scenarios. <http://economicstrategies.files.wordpress.com/2009/04/indonesia-scenarios-for-web.pdf>

Hoegh-Guldberg H (1998b) Indonesia Outlook: Four Scenarios to 2008: Background <http://economicstrategies.files.wordpress.com/2009/04/indonesian-scenarios-background-for-web.pdf>

Hoegh-Guldberg H, Hoegh-Guldberg O (2004) Great Barrier Reef 2050: implications of climate change for Australia's Great Barrier Reef., Brisbane, Queensland 345

Hoegh-Guldberg O (1999) Climate change, coral bleaching and the future of the world's coral reefs. Mar Freshw Res 50:839-866

Hoegh-Guldberg O, Mumby PJ, Hooten AJ, et al. (2007) Coral reefs under rapid climate change and ocean acidification. Science 2007 Dec 14;318(5857):1737-42

Hoeksema B (2007) Delineation of the Indo-Malayan Centre of Maximum Marine Biodiversity: The Coral Triangle Biogeography, Time, and Place: Distributions, Barriers, and Islands, pp117-178

Hogarth PJ (1999) The Biology of Mangroves. Oxford University Press, Oxford, UK

Howes S, Bell E, Fox G, Gilling J, Pieper L (2006) Pacific 2020: Challenges and opportunities for growth. AusAID, Canberra, ACT, Australia.

Hughes TP (1994) Catastrophes, Phase Shifts, and a Large-Scale Degradation of Caribbean Coral Reef. Science 265:1547-1551

Hughes TP, Rodrigues MJ, Bellwood DR, et al. (2007) Phase shifts, herbivory, and the resilience of coral reefs to climate change. Curr Biol 2007 Feb 20;17(4):360-5 Epub 2007 Feb 8

Hughes TP, Baird AH, Bellwood DR, et al. (2003) Climate change, human impacts, and the resilience of coral reefs. Science 2003 Aug 15;301(5635):929-33

IGES (2008) Climate change policies in the Asia-Pacific: Re-uniting climate change and sustainable development. Institute for Global Environmental Strategies, Hayama, Kanagawa, Japan

IPCC (2007) Synthesis Report. Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. In: Team CW, Pachauri RK, Reisinger A (eds). Intergovernmental Panel on Climate Change, 2008, Geneva, Switzerland 104

Jackson JB, Kirby MX, Berger WH, et al. (2001) Historical overfishing and the recent collapse of coastal ecosystems. Science 2001 Jul 27;293(5530):629-37

Jasarevic T (2002) Reviving fisheries in East Timor - Casting nets for development. UN Volunteers; http://wwwunvorg/en/what-we-do/countries/timor-leste/doc/reviving-fisheries-in-easthtml

Johannes R, MacFarlane J, Fisheries CDo (1991) Traditional Fishing in the Torres Strait Islands. CSIRO Division of Fisheries

Johannes R, Riepen M, Ltd R, Associates FD (1995) Environmental, Economic, and Social Implications of the Live Reef Fish Trade in Asia and the Western Pacific. RE Johannes Pty. Ltd.; Fisheries Development Associates

Johannes RE (1981) Words of the Lagoon: Fishing and Marine Lore in the Palau District of Micronesia. University of California Press, 245 pp

Jokiel P, Martinelli FJ (1992) The vortex model of coral reef biogeography. Journal of Biogeography 19:449-458

Jones RJ, Hoegh-Guldberg O (1999) Effects of cyanide on coral photosynthesis: implications for identifying the cause of coral bleaching and for assessing the environmental impacts of cyanide fishing. Marine Ecology Progress Series 177:83-91

Karl TR, Meehl GA, Miller CD, et al. (2008) Weather and Climate Extremes in a Changing Climate. Regions of Focus: North America, Hawaii, Caribbean, and U.S. Pacific Islands. Synthesis and Assessment Product 3.3. Report by the U.S. Climate Change Science Program and the Subcommittee on Global Change Research. Department of Commerce, NOAA's National Climatic Data Center, Washington, D.C., USA, 164 pp

Kerr AM, Baird AH, Campbell SJ (2006) Comments on "Coastal mangrove forests mitigated tsunami" by K. Kathiresan and N. Rajendran [Estuar. Coast. Shelf Sci. 65 (2005) 601-606]. Estuarine, Coastal and Shelf Science 67:539-541

Kleypas JA, Langdon C (2006) Coral reefs and changing seawater chemistry, Chapter 5 In: Phinney J, Hoegh-Guldberg O, Kleypas J, Skirving W, Strong AE (eds) Coral Reefs and Climate Change: Science and Management AGU Monograph Series, Coastal and Estuarine Studies. Geophys. Union, Washington DC, pp73-110

Kleypas JA, McManus JW, Menez LAB (1999a) Environmental Limits to Coral Reef Development: Where Do We Draw the Line? American Zoologist 39:146-159

Kleypas JA, Buddemeier RW, Archer D, et al. (1999b) Geochemical consequences of increased atmospheric carbon dioxide on coral reefs. Science 284:118-120

Kleypas JADG, Lough JM (2008) Potential role of the ocean thermostat in determining regional differences in coral reef bleaching events. Geophys Res Letters 35:L03613

Komiyama A, Ong J, Poungparn S (2008) Allometry, biomass, and productivity of mangrove forests: A review. Aquatic Botany 89:128-137

Koop K, Booth D, Broadbent A, et al. (2001) ENCORE: The Effect of Nutrient Enrichment on Coral Reefs. Synthesis of Results and Conclusions. Marine Pollution Bulletin 42:91-120

Kruyt N (1994) Carbon outwelling from a mangrove forest with adjacent seagrass beds and coral reefs (Gazi Bay, Kenya). Marine Ecology Progress Series 106:291-301

Lacerda LD, Abrao JJ (1984) Heavy metal accumulation by mangrove and salt marsh inter tidal sediments. Rev Bras Bot 7:49-52

Langdon C, Atkinson M (2005) Effect of elevated pCO_2 on photosynthesis and calcification of corals and interactions with seasonal change in temperature/irradiance and nutrient enrichment. Journal of Geophysical Research-Oceans 110:C09S07

Lasimbang C (2002) 'Indigenous Peoples of Sabah: Traditional Resource Management'. Indigenous Rights in the Commonwealth Project - South & South East Asia Regional Expert Meeting, New Delhi, India. <http://www.cpsu.org.uk/downloads/Claudia_.pdf>

Lasimbang J (2008) Malaysia. In: Wessendorf K. (ed), The Indigenous World 2008. International Work Group for Indigenous Affairs, Copenhagen, Denmark.

Leete R (2008a) Sabah's Human Development: Progress and challenges. United Nations Development Program. January

Leete R (2008b) Sabah's Human Developmenmt Progress and Challenges. UNDP, Kuala Lumpur.

Lough JM (2000) 1997-98: Unprecedented thermal stress to coral reefs? Geophysical Research Letters, 27:3901-3904

Lowe C (1999) ‘Who is to blame? Logics of responsibility in the live reef food fish trade in Sulawesi, Indonesia’. SPC Live Reef Fish Information Bulletin #10. http://www.spc.int/Coastfish/News/LRF/10/LRF10-04.htm

Loya Y, Rinkevich B (1979) Abortion effect in corals induced by oil pollution. Mar Ecol Prog Ser 1:77-80

Loya Y, Rinkevich B (1980) Effects of oil pollution on coral reef communities. Mar Ecol Prog Ser 3:180

Lu J, Lim H, Liew S, Bao M, Kwoh L (1999) Oil pollution statistics in Southeast Asian waters compiled from ERS SAR imagery. Earth Observation Quarterly 61:5

Lyon B, Camargo SJ (2009) The seasonally-varying influence of ENSO on rainfall and tropical cyclone activity in the Philippines. Climate Dynamics 32: 125-141

MAF (2009) Ministry of Agriculture and Fisheries. [Accessed 7 April 2009.] Government of the Democratic Republic of Timor-Leste. <http://www.maf.gov.tl/English/animal_fishers.htm>

Manzello DP, Kleypas JA, Budd DA, et al. (2008) Poorly cemented coral reefs of the eastern tropical Pacific: possible insights into reef development in a high-CO_2 world. Proc Natl Acad Sci U S A 105:10450-10455

Marguillier S, Velde G, Dehairs F, Hemminga MA, Rajagopal S (1997) Trophic relationships in an interlinked mangrove-seagrass ecosystem as traced by delta 13C and delta 15N. Marine Ecology Progress Series 151:115-121

McClanahan T, Maina J, Pet-Soede L (2002) Effects of the 1998 Coral Morality Event on Kenyan Coral Reefs and Fisheries. AMBIO: A Journal of the Human Environment 31:543-550

McClanahan T, Cinner J, Maina J, et al. (2008) Conservation action in a changing climate. Conservation Letters 1:53-59

McCoy ED, Heck KL (1976) Biogeography of Corals, Seagrasses, and Mangroves - Alternative to Center of Origin Concept. Systematic Zoology 25:201-210

McGregor GR, Nieuwolt S (1998) Tropical Climatology. An introduction to the climate of the low latitudes. John Wiley and Sons, Chichester, England, 339pp

McLean RF, Tsyban A (2001) Coastal Zones and Marine Ecosystems. Climate Change 2001: Impacts, Adaptation, and Vulnerability: Contribution of Working Group II to the Third Assessment Report of the Intergovernmental Panel on Climate Change

McManus JW, Reyes Jr RB, Na, Ntilde, Ola Jr CL (1997) Effects of Some Destructive Fishing Methods on Coral Cover and Potential Rates of Recovery. Environ Manage 21:69-78

McMillan C (1984) The distribution of tropical seagrasses with relation to their tolerance of high temperatures. Aquatic Botany 19:369-380

McPhaden M, Zebiak S, Glantz M (2006) ENSO as an integrating concept in earth science. Science 314:1740

Meehl G, Washington W, Collins W, et al. (2005) How much more global warming and sea level rise? American Association for the Advancement of Science 1769-1772

Meehl GA, Stocker TF, Collins WD, et al. (2007) Global climate projections. In Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Solomon S, Qin D, Manning M, Chen Z, Marquis M, Averyt KB, Tignor M, Miller HL PY - eds)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp 747-845

Meier MF, Dyurgerov MB, Rick UK, et al. (2007) Glaciers dominate eustatic sea-level rise in the 21st century. Science 317:1064-1067

Meyer CP, Geller JB, Paulay G (2005) Fine scale endemism on coral reefs: Archipelagic differentiation in turbinid gastropods. Evolution 59:113-125
Minura N (ed) (2008) Asia -Pacific coasts and their management. Springer, Dordrecht

Mittermeier R, Myers N, Thomsen J, Olivieri S (1998) Biodiversity hotspots and major tropical wilderness areas: approaches to setting conservation priorities. Conservation biology 12:516-520

MMAF (2007) Statistik Ekspor Hasil Perikanan. Dept Kelautan dan Perikanan Jakarta 568 pp

Moberg F, Folke C (1999) Ecological goods and services of coral reef ecosystems. Ecological Economics 29:215-233

Moore A (2008) 'The Oceans are our Front Yard'. Earth Day / IYOR Event Report from Palu, Central Sulawesi, Indonesia. http://forum.reefcheck.org/phpbb2/viewtopic.php?t=556

Moss R, Babiker M, Brinkman S, et al. (2008) Towards New Scenarios for Analysis of Emissions, Climate Change, Impacts, and Response Strategies

Mous PJ, Pet-Soede L, Erdmann M, et al. (2000) Cyanide fishing on Indonesian coral reefs for the live food fish market. What is the problem? SPC Live Reef Fish Information Bulletin 7:20-27

Mumby P, Edwards A, Arias-Gonzalez J, et al. (2004) Mangroves enhance the biomass of coral reef fish communities in the Caribbean. Nature (London) 427:533-536

Mumby P, Harborne A, Williams J, et al. (2007) Trophic cascade facilitates coral recruitment in a marine reserve. Proceedings of the National Academy of Sciences 104:8362

Mumby PJ, Chisholm JRM, Edwards AJ, Andrefouet S, Jaubert J (2001) Cloudy weather may have saved Society Island reef corals during the 1998 ENSO event. Marine Ecology Progress Series 222:209-216

Murray SP, Ariel D (1988) Throughflow into the Indian Ocean through the Lombok Strait, January 1985-January 1986. Nature 333

Muscatine L (1990) The role of symbiotic algae in carbon and energy flux in reef corals. . In: Dubinsky Z (ed) Ecosystems of the world. Elsevier, Amsterdam, pp75-87

Muscatine L, Porter J (1977) Reef corals: mutualistic symbioses adapted to nutrient-poor environments. BioScience 27:454-460

Myers N (1990) The biodiversity challenge: expanded hot-spots analysis. Environmentalist 10:243-256

Myers N, Mittermeier RA, Mittermeier CG, da Fonseca GA, Kent J (2000) Biodiversity hotspots for conservation priorities. Nature 403:853-858

Nagelkerken I, Faunce CH (2008) What makes mangroves attractive to fish? Use of artificial units to test the influence of water depth, cross-shelf location, and presence of root structure. Estuarine, Coastal and Shelf Science 79:559-565

Nagelkerken I, van der Velde G, Gorissen MW, et al. (2000) Importance of mangroves, seagrass beds and the shallow coral reef as a nursery for important coral reef fishes, using a visual census technique. Estuar Coast Shelf Sci 51:31-44

Nakamura T, van Woesik R (2001) Water-flow rates and passive diffusion partially explain differential survival of corals during the 1998 bleaching event. Marine Ecology Progress Series 212:301-304

Nakicenovic N, Swart R (2000) Emissions Scenarios 2000–Special Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, UK 96:98

Neale R, Slingo J (2003) The Maritime Continent and its role in the global climate: a GCM study. Journal of Climate 16:834-848

Neckles H, Wetzel R, Orth R (1993) Relative effects of nutrient enrichment and grazing on epiphyte-macrophyte (Zostera marina L.) dynamics. Oecologia 93:285-295

Newell RE (1979) Climate and the ocean. American Scientist 67: 405-416

Nicholls R (2002) Analysis of global impacts of sea-level rise: a case study of flooding. Physics and Chemistry of the Earth 27:1455-1466

Nicholls RJ (2004) Coastal flooding and wetland loss in the 21st century: changes under the SRES climate and socio-economic scenarios. Global Environmental Change 14:69-86

Nicholls RJ, Hoozemans FMJ, Marchand M (1999) Increasing flood risk and wetland losses due to global sea-level rise: regional and global analyses. Global Environmental Change 9:69-87

Olson D, Dinerstein E (1998) The Global 200: A Representation Approach to Conserving the Earth's Most Biologically Valuable Ecoregions. Conservation biology 12:502-515

Olson D, Dinerstein E, Wikramanayake E, et al. (2001) Terrestrial Ecoregions of the World: A New Map of Life on Earth. BioScience 51:933-938

Orr J, Fabry V, Aumont O, et al. (2005) Anthropogenic ocean acidification over the twenty-first century and its impact on calcifying organisms. Nature 437:681-686

Orth RJ, Carruthers T, Dennison WC, et al. (2006) A Global Crisis for Seagrass Ecosystems. BioScience 56:987-996

Pabon-Zamora L, Fauzi A, Halim A, et al. (2008) Protected areas and human well-being: Experiences from Indonesia, Mexico, Peru and Venezuela'. In: Protected Areas in Today's World: Their Values and Benefits for the Welfare of the Planet, pp.67-76. Secretariat of Convention on Biological Diversity Technical Series no. 36, Montreal.

Pearce F (2009) Arctic meltdown is a threat to humanity. New Scientist, 28 March

Pearson P, Palmer M (2000) Atmospheric carbon dioxide concentrations over the past 60 million years. Nature 406:695-699

Peñaflor E, Skirving W, Strong A, Heron S, David L (2009) in press, Sea-surface temperature and thermal stress in the Coral Triangle over the past two decades. . Coral Reefs

Penny S (2008) 'Reef check in Timor Leste'. http://www.reefcheck.org/news/news_detail.php?id=412

Pet-Soede C, Cesar HSJ, Pet JS (1999) An economic analysis of blast fishing on Indonesian coral reefs. Environmental Conservation 26:83-93

Petit JR, Jouzel J, Raynaud D, et al. (1999) Climate and atmospheric history of the past 420,000 years from the Vostok ice core, Antarctica. Nature 399:429-436

Piggin C (2003) 'Working group SWOT analysis on agricultural development in East Timor'. http://www.gov.east-timor.org/MAFF/ta100/ta123.pdf

Piou C, Feller I, Berger U, Chi F (2006) Zonation Patterns of Belizean Offshore Mangrove Forests 41 Years After a Catastrophic Hurricane 1. The Journal of Biology and Conservation 38:365-374

PNSC (2004) Seagrasses of the Philippines: Country Report. UNEP/GEF SCS Project: Reversing Environmental Degradation Trends in the South China Sea and Gulf of Thailand. PNSC Publ. Philippines, 130pp.

Poloczanska E, Babcock R, Butler A, et al. (2007) Climate change and Australian marine life. Oceanography And Marine Biology: An Annual Review 45:407-478

Pratchett MS, Munday PL, Wilson SK, et al. (2008) Effects of climate-induced coral bleaching on coral-reef fishes - Ecological and economic consequences. Oceanography And Marine Biology: An Annual Review 46:251-296

Primavera JH (1997) Socio-economic impacts of shrimp culture. Aquaculture Research 28:815-827

Primavera JH (2005) Global voices of science: Mangroves, fishponds, and the quest for sustainability. Science (New York, NY 310:57-59

Przeslawski R, Ahyong S, Byrne M, Worheide G, Hutchings P (2008) Beyond corals and fish: the effects of climate change on noncoral benthic invertebrates of tropical reefs. Glob Change Biol 14:2773-2795

Ramage CS (1968) Role of a tropical "maritime continent" in the atmospheric circulation. Monthly Weather Review 96:365-370

Rayner N, Parker D, Horton E, et al. (2003) Global analyses of sea surface temperature, sea ice, and night marine air temperature since the late nineteenth century. Journal of Geophysical Research-Atmospheres 108:4407

Reaka-Kudla ML (1997) Global biodiversity of coral reefs: a comparison with rainforests. In: Reaka-Kudla ML, Wilson DE (eds) Biodiversity II: Understanding and Protecting Our Biological Resources. Joseph Henry Press, pp551

Reaka-Kudla ML (2001) Known and unknown biodiversity, risk of extinction and conservation strategy in the sea. Waters In Peril:19-33

Ricklefs RE, Latham RE, Ricklefs, Schluter D (1993) Global patterns of diversity in mangrove floras. :215-229

Roberts CM, McClean CJ, Veron JE, et al. (2002) Marine biodiversity hotspots and conservation priorities for tropical reefs. Science 295:1280-1284

Rosen BR (1971) The distribution of reef coral genera in the Indian Ocean. In Stoddart, D.R. and Yonge, C.M. Regional variation in Indian Ocean coral reefs. Symp Zool Soc London 28:263-299

Sabine C, Feely R, Gruber N, et al. (2004) The Oceanic Sink for Anthropogenic CO_2. Science 305:367-371

Sadovy Y, Bank AD (2003) While Stocks Last: The Live Reef Food Fish Trade. Asian Development Bank

Saintilan N, Wilton K (2001) Changes in the distribution of mangroves and saltmarshes in Jervis Bay, Australia. Wetlands Ecology and Management 9:409-420

Salm R (1994a) Coral's hidden riches. People Planet 3:19-21

Salm R (1994b) Coral's hidden riches. People & the planet / IPPF, UNFPA, IUCN 3:19-21

Salm R (2008) 'Coral Triangle: Reflections on Halmahera.' The Nature Conservancy. http://www.nature.org/wherewework/asiapacific/coraltriangle/features/reflections.html

Samonte-Tan GPBWATTMADJTECC (2007) Economic valuation of coastal and marine resources: Bohol Marine Triangle, Philippines. Coast Manage 35:319-338

Semeniuk V (1994) Predicting the effect of sea-level rise on mangroves in northwestern Australia. Journal of Coastal Research 10:1050-1076

Sherman R, Fahey T, Martinez P (2001) Hurricane Impacts on a Mangrove Forest in the Dominican Republic: Damage Patterns and Early Recovery 1. Biotropica 33:393-408

Short FT, Neckles HA (1999) The effects of global climate change on seagrasses. Aquatic Botany 63:169-196

Shukla J, Hagedorn R, Hoskins B, et al. (2009) Revolution in climate prediction is both necessary and possible. A Declaration at the World Modelling Summit for Climate Prediction. Bulletin American Meteorological Society 90:175-178

Silvestre G, Pauly D (eds) (1997) Management of Tropical Coastal Fisheries in Asia: An Overview of Key Challenges and Opportunities1

Smith T, Robblee M, Wanless H, Doyle T (1994) Mangroves, Hurricanes, and Lightning Strikes. BIOSCIENCE-WASHINGTON- 44:256-256

Smith TM, Sapiano MRP, Arkin PA (2008) Historical reconstruction of monthly oceanic precipitation. Journal Geophysical Research 113, D17115, doi: 101029/2008JD009851

Snedaker S (1995) Mangroves and climate change in the Florida and Caribbean region: scenarios and hypotheses. Hydrobiologia 295:43-49

Solomon S, Plattner GK, Knutti R, Friedlingstein P (2009) Irreversible climate change due to carbon dioxide emissions. Proceedings of the National Academy of Sciences, USA, 106:1704-1709

Spalding M, Blasco F, Field C (1997) World Mangrove Atlas. Okinawa, Japan

Spalding M, Ravilious C, Green E (2001) World Atlas of Coral Reefs. University of California Press

Spalding M, Taylor M, Ravilious C, Short F, Green E (2003) The distribution and status of seagrasses. World Atlas of Seagrasses

Spalding MD, Fox HE, Allen GR, et al. (2007) Marine Ecoregions of the World: A Bioregionalization of Coastal and Shelf Areas. BioScience 57:573-583

Steffensen JP, Andersen K. K., Bigler M., Clausen H. B,. Dahl-Jensen D., Fischer H., Goto-Azuma K., Hansson M., Johnsen S. J., Jouzel J., Masson-Delmotte V., Popp T., Rasmussen S. O., Rothlisberger R., Ruth U., Stauffer B., Siggaard-Andersen M. L., Sveinbjornsdottir A. E., Svensson A., White J. W. C. (2008) High-resolution Greenland Ice Core data show abrupt climate change happens in few years. Science 321:680-684

Stehli FG, Wells JW (1971) Diversity and age patterns in hermatypic corals. Syst Zool 20:115[long dash]126

Steig EJ, Schneider DP, Rutherford SD, et al. (2009) Warming of the Antarctic ice-sheet surface since the 1957 International Geophysical Year. Nature 457:459-462

Steig EJ, Brook EJ, White JWC, et al. (1998) Synchronous climate changes in antarctica and the north atlantic. Science 282:92-95

Stenseth N, Mysterud A, Ottersen G, et al. (2002) Ecological effects of climate fluctuations. Science 297:1292-1296

Stevens GC (1989) The Latitudinal Gradient in Geographical Range - How So Many Species Coexist in the Tropics. American Naturalist 133:240-256

Strong A, Arzayus F, Skirving W, Heron S (2006) Identifying coral bleaching remotely via Coral Reef Watch—improved integration and implications for changing climate JT Phinney, et al [Eds], Coral Reefs and Climate Change: Science and Management Coastal and Estuarine Studies, Vol 61, American Geophysical Union, Washington, DC 163-180 pp,

Strong AE, Barrientos CS, Duda C, Sapper J (1996) Improved satellite technique for monitoring coral reef bleaching. Proceedings of the eighth international coral reef symposium, Panama, June:1495-1497

Sugiyama S, Staples D, Funge-Smith S (2004) Status and potential of fisheries and aquaculture in Asia and the Pacific. RAP Publication 25:2004–2025

Suharsono (1998) Bleaching event followed by mass mortality of coral reefs in 1998 in Indonesian waters. UJ. Mar. Fish Sci 179 - n187.

Tanzil J, Brown B, Tudhope A, Dunne R (2009) Decline in skeletal growth of the coral Porites lutea from the Andaman Sea, South Thailand between 1984 and 2005. Coral Reefs

Terangi (2006) Kakaban Lake: Unique marine in Indonesia. The Indonesian Coral Reef Foundation. http://www.terangi.or.id/en/index.php?option=com_content&task=view&id=57&Itemid=1

Thom R (1996) CO 2-Enrichment effects on eelgrass (Zostera marina L.) and bull kelp (Nereocystis luetkeana (mert.) P & R.). Water, Air, & Soil Pollution 88:383-391

Titus J, Park R, Leatherman S, et al. (1991) Greenhouse Effect and Sea Level Rise: The Cost of Holding Back the Sea. Coastal Management 19:171-204

TNC (2009a) East Kalimantan Program: Conservation from Ridges to Reef. The Nature, Conservancy, Kalimantan Timur

TNC (2009b) Coral Triangle Facts, Figures and Calculations: Part I Boundaries and Geographic Statistics; Part II Patterns of Biodiversity and Endemism. http://conserveonline.org/workspaces/tnccoraltriangle/documents/coral-triangle-factsheet-and-soundbites

TNC (2009c) The Raja Ampat Islands in the heart of the Coral Triangle. The Nature, Conservancy Coral Triangle Center, Sanur, Bali. http://www.rajaampat.org

TNC (2009d) Coral Triangle Center: Protecting the most diverse reefs on earth. The Nature, Conservancy Coral Triangle Center, Sanur, Bali. http://coraltrianglecenter.org

Tompkins E, Nicholson-Cole S, Hurlston L, et al. (2005) Surviving climate change in Small Islands - A guidebook. Tundall Centre for Climate Change Research, School of Environmental Sciences 128

Trenberth KE, Jones PD, Ambenje P, et al. (2007) Observations: surface and atmospheric climate change. In Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Solomon S, Qin D, Manning M, Chen Z, Marquis M, Averyt KB, Tignor M, Miller HL PY - eds)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp 235-336

Trench RK (1979) Cell biology of plant-animal symbiosis. Annu Rev Plant Physiol Plant Molec Biol 30:485-531

Turak E, DeVantier L Biodiversity and conservation priorities of reef-building corals in the Papuan Bird's Head Seascape. In L. S. Katz, A. Firman, and M. V. Erdmann, A Rapid Marine Biodiversity Assessment of Teluk Cendrawasih and the FakFak-Kaimana Coastline of the Papuan Bird's Head Seascape, Indonesia. RAP Bulletin of Biological Assessment. Conservation International, Washington, DC

Turak E, Souhoka J (2003) Coral diversity and the status of coral reefs in the Raja Ampat Islands. In R. Donnelly, D. Neville, and P. Mous, Report on a rapid ecological assessment of the Raja Ampat Islands, Papua, Eastern Indonesia, held October 30 – November 22, 2002. The Nature Conservancy Southeast Asia Center for Marine Protected Areas, Sanur, Bali Indonesia

UN (2004) United Nations, Department of Economic and Social Affairs, Population Division (2004), World Population to 2300.

UN (2007) United Nations, Department of Economic and Social Affairs, Population Division (2007), World Population Prospects: The 2006 revision. Highlights.

UN (2008) United NationsThe Millennium Development Goals Report. http://www.un.org/millenniumgoals/pdf/The%20Millennium%20Development%20Goals%20Report%202008.pdf. Also used several other reports and summaries from the MDG site, available there

UNDP (2007) United Nations Development Program, Human Development Report 2007/08, http://hdr.undp.org/en/statistics/)

UNEP (2004) Seagrass in the South China Sea. UNEP/GEF.SCS Technical Publication No. 3

UNESCO (1983) Coral reefs, seagrass beds and mangroves: their interaction in the coastal zones of the Caribbean. Unesco Rep. Mar. Sci. 130 pp.

Valiela I, Bowen JL, York JK (2001) Mangrove Forests: One of the World's Threatened Major Tropical Environments. BioScience 51:807-815

van Hooidonk R, Huber M (2009) Equivocal evidence for a thermostat and unusually low levels of coral bleaching in the Western Pacific Warm pool. Geophysical Research letters 36, L06705, doi: 101029/2008GL036288

Veitayaki J (1997) Traditional marine resource management practices used in the Pacific Islands: an agenda for change. Ocean and Coastal Management 37:123-136

Veron J (2008) Mass extinctions and ocean acidification: biological constraints on geological dilemmas. Coral Reefs 27:459-472

Veron JE, Devantier LM, Turak E, et al. (2009) submitted Delineating the Coral Triangle. Galaxea.

Veron JEN (1993) A biogeographic database of hermatypic corals: species of the central Indo-Pacific, genera of the world. Aust Inst Mar Sci Monogr Ser 9

Veron JEN (1995) Corals in space and time : the biogeography and evolution of the scleractinia. UNSW Press, Sydney

Veron JEN (2002) Reticulate evolution in corals. Proceedings Ninth International Coral Reef Symposium, Bali, 2000 1 43-48

Veron JEN (2009) Coral Geographic: a spatial database; http://www.coralreefresearch.org/html/crr_cg.htm

Veron JEN, Stafford-Smith M (2000) Corals of the world. Australian Institute of Marine Science, Townsville, Qld.

Vitousek PM, Cassman K, Cleveland C, et al. (2002) Towards an ecological understanding of biological nitrogen fixation. Biogeochemistry 57/58:1-45

Walker D (1991) The effect of sea temperature on seagrasses and algae on the Western Australian coastline. Journal of the Royal Society of Western Australia 74:71-77

Wallace AR (1863) On the physical geography of the Malay Archipelago. J Roy Geographical Soc 33:217-234

Wallace AR (1869) The Malay Archipelago; The Land of the Orang-utan and the Bird of Paradise; A Narrative of Travel With Studies of Man and Nature. . Macmillan & Co, London, UK

Wallace AR (1910) The World of Life. Chapman and Hall, London

Walton M, Samonte-Tan G, Primavera J, Edwards-Jones G, Le Vay L (2006) Are mangroves worth replanting? The direct economic benefits of a community-based reforestation project. Environmental Conservation 33:335-343

Wang B, Ding Q (2006) Changes in global monsoon precipitation over the past 56 years. Geophysical Research Letters 33, L06711, doi: 101029/2005GL025347

WCS (2007) 'Halmahera: surveying the last frontier in the Coral Triangle.' http://www.wcsmarine-indonesia.org, World Conservation Society, Marine Program Indonesia

Webster PJ, Holland GJ, Curry JA, Chang HR (2005) Changes in tropical cyclone number, duration, and intensity in a warming environment. Science 309:1844-1846

Wells FE (2002) Centres of species richness and endemism of shallow-water marine molluscs in the tropical Indo-West Pacific. Proc Ninth Intern Coral Reef Symp Bali, 2000 2:941-945

Wells JW (1955) A survey of the distribution of reef coral genera in the Great Barrier Reef region. Rep Gt Barrier Reef Comm 6:1-9

Werner TB, Allen GR (1998) A rapid biodiversity assessment of the coral reefs of Milne Bay Province, Papua New Guinea. RAP Bulletin of Biological Assessment 11, Conservation International, Washington, DC

Wigley TML (2005) The climate change commitment. Science 307:1766-1769

Wilkinson C (2008) Status of Coral Reefs of the World: 2008. Global Coral Reef Monitoring Network and Reef and Rainforest Research Center, Townsville, Australia 296pp

Williams N (2005) Tsunami insight to mangrove value. Current Biology 15:73-73

Wilson SK, Burgess SC, Cheal AJ, et al. (2008a) Habitat utilization by coral reef fish: implications for specialists vs. generalists in a changing environment. J Anim Ecol 77:220-228

Wilson SK, Fisher R, Pratchett MS, et al. (2008b) Exploitation and habitat degradation as agents of change within coral reef fish communities. Glob Change Biol 14:2796-2809

Wilton K (2002) Coastal wetland habitat dynamics in selected New South Wales estuaries

Witze A (2008) Losing Greenland. Nature 452:798-802

Woodroffe C (2002) Coasts: Form, Process and Evolution. Cambridge University Press

Woodroffe C, Grime D (1999) Storm impact and evolution of a mangrove-fringed Chenier Plain, Shoal Bay, Darwin, Australia Marine geology 159:303-321

World_Bank (2007) The Little Green Data Book 2007, The World Bank, Washington, DC

WRI (2005) Millennium Assessment: Ecosystems and human well-being, World Resources Institute Island Press, Washington, Covelo, London

Yusuf A, Francisco H (2009) Climate Change Vulnerability Mapping for Southeast Asia. Economy and Environment Program for Southeast Asia (EEPSEA), International Development Research Centre (IDRC) Singapore

Zhang J, Lindsay R, Steele M, Schweiger A (2008) What drove the dramatic retreat of arctic sea ice during summer 2007? Geophysical Research Letters 35:L11505, doi:11510.11029/12008GL034005,

Zimmerman R, Smith R, Alberte R (1989) Thermal acclimation and whole-plant carbon balance in Zostera marina L.(eelgrass). Journal of Experimental Marine Biology and Ecology 130:93-109

Zimmerman R, Kohrs D, Steller D, Alberte R (1997) Impacts of CO_2 Enrichment on Productivity and Light Requirements of Eelgrass. Am Soc Plant Biol 599-607

AUTHORS AND REVIEWERS

AUTHORS

Professor Ove Hoegh-Guldberg is Director, Centre for Marine Studies, at The University of Queensland, and Deputy Director of the ARC Centre for Excellence for Coral Reef Studies (www.coralcoe.org.au). Ove leads an active research group of more than 25 researchers (www.coralreefecosystems.org), is currently Queensland Smart State Premier's Fellow and has published over 140 scientific papers on coral reefs and environmental change. Ove is a member of the Royal Society (London) working group on ocean acidification and chairs the CRTR working group on coral bleaching and related ecological impacts (www.gefcoral.org). He won a Eureka Prize in 1999 and runs the popular blog: www.climateshifts.org.

Hans Hoegh-Guldberg runs Economic Strategies, a company he founded in 1984. He specializes in applied ecological and cultural economics, and has produced a large number of studies in the music, literature and other cultural sectors. He is on the board of the Music Council of Australia and edits its knowledge base. Twelve years ago he became involved in scenario planning (Indonesia) and shortly thereafter in the economics of coral reefs and climate change. He co-authored "Pacific in Peril" (2000) and "The Implications of Climate Change for Australia's Great Barrier Reef" (2004). He is currently completing a two-year climate change project on the Florida Keys for NOAA.

Professor J. E. N. (Charlie) Veron. Charlie Veron is best known as the author of the three volume Corals of the World. He is also the senior author of the major electronic products Coral ID and Coral Geographic. Veron is the author of 100 scientific articles, including 14 books and monographs. He is former Chief Scientist of the Australian Institute of Marine Science. He has been the recipient of the Darwin Medal, the Silver Jubilee Pin of the Australian Marine Sciences Association, the Australasian Science Prize, the Whitley Medal and received special mention in the Eureka Awards.

Dr. Alison Green is Senior Marine Scientist with The Nature Conservancy's Asia Pacific Conservation Region, and is the strategy lead for establishing resilient networks of marine protected areas in the Conservancy's Coral Triangle Program. Her role is to co-ordinate high priority research and provide scientific advice for The Nature Conservancy's Coral Triangle Program, particularly in the fields of coral reef ecology, biodiversity, monitoring and measuring success, and the design and implementation of resilient networks of marine protected areas (MPAs). Recently, she led the scientific design of a resilient network of MPAs in Kimbe Bay, Papua New Guinea, and is currently involved in designing several MPA networks in the Coral Triangle. She has also led several rapid ecological assessments in Indonesia, Papua New Guinea and the Solomon Islands, and played a lead role in delineating the Coral Triangle.

Professor Ed Gomez, Ed is world renowned coral reef biologist from the University of the Philippines where he has maintained an active research lab and academic group. He currently serves as the Coordinator of the Centre of Excellence for the Philippines and Southeast Asia under the Global Environment Facility/World Bank Coral Reef Targeted Research Program, where he also serves as a Co-Chair of the Restoration and Remediation Working Group. He has 140 technical publications to his credit and continues to publish actively.

Ms Melanie King. Melanie is the Executive Officer for the GEF/World Bank CRTR Program based at The University of Queensland, and has been involved in the administrative and project management fields for 20 years. Her experience working on natural resource management projects includes Australia, Cook Islands, Maldives, Philippines, Mexico and Zanzibar. During this time she has developed a sound knowledge of country and donor policies and management actions regarding coastal resources, and recently completed her Masters in Governance and Public Policy, focusing upon policy, institutional arrangements and organisational structures in Small Island States.

Dr Janice Lough, Janice is a Senior Principal Research Scientist at the Australian Institute of Marine Science (AIMS) where she leads the Responding to Climate Change Research Team and is also a partner investigator with the ARC Centre of Excellence for Reef Studies. Her current research focuses on the possible impacts of a changing climate and increasing CO_2 on coral reef ecosystems and extracting pre-instrumental histories of reef climates and environments from the annual records contained in long-lived massive corals. She has published over 100 scientific articles in these and related areas.

Dr. Ambariyanto. He is a marine scientist at Diponegoro University, Semarang, Indonesia. His research interest is mainly on marine endangered species, coral reef and mangroves rehabilitation and conservation. He has been working closely with coastal communities along Java Island coastal area, helping related government agencies as well as other marine and fisheries related NGOs.

Dr Lara Hansen, Lara has directed research on the biological effects of global change (including UV-B and climate change) since 1990. Her primary focus is the redesign of conservation strategies to incorporate responses to climate change She is currently engaged in developing the field of adaptation, building its capacity and getting it implemented through an organization she co-founded in 2008, EcoAdapt. Recognition for her research on the biological effects of stresses combined with global change is exemplified by being a Switzer Environmental Fellow in 1995 and an EPA Bronze Medalist in 2002. Dr. Hansen was the Chief Climate Change Scientist for World Wildlife Fund, leading their Impacts and Adaptations program, from 2001 to 2008.

Dr Josh Cinner, James Cook University. Dr Cinner's research explores how socio-economic factors influence the ways in which people use, perceive, and govern natural resources, with a specific focus on coral reef social-ecological systems. He often works closely with ecologists on interdisciplinary research topics such as defining the socio-economic factors that drive successful conservation, understanding resilience and thresholds in coral reef social-ecological systems, examining and operationalising vulnerability to environmental change, and examining the applicability of Western conservation models in developing countries.

Mr Geoff Dews, Adjunct Senior Lecturer, Centre for Marine Studies, The University of Queensland. Geoff is a marine resource specialist with extensive consulting experience in the Asia-Pacific region, including Melanesia. Since the beginning of the 1990s he has been involved in international development projects both as technical advisor and team leader. He has been Team Leader for long-term projects in the Republic of Maldives and Timor Leste undertaking strategic environmental assessments and developing coastal management plans. Geoff currently works for the Centre for Marine Studies at the University of Queensland and is involved in work in Solomon Is and Cook Is as a coastal catchment technical advisor. He is also the coordinator and key presenter of the Coastal Resource Management short course offered by CMS each year.

Dr C. Mark Eakin. Mark is the Coordinator of the Coral Reef Watch program of the US National Oceanic and Atmospheric Administration, which uses satellite data to observe environmental changes that threaten the health of corals and coral reef ecosystems. His background is in coral reef ecology, reef carbonate budgets, and paleoclimatology, currently focusing on the influence of climate change and ocean acidification on coral reefs. He has twice received the Bronze Medal from the US Department of Commerce for his work on climate variability and change.

Dr Tyler Christensen, Tyler is a coral reef scientist, a contractor with I.M. Systems Group at NOAA's Coral Reef Watch program. Her focus is on international programs: developing satellite data products for global coral reef managers, improving product delivery, and building capacity for the use of NOAA's satellite data. She is a member of the GEF/World Bank CRTR Program's Remote Sensing Working Group.

Dr Garry Russ, Garry is a Professor of marine science at James Cook University, Australia. His research interests are use of no-take marine reserves as fisheries-management tools and coral reef fisheries. He has an extensive international reputation and has published over 150 peer-reviewed papers on fisheries, conservation and coral reefs, specializing in southeast Asian and western Pacific countries

Ms Heidi Schuttenberg, Heidi is a PhD student at James Cook University where she specializes in understanding how to understand and strengthen effective coral reef governance in relationship to the better management of coastal environments and ecosystems. She was coauthor on the book "A Reef Manager's Guide to Coral Bleaching" over 10 articles on issues related to governments, marine conservation and coral reefs.

Dr Michael Abbey, National Oceanic and Atmospheric Administration (NOAA) Fisheries (U.S.A.). Michael is responsible for assessing, developing and managing international fisheries collaboration between NOAA Fisheries and the Asia/Pacific region. He is the NOAA Fisheries liaison to the Coral Triangle Initiative and the Coral Reef Conservation Program - International Working Group.

Dr Rosemary A. Kosaka, National Oceanic and Atmospheric Administration (NOAA) Fisheries (U.S.A). Rosemary works as an economist in the Office of Science & Technology and is editor of a new annual statistical series reporting economic information about domestic fishing activities and fishing-related industries. She also contributes to ongoing and emerging economics research and data collection activities focused on aspects of U.S. marine ecosystems.

Eileen L. Peñaflor is a PhD student at the Marine Science Institute, University of the Philippines. She is also a part of the World Bank/GEF Coral Reef Targeted Research and Capacity Building for Management Program - Remote Sensing Working Group. She's currently working on her dissertation investigating the surface warming and thermal stress patterns in the Coral Triangle. Her interest is mainly on the use of satellite-derived data for coastal and ocean studies.

Dr. Alexander Tewfik, WorldFish Center. Since 2006, Alex has been working on the implementation of practical and participatory systems for the diagnosis, restoration and adaptive management of coastal habitats, resources and livelihoods in Indonesia and the Solomon Islands. Prior to WorldFish, he spent more than 10 years conducting applied ecological research in coastal systems throughout the Caribbean and Central America. He has published a number of peer-reviewed papers on small-scale invertebrate fisheries, marine managed areas, impacts of disturbance and habitat restoration.

Dr Jamie Oliver, World Fish Centre. Jamie has worked for The WorldFish Center since 2000, first as senior scientist for coral reef projects and then as Director of Science Coordination. He is also the Secretary for the WorldFish Board of Trustees and the Chair of the International Coral Reef Action Network Steering Committee. Prior to WorldFish, he was the Director of Information Support at the Great Barrier Reef Marine Park Authority and a senior scientist at the Australian Institute of Marine Science. He has published extensively in the area of climate change and coral reefs and will help coordinate input from ReefBase.

EXPERT REVIEWERS

Professor Angel Alcala is currently the director of the Commission on Higher Education-Silliman Zonal Research Center, as well as the director of the Silliman University Angelo King Center for Resources and Environmental Management, in the Philippines. Dr Alcala has produced more than 60 scientific papers on marine issues and has presented at numerous international conferences. Dr Alcala has more than thirty years of experience in tropical marine resource conservation and coral reef research. The author of numerous papers, Professor Alcala has focused on marine reserves (particularly their effect on the fishery production of surrounding areas), and the ecology and mariculture of molluscan and fish species. He regularly works local communities and local governments in the Philippines on coastal resource management.

Dr Lauretta Burke is a Senior Associate in the People and Ecosystems Program of the World Resources Institute (WRI). She is a geographer and spatial modeller, who specializes in providing tools and information to guide sustainable resource management. Lauretta leads the “Reefs at Risk” project series (was lead author on “Reefs at Risk SE Asia”), evaluating threats to the world’s coral reefs, as well as WRI’s efforts on economic valuation of coastal resources. Prior to joining WRI, she analysed the potential impact of climate change on fisheries, wetlands and biological diversity for U.S. EPA’s Global Climate Change Program.

Dr Margaret “Meg” Caldwell, JD is the Executive Director of the Center for Ocean Solutions, a collaboration between Stanford University (including Hopkins Marine Station), the Monterey Bay Aquarium, and the Monterey Bay Aquarium Research Institute (MBARI). The Centre’s mission is to elevate the impact of the natural, physical and social sciences on ocean policy by integrating cutting-edge science and technology with economic, social, and political expertise to develop practical solutions to the major challenges facing the oceans. Meg is a member of the Stanford Law School faculty where she directs the Environmental and Natural Resources Law and Policy program. Her teaching and scholarship is at the interface of law, science and policy, presently focusing on governance of coupled coastal and marine ecosystems and human communities.

Dr John Cordell is an environmental anthropologist specializing in coastal management. He currently operates a non-profit research centre in Berkeley, California, USA, The Ethnographic Institute. Ethnographic is dedicated to assisting tropical small-scale, artisanal fishing, communities sustain their culturally-based livelihoods. Studying at Stanford University, and teaching at University of California Berkeley, University of Queensland, and University of Sao Paulo in Brazil, Cordell also engaged in extensive fieldwork and writing about fishing societies in Bahia, Brazil and in Torres Strait.

Dr Marea Hatziolos is a marine ecologist and a senior specialist in coastal and marine management in the Environment Department of the World Bank. Her work focuses on improving policies and practices for sustainable use of marine resources and conserving marine biodiversity through an ecosystem approach to development planning and management. She is the team leader for a global partnership between the GEF, the World Bank, the University of Queensland and some 40 research institutions world-wide to support science based management of coral reefs through the Coral Reef Targeted Research and Capacity Building for Management Program. In addition to her work on ecosystem based-adaptation to climate change, she is part of an international working group on valuation of marine ecosystem services and leads the Bank's work on integrated coastal management and coral reefs and climate change.

Professor Dr Suharsono is Director of Research Centre for Oceanography in Indonesia Institute of Sciences (LIPI). He studied in Newcastle University UK on ecology coral reef. He is a senior researcher on coral reef and took the lead of Coral Reefs Rehabilitation and Management Program (COREMAP) to monitoring status of coral communities in Indonesia. Suharsono is a member of The International Society for Reef Studies (ISRS) and is acts as an Indonesian Focal point on Coral Working Group-CITES and International Coral Reef Initiative.

ACKNOWLEDGMENTS

Ove Hoegh-Guldberg and his co-authors would like to thank Richard Leck (Task leader, WWF-Australia), Kate Newman (WWF-USA), Francis Areki (WWF-South Pacific), Bronwen Golder (WWF-International), and Lida Pet-Soude (WWF-Indonesia) for stimulating discussion and support during this study. They would also like to thank workshop participants, especially Lindsay Saunders, Jo Ackroyd and Ben Mullen (CTI Pacific Project), and Siham Afatta (University of Diponegoro and University of Queensland). The authors would also like to thank Dr Mark Spalding, The Nature Conservancy, UNEP World Conservation Monitoring Centre, and the World Resources Institute for the use of images and other resources. Charlie Veron (lead author of Chapter 1) thanks Lyndon DeVantier and Emre Turak for their major contribution to the database of Coral Geographic, and The Nature Conservancy for supporting this work. Figures 3, 4 and 6 were produced from Coral Geographic by Stuart Kininmonth (Australian Institute of Marine Science) assisted by Nate Pearson (The Nature Conservancy). Janice Lough (lead author of Chapter 7) would like to thank to Julie Arblaster, Bureau of Meteorology Research Centre, Melbourne for extracting and preparing the multi-model climate projections presented in Figures 11 and 13. Thanks also to Felicity McAllister, AIMS, for preparing Figures 2, 3 and 12.

Appendix 1: Additional resources used for country profiles

The following web resources were used (in addition to the published literature listed in the reference section) to construct the specific country profiles of chapter 6. These resources were accessed between 31.3.09 and 4.4.09

Bali:
http://www.baliblog.com/travel-tips/bali-barat-national-park.html
http://www.bukisa.com/articles/42172_coral-reef-of-bali
http://www.globalcoral.org/Pemuteran%20Artificial%20Reef%20Project.htm
http://www.wolfhilbertz.com/
http://www.globalcoral.org/Tulamben%20Newsletter.pdf
http://www.aquamarinediving.com/sites_tulamben.html

Nusa Tenggara:
http://regionalinvestment.com/sipid/en/commodityarea.php?ic=742&ia=53
http://www.wwf.or.id/index.php?fuseaction=wherewework.riung&language=e
http://www.wwf.or.id/index.php?fuseaction=wherewework.alor&language=e
http://baliwww.com/ntt/place.htm

East Kalimantan:
http://www.absoluteastronomy.com/topics/Derawan_Islands
Sulawesi:
http://www.ssn.org/Meetings/cop/cop14/Factsheets/Cardinalfish_EN.pdf

Maluku:
http://www.antara.co.id/en/arc/2007/9/17/five-coral-reef-zones-in-s-maluku-badly-damaged/
http://www.minesandcommunities.org/article.php?a=997
http://www.worldwildlife.org/what/wherewework/coraltriangle/thehalmaheraexpedition.html
http://www.fao.org/docrep/010/ag122e/AG122E05.htm
http://www.preventconflict.org/portal/main/maps_maluku_overview.php

West Papua:
http://travels.patrik.com/ra/
http://www.papua-diving.com/Main-page.html
http://www.conservation.org/explore/priority_areas/oceans/birds_head/Pages/birdshead.aspx

Sabah:
http://kepkas.sabah.gov.my/archived-news-2007/59-sabahs-coral-reefs-under-big-threat.html
http://www.sabahtourism.com/sabah-malaysian-borneo/en/news/95-sipadan-corals-recover/
http://www.divephotoguide.com/news/sabah_parks_to_start__coral_reef_monitoring_program
http://www.etawau.com/Semporna.htm
http://www.icran.org/awareness-sempornaisland.html
http://www.sempornaislandsproject.com/pages/intro/tsmp.htm
http://www.panoramaacuicola.com/noticia.php?art_clave=3522

Philippines:
http://www.reefcheckphilippines.org/entry.php?id=5
http://www.wildlifeextra.com/go/news/apo-reef935.html#cr (about Apo Reef)
http://www.philreefs.org/index.php?option=com_content&task=view&id=66&Itemid=62
http://www.philreefs.org/index.php
http://www.tubbatahareef.org/main/about
http://www.oneocean.org/ambassadors/track_a_turtle/tihpa/pti.html
http://www.philippines.hvu.nl/animals10.htm

Papua New Guinea:
http://www.coral.org/where_we_work/asia/pacific/papua_new_guinea
http://www.wcs.org/international/marine/marineasiapacific/asiapacificcoralreefprogram

Solomon Islands:
http://www.unep-wcmc.org/marine/coralatlas/Solomon_Islands.pdf

Appendix 2: Indonesian regional statistics

The tables in this appendix put the Indonesian provinces adjacent to the Coral Triangle in perspective, relative to the total Indonesian economy. They deal in turn with population, infant and child mortality and total fertility rates, regional GDP or Gross Regional Product (GRP), construction activities, fisheries and aquaculture, and international and domestic visitors. All were derived from the Indonesian statistical office (Badan Pusat Statistik), as shown below Table A1.

A. Population

The last official population census was in 2000, with estimates of varying quality for some subsequent years. In 2000, 35.7 million people lived in the 15 provinces adjacent to the Coral Triangle (summarized in Table A1). This was equivalent to 17.3% of the total Indonesian population, in an area that covered just under one million square km compared with just over 900,000 km^2 in the total of Sumatra, Java, West and Central Kalimantan. Population densities are therefore much lower in the Coral Triangle provinces (36 per km^2 in 2000) than in the western provinces (187 per km^2). Total population density in Indonesia in 2000 was 109 per km^2.

Table A1: Population and population growth

	Thousand persons				Annual growth		
Provinces	1971	1980	1990	2000	1971-80	1980-90	1990-2000
Bali	2,120	2,470	2,778	3,151	1.7%	1.2%	1.3%
West Nusa Tenggara	2,206	2,725	3,370	4,009	2.4%	2.1%	1.8%
East Nusa Tenggara	2,295	2,737	3,269	3,952	2.0%	1.8%	1.9%
South Kalimantan	1,699	2,065	2,598	2,985	2.2%	2.3%	1.4%
East Kalimantan	734	1,218	1,877	2,455	5.8%	4.4%	2.7%
Sulawesi	8,527	10,410	12,521	14,946	2.2%	1.9%	1.8%
Maluku and Papua	2,014	2,585	3,507	4,212	2.8%	3.1%	1.8%
Total Coral Triangle	19,595	24,209	29,917	35,711	2.4%	2.1%	1.8%
Rest of Indonesia	99,614	123,282	149,461	170,554	2.4%	1.9%	1.3%
Total Indonesia	119,209	147,490	179,378	206,265	2.4%	2.0%	1.4%

Source: Badan Pusat Statistik: Statistical information by subject (http://www.bps.go.id/site_map/)

Within the rest of Indonesia, Java accounted for the bulk of the population: 121 million in 2000 on an area of about 128,000 km^2 (951 per km^2), compared with 43 million in Sumatra on about 480,000 km^2 (90 per km^2), and less than six million on about 300,000 km^2 in West and Central Kalimantan (19 per km^2). One evident issue is whether Java in particular can cope with a growing and even static population under climate change, and what would be the implications for the rest of the country under alternative scenarios.

Population growth has declined in Indonesia during the 30 years under review in Table A1, from 2.4% pa during the seventies to 2% during the eighties and 1.4% during the nineties. The CIA data in Table 2 suggest a further decline in the annual growth rate in the early 2000s, to 1.1%. The decline up to 2000 was strongest in the western parts of Indonesia while the deceleration in the provinces around the Coral Triangle was from 2.4% pa in the seventies to 2.1% in the eighties to 1.8% in the nineties.

This difference may well have widened in the early 2000s but it is difficult to find consistent comparable statistics at provincial level. Between 1990 and 2000, the growth rates in the Coral Triangle provinces were lowest in Bali (which in many respects have the characteristics of a Western Indonesian province and in official statistics are often counted as such together with Java and Sumatra) and South Kalimantan (where the population is reported to be migrating north to East Kalimantan, which is the outstanding growth province along the Coral Triangle).

East Kalimantan is rich in timber, gold and coal mining, petroleum and natural gas. While illegal logging has destroyed a large proportion of the rainforests in the area, it did establish the 13,605 km^2 Kayan Mentareng National Park in the northern interior of the province in 1996, near the border with Sabah.

Agriculture and tourism are also listed as growth industries in East Kalimantan, with the latter focused on the Derawan Islands off the coast – islands reported to have 872 species of reef fishes and 507 species of coral.

There is a population estimate for East Kalimantan suggesting that growth has continued well into the 2000s, with an estimated population in 2004 of 2,759,000.

B. Infant and child mortality and total fertility rate

These statistics again are somewhat out of date. Over the three final decades of the 20th century, mortality rates did fall strongly for both infants and children under five years of age. Table A2 sorts the eleven provinces then existing around the Coral Triangle according to the infant mortality rate in 1999. The situation is clearly best in Bali and East Kalimantan, and least favourable in West Nusa Tenggara, which is dominated by the islands of Lombok and Sumbawa. The ordering was the same for the infant and under five mortality rates.

Table A2: Child mortality and total fertility rates						
Ranked according to infant mortality 1999	Infant mortality rate		Under 5 mortality rate		Total fertility rate	
	1971	1999	1971	1999	1971	1999
Bali	130	31	194	38	6.0	2.0
East Kalimantan	104	33	150	39	5.4	2.6
South Sulawesi	161	36	242	45	5.7	2.7
North Sulawesi	114	37	166	46	6.8	2.4
Maluku	143	40	215	50	6.9	2.8
Southeast Sulawesi	167	50	251	66	6.4	2.9
Papua	86	52	122	69	7.2	3.0
East Nusa Tenggara	154	56	231	75	6.0	3.1
Central Sulawesi	150	60	225	80	6.5	2.7
South Kalimantan	165	63	248	85	5.4	2.5
West Nusa Tenggara	221	81	328	114	6.7	3.1
Indonesia	145	46	218	60	5.6	2.6

Red: urban areas only, according to Hill et al. (2008).

Source: See Table A1

In comparison, infant mortality rates in Sumatran provinces varied between 38 and 49 in 1999, while Javanese rates showed variations from a low 36 in Central Java to 48 in East Java and 53 in West Java. Rates were much lower in metropolitan Jakarta (24) and the special area of Yogyakarta (25). The rate differed significantly between Central Kalimantan (32) and West Kalimantan (54).

Like the child mortality rates, the total fertility rate (the average number of children born to a woman over her lifetime, based on age-specific fertility rates over her child-bearing years) also dropped significantly between 1971 and 1999. In 1971, it averaged 5.6 children in Indonesia as a whole, rates that were exceeded in nine of the Coral Triangle provinces, with only South and East Kalimantan showing slightly lower rates. By 1999, the rate had fallen to an average 2.6 for total Indonesia, varying between 2.0 and 3.1 in the eastern provinces. In western Indonesia, the lowest total fertility rate was in Jakarta, Yogyakarta, and East Java (2.0); the highest in the province of North Sumatra (3.0) and generally in Sumatran and Kalimantan provinces (around 2.8).

In Eastern Indonesia, the total fertility rate remains higher than the Indonesian average in West and East Nusa Tenggara, Papua, and Maluku. It was significantly lower in Bali (2.0).

C. Economic indicators

Recent gross regional product statistics are shown at constant market prices in Table A3. Two significant observations can be made, the first concerning differences in recent growth rates.

Table A3: Provincial gross domestic product

	GDP at 2000 constant market prices (trillion rupiah)					Average change pa
	2003	2004	2005	2006	2007	
Sumatra	346.7	356.9	369.6	389.1	408.4	4.2%
Java	908.5	957.6	1,012.6	1,071.1	1,137.2	5.8%
West & Central Kalimantan	34.0	35.7	37.6	39.6	42.0	5.4%
Subtotal	1,289.2	1,350.2	1,419.8	1,499.8	1,587.6	5.3%
Bali	19.1	20.0	21.1	22.2	23.5	5.3%
Nusa Tenggara	23.1	24.5	25.1	26.0	27.3	4.2%
South & East Kalimantan	110.6	113.2	117.2	121.1	123.7	2.8%
Sulawesi	66.0	69.7	74.1	79.2	84.7	6.4%
Maluku, Papua	30.6	26.5	33.0	29.7	31.2	1.6%
Subtotal	249.4	253.8	270.4	278.2	290.4	3.9%
Total Indonesia	1,538.7	1,604.0	1,690.2	1,778.0	1,878.0	5.1%
West Indonesia*	1274.3	1334.4	1403.3	1482.4	1,569.1	5.3%
East Indonesia**	264.3	269.6	286.9	295.6	308.9	4.0%

* Sumatra, Java and Bali
** Kalimantan, Sulawesi, Nusa Tenggara, Maluku, and Papua

Source: See Table A1

Total GDP in Indonesia averaged 5.1% per annum from 2003 to 2007 according to these statistics (measured as the average of four annual observations from 2003-04 to 2006-07). The growth rate was higher in the west (5.3% pa) than around the Coral Triangle (3.9% pa), a result echoed by the slightly different 'official' distinction between West Indonesia (Sumatra, Java and Bali) and the rest, in the bottom of Table A3.

Within the Coral Triangle, Sulawesi showed the highest annual growth (6.4%) followed by Bali (5.3%). Maluku and Papua combined showed the lowest average annual growth (1.6%), and South and East Kalimantan the second-lowest despite East Kalimantan being the economic powerhouse in the region. The two provinces in Nusa Tenggara clocked in at 4.2%. These rates, of course, are based on a short time series and the less than perfect calculation method used by the Indonesian statistical office.

The short time series for Indonesia's GDP does not cover the impact of the Asian financial crisis in 1998. This is revealed by United Nations statistics. GDP fell by 13.1% at constant 1990 prices, from $US206.9 billion in 1997 to $179.7 billion in 1998. There was a small recovery of 0.8% in 1999 and a larger 4.9% in 2000, but it took until 2002 before total GDP had recovered to the 1997 level. From 2001, however, there has been an almost continuous acceleration in Indonesia's GDP, from 3.6% growth that year through 4.5%, 4.8%, 5.0%, 5.7%, 5.5%, and 6.3% in the subsequent years to 2007. These statistics, incidentally, show higher annual growth between 2003 and 2007 than revealed by Table A3 (5.6%). We don't know how this would translate to the provincial statistics published by the Indonesian Statistical Office.

There is another more revealing method of analysing these statistics, by estimating regional GDP per head of population. Again, the database is less than perfect, as the official population census is from 2000 and the data relate to later years. But it is legitimate to construct an index allowing us to compare different areas with one another, based on an assumption that population growth was reasonably uniform across the country between 2000 and 2007. The resulting distortions from this should be relatively minor.

Setting the index to 100 for total Indonesia, we find that the average for the Coral Triangle provinces was 89 and for the rest of Indonesia 102 (Sumatra 104, Java 103, and West and Central Kalimantan 78). However, there were large differences within the Coral Triangle, with South and East Kalimantan having a per capita GDP index of 252 (2.5 times the national average, due to East Kalimantan), compared with 82 in Maluku and Papua combined, 81 in Bali, 62 in Sulawesi, and a mere 37 for the two Nusa Tenggara provinces.

The Javanese average hides the fact that Jakarta had a per capita GDP index of 436 – over four times the national average. All the rest of the island had lower than average GDP per head: an index of 91 for East Java, 88 in the new province of Banten on the western tip of Java, 84 in West Java, and a low 56 in Central Java and 64 in the special area of Yogyakarta.

Table A4: Construction activity (million rupiah, 2000 constant prices)

Million rupiah, 2000 prices	2002	2003	2004	2005	2006	2007	Average
Bali	402	402	475	455	452	461	441
Nusa Tenggara	361	389	473	724	509	570	505
South & West Kalimantan	2,267	2,514	3,053	2,981	2,916	2,945	2,779
Sulawesi	1,452	1,341	1,806	2,449	2,222	2,090	1,893
Maluku & Papua	913	944	988	1,534	1,476	1,467	1,220
Subtotal	5,395	5,591	6,796	8,143	7,575	7,534	6,839
Rest of Indonesia	22,007	23,194	33,614	34,340	32,221	31,925	29,550
Indonesia	27,402	28,785	40,409	42,483	39,796	39,458	36,389

Source: See Table A1

Construction statistics (Table A4) cover activities by firms involved in housing and other building, alterations and repair, demolitions and also highways and streets, according to the statistical office. The 2002-07 average distribution across Indonesia is slightly more in favour of Eastern Indonesia than GDP, at 18.8% of the total compared with 15.5% of GDP. The difference is largest in Maluku and Papua (3.4% as against 1.7%), South and West Kalimantan (7.6% of construction activity, 6.6% of GDP), and Sulawesi (5.2% compared with 4.5%). The exception is the Lesser Sundas (Bali, West and East Nusa Tenggara), with 2.6% of total Indonesian construction activity, compared with 2.8% of GDP.

The generally larger share of construction activity around the Coral Triangle may indicate some emphasis on developing the area, relative to Sumatra and Java in particular.

D. Fisheries

The statistics cover marine fisheries and fish culture (aquaculture) production. Marine fisheries are shown in Table A5. Production has fluctuated over the eight years for which data are readily available (2000-07). It generally started high and declined to 2004, with some recovery over the years to 2007. Most marine fisheries are associated with Java, with Sumatra in second position until production collapsed from 2003 according to these statistics.

Marine fisheries averaged 437,000 tons per annum over these years with 80,000 tons in the Coral Triangle provinces (18%).

Table A5: Marine fisheries

Thousand tons	2000	2001	2002	2003	2004	2005	2006	2007	Average
Sumatra	108.9	111.9	100.7	33.0	15.7	14.5	21.8	25.7	54.0
Java	369.9	341.1	318.8	214.0	220.1	270.4	273.2	321.4	291.1
West Kalimantan	10.9	15.9	8.9	5.2	5.7	6.3	6.6	10.2	8.7
Central Kalimantan	8.2	7.8	7.8	-	0.3	0.4	-	-	3.1
Subtotal	497.9	476.7	436.3	252.1	241.8	291.6	301.6	357.3	356.9
Bali & Nusa Tenggara	10.7	11.3	9.7	14.7	16.4	21.6	14.8	29.3	16.1
South Kalimantan	7.4	10.9	8.9	34.7	8.7	8.5	6.6	14.9	12.6
East Kalimantan	8.8	10.2	5.3	7.6	7.4	8.3	6.5	11.1	8.2
Sulawesi	45.2	44.9	36.9	34.9	31.2	32.0	32.3	48.9	38.3
Maluku	3.6	6.7	14.7	-	-	3.1	4.3	4.6	4.6
Subtotal	75.8	83.9	75.5	91.9	63.8	73.4	64.5	108.7	79.7
Total	573.8	560.6	511.8	344.1	305.6	365.0	366.1	466.0	436.6

Source: See Table A1

Marine fisheries, however, are dwarfed by aquaculture, with an average 2004-06 production of 2.1 million tons (Table A6). Of this, 1.1 million tons was in the Coral Triangle, of which Sulawesi accounted for 539,000 tons and Bali and Nusa Tenggara for 500,000 tons. The bulk of the production is in marine cultures (these areas produced 95% of fish from marine culture in Indonesia). Sulawesi also produced significant amounts in brackish water ponds. In the rest of Indonesia, Java was the main producer using a range of technologies (621,000 tons), followed by Sumatra (365,000 tons).

Table A6: Fish culture production							
Average 2004-06 (000 tons)	Marine culture	Brackish water pond	Fresh water pond	Cage	Floating cage net	Paddy field	Total
Sumatra	6.2	182.0	118.5	26.0	12.5	19.6	364.8
Java	31.4	229.2	190.6	5.3	85.7	79.2	621.4
West & Central Kalimantan	3.1	3.8	2.5	5.4	0.0	0.3	15.1
Subtotal	40.7	415.0	311.6	36.7	98.2	99.1	1,001.3
Bali and Nusa Tenggara	479.2	14.9	4.3	0.4	0.1	0.8	499.7
South & East Kalimantan	1.8	29.3	4.5	20.1	0.3	0.1	56.1
Sulawesi	366.6	150.1	10.4	1.7	6.4	3.9	539.1
Maluku & Papua	4.1	1.7	2.6	0.4	0.0	0.0	8.8
Subtotal	851.6	196.1	21.8	22.6	6.8	4.8	1,103.7
Indonesia	892.3	611.1	333.4	59.3	105.0	104.0	2,105.0

Source: See Table A1

E. Tourism

Table A7 shows number of beds in ‘classified’ and ‘non-classified’ establishments in Indonesia, and domestic and international visitors. Classified hotels fulfil the requirements of the Department of Culture and Tourism, and have a star rating. Of non-classified establishments, melati hotels provide budget-type accommodation that is not star-rated; losmen are home-stay type lodgings; and youth hostels provide low-cost facilities, mainly for young people.

Table A7: Visitor statistics, total accommodation establishments, 2008							
Ranked by percentage of foreign guests	Number of rooms	Guests per day			In classified hotels		
		Domestic	Foreign	Total	Rooms	Domestic	Foreign
Bali	42,363	9,888	16,277	26,165	48%	33%	72%
Nusa Tenggara West	6,109	1,328	593	1,921	36%	49%	71%
Nusa Tenggara East	3,515	541	67	608	9%	24%	28%
North Sulawesi	4,253	1,629	111	1,740	28%	37%	43%
Papua	2,992	881	44	925	24%	21%	43%
East Kalimantan	11,650	3,769	188	3,957	30%	38%	77%
South Sulawesi	9,727	5,741	250	5,991	31%	48%	74%
West Papua	1,286	235	8	243	41%	56%	100%
Maluku	1,888	334	9	343	28%	31%	56%
Southeast Sulawesi	2,365	706	16	722	1%	3%	0%
Central Sulawesi	2,843	687	14	701	2%	8%	7%
South Kalimantan	5,341	2,320	42	2,362	28%	38%	90%
Gorontalo	915	225	3	228	6%	9%	33%
West Sulawesi	969	452	4	456	8%	7%	0%
Maluku North	1,529	307	1	308	3%	2%	0%
Subtotal	97,745	29,043	17,627	46,670	35%	35%	72%
Indonesia	325,218	139,474	27,863	167,337	34%	39%	78%
Rest of Indonesia	227,473	110,431	10,236	120,667	34%	40%	88%

Source: See Table A1

Of 325,000 rooms at the latest count, almost 98,000 (30%) were in provinces adjacent to the Coral Triangle, but over 42,000 of these were in Bali. The daily average number of guests was 46,700, yielding an apparent room occupancy rate of about 48%. This compares with 53% in the rest of Indonesia, and 51% overall. Again, Bali dominated the number of guests (26,200 or 56% of the Coral Triangle total).

Table A7 ranks the provinces adjacent to the Coral Triangle according to percent of foreign guests. This is particularly high for Bali (62%), followed, with much smaller total figures, by West Nusa Tenggara (Lombok and Sumbawa) with 31% and East Nusa Tenggara (Flores, Sumba, West Timor and other islands) with 11%. The foreign guest percentage declines further at a rapid rate from here: North Sulawesi 6%, Papua 5%, and East Kalimantan 5%.

The proportion of classified rooms (in starred hotels) is highest in Bali (48%) followed by West Papua (41%), West Nusa Tenggara (36%), South Sulawesi (31%), East Kalimantan (30%), South Kalimantan, North Sulawesi and Maluku (28% each), and Papua (24%).

There is no set pattern for what comes first as a tourist region develops. Bali is obviously in a unique position with a high proportion of foreign visitors and a number of international hotels catering for part of that market. But Bali also attracts other visitors either arriving in groups or as independent travelers. So unstarred family and losmen accommodation has a big market too.

The mixed characteristics in individual provinces are illustrated by the six provinces with the largest number of guests (derived from Table A7 and associated calculations). Bali and to a lesser extent West Nusa Tenggara have the highest proportions of foreign visitors; there are few almost anywhere else. The six provinces, however, have the highest proportions of classified hotel rooms, and most foreigners do prefer to stay in such accommodation, whether they come in great numbers as in Bali, or in lesser numbers as in South Sulawesi, East and South Kalimantan. It is not clear why the proportion of foreigners checking into classified hotels in North Sulawesi is smaller than in the six other provinces, but even here the proportion exceeds the average in the other Coral Triangle provinces.

Province	Guests per day	Foreign visitors	In classified hotels	
			Rooms	Foreigners
Bali	26,165	62%	48%	72%
South Sulawesi	5,991	4%	31%	74%
East Kalimantan	3,957	5%	30%	77%
South Kalimantan	2,362	2%	28%	90%
West Nusa Tenggara	1,921	31%	36%	71%
North Sulawesi	1,740	6%	28%	43%
All other CT adjacent	4,534	4%	14%	32%
Total Coral Triangle	46,670	38%	35%	72%

F. 30 years of regional development in Indonesia

A new study of Indonesia's regional socioeconomic surveys since the 1970s was published in December (Hill et al., 2008). It provides a perspective on the analysis contained in this appendix. Concentrating of the five main island groupings of Java-Bali, Sumatra, Kalimantan, Sulawesi, and Eastern Indonesia defined as the rest of the islands, it notes that there has been a clear shift of economic activity towards Java-Bali, centred on Jakarta. Sumatra has shown a stable share when mining is excluded but a declining share when oil and gas are included.

In Kalimantan, the largest and most dynamic province has clearly been East Kalimantan. On the other hand, the share of the eight eastern provinces (as they existed until the new provinces were created from 2000) has been gradually declining, including North and South Sulawesi, and Maluku which declined from above average to less than one-third of its share in 1975.

Very poor provinces with a non-mining Gross Regional Product of half or less the national average include the two halves of Nusa Tenggara that are slipping further behind, Maluku (the authors note that conflict has had a damaging effect on economic development both here and previously in the northern Sumatran province of Aceh), and Southeast Sulawesi, the poorest province in the island. They also note that some provinces have been slipping behind, mainly traditional agricultural exporters such as South and West Kalimantan, North and South Sulawesi, and Papua (though the latter has benefited from a combination of mining boom and special government programs).

Despite such differences, the authors conclude that there has been n significant change in concentration of economic activity across major island groupings. Java, or more broadly Java, Bali, Sumatra and Kalimantan have dominated, though Sulawesi has gone from below-average to above-average growth. Greater Jakarta has increased its role as the nation's key economic agglomeration.

Nevertheless, the poorest regions, located mainly in Eastern Indonesia, have generally grown only a little more slowly than the national average. No province has shown consistently poor performance for decades. Regional disparities are either high and declining or moderate and stable. Mining activities have tended to accentuate disparities, such as the success of East Kalimantan.

References

Badan Pusat Statistik (Indonesian Statistical Office), assorted sources of tables.

Hal Hill, Budy P. Resosudarmo and Yogi Vidyattama (2008), 'Indonesia's changing economic geography'. Bulletin of Indonesian Economic Studies 44-3 407-435. December.

WWF is one of the world's largest and most experienced independent conservation organizations, with almost 5 million supporters and a global network active in more than 100 countries.

WWF's mission is to stop the degradation of the planet's natural environment and to build a future in which humans live in harmony with nature, by:
- conserving the world's biological diversity
- ensuring that the use of renewable natural resources is sustainable
- promoting the reduction of pollution and wasteful consumption.

WWF

for a living planet®