Climate change vulnerability assessment

of the Verde Island Passage, Philippines

CONSERVATION INTERNATIONAL

For more information on the Verde Island Passage Vulnerability Assessment Project, contact:

Emily Pidgeon, PhD
Director, Marine Climate Change Program
Conservation International–Global Marine Division
epidgeon@conservation.org

Rowena Boquiren, PhD
Socioeconomics and Policy Unit (SEPU) Leader
Conservation International–Philippines
rboquiren@conservation.org

Conservation International
2011 Crystal Drive, Suite 500
Arlington, VA 22202 USA
Web: www.conservation.org

This document should be cited as: **R. Boquiren, G. Di Carlo, and M.C. Quibilan (Eds). 2010.** *Climate Change Vulnerability Assessment of the Verde Island Passage, Philippines*. Technical report. Conservation International, Arlington, Virginia, USA.

Photo credits
©Teri Aquino
©CI/photo by Haraldo Castro
©Tim Carruthers
©Benjamin De Ridder, Marine Photobank
©CI/photo by Giuseppe Di Carlo
© Google Earth
©Keith Ellenbogen
©CI/photo by Michelle Encomienda
©CI/photo by Jürgen Freund
©Leonard J McKenzie
©CI/photo by Miledel C. Quibilan
©rembss, Flickr
©Badi Samaniego
©CI/photo by Sterling Zumbrunn

Science Communication Team
Tim Carruthers and Jane Hawkey
Integration & Application Network
University of Maryland Center for Environmental Science
www.ian.umces.edu

Preface

The Verde Island Passage, in the sub-national area of Luzon in the northern Philippines, is located within the globally significant Coral Triangle, an area considered the center of the world's marine biodiversity. The Verde Island Passage is a conservation corridor that spans five provinces: Batangas, Occidental Mindoro, Oriental Mindoro, Marinduque and Romblon. The abundant fish and charismatic megafauna support over 7 million people in those provinces, whose livelihoods include fishing, aquaculture, and tourism.

It is projected that climate change will cause rising sea levels, higher ocean temperatures, and more acidic waters. As the ocean largely regulates the climate, changes in ocean temperatures and currents are already altering the frequency, intensity, and distribution of storms, floods, heat waves, and the amount and distribution of rainfall. The unique biodiversity of the Verde Island Passage is at risk. In addition, the loss of biodiversity directly impacts its local communities, as their livelihoods are dependent primarily on tourism, fisheries, and agriculture, all of which are dependent on these threatened natural resources.

In September 2008, Conservation International, in cooperation with several partners, conducted a vulnerability assessment to gauge the likely impacts of climate change on marine ecosystems of the Verde Island Passage and the human communities that are dependent upon them. The assessment evaluated the vulnerability of the Verde Island Passage to climate change and determined the priority actions needed to ensure that its ecosystems and coastal societies can adapt to future climate conditions.

This study brought together experts on the Verde Island Passage marine environment, climate scientists, social scientists, government officials, and local stakeholders, all working under a common agenda: the need to maintain and increase the resilience of biodiversity of this area.

This report contains the scientific studies that underpin the immediate and substantial actions needed to increase the adaptive capacity of Verde Island Passage's ecosystems and the people that depend on them. Adapting to climate change is the only solution to ensure ecosystems and human societies can survive and maintain their wellbeing when exposed to climate change impacts. These studies will support the development of "climate-smart" plans for the local governments of the Verde Island Passage.

Conservation International and it partners are committed to continue to support their efforts towards ensuring the biodiversity of the Verde Island Passage is protected and can adapt to future conditions for the benefit of the society and its future generations.

Romeo B. Trono
County Executive Director
Conservation International–Philippines

Acknowledgements

This document is the result of a collective effort and would not have been possible without the contributions of many people and organizations. Conservation International would like to acknowledge the work of the faculty and researchers of the Marine Science Institute, University of the Philippines–Diliman, and De La Salle University: Niva Gonzales, Rina Rosales, Miledel C. Quibilan, Sheila Vergara, Michelle Reyes, and Annabelle Trinidad.

This work would not have been possible without the kind support and contribution of the Presidential Task Force on Climate Change of the Government of the Philippines, the Provincial Government of Batangas, the Provincial Governments of Occidental and Oriental Mindoro, the Provincial Government of Marinduque, the Provincial Government of Romblon, and all their Municipal Governments, the Department of Environment and Natural Resources (DENR), and the Philippine Atmospheric, Geophysical and Astronomical Services Administration (PAGASA).

We also express our gratitude to each of the Climate Change Vulnerability Assessment Workshop participants and their home institutions, and to the numerous staff at Conservation International who provided feedback and input in several stages of this project.

Table of contents

Chapter 1: Vulnerability assessment of marine ecosystems and fisheries to climate change in the Verde Island Passage

Laura T. David[1], **Lead Integrator**

Contributing Authors: Porfirio Alino[1], Vera Christine Horigue[1], Wilfredo Licuanan[2], Samuel Mamauag[1], Evangeline Magdaong[1], Eileen Penaflor[1], Riovie Ramos[1], Maricar Samson[1], Fernando Siringan[1], Leah Soria[1], Victor Ticzon[1], Cesar Villanoy[1]

[1] Marine Science Institute, College of Science, University of the Philippines–Diliman, Quezon City, Philippines
[2] De La Salle University, 2407 Taft Avenue, Manila, Philippines

Executive summary

This report synthesizes the five studies of the "Vulnerability Assessment of Marine Biodiversity and Related Human Well-Being in the Verde Island Passage" project funded by the Conservation International. Implemented by researchers from the Marine Science Institute of the University of the Philippines and De La Salle University, the research activities focused on the characterization of the geological, physical and biological environment and fisheries of the Verde Island Passage (VIP). The objective was to determine the vulnerability of the VIP marine biodiversity to impacts of climate change, which included changes in ocean temperature, sea level rise, and increased frequency of more devastating typhoons.

Rationale

The Verde Island Passage, located in the Sulu-Sulawesi Seascape is the area of interest since it has been identified as a Marine Biodiversity Conservation Corridor as identified under Ong et al. 2002 and EO 578. Based on the recent coral reef assessments by CI–Philippines, 319 coral species belonging to 74 coral genera have been observed in the passage (CI 2009). Carpenter and Springer (2005) noted that more than half of the documented fish species worldwide overlap in this area of the Philippines. Furthermore, iconic species such as dolphins, whales, turtles, and whalesharks occur in the passage (Dolar 2006). Moreover, of added significant value to the project is the fact that the VIP is the area where the State of the Coast has been piloted in the province of Batangas hence there exists an opportunity to scale up these efforts and at the same integrate within an ICM approach.

Description of approach

The vulnerability analyses of the VIP to the potential impacts of climate change required considering its degree of physical and geological exposure, the sensitivity of its coastal habitats, and their inherent adaptive capacity to cope with such an impact (IPCC 2007). Because of the particular characteristics of the VIP, the availability of data and related literature, and time constraints, the climate change impacts that were considered for biodiversity were limited to sea surface temperature rise, storminess, and sea level rise.

The research activities on exposure included studying:

- time series of heating stress;
- wave and storm surge simulations;
- historical coastal erosion;
- likelihood of inundation; and,
- additional naturally occurring exacerbating features.

Sensitivity studies focused on qualifying impacts of increase in sea surface temperature (SST), storminess, and sea level rise to corals, seagrasses, and mangroves. While the ecological adaptive capacity was investigated using a change detection over a time series of remotely sensed images as a proxy for the ability of the system to withstand an impact.

Together these exposure, sensitivity, and adaptive capacity give insight to the Verde Island Passage vulnerability to climate change. In particular, the study highlighted the effect of climate change to coral and reef fish diversity and consequently also to fisheries.

Pertinent results

A 0.15-0.30°C/decade sea surface temperature increase in the VIP region was seen over the last 2 decades. In general in the VIP, coastal areas experienced less increase relative to areas offshore. However, embayed areas were observed to be more susceptible to prolonged extreme heating events most likely due to longer residence time of warm water within bays as compared to open coasts.

Analysis showed that the probable percentage loss of live hard coral cover due to increase in ocean temperature ranged from 3% to 22% across the Verde Island Passage. The sites deemed to be highly vulnerable are those with high cover of *Acropora* sp. and pocilloporids. Sites with minimal losses are mostly dominated by the coral *Porites* sp. As such, the municipalities of Mabini and Tingloy have the highest vulnerability with percentage loss of 11% to 22% and 14% to 21% respectively. The municipality of Lubang had an estimated loss 8% to 15%.

It should be noted however, that longer-term time series SST from HadISST1 (1900-2008 for the VIP) shows a lesser degree of increase of only a 0.06 oC/decade in the longer-term. In addition, the 10-yr smoothed and de-trended annual HadISST1 also compares particularly well with the Pacific Decadal Oscillation (PDO) index for the same period with an observed lag of 5-10 years. This observation emphasizes the telecommunication between the Pacific and the VIP region and suggests that use of the last 2-3 decades of data to simulate future scenarios should be interpreted with caution. Specifically, all satellite-derived images go back in time only as far as the last PDO-shift in 1977 from negative to positive. All synoptic data available therefore belong to the PDO positive regime. In 2008, the early stage of a cool phase of the PDO was observed. Aside from the increase in temperature averages, the degree and frequency of anomalies might be what is crucial as the succession of effects would prevent its recovery rate and steady increases may cause more adaptive capacity.

An average of two to three storms passed near the Verde Island Passage corridor annually. There were no strong typhoons (Category 4-5) in the period before 1975 but in recent years roughly more than half belong to the strong typhoon categories. Fortunately, the wave fetch within Verde Passage is not large because of the narrow configuration of the passage thus waves do not develop into large waves during typical monsoon conditions or even during storm conditions. The only areas prone to surges in Verde Island Passage are those that are exposed to wide areas of water such as the coastlines facing the Sibuyan Sea (eastern Batangas, Quezon, and eastern Mindoro coasts) and those facing the South China Sea including Lubang Island.

Storms bring about high sedimentation from the uplands and potential erosion at the coast. Overall large sediment supply to the coast results in net land gain is observed on most of the delta plains during the last 50 to 60 years. In Batangas, land progradation in delta plains coincide with periods of high annual rainfall, while erosion occurred during periods of decreased precipitation over the last 40 years. Long steep slopes have practically no forest cover, which also promotes higher sediment yield. In Batangas, where sugarcane is a major agricultural product, erosion is not arrested by any structure that would break the flow of surface runoff resulting in high rates of erosion. Areas such as Nasugbu, Balayan, Batangas, Boac, and Calapan that experienced rapid accretion in recent years, are also the most vulnerable to coastal inundation. However, coastal erosion in Batangas City and Calapan is instead attributed to improperly placed and designed engineering structures and removal of mangrove forests; and liquefaction due to tsunami associated with 7.1M 1994 earthquake, respectively.

Based on the monitoring of reefs east of the VIP, estimated coral cover losses during tropical storm is about 8% to 21%. These projections are considered conservative. Diversity is already low in the municipalities surveyed, thereby making them even more vulnerable to storm events based on the estimates. The municipality of Nasugbu is deemed to be the most vulnerable of all the sites regardless of low or severe impact. Losses in coral genera will change from 28 to 21.8% during severe impact.

The four sites in the VIP with known seagrass distribution are analyzed to have low sensitivity to sediment perturbation caused by an increase in storm intensity and frequency. The projection may be different if analysis will include eutrophication caused by influx of freshwater from increased storm/rainfall frequency.

The VIP corridor is within a very tectonically active area where there are numerous active faults and volcanoes and where earthquakes are very frequent. Liquefaction, subsidence and tsunami can cause extensive and rapid coastal inundation, thus, global sea-level rise would be amplified. On the other hand, land emergence or uplift can counter the effect of sea-level rise. The predominance of net land gain, during a period when sea level is supposed to be rising, can be due to uplift. However, there are no tide gauge records in the VIP corridor that can be examined to test this idea.

Reef area loss due to sea level rise for the VIP ranges from 0.38% to 7%. Note that these only apply to the deepest portion of the reef slope. Assuming that the coral distribution and diversity are even for the entire reef area, diversity loss obtained using the species area curve estimated 0.60% to 0.80% loss. Specifically, Batangas City and Nasugbu are highly vulnerable with 0.60% to 0.80% diversity loss while the rest of the municipalities surveyed have relatively lower estimates of 0.60% to 0.70% diversity loss.

If sensitivity assessment will be based on the areal extent of potential mangrove areas almost all areas included in this report will be inundated with 1m rise in sea level except for the municipalities of San Juan, Batangas and Calapan City, Oriental Mindoro.

Overall, Calatagan, followed by Puerto Galera-Naujan appears stable in that changes to live coral and macrophyte cover are minimal through the years. The live coral cover of Batangas East and West Marinduque also appears stable. The most significant live coral cover loss can be seen for the islands of Lubang and Maricaban.

Chlorophyll data within and around the VIP shows the seasonality of the signal with higher signal during the NE monsoon. Further investigation of the NE signal shows the higher chlorophyll concentration in the western side of the VIP. Sites within the VIP showed a positive chl anomaly during a strong La Niña (1999-2001) with a 1 year lag between the eastern and western part. This could have implications in the near future because PDO negative (in which we are in now) have been associated with more La Niñas.

In an increasing sea surface temperature, most of the fisheries target species will be affected through disruption in timing of reproduction, decreased reproductive output, shorter larval duration, lower recruit survivorship, and recruitment failure leading to changes in fisheries productivity. Impact on critical habitats such as coral reefs, seagrasses, and mangroves will affect the aforementioned attributes of the associated fauna that include high value target species (e.g., siganids, groupers, snappers). For sea level rise, some habitats such as mangroves will be inundated that will reduce available areas for recruitment of associated fauna that have fisheries value. In coral reefs, species on shallower parts (e.g., reef flats) will be affected compared to those on reef slopes. Increase in frequency and intensity of storms can greatly affect recruitment of target species through reduction of suitable sites for recruitment and reduction in abundance and species diversity due to habitat loss and decreased habitat complexity.

A total of 16 species of reef fishes listed in Pratchett et al. (2008) was observed in the VIP. Percentage loss of reef fish species ranged from 9% to 14%. The municipality of Nasugbu was deemed to have the highest vulnerability as it could lose 16% of the 44 observed fish species, followed by Looc, Calatagan, and San Juan with estimated losses of 14%, 12%, and 10% respectively.

The vulnerability assessment for the fisheries utilizes the information gathered from the literature to identify the fisheries resources (target species, fishery stocks) that will be most affected (i.e., vulnerable vis-à-vis the prospective climate impacts) by extreme changes in the climate. Emphasis was placed upon knowledge of the critical life stages (e.g., larvae, juveniles, reproductive stages) of the species as well as some information on their catch rates and habitat conditions. It has been acknowledged that changes in the climate (e.g., rising sea surface temperature, increase in storm frequency, storm surges) would possibly introduce greatest impact upon larval, juvenile and reproductive stages of target species affecting distributional patterns (e.g., Munday et al. 2008). Target species may also be influenced by changes in the climate indirectly through habitat loss and fragmentation (e.g., coral loss through bleaching events, inundation of mangroves areas) affecting their recruitment, survivorship and abundance (Pratchett et al. 2008). The associated habitats of the target species were determined as this will allow further examination of the conditions of these habitats harboring the critical life stages. The presence of habitat types (e.g., seagrass beds, mangroves) that enhances the growth and survivorship and what drives the population dynamics of the species potentially will serve as a gauge or index as what would be vulnerable to climate change.

The fisheries that are most vulnerable are those involving fishes that need different habitats throughout their life stages. For example, Mabini and Lubang/Looc have grouper and snapper fisheries. These fishes make use of estuaries, mangroves, seagrasses, corals, and the pelagic realm during the different stages in their life.

Key recommendations

The fisheries ecosystem approach to management will need to be put in place as natural links to the present conservation efforts with the tourism industry. Environmental concerns will not only marginalize fishers and their fishing grounds, exacerbate the impending climate change impacts but will jeopardize the future of our next generations.

- Adaptation mechanisms would require that the present CRM programs need to be more tightly integrated through establishing knowledge based communities. The various CRM working groups would also need to engage with each other through inter-LGU arrangement joint fisheries law enforcement teams (FLET) and bay management councils or VIP level alliances can be formed. Coastal law enforcement will need to integrate ecosystem management and zoning policy considerations, e.g., foreshore management, infrastructure and human settlements regulations
- Based on available literature on the interconnectivity of mangrove, seagrass and coral reef, protecting adjacent ecosystems may increase the resilience of these ecosystems to the impacts, including that of climate change. Therefore, in sites that have shown significant adaptive capacity and at the same time in sites where the fisheries were found vulnerable, measures must be taken to reduce of prevailing threats such as illegal and destructive fishing, emerging pollution and habitat degradation from urban and industrial development. Where critical life stages are important it would be important to consider a combination of establishment of an expanded protection zone to serve both as a canary for improving adaptive management and (see also adaptive management below), and have regulated activities through close and open seasons and gear regulations in conjunction with safety nets and incentives for affected sectors.
- In addition, given that sea level will accelerate in the coming years and that storms are likely to increase in frequency and possibly strengthen, the natural buffers to sea level rise and impact of large waves, such as coral reefs and mangroves, should be protected and rehabilitated.
- Deforestation and extensive agriculture in the watersheds, long steep slopes, and presence of numerous faults, high seismicity, and volcanoes all

promote a high sediment yield. These have likely played a large role in the degradation of coral reef ecosystems and in the decline of coastal and offshore fisheries. In the formulation of mitigation and adaptation measures, this link between the marine ecosystem and the watershed should be considered.

- In some areas, this high sediment yield has resulted to rapid accretion. Instead of utilizing the newly prograded lands in the VIP for various development, these can instead be used by the LGUs and national agencies as buffers to erosion and action of large waves. Greenbelts, of the appropriate assemblage, can be established in these newly prograded lands. Wide mangrove plains will also reduce the level of nutrients and sediments entering the sea and create nursery habitats for fisheries.
- Erosion along the coast is mostly caused about by human modifications such as inappropriate ports, quarrying, and removal of mangroves and seagrasses. Steps must be taken to position ports in such as way as not to impede longshore sediment drift and advocate constructing open ports that allow water to flow in between pilings. Stop stone mining and educate people from various strata of the functions of mangroves and coral reefs towards the protection of the beach.

Areas that suggest that adaptation measures are imperative shall be those which are crucial to marine biodiversity, the life histories of important fisheries species, and human well-being.

For biodiversity and fisheries, these areas would be high candidate sites for expanding sizes or establishing areas as marine protected areas (MPA). This will not only help in the conservation of existing flora and fauna but also in the replenishment of fisheries stocks by regulating fishing effort. In addition to MPA, it is imperative that adoption of access and use rights fisheries management interventions are put in place such as closed and open seasons, gear regulations and effort controls, combined with access incentives linked to stewardship (e.g., reserves related to enhancement and sea ranching of highly valued invertebrates species).

For human well-being, these areas would also be sites which deliver multiple services to the community not only as source of livelihood but also provide protection from climate-related hazards.

Adaptive management

Considering the constraints on the available information and the unfolding changes occurring in the VIP, it is imperative to incorporate an adaptive management approach to the climate change adaptation measures. These would require the formulation of a research, development and extension program that incorporates an appropriate monitoring design for the impending potential impacts. It would require the participation of the local higher education institutions to engage with the relevant stakeholders to build knowledge-based communities in the VIP where lessons learned and knowledge gained are regularly fed back, e.g., through the State of the Coasts report.

Targeted research

Complementary to the monitoring would be a targeted research, development and extension agenda that look at how the adaptive capacity of the coastal areas, their ecosystems and fisheries can cope with climate change. Long-term monitoring together with simulation models that investigates how to enhance the adaptive capacity (e.g., abundance, coverage and range of vulnerable ecosystems and habitats) will need to define the priority research questions and their interdisciplinary concerns. A network of sensors (e.g., thermal sensors and weather stations) linked or akin to the ICE CREAM program will be useful for the VIP in mainstreaming climate change adaptation measures.

Introduction

The vulnerability analyses of the Verde Island Passage (VIP) requires considering the components and measures of potential impacts to and adaptive capacity of the critical marine habitats and fisheries (Allison et al. 2009, Worldfish Center 2009).

The potential impact of climate change to an ecosystem includes the degree that it is exposed and its ecological and social-economic state which has an inherent sensitivity to a changing environment. The adaptive capacity of an ecosystem on the other hand would depend on their congenital capacity (including associated symbionts like their zooxanthellae) and survival from historical exposures. The focus of study presented here, given the time restrictions and budget constraints, is on sensitivity and exposure.

Predictions of changes in temperature, precipitation and sea level as a result of climate change in the Philippines are summarized by Hulme and Sheard (1999). These predictions were derived from climate experiments from several global climate models conducted for the Intergovernmental Panel on Climate Change (IPCC) and historical observed climate data. Some general climate predictions for the Philippines include a temperature increase of about 0.1-0.3°C/decade, an enhanced seasonal precipitation variation (e.g., drier months become drier and wetter months become wetter) and a slight sea level increase of about 30cm by 2045.

The goal of this study is to estimate, using the best available information, oceanographic and climate change effects and its potential impacts on critical marine habitats, threatened species and fisheries in the VIP. Because of the particular characteristics of the Passage, the availability of data and related literature, and time constraints, the climate change impacts that were considered for biodiversity were limited to sea surface temperature rise, storminess, and sea level rise (Figure 1).

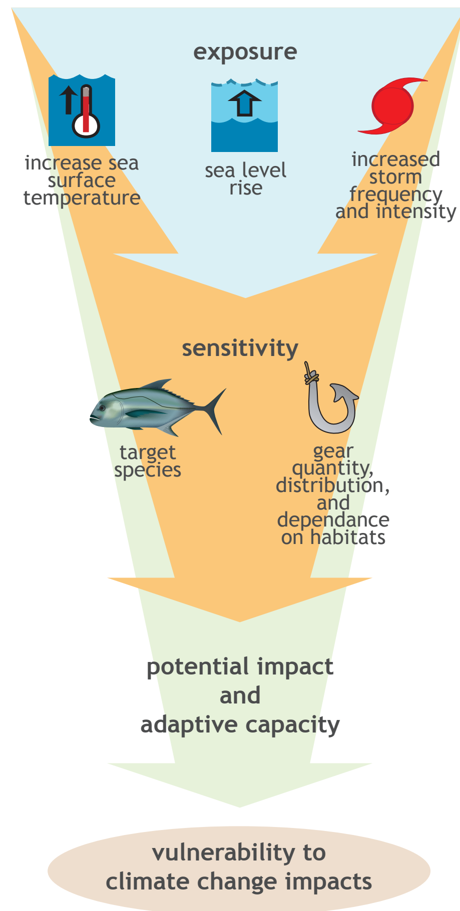


Figure 1. Diagram of each of the elements considered and how they relate to one another in the assessment.

Study area

The Verde Island Passage is an important strait for water exchange between the South China Sea and the Sibuyan Sea and eventually the Pacific. It also forms a natural boundary between basins. The shallowest and narrowest point of the passage is in the vicinity of the Verde Island (Figure 2). Net flow in Verde Island Passage is to the west during the northeast monsoon and to the east during the southwest monsoon (Figure 3).

The coasts along the Verde Island Passage corridor are geomorphologically varied. Cliffed rocky shorelines occur where steep mountain slopes adjoin the sea. In some areas, these rocky coastlines are fringed with narrow sandy or gravelly beach and coral reefs. Narrow and gently sloping sandy coastal plains develop from small rivers draining the flanks of volcanoes. Large rivers, on the other hand, form broad and relatively flat sandy to muddy delta plains with or without associated mangroves.

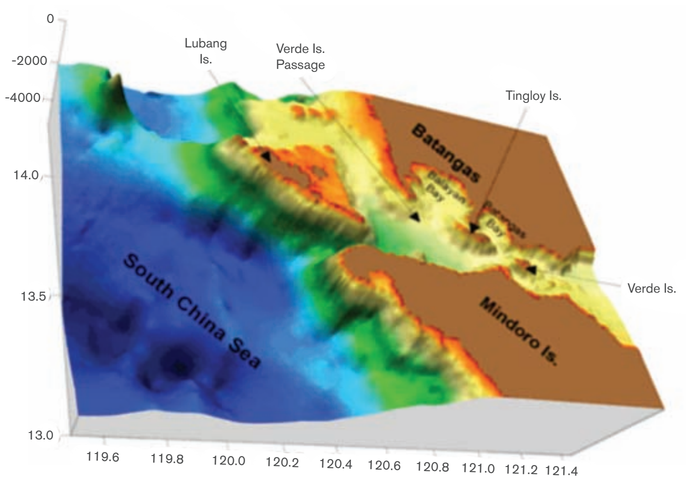


Figure 2. Bathymetry of the Verde Island Passage.

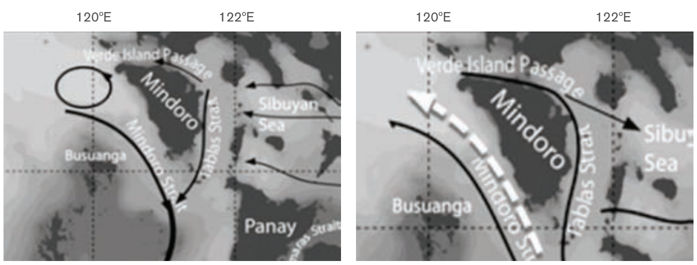


Figure 3. Schematic of seasonal circulation during the northeast monsoon (left) and the southwest monsoon (right) around Mindoro (Han et al. 2009).

The Verde Island Passage, located in the Sulu-Sulawesi Seascape, has been identified as a Marine Biodiversity Conservation Corridor as identified under Ong et al. 2002 and EO 578. Based on the recent coral reef assessments by CI–Philippines, 319 coral species belonging to 74 coral genera have been observed in the passage (CI 2009). Carpenter and Springer (2005) noted that more than half of the documented fish species worldwide overlap in this area of the Philippines. Furthermore, iconic species such as dolphins, whales, turtles, and whalesharks occur in the Passage (Dolar 2006).

Surrounding VIP are 5 provinces: Batangas, Mindoro Occidental, Mindoro Oriental, Quezon, and Marinduque (Figure 4) with a total population of 7,800,175 (as of 2007).

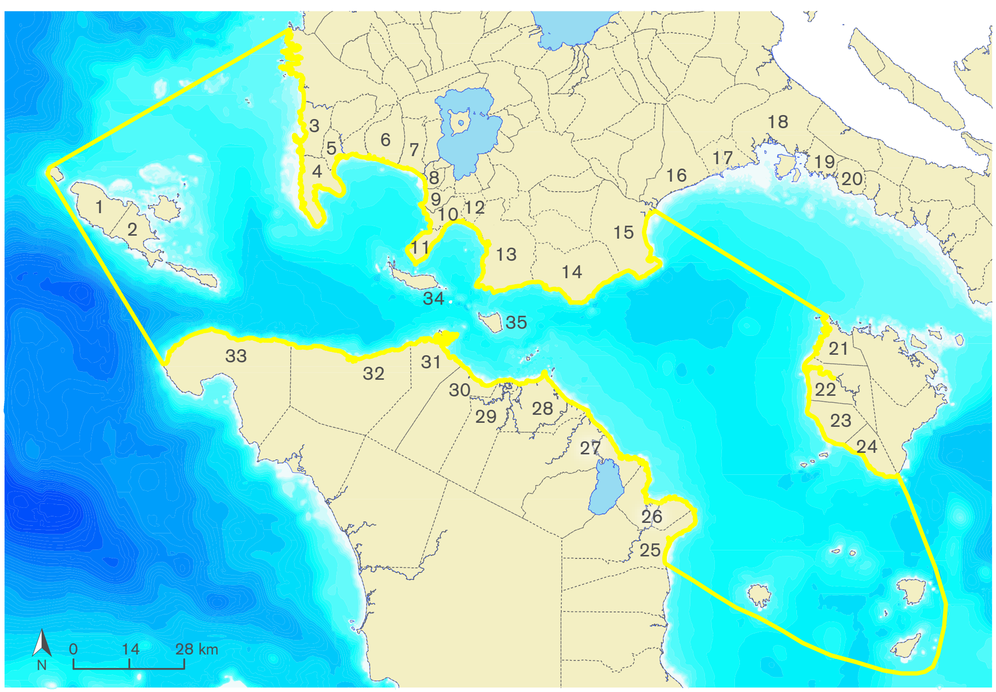


Figure 4. The municipalities surrounding the VIP (clustered by Province) in clockwise order: Batangas Province (1-15; 34, 35) Lubang(1), Looc(2), Lian(3), Calatagan(4), Balayan(5), Calaca(6), Lemery(7), Taal(8), San Luis(9), Bauan(10), Mabini(11), Tingloy (34), San Pascual(12), Batangas City(13), Verde Island (35), Lobo(14), San Juan(15); Quezon Province (16-20) Sariaya(16), Lucena(17), Pagbilao(18), Padre Burgos (19), Agdangan(20); MarinduqueProvince (21-24) MogPog(21), Boac(22), Gasan(23), Buenavista(24); Mindoro Oriental (25-31) Pinamalayan(25), Pola(26), Naujan(27), Calapan(28), Baco(29), San Teodoro(30), Puerto Galera(31); Mindoro Occidental (32, 33) Abra de Ilog(32), Paluan(33).

Hazards

Among the components of climate change that may affect marine biodiversity include temperature, storminess, precipitation, sea-level rise, air-sea CO_2 concentration, changes in ocean circulation patterns, health of functionally linked neighboring ecosystems, as well as, human responses to climate change (Gilman et al. 2008). Knowledge of the extent or severities of vulnerability of coastal areas to these threats are needed in the formulation of mitigation and adaptation measures.

Increase in ocean temperature

Philippine-wide sea surface temperature (SST) has experienced an average increase of about 0.025°C/year. However, the increase has not been spatially homogenous with areas in the northern tip of Luzon and eastern Visayas increasing the fastest while the lowest increase is found in western Mindanao (Figure 5).

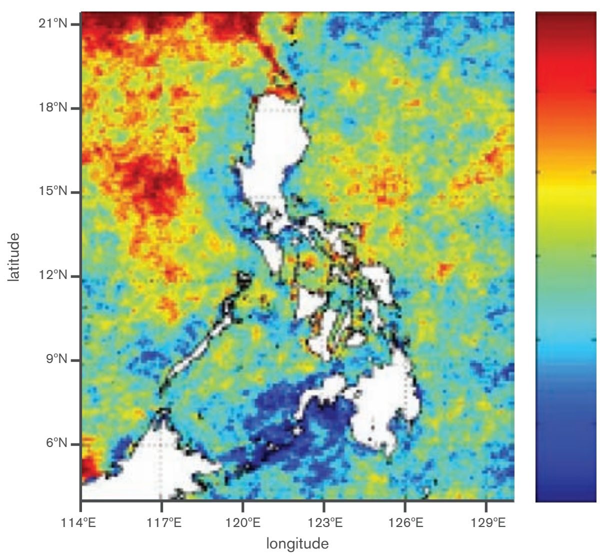


Figure 5 SST increase (°C/year) from 1985-2005 (taken from ICE-CREAM Proj.1 mid-term report).

For the Verde Island Passage, the study on sea surface temperature utilized the 1985-2006 gap-filled, 4 km resolution, weekly SST product developed by the National Oceanographic and Atmospheric Administration–Coral Reef Watch (NOAA–CRW). The NOAA AVHRR 22-year data showed a 0.15-0.30 oC/decade increase in the VIP region (Figure 6). In general in the VIP, coastal areas experienced less increase relative to areas offshore. The only exception to this observation is the northeast side of Occidental Mindoro and the northwestern tip of Lubang Island. Offshore of Calatagan in western Batangas is also exceptional since it is the only site that shows near-zero increase in the last 22 years.

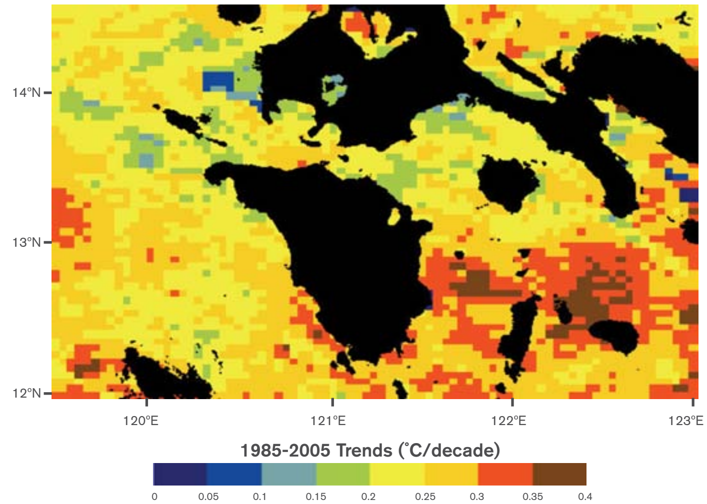


Figure 6. SST increase (°C/year) in the Verde Island Passage from 1985-2006.

Overall, SST anomalies exhibited inter-annual variability. This was explored by comparing the Maximum SST calculated for each year with the long-term average annual maximum SST (also referred to as the BaseMax as defined by NOAA–CRW) (Figure 7). The BaseMax is calculated using the entire data set but without the identified anomalous years 1987-88, 1992-93, 1998-99, 2001-02. Results show significantly warmer SST occurred in the VIP during transition from a strong El Niño to a strong La Niña (i.e., 1987 and 1998 determined from Niño 3.4 data from the ENSO region in the middle of the Pacific). The annual variability is further highlighted using spatially-explicit difference between the Maximum SST for the year and the BaseMax (Figure 8). Again, 1987 and 1998 are seen as significantly warm years for the VIP, along with 1992, 2001, and 2005.

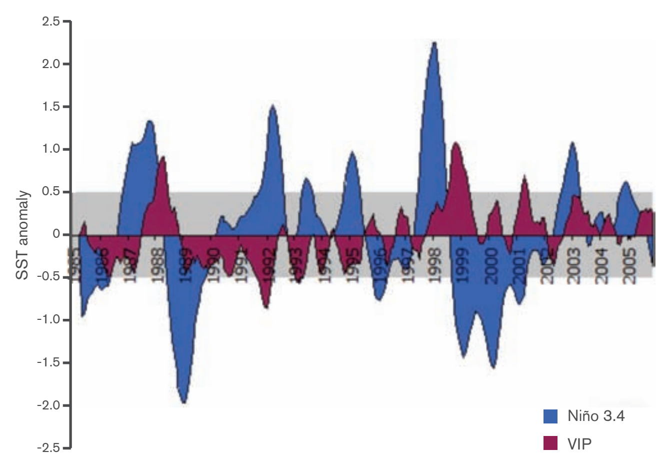


Figure 7. Niño 3.4 region SST anomalies compared to VIP 5 month running mean. Highlighted beyond the gray shading are anomalies > ENSO +0.5 C.

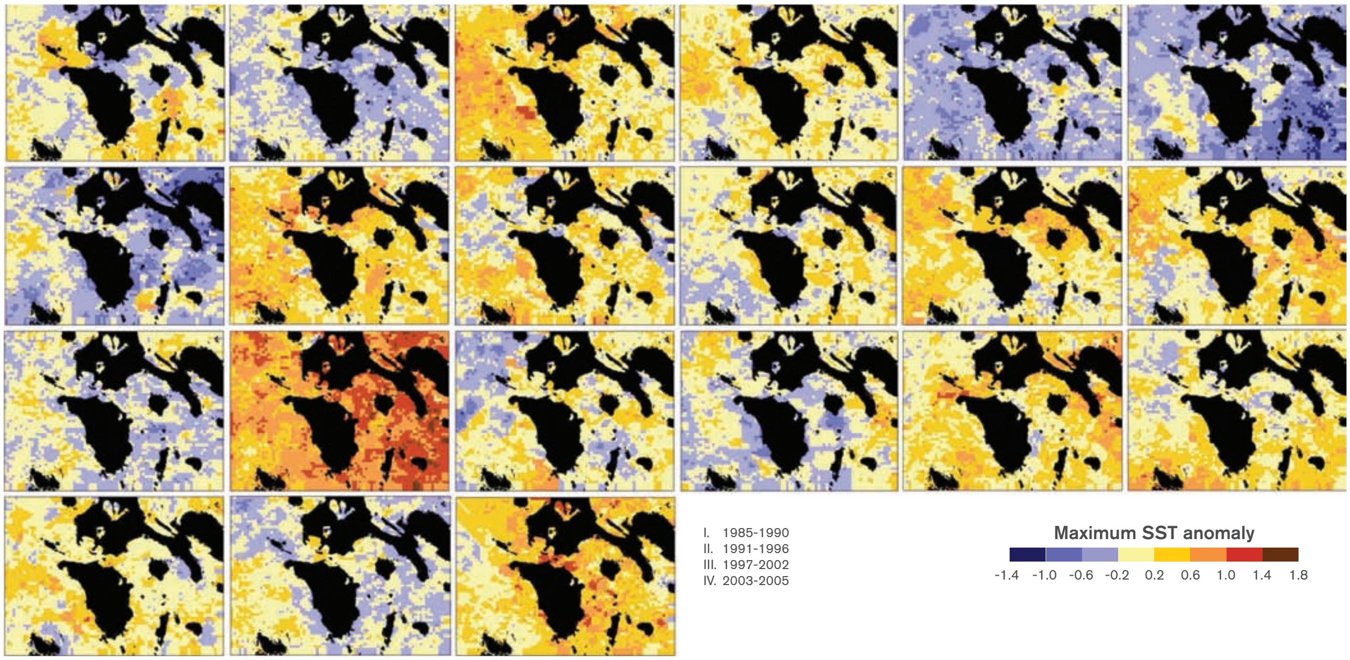


Figure 8. Annual maximum SST anomaly: Max SST-basemax.

Longer-term time series SST from HadISST1 (1900-2008 for the VIP) shows a lesser degree of increase of only a 0.06°C/decade in the longer-term (Figure 9a). HadISST1 is an interpolated SST global product of the UK Met Office Hadley Centre which makes use of “both in situ SST observations from ships and buoys, and bias-adjusted SST from the satellite-borne AVHRR (inclusion started in 1982)” (Rayner et al. 2003).

The 10-yr smoothed and de-trended annual HadISST1 (Figure 9b) also compares particularly well with the Pacific Decadal Oscillation (PDO) index for the same period (Figure 9c) (http://jisao.washington.edu/pdo/PDO.latest) with an observed lag of 5-10 years. This observation emphasizes the telecommunication between the Pacific and the VIP region and suggests that use of the last 2-3 decades of data to simulate future scenarios should be interpreted with caution. Specifically, all satellite-derived images go back in time only as far as the last PDO-shift in 1977 from negative to positive. All synoptic data available therefore belong to the PDO positive regime. In 2008, the early stage of a cool phase of the PDO was observed. There are no long-term synoptic data or satellite-derived data to represent the this cool phase.

Increase in cyclonicity

High SST fuels creation of storms. The Philippines, in particular, lies at the western boundary of the Pacific and typically experiences more than 20 typhoons per year. Patterns of typhoon generation and propagation in the western North Pacific have been shown to be related to the ENSO cycle as well as to other large scale atmospheric circulation (Camargo et al. 2007). Analysis of western Pacific Typhoon track data that

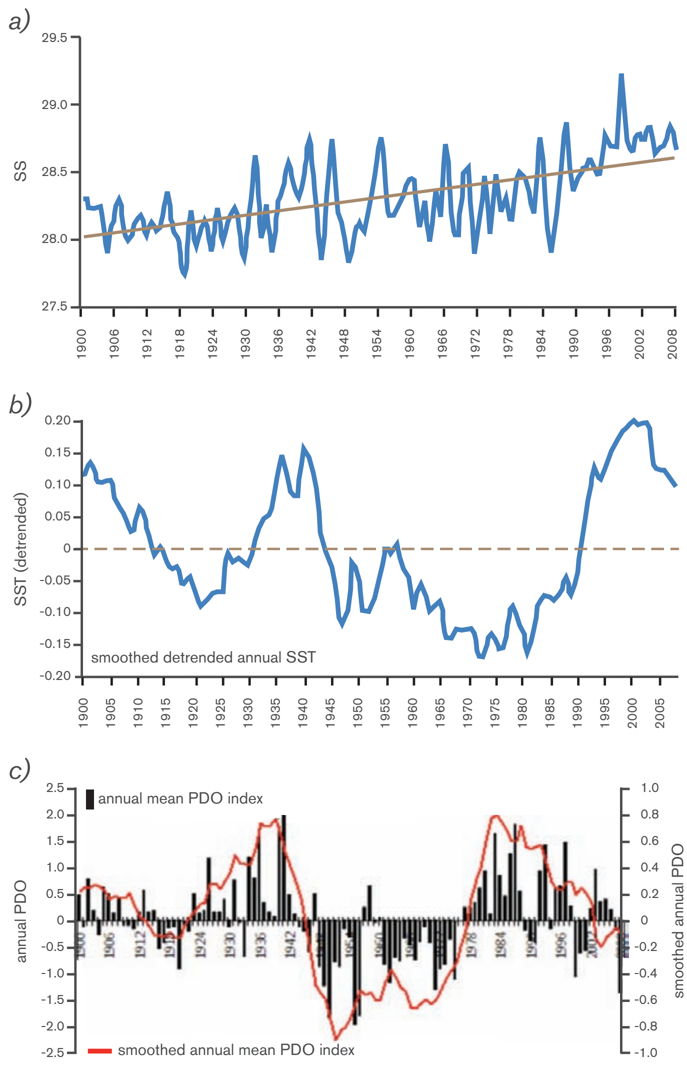


Figure 9. HadISST1 data for the VIP: a) annual mean SST; b) 10-yr smoothed and detrended annual HadISST1; and c) Pacific Decadal Oscillation (PDO) index (1900-2008).

passed through the Philippines indicate a southward shift in the typhoon trajectories in the past decade (Anglo 2005) and an increased relative frequency of typhoons generated in the South China Sea (Ho et al. 2004) (Figure 10). Several investigators however, have indicated the high natural variability of tropical storms and typhoons, which makes it difficult to detect long term changes that can be attributed to climate change.

The Verde Island Passage lies within the track of most of the typhoons in the western Pacific and it is during these events that sea conditions can become rough. Historical typhoon track data (Figure 11a) show that 160 typhoons passed to within 200 km of the VIP from 1952-2008 (Japan Meteorology Agency 2009) amounting to about 11% of the total tropical cyclones in the Western Pacific since the 1950s. The typhoon track data within 200 km from VIP are shown in (Figure 11b). The color of the data points represent year with blue as the oldest (1952) and dark red as the most recent (2008), and the size is scaled according to the storm category. It can be seen that there were no strong typhoons (Category 4-5) in the period before 1975 and for the most recent years (dark red points), roughly more than half belong to the strong typhoon categories.

From the JWTC dataset which starts after WWII, an average of two to three storms passed near the Verde Island Passage corridor annually. However, there were some years when at least six typhoons crossed the area. The highest occurrence was in 1993 with eight storms (Figure 12).

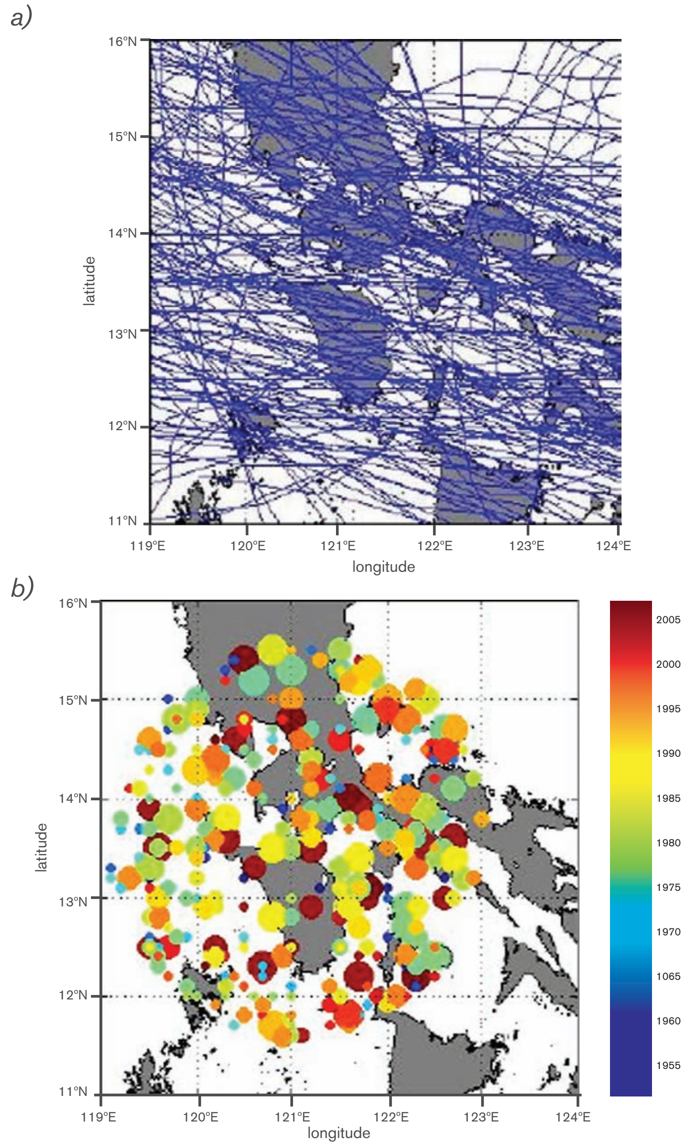


Figure 11 a) Plot of typhoon tracks from 1950- 2009; and b) Storm track data from 1952-2008 within 200 km from Verde Island. Size of points scaled to storm category (2-5) while color is scaled to year. (Data source: Japan Meteorology Agency 2009).

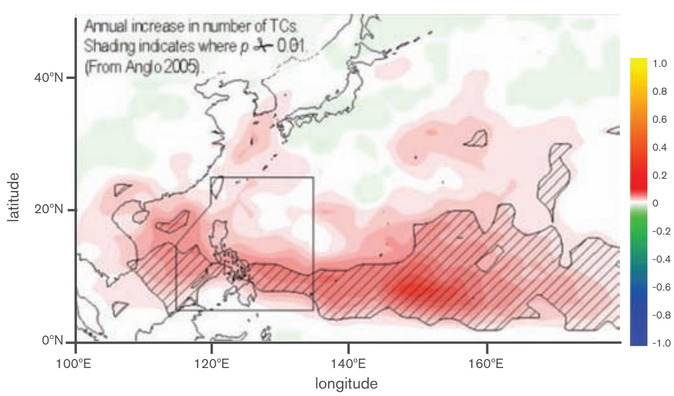


Figure 10. Number of tropical cyclones are increasing in the Pacific and significantly passing through the middle of the Philippines (Anglo 2005).

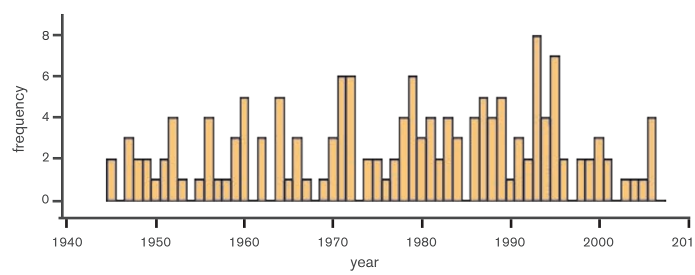


Figure 12. Storm frequency within a 200 km radius from Calapan, Mindoro. Data is from JWTC.

Changes in rainfall

PAGASA precipitation records from Calapan, Mindoro and Ambulong, Batangas for the period 1961 to 2004 show that annual rainfall fluctuates from 1000 to 3500 mm (Figure 13). The two records display similar seasonal fluctuations but opposing long-term precipitation trends over the 43-year period. Annual rainfall has increased in Calapan, but Ambulong shows an overall decrease. This highlights the spatial heterogeneity of rainfall and the need for more monitoring stations. More specifically, there is a need for meteorological stations distributed along representative coastal areas of the VIP.

Sea level rise

The Global Sea Level Observing System has two sites in the Philippines (i.e., Manila and Legaspi). Both of these coastal data show a relative sea-level increase of between 20cm and 40cm since the 1960s (Figure 14). This observed rise is most likely a compounded consequence of excessive land reclamation, possible subsidence due to groundwater extraction and residual rise in sea-level due to warmer oceans.

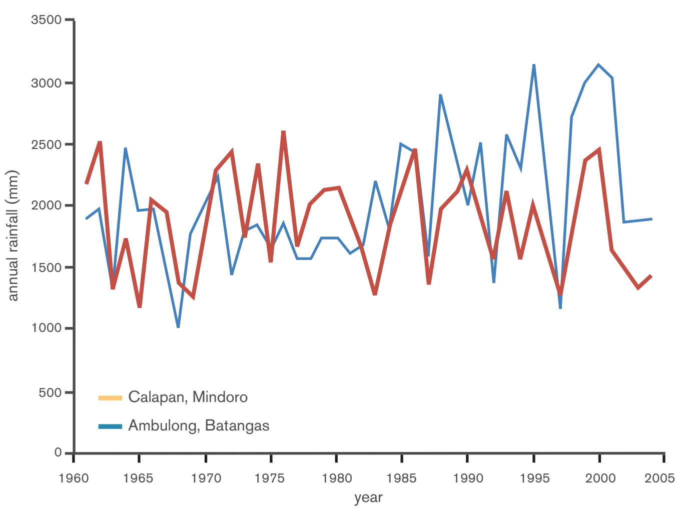


Figure 13. Annual rainfall from 1961 to 2004 for Calapan, Mindoro and Ambulong, Batangas. Data is from PAGASA.

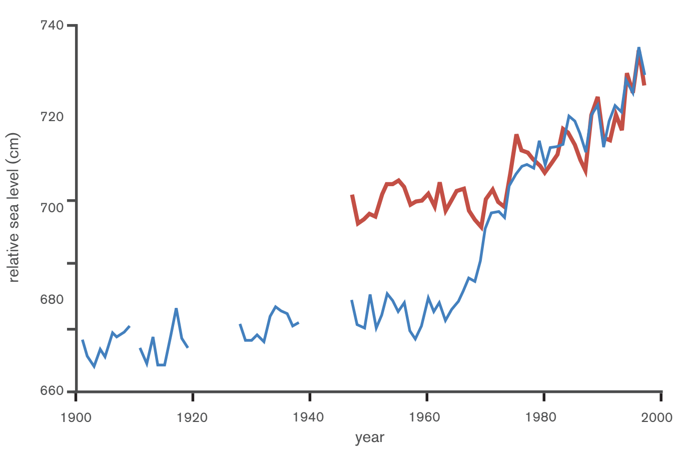


Figure 14. Relative annual-mean sea-level for Manila, South Harbour, (blue; 1901-1997; 14.58°N, 120.93°E) and Legaspi (red; 1947-1997; 13.15°N, 123.75°E) in the Philippines. (http://www.cru.uea.ac.uk/~mikeh/research/philippines.pdf)

Altimetry data from the satellites TOPEX–Poseidon (1992-2005) and JASON–1 (2001-present) gives a time series of offshore sea level on either side of Verde passage (Figure 15). Both sides have undergone changes fluctuating around mean sea level with the eastern side of the passage being more variable. Since 2005, there seems to be a more steady positive increase of about 1.0 mm/yr on the east and 0.5 mm/yr on the west.

These offshore altimetry observations however are not enough to determine site-specific relative sea level rise. Unfortunately, there are no long-term tide gauge data along the VIP. This poses a problem for local decision development planning.

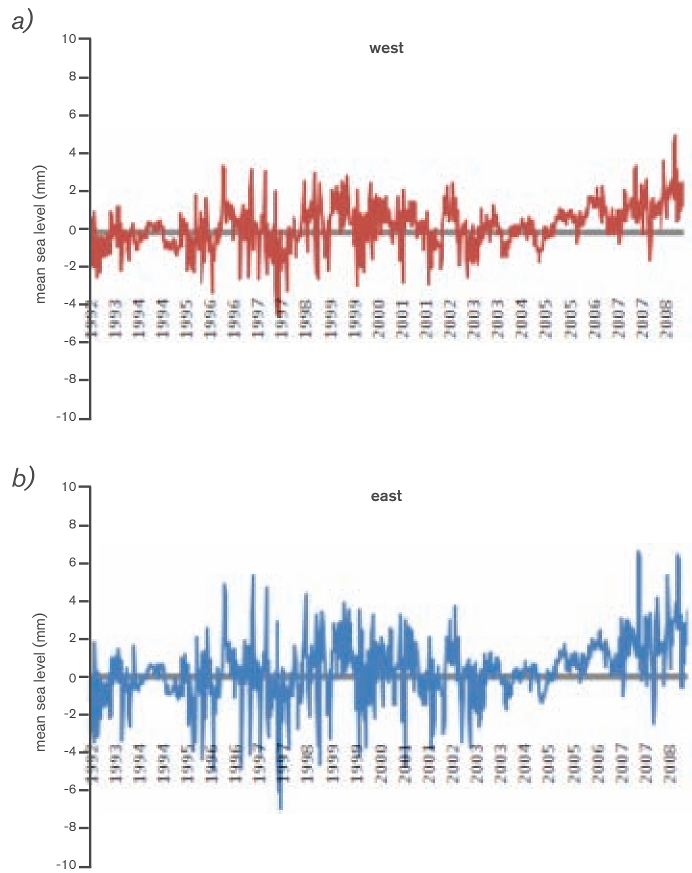


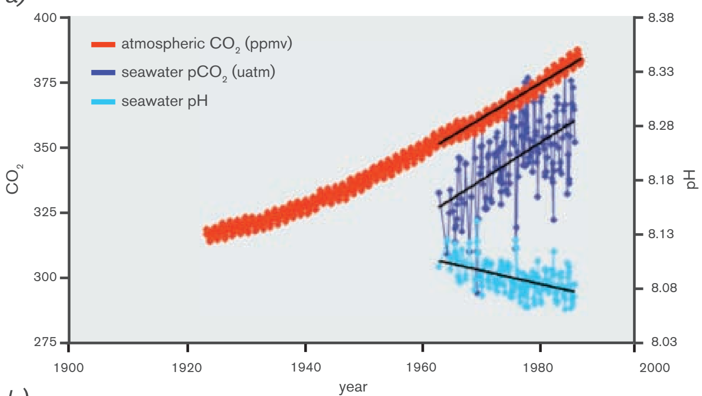
Figure 15. SSH time series from satellite altimetry.

Ocean acidification

Increasing dissolved CO_2 in ocean water results to a decrease in ocean pH. This has been observed in Manoa Lua-Pacific time series (Figure 16a). The decrease in pH is projected to cause harm in marine life ocean fisheries and mariculture (Cooley and Doney 2009, Pew Center 2009).

The problem is that there are no available long-term data for the Philippines and therefore it is not part of any future prediction scenarios (Figure 16b).

a)



b)

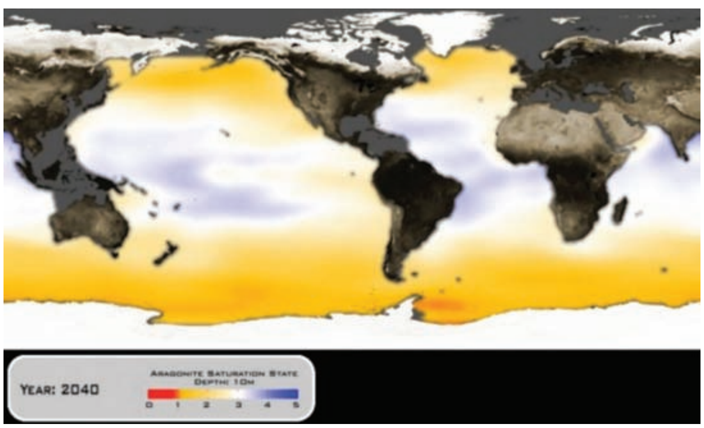


Figure 16. a) Observed decrease in ocean pH. Figure credit: Richard A. Feely, Pacific Marine Environmental Laboratory, National Oceanic and Atmospheric Administration, USA, with atmospheric data from Pieter Tans and seawater data from David Karl. Adapted from Feely (2008) in Levinson and Lawrimore (eds), Bull. Am. Meteorol. Soc, 89(7): S58; and b) Ocean acidification model 2040 from http://colli239.fts.educ.msu.edu/?p=19864.

Exposure

SST in the Verde Island Passage

From the satellite-determined 2009 coral cover in the Verde Island Passage (VIP), representative sites were chosen for thermal stress analysis. For a total of 10 sites, accumulated hotspots and degree heating months were calculated. Accumulated hotspots pertain to the number of times in a given year that the temperature reached at least 1 degree higher than maximum mean monthly climatological sea surface temperature (SST). Degree heating months pertain to number of times the accumulated hotspots lasted for at least one month in a given year.

Results show that 1998 was definitely a warm year for all of the sites. Lubang in particular, located in the western extent of the VIP has also constantly experienced warm events through the years (Figure 17). Surviving live corals in these areas could be already adapted to warm anomalies and are therefore good candidates for protection if the aim is to have at least one remaining surviving site in the VIP in case of continued ocean warming. In contrast Naujan-Gloria and Marinduque located in the eastern extent seems to be the least prone to warm anomalies (except for the 1998 event).

DHMs show areas where hotspots lasted for at least one month in a given year (Figure 18). This prolonged heating is an index of likely mass bleaching occurrences in the last 20 years. Sites in the middle of the passage seem to suffer more frequent DHMs. Interestingly, although Lubang intermittently experience warm anomalies, it was the only one that did not suffer from a DHM event during the 1998 event. It did however, experience a DHM event in 1985 when none of the other sites did so. In contrast, sites on the eastern VIP (Batangas East, Marinduque, and Naujan-Gloria) experienced DHM at no other time but the 1998 event.

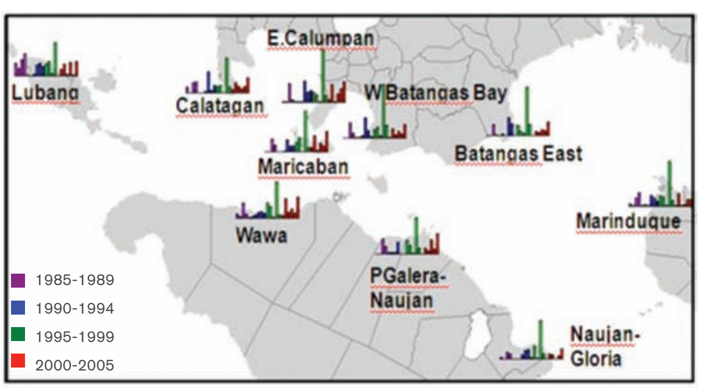


Figure 17. Accumulated HOTSPOTS from 1985-2005 for 10 representative sites in the VIP.

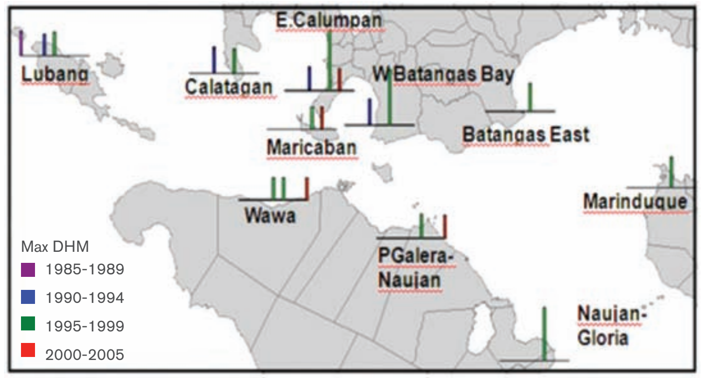


Figure 18. Degree Heating Months from 1985-2005 for 10 representative sites in the VIP.

The embayments of east Calumpan, west Batangas Bay, and Naujan-Gloria suffered the highest occurrence of DHM in 1998. In general, therefore it seems that reefs in more embayed areas may be more susceptible to prolonged extreme heating events most likely due to longer residence time of warm water within bays as compared to open coasts.

Wave exposure

Wave and storm surge models were used to simulate conditions during natural low (non-storm events) and high (storm events) energy conditions. The wave model was based on third-generation SWAN (Simulating WAves Nearshore) while the storm surge used the 2-dimensional Delft3D Flow model, both developed by Delft University of Technology (DELFT3D Hydraulics). Both models were computed on a horizontal orthogonal curvilinear grid. The wave model made use of coarse and high resolution nested grids in order to obtain wave and wind conditions in the open boundary of the high resolution grid. The coarse grid model covers the northern coast of Lubang Island (western boundary) extending to the southern tip of Masbate. The high resolution grid model occupies offshore of Lubang Island (western boundary) extending to Verde Island Passage up to the southern tip of Quezon and eastern coast of Mindoro (southern boundary). Finer grids were nested to the high resolution grid to investigate wave energy propagation in specific areas such as Balayan Bay and Batangas Bay. Wave and wind forcings imposed at the open boundaries were obtained from the available typhoon track analysis (JMA) and archive forecast data (www.buoyweather.com derived from WAVEWATCH III of NOAA).

Historical data off Lubang Island shows a strong correlation between winds and waves in the study area (Figure 19). Wind speeds are generally stronger (8-10 ms^{-1}) during the northeast monsoon months (November-March). Southwest monsoon (June-October) wind speeds are weaker (<5 ms^{-1}) but are interrupted by spikes in wind speeds associated with typhoons. The northeast monsoon dominates the wind field at this location. Consequently, the wind forcing used for the monsoon wind wave simulations was based on the mean northeast monsoon wind velocities and was assumed to be spatially uniform because not enough weather data are available within the VIP to resolve spatial variations.

Wave simulations were conducted during the monsoon season for three selected years: 1997, 1998, and 2008. Overall, the wave fetch within Verde Passage is not large because of the narrow configuration of the passage thus waves do not develop into large waves during typical monsoon conditions. The significant wave height field showed an inter-annual variation very similar to the wind strength; the wave height was lowest (0.25 m) in 1998, followed by 0.35 m wave height in 1997, and highest in 2008 at 0.5 m (Figure 20). The weakening of monsoonal winds thereby dropping of wave heights in 1998 may be associated to ENSO events which alters the large scale monsoonal system.

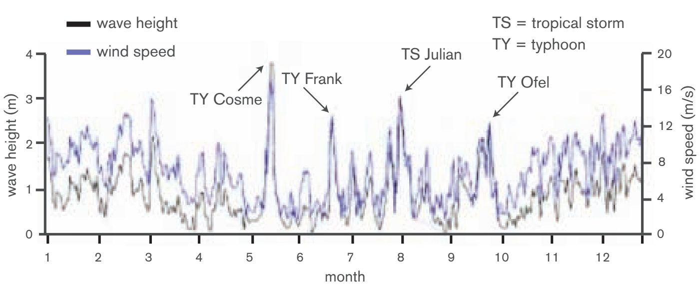


Figure 19. 2008 daily average wind speed and wave height off Lubang Is. showing positive response to typhoon events.

Compared to typhoon intensities east of the Philippines, typhoons passing near the Verde Island Passage are weaker because typhoons start to lose some of its energy as it passes over land. The storm surge potential was therefore simulated by onshore winds blowing at wind speeds 20 m/s or roughly 40 knots (72kph) depicting a typical typhoon condition within the VIP.

The predicted storm surge showed an overall sea level rise by only 0.01 m to 0.04 m at the west of VIP (Figure 21). The coastline topography shelters most of the Verde Passage from large waves. Areas prone to surges in Verde Island Passage are those that are exposed to wide areas of water such as the coastlines facing the Sibuyan sea (eastern Batangas, Quezon and eastern Mindoro coasts) and those facing the South China Sea including Lubang Island.

To examine the effect of extreme storm winds on waves within the Verde Passage, the waves during two periods in the life of Category 5 Typhoon Niña in 1987 were simulated with a maximum wind speed of around

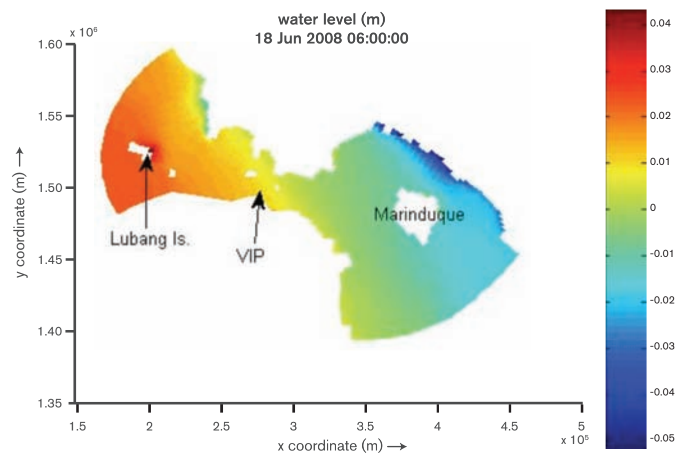


Figure 21. Sea level distribution forced by northeasterly winds blowing at 40 knots.

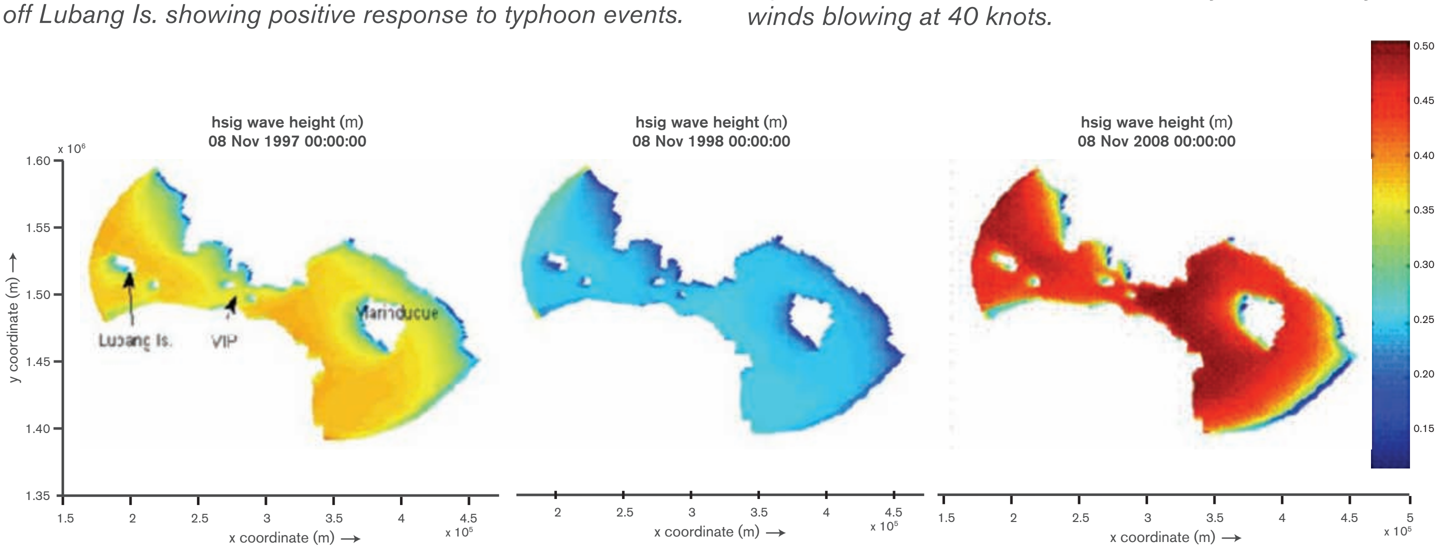


Figure 20. Significant wave height in the Verde Island Passage for 1997 (left), 1998 (middle), and 2008 (right).

80 knots. Even during this high intensity event, winds within the Verde Passage move across the passage thus fetch is limited and waves do not become fully developed. The maximum significant wave heights were about 10m and were found in the area east and northeast of Marinduque.

For the first period, the center of the storm can be seen in the area west of Marinduque with relatively low significant wave heights (Figure 22a). Within the Verde Passage, waves can still be significant (8m) although smaller in magnitude compared to the waves in the Sibuyan Sea. An estimate of the amount of wave energy available at the coast to stir up sediments and infer erosion potential is the plot of bottom orbital velocity (Figure 22b). Note that the largest values of orbital velocity are found in areas with shallow gently sloping bathymetry such as along the coast of Tayabas Bay and the northern coast of Lubang.

For the second period used was after a period of 6 hours, the typhoon has moved westwards and the center can be found west of Puerto Galera. Maximum significant wave heights can still be found in the northwestern Sibuyan Sea along the coast of Batangas and Quezon (Figure 23a). Wave heights within the VIP although quite large, are still much lower than the maximum significant wave heights.

Surprisingly the areas with high bottom orbital velocities are essentially the same as the model results 6 hours earlier (Figure 23b). These areas have two things in common; shallow gently sloping bathymetries and wide expanse of water facing the coast.

With almost 160 typhoons going through within 200 km from Verde Island since 1952, it becomes necessary to integrate the effects of all these typhoons to assess the vulnerability with regards to storminess. This was

a) b)

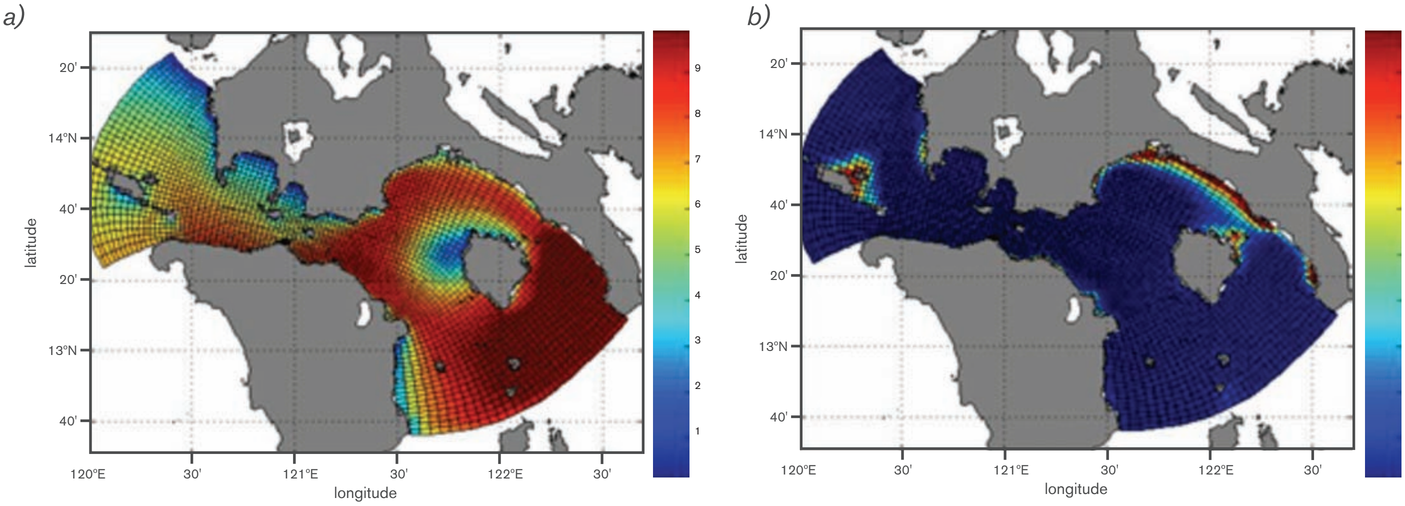


Figure 22. Simulations for a category 5 typhoon when storm was still on the eastern side of the VIP. a) Significant wave height during typhoon with center west of Marinduque, and b) Bottom orbital velocity during typhoon with center west of Marinduque.

a) b)

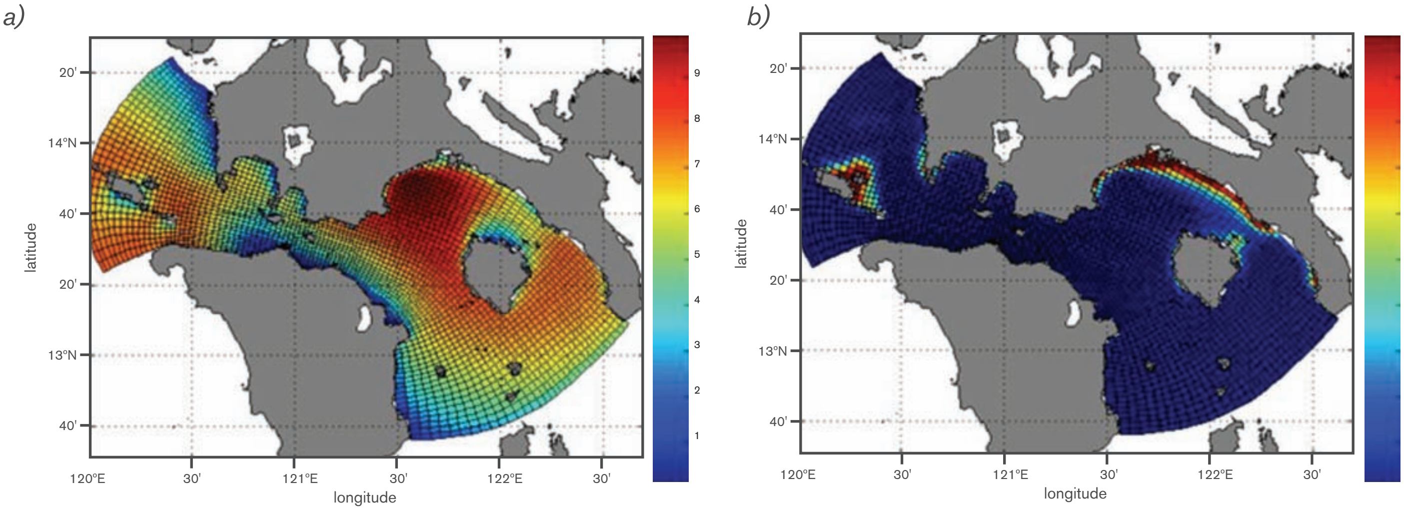


Figure 23. Simulations for a category 5 typhoon when storm was still on the western side of the VIP. a) Significant wave height (m) during a typhoon with the center located near Puerto Galera, and b) Bottom orbital velocity (ms^{-1}) from wave model forced by typhoon with center west of Puerto Galera.

done by getting the frequency of storm track data points along a grid over the VIP and running wave simulations for storm locations at the center of each grid. The resulting wave fields were then averaged weighted by their frequency. The resulting average wave heights are shown in Figure 24 . Note that the highest average wave heights are found in the Sibuyan Sea to the east of Verde Passage covering the eastern coast of Batangas, the northeast coast of Mindoro and the western coast of Marinduque. The next highest wave heights are found in areas to the east of Lubang

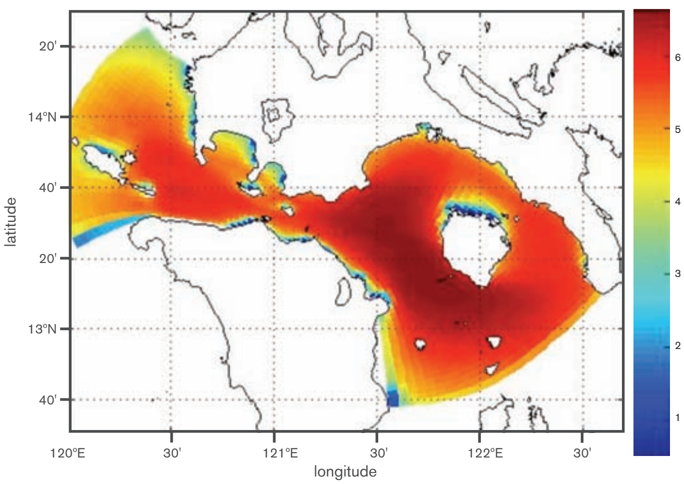


Figure 24. Average wave height field calculated from storm frequency and location of historical storms within the Verde Passage.

or the western part of the Verde Passage. In general, the areas where the largest waves are found are also the areas where wave fetch is longer (i.e., more wide open ocean area) thus waves have sufficient time and distance for it to fully develop.

Coastal erosion

The coastal response to rising sea level is controlled by the balance between the underlying lithology, coastal gradient, sediment supply, and exposure to coastal processes such as tides and waves. Continuing rise in sea level will cause coastal erosion or enhance that are already occurring. Low lying coastal plains will likewise be affected by seawater inundation, flooding, and storm surges, which will cause drastic changes to coastal habitats, infrastructures, and livelihood. The possible contribution of sediment supply and wave processes to shoreline changes was explored.

Only wide coastal plains were included in the work because changes in shoreline positions there are amenable to analysis using satellite images. Where rivers are small or absent, the changes in shoreline position cannot be resolved using the resolution of available satellite images.

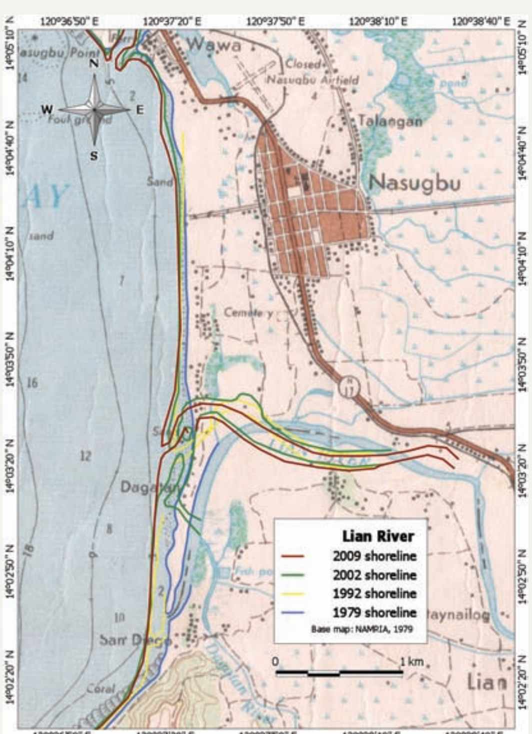


Figure 25. Changes in shoreline position along Lian-Nasugbu coast.

Lian River—Nasugbu

The sandy linear coast fronting Nasugbu Bay, from Wawa to San Diego Point, is about 5 km long and has an associated coastal plain that is more than 250 m wide (Figure 25). The satellite images show a more seaward shoreline position than that of the 1979 topographic map. Sometime between 1979 and 1992, Lian river shifted its course about 1.2 km northward from its previous position. Maximal progradation of 250 m has occurred within the area of the new river mouth. Progradation decreases away from the river mouth.

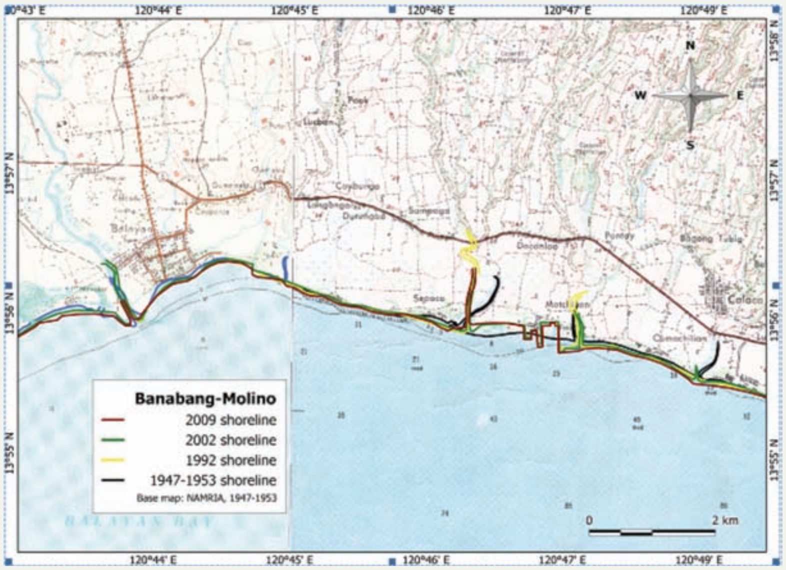


Figure 26. Changes in shoreline position along Banabang-Molino-Balayan coast.

Banabang-Molino River—Balayan

Banabang-Molino is one of the watersheds draining Balayan (Figure 26). The satellite images show a net land gain of about 100 meters just near its river mouth. The coast east of Balayan, on the other hand, which is relatively straight and dissected by several small rivers, shows both erosion and progradation brought about by human modifications. Between 1953 and 1992, Dacanlao River appears to have shifted from a slightly meandering to a straight channel—from a NE-SW orientation to a more north-south position. This change in channel course is probably man-made and is probably related to land modifications during the establishment of the Calaca power plant. Progradation by as much as 80 meters appears to have occurred at the river mouth. However, this progradation is likely to due to the river straightening. Before 2002, coastal modifications were made off the power plant complex. These coastal modifications led to ~200 m erosion and ~200 m progradation west and east of the power plant, respectively.

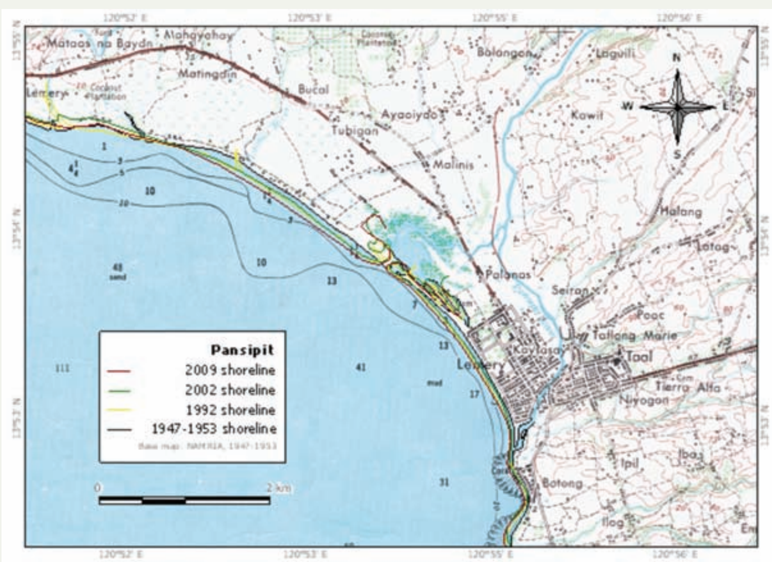


Figure 27. Changes in shoreline position along Pansipit-Lemery coast.

Pansipit River—Lemery

Pansipit River, which drains Taal Lake, is located northeast of Balayan Bay. Downstream, Pansipit River splits into two with one of the distributaries passing through the built-up area of Lemery (Figure 27). The coastal plain is relatively wide at about 1.2 km. Progradation of about 80 m occurred between the 1950s and 1992. The northern river mouth also shifted towards the northwest. Erosion, reaching 40 m in front of the built-up area, ensued between 1992 and 2002. The following years from 2002 to 2009, the area has again prograded by as much as 80 meters. Overall, from 1950s to present, the Pansipit River coastal plain shows a net land gain of as much as 150 m.

Figure 28. Changes in shoreline position along Kampumpong-Batangas City coast.

Kampumpong River—Batangas City

Between 1947 to 2009, erosion of about 200 m occurred along the mouth of Kampungpong River in Batangas City (Figure 28). Topographic maps reflecting conditions prior to 1947 indicate that mangroves covered this area. However, a Google Earth® image indicates that the mangrove is no longer there. Removal of the mangrove is likely linked to the erosion. Large constructions and expansions of piers along the coast of Batangas City also took place in recent years. These include the oil refineries of Caltex and Shell located north and south of the river mouth, respectively; the expanded Batangas pier and a large excavated land near Santa Clara prior to 2009. These coastal modifications would have altered the pathways of sediments resulting to erosion.

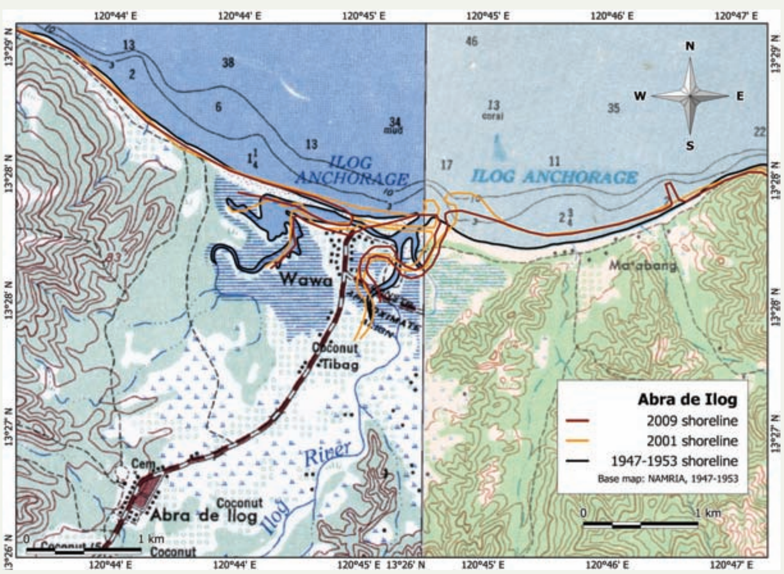


Figure 29. Changes in shoreline position along Abra de Ilog coast.

Abra de Ilog

The river mouth and flanks of Abra de Ilog, from 1953 to 2001, show a net land gain of about 300 m and erosion of ~150 m between 2001 and 2009 (Figure 29). Erosion is probably due to the construction of a pier about 2 km east of the river mouth. Pebble picking activities is most likely contributing to, if not the main cause, of the erosion west of the river mouth.

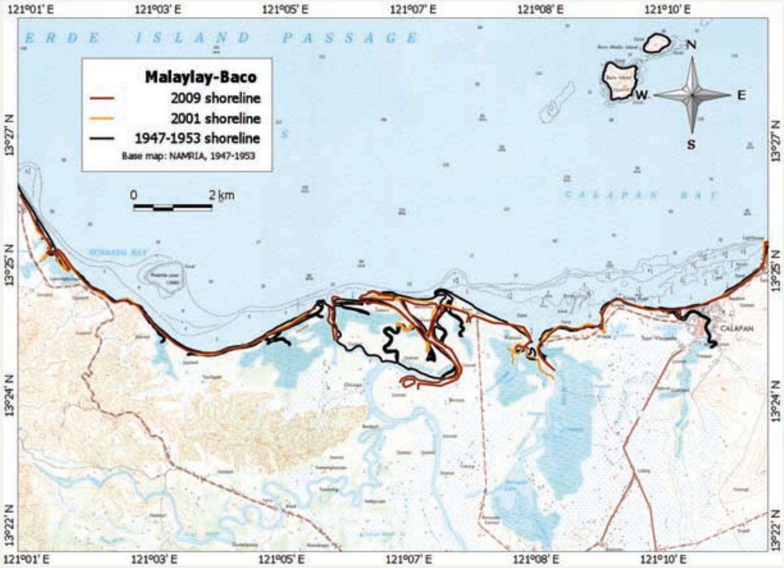


Figure 30. Changes in shoreline position along Malaylay-Baco coast.

Malaylay-Baco

Erosion of as much as 300-m occurred along the Baco-Malaylay delta between 1953 and 2001 (Figure 30). From 2001 to 2009, this coastline remained stable. The erosion prior to 2001 may have been triggered by liquefaction caused by the magnitude 7.1 earthquake on a segment of Lubang Fault, south of Verde Island on November 15, 1994. This earthquake also generated a tsunami that inundated the northeastern coast of Mindoro from Puerto Galera to Pinamalayan, Baco islands, and Verde Island (Phil. Insti. Vol. Seis. 1994). The tsunami also traveled northwards affecting Batangas Bay and Lobo (Imamura et al. 1995). Coastal lowlands along the Calapan Bay including Malaylay, Baco, Wawa, and Baco islands were hardest hit by the tsunami of at least 6 m high, flooding areas 50 to 200 m landward. Highest wave run-up of as high as 8.5 m occurred in Baco Island. The steep coastal gradient also facilitated the strong rundown that caused beach erosion of about 20 m. On the other hand, in the gently sloping delta plains of the Malaylay-Wawa coast, aggradation occurred. Strong incoming waves scoured sands along the foreshore area and deposited the sediments inland forming a ridge, which was preserved because of the weakened backflow in relatively flat areas. The rest of Calapan, San Teodoro, and Puerto Galera experienced tsunami ranging from 2 to 3 m high. Low run-up heights of 0.5 m, 0.9, and 1.2 were respectively observed in Pola, Pinamalayan, and Naujan (Phil. Insti. Vol. Seis. 1994).

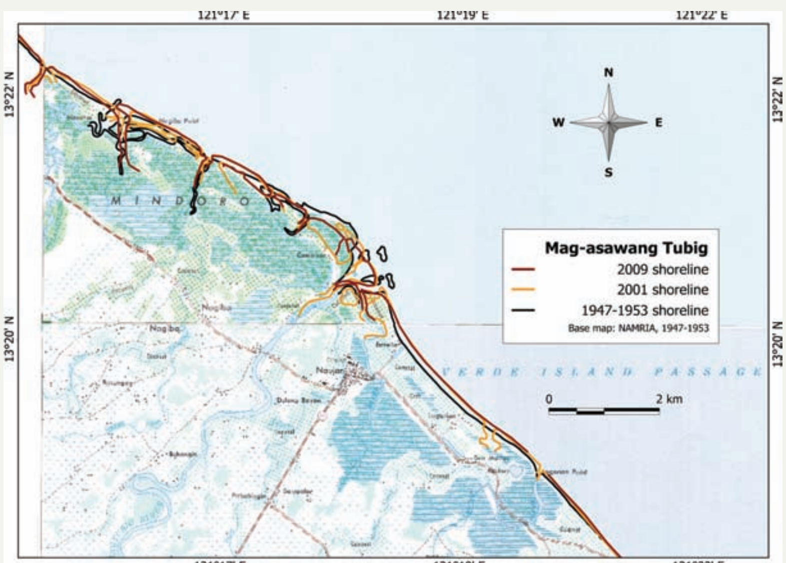


Figure 31. Changes in shoreline position along Mag-asawang Tubig-Naujan coast.

Mag-asawang Tubig

From 1950s to 2009, there was a net land loss at the mouth and net land gain along the flanks of the Mag-asawang Tubig River in Naujan, Oriental Mindoro (Figure 31). This trend is possibly due to river switching upstream which may have been induced by differences in river discharge and amount of sediment load. The 1977 topographic map shows that Mag-asawang Tubig directly drained into the Verde Island Passage just north of Bgy. Estrella in Naujan. But recent Google Earth® images indicate that at present, Mag-asawang Tubig joins the Bucayao River upstream, before emptying to the Verde Island Passage through the Silonay River in Calapan.

Coastal erosion in Batangas City and Calapan is attributed to improperly placed and designed engineering structures and removal of mangrove forests; and liquefaction due to tsunami associated with 7.1M 1994 earthquake, respectively. Overall, a net land gain is observed on most of the delta plains during the last 50 to 60 years. This net land gain is probably due to the large sediment supply to the coast that is still able to offset the effect of sea level rise. Typically, sediment yield increases during high river discharge events. In Batangas, land progradation in delta plains coincide with periods of high annual rainfall, while erosion occurred during periods of decreased precipitation over the last 40 years. In Mindoro, periods of high precipitation over the last decade may have resulted in high discharge events and rain-induced landslides that in turn caused recent shifts in the course of Mag-asawang Tubig River. Consequently, new lands are being formed along the new river mouth in Calapan while the old river mouth in Naujan is undergoing erosion. The episode of net erosion from 1990s to early 2000 coincides as well with a period when more storms passed through the region; the years 1993 and 1995 had 8 and 7 storms, respectively.

The observed net land gain in most of the shorelines along the VIP corridor may be beneficial to the remaining mangrove areas along this corridor such that it can possibly offset the effect of sea level rise (Siringan et al., this report). Newly accreted lands may be a potential landward progression area for mangroves given the right condition for its recruitment, settlement and survival.

Marine flooding

Changes in shoreline positions, over the last 50 years of coastal plains within the Verde Island Passage (VIP) corridor were established through time-series analysis of maps and remotely sensed images. The likelihood to marine inundation resulting from a 1-m, 2-m, or 3-m sea-level rise was estimated from the 30-m Advanced Space-borne Thermal Emission and Reflection Radiometer (ASTER) data sets. The spatial resolution of the images limits the analysis only to coastal plains that cover more than 30 m. In rocky coasts, which are typically associated with narrow beaches, the extent of inundation is no longer evident.

The low-lying coastal plains of Batangas are the most vulnerable to inundation by a 1 meter rise of sea level. Based on pixel counts alone, the land that will be inundated is about 175 ha in Nasugbu, 795 ha in Calatagan, 199 ha in Balayan, and 122 ha in Batangas City. Sea level rise of 1 m will predominantly affect the mangrove and fishpond areas. Two and 3-m (Figure 32) rises of sea level were also mapped. Areas such

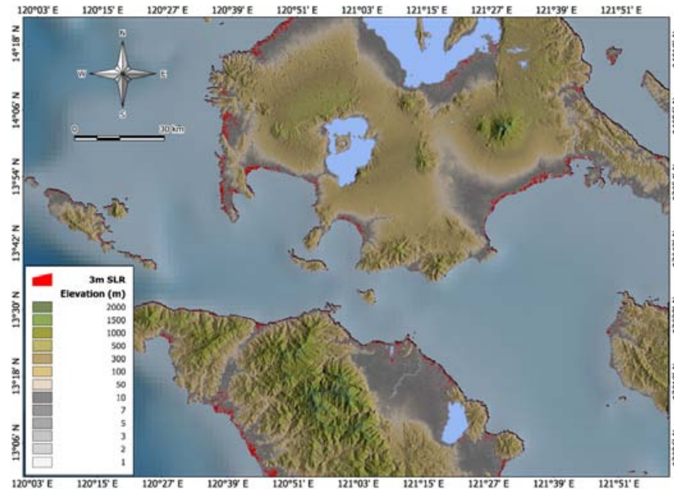


Figure 32. Shaded in red are the areas to be inundated by a 3-m rise of sea level.

as Nasugbu, Balayan, Batangas, Boac, and Calapan that experienced rapid accretion in recent years, are the most vulnerable to coastal inundation.

Table 1 summarizes the areas that will likely be inundated given a 1-m, 2-m, and 3-m sea level rise. Built-up areas in Balayan and Lemery are vulnerable even to just 1 and 2-m rise in sea level. Two to 3-m rise in sea level will inundate rice fields and coconut plantations that are about 5 to 10 kilometers further inland, especially in Nasugbu and Calapan.

Table 1. Area (ha) to be inundated given a 1-m, 2-m, 3-m sea level rise (SLR).

	1-m SLR	2-m SLR	3-m SLR
Batangas			
Nasugbu	175.08	519.24	1049.88
Lian	140.86	373.6	676.18
Calatagan	795.21	1227.12	1700.25
Canda, Balayan, Calaca	199.09	552.34	902.26
Lemery, Taal, San Luis	154.64	286.13	504.29
Bauan, Mabini, Tingloy	203.22	358.38	532.62
San Nicolas, Batangas City	122.31	242.91	440.37
Lobo	62.28	97.2	152.28
San Juan	92.8	152.2	267.31
Mindoro			
Lubang	413.37	681.39	1069.02
Paluan	242.28	493.92	837.36
Abra de Ilog	119.79	220.86	402.84
Puerto Galera, San Teodoro, Baco, Verde	208.25	364.58	652.76
Calapan	110.02	204.43	527.17
Naujan	217.39	303.16	533.92
Pola, Pinamalayan	86.85	141.93	262.35
Marinduque	236.75	414.59	649.67

Exacerbating features of the VIP

The Verde Island Passage (VIP) corridor is within a very tectonically active area where there are numerous active faults and volcanoes and where earthquakes are very frequent (Figure 33). Several volcanoes are also present in the area including Mt. Taal and Mt. Banahaw which are both classified as active.

Consequent vertical land movements and tsunamis generated from these earthquakes can modify the vulnerability of coasts to sea-level rise due to global warming. Liquefaction, subsidence and tsunami can cause extensive and rapid coastal inundation, thus, global sea-level rise would be amplified. On the other hand, land emergence or uplift can counter the effect of sea-level rise. The predominance of net land gain, during a period when sea level is supposed to be rising, can be due to uplift. However, there are no tide gauge records in the VIP corridor that can be examined to test this idea. Relatively loose pyroclastic materials which abound upstream, are easily mobilized downstream even by normal river flow. Landslides triggered by earthquakes help in supplying more sediment to the coast.

At the upstream end of the rivers, long steep slopes have practically no forest cover, which also promotes higher sediment yield. Siltation caused by massive deforestation elsewhere in the Philippines cause not only shift in species composition but also mortality of seagrasses. In Batangas, where sugarcane is a major agricultural product, erosion is not arrested by any structure that would break the flow of surface runoff resulting in high rates of erosion. In rice fields, surface runoff passes through a series of paddies which promote settling of sediments before the water reaches a river thereby lowering the sediment load a bit.

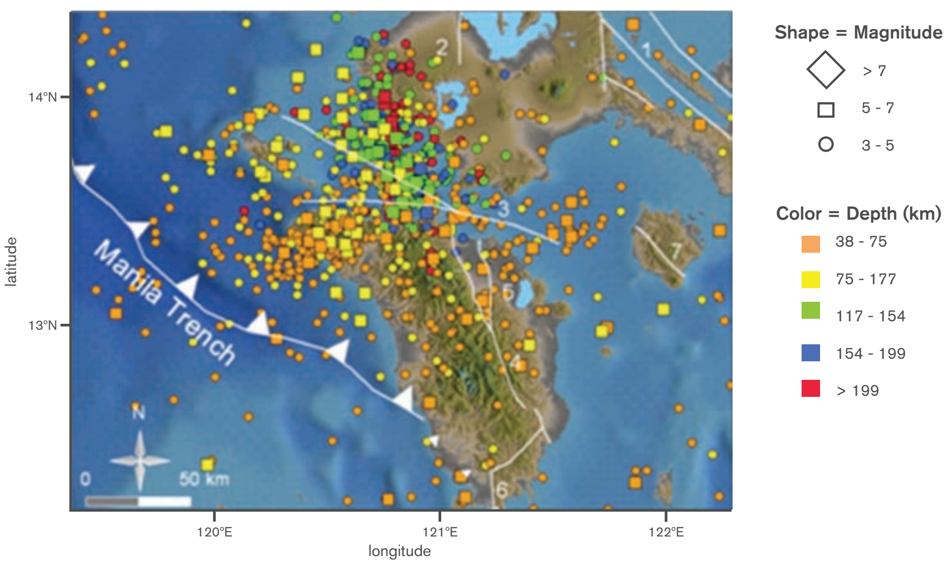


Figure 33. Tectonic and earthquake epicenter map of the Verde Island Passage Corridor. The active faults mapped by Phil. Insti. Vol. Seis. are the following: 1-Philippine Fault Zone; 2-WMVF; 3-Lubang Fault; 4-Central Mindoro Fault; 5-Aglubang River Fault; 6-Southern Mindoro Fault; and, 7-Central Marinduque Fault. Earthquake epicenters were compiled by the NEIC-USGS.

Sensitivity

Habitat and data description

Coral

Coral reefs are the most dominant habitat in the VIP, with a total reef area of around 7,031 hectares of which about 1,767 hectares are covered by live coral (Table 2). Based on the satellite images, the reefs are fringing and generally narrow. The coral reef areas are mostly shallow, particularly on inshore areas near the bay heads. Although, some reefs still occur in deep areas particularly in the bay mouths (e.g., Bauan municipality in Batangas). The reefs are well developed on the west side of the VIP, particularly in Calatagan (including the municipalities of Lian, Calatagan, and Nasugbu) and Lubang (including municipalities of Lubang and Looc, and Ambil Island) areas. On a per province basis, reef areas are more extensive in Batangas, compared to Mindoro Occidental, Mindoro Oriental, and Marinduque.

Data used for the analysis were obtained from the 2007 to 2008 surveys of the municipalities surrounding the Verde Island Passage. These data sets were originally collected from various researchers that were contracted by Conservation International–Philippines to conduct marine protected area site identification and monitoring assessments. A total of 41 survey stations belonging to eight (8) municipalities were considered in this assessment. Table 3 presents the municipalities and survey stations that were included in this study.

Each site indicated in Table 3, were used as replicates to compute for the percentage cover of live hard corals per municipality. Data used were obtained with the use of video or phototransect methods.

Overall status of the coral communities in the Verde Island Passage fell under the poor category with 24% mean cover of live hard corals (Table 4). The municipalities of Mabini, Looc, and Nasugbu had the highest live hard cover but still fell under the fair category (Gomez et al. 1994) with percent cover values of 33.8%, 29.4%, and 29.3% respectively. Batangas City had the lowest percentage of live hard corals with only 12.9%. The municipalities of Calatagan, Lubang, San Juan, and Tingloy fell under the poor category with covers of 24.2%, 24.8%, 19.6%, and 19.2% respectively.

Table 2. Area (ha) of coastal habitat in the Verde Island Passage.

Bay area	Live corals	Mixed LC+DCA+RCK	Overgrown DCA+RCK	Abiotics S+R	Total area
Lubang Island	572	1118	759	189	**2638**
Calatagan	560	802	670	146	**2178**
East Calumpan	16	7	0	23	**46**
Batangas Bay West	2	0	0	8	**10**
Batangas Bay East	172	168	60	93	**493**
Maricaban Island	20	10	2	35	**67**
West Marinduque	7	10	0	1	**18**
Wawa-Paluan	121	104	27	147	**399**
Puerto Galera-Naujan	248	174	48	565	**1035**
Naujan-Gloria	49	68	3	27	**147**

LC–live corals; DCA–dead coral with algae; RCK–rock; S–sand; R–rubble

Table 3. Study sites and municipalities considered in the vulnerability assessment of the coral and reef fish communities in the Verde Island Passage.

Municipality	Study sites	Survey date	Researchers
Batangas	Grotto	Oct-08	CI–Hilomen et al.
	Napayong		
	Pitong Gatang		
	Promontory/ Matuko Pt.		
Calatagan	East Sta. Ana	May-07	CI–Menez and Cabansag
	Gulod		
	Karitonan/ Carretunan		
	South Bagong Silang		
	Talisay		
	Tanagan		
	West Bagong Silang		
	West Sta Ana		
Looc	Antipolo	Oct-08	CI–Menez et al.
	East Tabajin		
	Nagbati		
	Pandan		
	Tagbanan		
	West Tabajin		
Lubang	Ambil	Oct-08	CI–Menez et al.
	Balagin		
	East Vigo		
	Nagtalon		
	Tagbak		
	West Vigo		
Mabini	Cazador Pt.	Oct-08	CI–Hilomen et al.
	Ligaya North		
	Ligaya South		
	Mainit School		
Nasugbu	Fuego Point	Aug-08	CI–Menez and Cabansag
	Sunset cove		
San Juan	Catmon	Aug-08	CI–Menez and Cabansag
	Hugom		
	Imelda		
	Kalubkub/ Calubcub		
	Laiya Aplaya		
	Laiya Ibabao		
	Puting Buhangin		
	Tikalaan		
Tingloy	Bonito Island	Oct-08	CI–Hilomen et al.
	Devil's Pt.		
	Malahibong Manok		

Table 4. Percentage cover of living hard coral (LHC) per municipality in the Verde Island Passage.

Municipality	Year	Sites	% LHC cover
Batangas City	2008	4	12.9
Calatagan	2007	8	24.2
Looc	2008	6	29.4
Lubang	2008	6	24.8
Mabini	2008	3	33.8
Nasugbu	2008	2	29.3
San Juan	2008	8	19.6
Tingloy	2008	3	19.2
Mean			24.2

Seagrass

Table 5 lists the number of species and species composition in areas around VIP where seagrass assessment reports were available for this study. Most of the seagrass areas included in this study have 8 species except for Puerto Galera which has 10 species due to the presence of *Halophila minor* and *H. spinulosa*. In a study conducted by Tiquio and Cayabyab (2008) in Calatagan, they reported that the species diversity in this area is comparable with Cagayancillo, and Balabac, Palawan, however it is less extensive than those areas studied in Palawan. In terms of abundance, they reported that Calatagan seagrass meadows are less dense than Cagayancillo but denser than Tubbataha and Balabac.

In an assessment conducted in Lubang Islands, Occidental Mindoro (Genito et al. 2009), results showed that the percentage seagrass cover in these areas ranged from low to moderate with 46% of the surveyed sites showing moderate cover, but mostly on the low-end values of the range. *Thalassia hemprichii* and *Cymodocea rotundata* were noted in almost all of the sites surveyed. According to this report, the multispecies meadows in these islands were comparable with areas in Palawan and Guimaras.

Most of the seagrass meadows that surround the VIP are in constant threat from overexploitation of its associated organisms (i.e., sea cucumber, sea urchin), coastal developments (i.e., resort establishment) and even mangrove afforestation (i.e., Calatagan).

Table 5. Number of species and species composition in Lian and Calatagan, Batangas; Puerto Galera, Oriental Mindoro; and Lubang, Occidental Mindoro.

Municipality	No. of species	Species composition
Batangas		
Lian	8	Ea, Th, Cr, Cs, Hp, Hu, Ho, Si (Talim Bay CRM Plan)
Batangas		
Calatagan	8	Ea, Th, Cr, Cs, Hp, Hu, Ho, Si (Tiquio and Cayabyab, 2008)
Oriental Mindoro		
Puerto Galera	10	Ea, Th, Cr, Cs, Hp, Hu, Hm, Ho, Hs, Si (Fortes, 1997)
Occidental Mindoro		
Lubang	8	Ea, Th, Cr, Cs, Hp, Hu, Ho, Si (Genito et al, 2009)

Ea–*Enhalus acoroides*, Th–*Thalassia hemprichii*, Cr–*Cymodocea rotundata*, Cs–*Cymodocea serrulata*, Hp–*Halodule pinifolia*, Hu–*Halodule uninervis*, Hm–*Halophila minor*, Ho–*Halophila ovalis*, Hs–*Halophila spinulosa*, Si–*Syringodium isoetifolium*

Mangrove

The total area of mangrove forests surrounding the VIP in Batangas and Oriental Mindoro is 1,494.16 ha, 716.16 ha in Batangas, and 778 ha in Oriental Mindoro. Most of these mangrove areas are of the riverine and fringing types dominated by species of *Rhizophora* and *Avicennia*. However, most of these mangrove areas are near coastal communities and are being affected by anthropogenic activities such as conversion to fishponds, and resort and port establishment.

Table 6 and Figure 34 present a summary of available information on the condition of mangrove forests in the provinces of Batangas and Oriental Mindoro. The only information available for analysis were the type of mangrove forest and substrate, areal extent, dominant species and issues and problems affecting these mangrove areas. No available information on the density and other parameters that will characterize the present mangrove cover in these areas were accessible at the time of data collection.

Table 6. Available information on the status of mangrove forests in Batangas and Oriental Mindoro.

Province/ municipality	Type of mangrove forest	Type of substrate	Area (ha)	Issues and concerns
Batangas				
Balayan	fringing/riverine	sandy/clay loam	19.09	▪ conversion to fishponds; establishment of resorts; presence of coastal communities; illegal cutting
Batangas City	fringing/riverine	sandy/clay loam/muddy	23.64	▪ development of industries and ports; presence of coastal communities; conversion to fishponds
Calatagan	fringing	coralline/stony/rocky/muddy	244.98	▪ conversion to fishponds and saltbeds; establishment of resorts; presence of coastal communities; illegal cutting; existing tenurial instruments
Lian	fringing/riverine	sandy/clay loam	79.99	▪ conversion to fishponds; presence of coastal communities; illegal cutting
San Juan	fringing/riverine	coralline/sandy/clay loam/muddy	348.46	▪ conversion to fishponds; presence of coastal communities; illegal cutting; gleaning activities
Oriental Mindoro				
Calapan City	riverine/fringing	sandy/clay loam/muddy	332.00	▪ presence of coastal communities; conversion to fishponds; presence of piggeries; illegal cutting
Naujan	riverine/fringing	sandy/clay loam/muddy	165.00	▪ presence of coastal communities; conversion to fishponds; illegal cutting
Baco	fringing/riverine	sandy/clay loam/muddy	134.00	▪ presence of coastal communities/ conversion to fishponds; illegal cutting
Pola	no data	no data	147.00	▪ illegal cutting; conversion to other uses

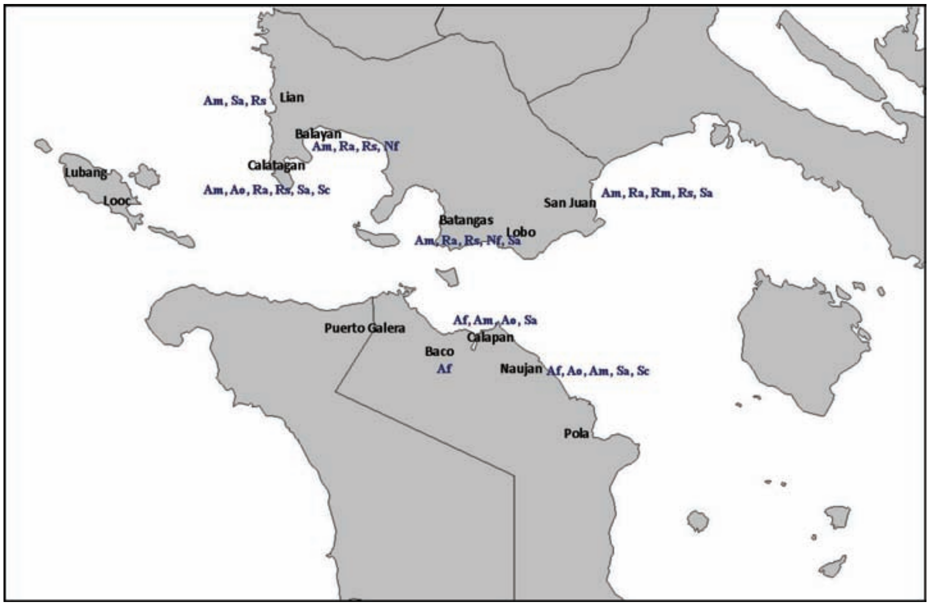


Figure 34. Dominant species present in mangrove areas included in this study along the VIP (Af- Aegiceras floridum*, Am-* Avicennia marina*, Ao-* A. officinalis*, Nf-* Nypa fruticans*, Ra-* Rhizophora apiculata*, Rm-* R. mucronata*, Rs-* R. stylosa*, Sa-* Sonneratia alba*, Sc-* Sonneratia caseolaris*).*

Method of assessing sensitivity

Coral

Percentage of live hard coral cover and number of observed coral genera of each survey site per municipality were collated for the analysis. Percentage of live coral cover per municipality was calculated by getting the average of the percentage coral cover of all the reefs surveyed in that municipality. The number of genera was determined based on what was encountered along the survey transects in each of these towns. Total number of genera was obtained by pooling all the occurrences of the coral genera per municipality. Dominant genera were based on the occurrences of the coral genera per site in each municipality. Very little species level data is available for almost all reefs in the Philippines. The authors also had to rely on reports (some of which were still unfinished at the time this analysis was made) and thus were in no position to assess the relative importance of the other factors such as proximity to human settlements and activities that might be relevance to the sensitivity of particular coral communities to climate change.

A total of 61 coral genera were observed along the survey transects during the assessments (Table 7). The municipality of Mabini had the highest number of observed coral genera, with 45 genera present. Nasugbu municipality on the other hand, had the lowest number of observed coral genera with only 28 genera noted. Around 39 to 44 coral genera were observed in the remaining municipalities of Batangas City, Calatagan, Looc, Lubang, San Juan, and Tingloy. The reefs assessed were mostly dominated with the coral *Porites* sp., followed by *Acropora* sp., *Diploastrea heliopora*, *Montipora* sp., *Goniastrea* sp., *Echinopora* sp., *Pocillopora* sp., and *Seriatopora* sp.

In the subsequent analyses, the above data on generic composition was only considered in the assessing the impact of sea surface temperature increase on coral cover. Hence, the projections on cover loss due to storms and sea level rise assumed coral genera were equally sensitive to these factors since no “dose”-response function was available for coral communities.

Impacts of climate change (e.g., temperature increases, sea-level rise, storminess) on coral diversity were analyzed in two stages, beginning with the estimation of coral cover loss described earlier. The inverted species-area curve based on the Calamianes study by Veron and Fenner (2000) was then used to estimate the loss of coral diversity from the projected coral cover (=area of habitat) loss (Figure 35). This species-area

Table 7. Total number of coral genera observed per municipality in the Verde Island Passage.

Municipality	Sites	# genera	Dominent genera
Batangas City	4	39	*Porites*
Calatagan	8	44	*Porites, Diploastrea, Galaxea*
Looc	6	41	*Porites, Acropora, Montipora, Echinopora*
Lubang	6	39	*Porites, Acropora, Seriatopora*
Mabini	3	45	*Porites, Acropora, Montipora*
Nasugbu	2	28	*Porites*
San Juan	8	42	*Porites, Diploastrea, Goniastrea*
Tingloy	3	41	*Acropora, Pocillopora, Porites*

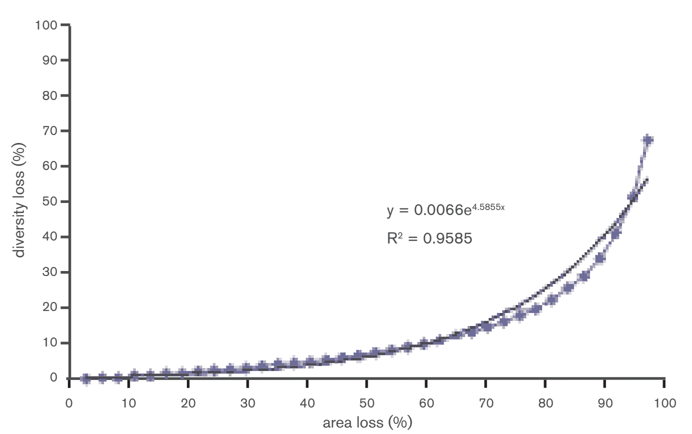


Figure 35. Inverted species-area curve based on the Calamianes (Veron and Fenner 2000). Coral diversity loss was determined by calculating the y-value using the formula shown above.

curve was used since it is the only published account available for the Philippines. However, the estimates computed from these are considered conservative because the Veron and Fenner's curve is based on beta/between-reef diversity while the current application is seeks to estimate changes in alpha/ within-reef diversity. The latter is typically much higher locally.

Coral diversity loss due to sea surface temperature increase was estimated by obtaining the percentage of coral genera that will be lost by removing the thermally sensitive coral genera listed in Pratchett et al. (2008) (Table 8). Lower range estimates were obtained by removing the top 10 most vulnerable genera from the total genera present per municipality. Whereas, higher range estimates were calculated by removing all the vulnerable coral genera based on the list to the total genera present in each municipality. This decision is arbitrary since, again, no dose-response curve for coral communities and bleaching is available and thus we based the cut-off on observations of vulnerable taxa made in western Batangas during the 1998 bleaching event, apparently the worst one for the VIP (Arceo et al. 2001). The estimates based on projected cover loss and the species-area curve served as the lower range estimates of diversity loss, whereas the direct vulnerabilities served as the higher range estimates.

Table 8. Coral genera thermally sensitive to bleaching events.

Acropora sp.	*Leptoria sp.*	*Favia sp.*
Stylophora sp.	*Echinophyllia sp.*	*Echinopora sp.*
Mycedium sp.	*Lobophyllia sp.*	*Favites sp.*
Isopora sp.	*Acanthastrea sp.*	*Pavona sp.*
Montastrea sp.	*Goniopora sp.*	*Merulina sp.*
Hydnophora sp.	*Pectinia sp.*	*Turbinaria sp.*
Coeloseris sp.	*Galaxea sp.*	*Astreopora sp.*
Cyphastrea sp.	*Goniastrea sp.*	
Pocillopora sp.	*Seriatopora sp.*	
Montipora sp.	*Porites sp.*	

Source: Pratchett et al. 2008.

The assumptions of Pratchett et al. (2008) were based on the numerous studies on the hierarchy of bleaching susceptibilities of coral genera. Impacts of climate-induced coral bleaching are less selective compared to increased storminess and *Acanthaster planci* out-breaks. Thermal sensitivities of coral genera have been attributed to physiological and morphological attributes such as colony integration, tissue thickness and sensitivities of symbiotic zooxanthellae. Moreover, differences in depth and habitats, history of thermal stresses and hydrodynamics also play crucial roles in coral bleaching susceptibility.

Seagrass and mangrove

The sensitivity assessment of mangrove and seagrass areas surrounding the VIP was conducted using available secondary information from municipal and provincial agriculture offices, coastal resource management plans and assessment reports from various institutions. Using the most relevant information, the status and sensitivity of mangroves and seagrasses to climate change were assessed based on likely response to the climate change component that will have greatest impact on these ecosystems. In particular, mangroves' sensitivity to increasing sea level rise was assessed based on the effects of flooding and the most available areas for recruitment and settlement. The vulnerability of these areas was assessed using McLeod and Salm (2006) vulnerability conditions (Table 9). Seagrass' sensitivity and vulnerability to increasing sea surface temperature and storm frequency and intensity were assessed using information from Campbell et al. (2006), Duarte et al. (1997), and Terrados et al. (1998). In particular, seagrass response to thermal stress, sediment perturbation, and eutrophication were given emphasis to assess the vulnerability of this ecosystem to climate change. However, since the available data did not include information on the zonation of species within a meadow, the sensitivity assessment was species-specific.

Table 9. An assessment of mangrove vulnerability to sea-level rise based on environmental conditions.

Vulnerability	Local conditions	Explanation
Most vulnerable	low relief islands	▪ low rates of sediment and peat accretion, particularly vulnerable to sea-level rise because they are subject to drought and wave erosion ▪ expected to experience increased flooding, inundation and salinization of soils and freshwater (Shea et al. 2001)
	lack of rivers	▪ lack of sediment and freshwater
	carbonate settings	▪ often associated with atolls and islands, where landward migration to escape sea-level rise may not be possible ▪ sediments are mostly locally derived
	areas subsiding due to tectonic movements, groundwater extraction, or underground mining	▪ will experience higher sea-level rise and inundation
	micro-tidal sediment-starved environments (small Caribbean islands) (Ellison 1993)	▪ lack of sediment will lead to decreased geographic distribution and species diversity of mangroves (Houghton et al. 2001)
	mangroves blocked by coastal development or steep topography	▪ unable to move inland when sea level rises
Least vulnerable	mangroves in deep sediment on high islands	▪ structurally stronger than mangroves in shallow sediment on low islands (Gillison 1980) and less vulnerable to storm surges than low islands (UNEP 1994) ▪ high islands will be better adapted to survive predicted climate changes due to their larger surface areas, freshwater availability, better soils, and more diverse resources (Shea et al. 2001)
	riverine mangroves	▪ receive large amounts of sediment from other areas (Woodroffe and Grindrod 1991) ▪ most productive mangrove habitats due to high nutrient concentrations associated with sediment trapping (Ewel et al. 1998)
	macro-tidal sediment rich environments (mangroves in northern Australia)	▪ access to sediment and strong tidal currents to redistribute sediment (Woodroffe and Grindrod 1991)
	mangroves with room to move landward (backed by low-lying areas, salt flats, undeveloped areas)	▪ have the opportunity to expand inland when sea level rises
	mangroves in remote areas	▪ have limited anthropogenic stresses and not blocked by coastal communities from moving landward
	mangroves surrounded by flourishing dense mangrove forests	▪ have steady supply of propagules and seeds

Source: McLeod and Salm 2006.

Sea surface temperature impact

Coral

Increasing sea surface temperatures have been documented as a cause of coral bleaching. Sea-surface temperature (SST) vulnerability estimates of coral communities were computed by subtracting the percentage covers of the taxa that are susceptible to temperature increases. Lower range estimates were calculated by removing the percentage cover of *Acropora* sp., whereas the higher range estimates were calculated by removing the percentage cover of *Acropora* sp. and pocilloporids (*Pocillopora* sp., *Seriatopora* sp,. and *Stylophora* sp.). Acroporids and pocilloporids are deemed to be the most thermally sensitive due to the low thermal thresholds of these families, their symbionts, and other factors. There have also been observations of high mortalities in Lian, Batangas where the first coral bleaching cases in the 1998 bleaching (the worse one on record) where first observed (Arceo et al. 2001) and is the only place where it has been studied in the entire VIP region. Although analyses of past thermal events suggest this part of the VIP is more prone to temperature fluctuations, the response of acroporids and pocilloporids were similar in other parts of the country (Arceo et al. 2001).

Analysis showed that the percentage loss of live hard coral cover ranged from 3% to 22% across the Verde Island Passage. The sites deemed to be highly vulnerable are those with high cover of the taxa listed above. Sites with minimal losses are mostly dominated by the coral *Porites* sp. As such, the municipalities of Mabini and Tingloy have the highest vulnerability with percentage loss of 11% to 22% and 14% to 21% respectively. The municipality of Lubang had an estimated loss 8% to 15% (Table 10).

Table 10. Percentage (%) cover and percentage loss of coral cover during elevated sea surface temperatures (SST) in the eight municipalities surveyed in the Verde Island Passage.

		% living hard coral			
Municipality	**Sites**	**before bleaching**	**low**	**high**	**Cover loss (%)**
Batangas City	4	12.9	12.2	11.6	6-10
Calatagan	8	24.2	23.5	22.3	3-8
Looc	6	29.4	28.0	26.8	5-9
Lubang	6	24.8	22.8	21.2	8-15
Mabini	3	33.8	29.9	26.4	11-22
Nasugbu	2	29.3	27.6	26.8	6-9
San Juan	8	19.6	19.0	18.5	3-6
Tingloy	3	19.2	16.5	15.1	14-21

Seagrass

Campbell et al. in 2006 studied the acute photosynthetic response of 7 tropical species of seagrasses to thermal stress and their ability to recover from this stress. As mentioned in this article, temperatures rising above the tolerable limit of 35°C inhibit plants' ability to produce carbon and bring about increased respiration and breakdown of photosynthetic enzymes. Although tropical species of seagrasses may have adopted to high temperature as some of the meadows are more exposed to extreme temperatures than meadows in temperate region, the photosynthetic responses of most seagrass species (as shown in this article)may likely suffer from short term or episodic exposure to seawater temperature ranging from 40 to 45°C. Of the species studied by Campbell et al. (2006), *Cymodocea rotundata*, *C. serrulata*, *Halodule uninervis,* and *Thalassia hemprichii* were more tolerant to thermal stress than other species. Using this study to determine the sensitivity of seagrasses in areas that surround VIP to increasing SST, the four areas included in this report may be least sensitive to increase in SST due to the presence of species which are tolerant to thermal stress (Table 5), however, this projection may further be refined when available data on seagrass densities and zonation of species will be considered.

Of the two habitats assessed to be sensitive to increase in temperature, corals are deemed more sensitive. Indeed globally, documentations of positive sea surface temperature (SST) anomalies have been associated with mass coral bleaching, mortality (Hoegh-Guldberg 1999, Wilkinson 2004), and coral disease outbreak (Bruno et al. 2007).

Storm impact

Coral

Analysis of the impacts of typhoons was based on the study by Licuanan (unpublished report) in Pagbilao, Quezon. Based on the monitoring of reefs in Pagbilao, Quezon (just to the east of the VIP) estimated coral cover losses during tropical storm Caloy was 12.5% for sheltered sites and 37.5% for exposed sites. These estimates were then used to calculate the change of the percentage coral cover during low to severe impacts since no function relating storm strength and cover loss is available. Coral cover in Quezon is comparable to the sites in the VIP, as are the reefs—which are generally narrow fringing type. Both areas are within the Philippines' typhoon belt.

Table 11 presents the changes in percentage covers of live hard corals when a typhoon similar to Caloy passed by the VIP. The municipalities of Mabini, Looc, and Nasugbu coral covers will remain in the fair category if the effect of the storm is low. However, if the impact is severe the status of the coral communities in these municipalities will become poor. Five out of the eight the municipalities' surveyed have poor coral covers, thereby increasing their vulnerability in the event of a severe impact. Batangas City for example after severe impact will have the lowest coral cover of 8.1% from 12.9%. Note that Caloy was merely a tropical storm and not of typhoon strength. Hence projected losses stated here are considered conservative.

Table 11. Estimated percentage (%) cover of live hard corals during low to severe impacts of typhoons.

Municipality	Sites	% living hard coral before impact	% living hard coral low impact	% living hard coral severe impact
Batangas City	4	12.9	11.3	8.1
Calatagan	8	24.2	21.2	15.1
Looc	6	29.4	25.7	18.4
Lubang	6	24.8	21.7	15.5
Mabini	3	33.8	29.5	21.1
Nasugbu	2	29.3	25.6	18.3
San Juan	8	19.6	17.2	12.3
Tingloy	3	19.2	16.8	12.0
All municipalities		**24.2**	**21.2**	**15.2**

Seagrass

Increase in storm intensity and frequency will likely cause changes in sediment morphology and dynamics as well as salinity levels in seagrass meadows. Sediment perturbation caused by strong typhoons increases mortality of seagrasses due to uprooting, dislocation and burial of seagrass modules.

Of the tropical species, *Enhalus acoroides* is the most resistant to sediment perturbation, followed by *Halophila ovalis, Halodule uninervis, Cymodocea serrulata, Thalassia hemprichii, Cymodocea rotundata,* and *Syringodium isoetifolium* (Duarte et al. 1997, Terrados et al. 1998).

The four sites in the VIP with known seagrass distribution are analyzed to have low sensitivity to sediment perturbation caused by an increase in storm intensity and frequency. The projection may be different if analysis will include eutrophication caused by influx of freshwater from increased storm/rainfall frequency. As observed in a lot of areas around the Philippines, seagrasses are overgrown by algae when the flow of water is impeded or when there is an increase in freshwater input.

Sea level rise impact

Coral

For the effects of sea level rise (SLR), area loss was computed using the following formula:

$$\text{\% area loss } \frac{(a'/\sin A) - (a/\sin A)}{a/\sin A} \times 100$$

Wherein, **a** is the maximum depth of the reef community before sea level rise; **a´** is the maximum depth of the reef community after sea level rise; and, **A** is the angle of the reef slope. The angle of the reef slope was measured as the elevation from the horizontal.

This formula, however, only applies to deep coral communities along the reef slope. It is assumed that in the event of sea level rise, the coral communities located at the bottom of the reef slope will drown even if factors other than depth may control the lower extent of reefs in particular sites (note that the entire study is based on secondary data aggregated to the town level). Coral reefs in the Philippines are generally shallower around high islands such as Luzon and Mindanao where water clarity is also lower mostly due to human activities on land. Exceptions are the sparsely populated areas facing the Pacific Ocean.

Table 12 presents the estimated area following sea level rise. Reef area loss for the VIP ranges from 0.38% to 7%. Note that these only apply to the deepest portion of the reef slope. Specifically, Batangas City and Nasugbu are highly vulnerable and have estimated 0.38% to 7% area loss. Whereas, the rest of the municipalities surveyed are still vulnerable but have lower estimates of 0.25% to 4% area loss.

Table 12. Estimated area and diversity losses in the event of sea level rise. Area loss estimates were based on the 5 cm (low) and 88 cm (high) sea level rise scenarios. Diversity loss was computed using the species area curve.

Municipality	% area loss	% diversity loss
Batangas City	0.38-7	0.60-0.80
Calatagan	0.25-4	0.60-0.70
Looc	0.25-4	0.60-0.70
Lubang	0.25-4	0.60-0.70
Mabini	0.25-4	0.60-0.70
Nasugbu	0.38-7	0.60-0.80
San Juan	0.25-4	0.60-0.70
Tingloy	0.25-4	0.60-0.70

Mangrove

Table 13 presents the vulnerability assessment of mangrove areas along the VIP, the study is delimited with the availability of information on mangroves in these areas. The 1 mm per year accretion rate observed by Fujimoto et al. (1995) in Abatan River, Bohol was used as there is no other available information on rates of accretion in other parts of the country.

If sensitivity assessment will be based on the areal extent of potential mangrove areas and the projected 1, 2- and 3-m rise in sea level (Siringan et al., this report), almost all areas included in this report will be inundated with 1-m rise in sea level except for the municipalities of San Juan, Batangas and Calapan City, Oriental Mindoro (Figure 36). For Batangas province, the mangrove forests in San Juan will be the least vulnerable, followed by Calatagan, Lian, Nasugbu. For Oriental Mindoro, Calapan City will be the least vulnerable, followed by Naujan, Pola, and Baco. However as stated earlier most of these mangrove areas have been converted to fishponds, resorts and other land uses and are near coastal communities, hence progression landward may be hindered.

Balayan and Batangas City were seen as the most vulnerable mangrove areas due to its small size in terms of area covered and the presence of coastal developments (fishponds, ports, industries) which may be a barrier to the settlement and growth of mangroves. The dikes of active and abandoned fishponds for example, would impede the settlement of seeds and propagules to these ponds and the normal hydrology in the area that could promote growth of mangroves is also altered. With all these barriers, even if there will be a 1mm per year accretion rate, offsetting the impact of sea level rise may be difficult unless some measures are made to relieve the stress. An example would be the restoration of abandoned fishponds into its natural mangrove forest. A number of publications have already laid down protocols and steps on restoration of ponds into mangrove forests (i.e., Lewis and Marshall 1997, Stevenson et al. 1999, Samson and Rollon 2008, Primavera and Esteban 2008, Lewis 2009).

Table 13. Vulnerability of mangrove areas along the Verde Island Passage to projected sea level rise (SLR) and rate of accretion.

Municipality	Area (ha) to be inundated given a 50-year SLR projection			Mangrove area (ha)	Dominant mangrove species[1]	Issues affecting mangrove area	Degree of vulnerability given 1mm/year accretion rate[2]
	1-m	2-m	3-m				
Nasugbu	64.26	366.84	848.97	no data	no data	no data	no data
Calatagan	235.8	369.72	765.45	244.98	Am, Ao, Ra, Rs, Nf	conversion to fishponds and saltbeds; establishment of resorts; presence of coastal communities; illegal cutting; existing tenurial instruments	LV
Balayan	165.06	439.92	761.85	19.09	Am, Ra, Rs,Nf	conversion to fishponds; establishment of resorts; presence of coastal communities; illegal cutting	MV
Lemery	101.88	222.48	427.95	no data	no data	no data	no data
Batangas	92.97	137.52	307.26	23.64		development of industries and ports; presence of coastal communities; conversion to fishponds	MV
Lobo	20.88	36.36	70.65	no data	no data	no data	no data
Abra de Ilog	34.56	77.58	191.88	no data	no data	no data	no data
Calapan	69.66	160.65	511.92	332.0	Af, Am, Ao, Sa	presence of coastal communities; conversion to fishponds; presence of piggeries; illegal cutting	LV
Naujan	90.63	182.97	446.58	165.0	Af, Am, Am, Sa, Sc	presence of coastal communities; conversion to fishponds; illegal cutting	LV
Lubang	426.51	701.91	1096.38	no data	no data	no data	no data
Boac	45.81	92.52	199.98	no data	no data	no data	no data

[1] Af–*Aegiceras floridum*, Am–*Avicennia marina*, Ao–*A. officinalis*, Nf–*Nypa fruticans*, Ra–*Rhizophora apiculata*, Rm–*R. mucronata*, Rs–*R. stylosa*, Sa–*Sonneratia alba*, Sc–*Sonneratia caseolaris*
[2] MV–most vulnerble; LV–least vulnerable

Source: McLeod,E. and R. V. Salm. 2006. *Managing Mangroves for Resilience to Climate Change*. IUCN, Gland, Switzerland. 64pp.

Figure 36. Effect of sea level rise on existing mangrove stands (based on number of species present).

If the impacts of flooding due to sea level rise and the presence of species which are least sensitive to changing water quality, i.e., *Avicennia marina*, *Rhizophora stylosa* (Alongi 2008), will be considered, most of the areas studied will have low sensitivity to flooding except for the municipalities of Puerto Galera and Baco, Oriental Mindoro (Figure 37). Aside from their greater ability to cope with changes in water quality, the species of *A. marina* and *R. stylosa* have higher rates of colonization potential.

Using the vulnerability assessment conditions presented by McLeod and Salm (2006) in Table 9 and the projected sea level rise in VIP (Siringan et al., this report), mangrove areas around the VIP are vulnerable to any rise in sea level and other impacts that may be brought about by this factor. Though some municipalities have considerable large areas of mangroves (i.e., Calatagan and San Juan, Batangas; Calapan City, Oriental Mindoro), most of these areas are near coastal communities which according to McLeod and Salm (2006) will be unable to progress landward due to present anthropogenic developments.

Gilman et al. (2008), based on their analysis of available evidence, predicted that of all climate-related changes, sea level rise will have great impact on the remaining mangrove ecosystems.

The projections presented here are conservative because interactions between climate change impacts are not considered. Increase in ocean temperature, sea level rise, and more frequent typhoons acting together are likely to have greater impacts than the sum of their individual impacts. As an example, sea level rise is likely to liberate sediments from the inundated lands, and drowned mangroves and seagrasses. These sediments, in turn, will reduce water transparency (for one) further aggravating the drowning of the lower reef slope. Even more sediments will be liberated by strong waves and heavy rainfall generated by storms and typhoons. (Also consider possible changes in rainfall patterns, this is a gap area).

Figure 37. Effect of flooding due to sea level rise on existing mangrove stands (based on presence of flood resistant species).

Another reason why the projections presented here should be considered conservative is because they were made with the implicit assumption that the impacts of human activities are already incorporated in the baseline data used and will remain at current levels in the future. However, the coasts of the VIP host rapidly growing populations and are subject to increasing development. There is already evidence from Lian, Batangas and Puerto Galera, Oriental Mindoro of eutrophication resulting from agriculture and urban sewage, respectively (please cite reference). This leads to algal blooms that will have detrimental impact on the reef. Also, the impact of garbage on VIP waters has not been studied.

Adaptive capacity

The adaptive capacity of an ecosystem would depend on their historical stress experience and their natural ability to withstand an impact. This was explored using 1) change detection analysis for 10 representative sites in the Verde Island Passage, and 2) time series of pelagic primary productivity.

Coastal habitat

Changes in coastal habitat were done using latest available cloud-free Landsat images: the oldest available (1991-92); after the 1998 massive bleaching (2001-02); and the latest available (2007/2009). Each of the images were pre-processed for atmospheric correction using dark pixel subtraction and subsequently land masked. A new set of spectral layers were then created using the following band ratios: B1-B2; B4-B3; B5-B4; B5-B2. This was done to eliminate/ minimize the shadow effect of clouds and mountain shading. PCA images were then density sliced to collect ROI's representative of the known habitats, i.e., Live Corals; Mixed Live with Dead Coral-Rock (DCA-Rck); Algae overgrown DCA-Rck and Macrophyte Bed; and Sand-Rubble) on the reef. Between 30 to 80 points per habitat were collected and used as training pixels for supervised parallelepiped classification. Generation of class statistics (area coverage per microhabitat) was conducted in selected areas of VIP. It should be noted, however, that the 2009 images have the inherent problem of presence of stripping. This results in an over/under estimate of total cover. Correction was done by multiplying the % cover from the 2009 data multiplied by the more reliable 1991-1992 total coverage data. The same was done for the 2001-2002 images. Percent covers of live coral; mixed live and dead coral/rock; algae dominated/macrophyte beds; and sandy areas are highlighted in Table 14.

Calatagan, followed by Puerto Galera-Naujan appear stable in that changes to live coral and macrophyte cover are minimal through the years, and this appears consistent with limited monitoring data from a people's organization in Calatagan. The live coral cover of Batangas East and West Marinduque also appears stable. The most significant live coral cover loss can be seen for the islands of Lubang and Maricaban. Coral cover loss (1991/92 to 2002) and then recovery (2002 to 2009) was observed for Naujan-Gloria. In several sites (Lubang Island, Naujan-Gloria, and West Marinduque), shifts in dominant substrate type from loose, to dead coralline/rocky substrate was observed. Processes underlying such shifts are usually biological and physical in nature, operating in a predominantly local scale.

In Lubang Island and West Marinduque, the increase in relative cover of dead coralline algae/rock from 2002 to 2009 could be the result of rubble aggregation and lithification. This type of substrate shift was also observed in Ngaderrak Reef in the Republic of Palau (Ticzon et al. 2008), where rubble areas were consolidated and cemented by coralline algae and the encrusting sponge Clathria. However, this process of lithification in Lubang Island and West Marinduque could have been limited in areas of low wave energy, and minimal anthropogenic disturbance. This would allow for loose rubble to aggregate and provide time for biological processes to initiate the process of cementation.

A different process is believed to be behind a similar shift in dominant substrate type in the Naujan-Gloria reefs. Characterized by strong wave action and steep

Table 14. Change in coastal habitat cover through time. Size of the circle depicts extent of total coastal habitat cover in hectares (small = tens; medium = more than a hundred; large = beyond 1000 hectares).

Blues–corals, maroons–mixed live/dead coral and rock, greens–algal covered substrate or macrophyte beds, yellow–sandy areas.

slopes, erosion of loose substrate to the deeper section of the shelf is seen as the primary reason in the increase in percent cover of dead coralline/rocky substrate in this section of the VIP, specifically from Barangay Calima to Mag-Asawang Tubig, in Pola. The erosion of loose substrate exposed the underlying bed rock in some areas, contributing to the increased cover of DCA/Rock. However, the image also shows that the increase in relative cover of DCA/Rock is due to coral mortality, which consistently occurred in this section of the VIP from 1992 to 2009.

Pelagic primary productivity

In temperate regions, primary productivity has been shown to be affected by changes in precipitation pattern (Mallin et al. 1993), and changes in intensity of storm (Vinayachandran and Mathew 2003). Moreover, the northward shift of warm-water plankton, the retreat of cold-water plankton and the altered timing of spring plankton production are already seen to affect higher trophic levels (MCCIP 2008). The primary productivity adaptive capacity in the VIP is explored by describing the behavior of chlorophyll *a* signal through time using SeaWIFs monthly dataset with a 9 km resolution (September 1998-March 2009).

Chlorophyll data within and around the VIP shows the seasonality of the signal with higher signal during the NE monsoon (Figure 38). This is because during the northeast monsoon, winds through the passage are funneled by the topography and coastline of the strait resulting in very strong wind jets. Such wind jets have been described as the driving force behind the dipole eddy that sometimes forms off Lubang Island in the South China Sea (Pullen et al. 2008). The strong northeast monsoon winds through the strait may also enhance mixing resulting in the transport of nutrients towards the surface thus enhancing productivity. This is supported by both satellite and ship-based measurements showing elevated chlorophyll concentrations in the area west of the Verde Island (PhilEx, unpub data).

Further investigation of the NE signal shows the higher chlorophyll concentration in the western side of the VIP (Figure 39). Long-term anomalies show all clusters having negative chl anomaly in 1998, hence chl also decreased in the VIP during the 1998 high thermal anomaly that is responsible for mass coral bleaching (Figure 40). The 2 clusters within the VIP showed a positive chl anomaly during the following strong La Niña

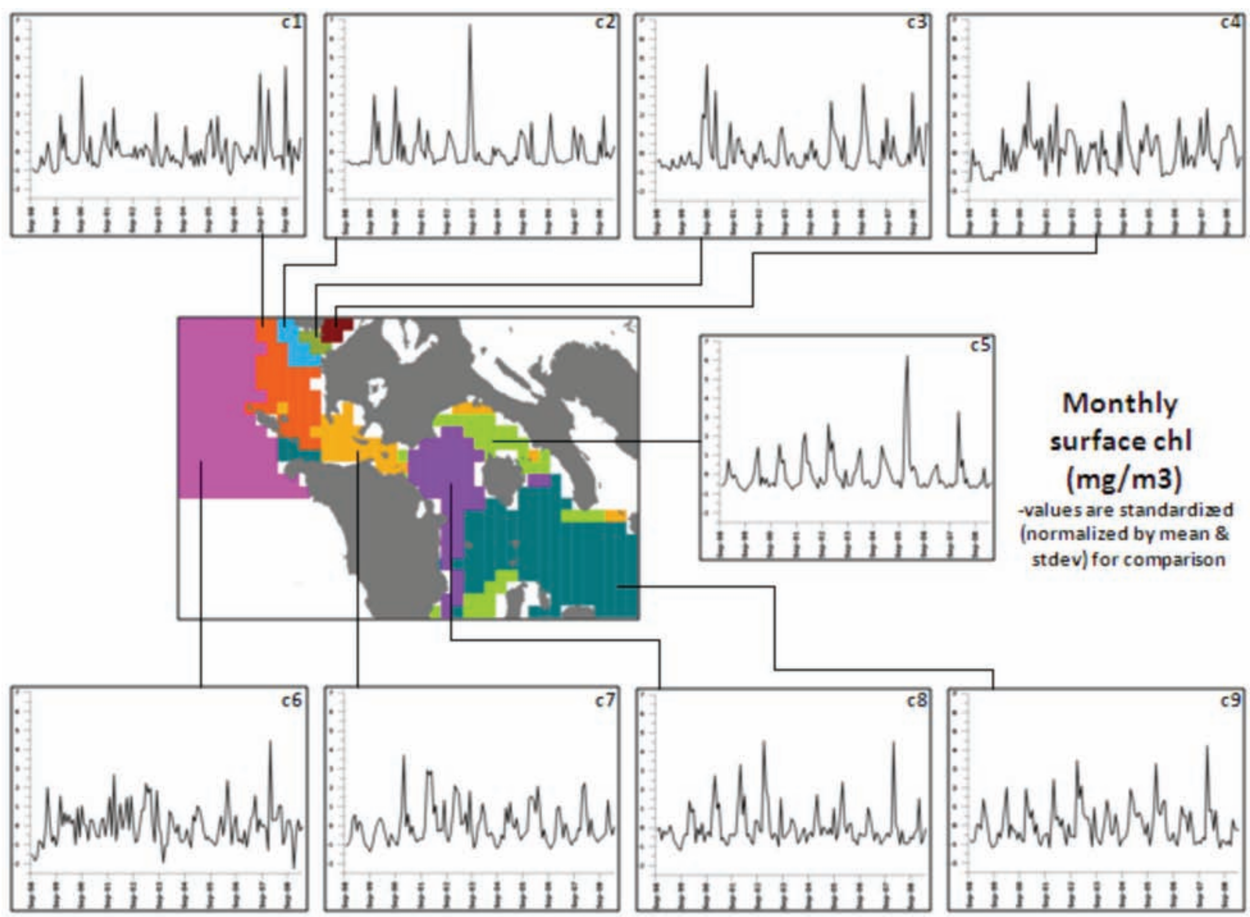


Figure 38. SeaWiFs derived monthly surface chlorophyll in and around the VIP from September 1998-March 2009 clustered into 9 distinct classes. Signature time-series for each cluster are shown above. Peaks pertain to elevated chlorophyll concentrations during the NE monsoon.

(1999-2001) with a 1 year lag between the eastern and western part. This could have implications in the near future because PDO negative (in which we are in now) have been associated with more La Niñas. During the prolonged weak El Niño from 2003-2006 no significant anomalies were observed. In 2007-08, there was again a positive chl anomaly during La Niña. Then, in 2008 just as the La Niña was weakening, there was a PDO was shift from a warm phase to a cold phase and a negative chl anomaly was observed.

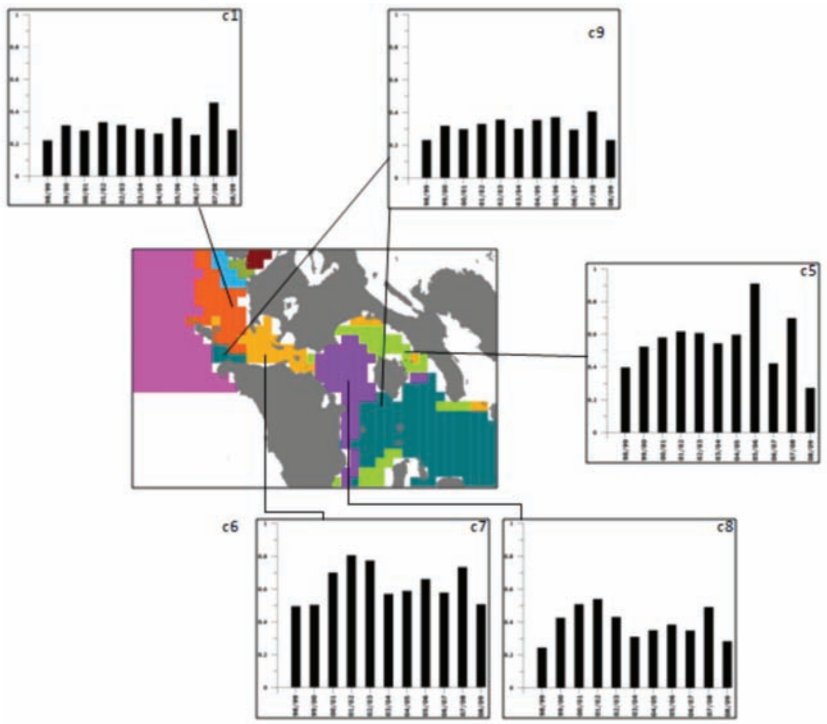


Figure 39. Average signal during the NE monsoon (Dec-Feb) in surface chl (mg/m^3). Values are standardized (normalized by mean and st dev) for comparison (Dec 1997-Feb 2009).

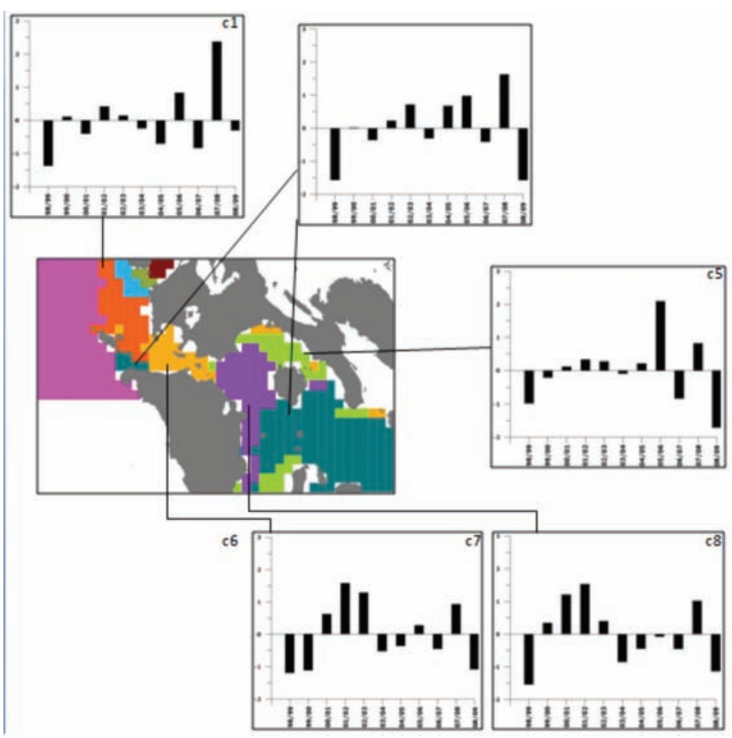


Figure 40. Anomaly signals for the NE monsoon (Dec-Feb) in surface chl (mg/m^3).

Vulnerability

Measuring vulnerability requires various hierarchical scales of analyses and perspectives vis-à-vis the impending impact on the socio-ecological system. Measuring their eventual interactive effects would require a nuanced perspective. By putting in a matrix or geographic overlay of how each aspect interacts is useful as a first order analyses. But putting into context the different weights and importance factors of the climate change impacts and their functionality would have give varying impacts at a habitat level vis-à-vis their species level concerns.

Consequence of this habitat sensitivity to diversity

Coral diversity

The number of observed coral genera and reef fish abundance and species richness of each survey site per municipality were collated for the analysis. The number of observed coral genera per municipality was obtained by pooling all the occurrences of coral genera per municipality. Species richness of reef fish assemblages per municipality was also obtained by pooling all the observed reef fishes during these surveys. Reef fish abundances values were obtained by getting the total number of individuals per municipality.

Based on the percentage loss of coral cover due to increase in ocean temperature, coral diversity loss was estimated to range from 0.7% to 1.6% across the VIP using the species-area curve for Calamianes. Specifically, diversity loss in the municipalities of Mabini, Tingloy and Lubang ranged from 1.0% to 1.6%, 1.1% to 1.6% and 0.9 to 1.2% respectively (Table 15). The remaining municipalities of Batangas City, Calatagan, Looc, Nasugbu and San Juan are deemed to lose 0.7% to 0.9% of their coral diversity. However, using Pratchett et al. (2008) as basis, diversity loss across the VIP ranged from 10% to as high as 75%. The municipality of Nasugbu was considered as highly vulnerable as it could lose 21% to 75% of its coral diversity. This is attributed to the low number of coral genera occurring in its reef areas. Whereas, the municipality of Tingloy and Batangas City were considered to be vulnerable since it could lose 10% to 41% and 15% to 49% of its coral diversity, respectively. Other municipalities such as Calatagan, Looc, Lubang, Mabini, and San Juan have estimated losses of 13% to 59%.

It should be noted however, that not all of the identified coral genera (27) were present in each municipality. As explained earlier, the lower estimates based on Pratchett et al. (2008) was obtained by deducting the top ten (10) genera from the total number of genera present. Whereas, the higher estimates was obtained by removing all of the genera that were indicated in the list in Pratchett et al. 2008.

Table 16 presents the changes in the occurrence of coral genera when a storm similar to Caloy passed by the VIP. Coral diversity loss estimates during tropical storm Caloy in Pagbilao, Quezon ranged from 7% for low impact to 22% for severe impact. Diversity is already low in the municipalities surveyed, thereby making them even more vulnerable based on the estimates. The municipalities of Calatagan and Mabini are the least to be affected during low impact as they have the highest diversity among all the sites surveyed. However, if the impact is severe, coral diversity in these municipalities will be less ranging from 30 to 35 genera only. The municipality of Nasugbu is deemed to be the most vulnerable of all the sites regardless of low or severe impact. Losses in coral genera will change from 28 to 21.8% during severe impact. This is attributed to the very low occurrences of coral genera in the municipality.

Following sea level rise and assuming that the coral distribution and diversity are even for the entire reef area, diversity loss obtained using the species area curve estimated 0.60% to 0.80% loss. Specifically, Batangas City and Nasugbu are highly vulnerable with

Table 15. Percentage (%) loss of coral diversity during elevated sea surface temperatures in the eight municipalities surveyed in the VIP.

Municipality	Sites	# genera	Diversity loss (%) sp-area curve	Pratchett et al. 2008
Batangas City	4	39	0.8-0.9	15-49
Calatagan	8	44	0.7-0.9	18-57
Looc	6	41	0.8-0.9	15-54
Lubang	6	39	0.9-1.2	21-59
Mabini	3	45	1.0-1.6	13-53
Nasugbu	2	28	0.8-0.9	21-75
San Juan	8	42	0.7-0.8	17-57
Tingloy	3	41	1.1-1.6	10-41

Table 16. Estimated percentage (%) of diversity of live hard corals during low to severe impacts of typhoons.

Municipality	Sites	Before impact	Low impact	Severe impact
Batangas City	4	39	36.3	30.4
Calatagan	8	44	40.9	34.3
Looc	6	41	38.1	32.0
Lubang	6	39	36.3	30.4
Mabini	3	45	41.9	35.1
Nasugbu	2	28	26.0	21.8
San Juan	8	42	39.1	32.8
Tingloy	3	41	38.1	32.0
All municipalities		63	58.6	49.1

0.60% to 0.80% diversity loss while the rest of the municipalities surveyed have relatively lower estimates of 0.60% to 0.70% diversity loss.

Reef fish diversity

Recent studies of Wilkinson (2000a and 2000b) have shown that climate-induced coral bleaching has had major effects on the biological and physical structure of coral reef habitats. Numerous studies (e.g., Shibuno et al. 1999, McClanahan et al. 2002a, Munday 2004a, Sano 2004, Graham et al. 2006, Pratchett et al. 2006) have documented consequent changes in the species composition and abundance of associated reef fish assemblages. Changes in the topographic complexity and loss of coral cover affect reef fishes by reducing viable coral growths that provide shelter and protection and food source which ultimately affect settlement, recruitment and overall biological diversity.

The municipality of Mabini had the highest number of reef fishes observed within the belt transects with 151 species (Table 18). Mabini is closely followed by the municipalities of Lubang, Tingloy and Batangas City with 147, 142, and 139 species, respectively. The municipalities of Looc and Nasugbu, despite having higher percentages of live hard coral cover, only harbored 87 and 44 reef fish species, respectively. San Juan and Calatagan fell in the middle with 100 and 113 species. Lubang municipality had the highest estimated reef fish abundance with more than 2,000 reef fish individuals, whereas the municipality of Nasugbu had the lowest reef fish abundance with only 171 individuals. The municipality of Looc despite having less than a hundred reef fish species still had more than 1000 reef fish individuals. Mabini municipality on the other hand, only had more than 1,200 individuals despite having the highest species richness. The remaining municipalities, Batangas City, Calatagan, San Juan, and Tingloy had reef fish abundances of more than 1,400 individuals. The Fish Visual Census (FVC) method was used to assess the reef fish assemblages. Reef fish species richness was accounted by pooling all the observed species in the belt transects during the surveys. Fish abundance was estimated by pooling total fish abundance (number of individuals/1000m^2) per survey site and getting their means.

Effects on the reef fish abundance and diversity were determined by calculating the percentage losses of vulnerable species that Pratchett et al. (2008) identified. Table 17 presents the vulnerable reef fish species adapted from Pratchett et al. (2008) found in the Verde Island Passage.

Losses in reef fish abundances were estimated by deducting the abundances of the vulnerable species from the total reef fish abundance per municipality.

Similarly, reef fish diversity loss per municipality was computed by subtracting the total number of vulnerable species to the total number of species present in each municipality.

A total of 16 species of reef fishes listed in Pratchett et al. (2008) was observed in the VIP. Percentage loss of reef fish species ranged from 9% to 14% (Table 18). The municipality of Nasugbu was deemed to have the highest vulnerability as it could lose 16% of the 44 observed fish species, followed by Looc, Caltagan, and San Juan with estimated losses of 14%, 12%, and 10% respectively. The municipalities of Batangas City, Lubang, Mabini, and Tingloy had the lowest estimated loss of 9%. The total number of species observed, only included reef fish species observed during the transect surveys.

The estimated percentage losses of reef fish diversity and abundance is relatively high. However, these estimates are still considered to be conservative as the compounded impacts of the other climate change impacts and human activities are still not accounted for. Although the effects of loss of coral cover can be minimal and limited to highly-dependent fishes (e.g., corallivores), changes in topographic complexity can

Table 17. Reef fish species observed in the Verde Island Passage that are affected by coral bleaching due to their association and dependence on coral communities.

Family	Species	Habits
Acanthuridae	*Ctenochaetus striatus*	herbivores
Chaetodontidae	*Chaetodon baronessa*	corallivore
Chaetodontidae	*Chaetodon lunulatus*	corallivore
Chaetodontidae	*Chaetodon melannotus*	corallivore
Chaetodontidae	*Chaetodon trifascialis*	corallivore
Labridae	*Gomphosus varius*	benthic carnivore
Labridae	*Halichoeres melanurus*	others
Labridae	*Labrichthys unilineatus*	corallivore
Pomacentridae	*Amblyglyphidodon curacao*	omnivores
Pomacentridae	*Chrysiptera rollandi*	others
Pomacentridae	*Neoglyphidodon melas*	corallivore
Pomacentridae	*Plectroglyphidodon lacrymatus*	herbivores
Pomacentridae	*Pomacentrus lepidogenys*	coral dweller
Pomacentridae	*Pomacentrus moluccensis*	coral dweller
Pomacentridae	*Pomacentrus vaiuli*	others
Siganidae	*Siganus spinus*	herbivores

Source: adapted from Pratchett et al. 2008.

Table 18. Percentage (%) loss of associated reef fish species and abundance in the event of coral bleaching.

		Species richness			Abundance		
Municipality	Sites	# species observed	lost	loss	before	after	% loss
Batangas City	4	139	13	9	1660	1205	27
Calatagan	8	113	13	12	1874	1377	27
Looc	6	87	12	14	1086	830	24
Lubang	6	147	13	9	2227	1658	26
Mabini	4	151	14	9	1215	652	46
Nasugbu	2	44	7	16	171	133	22
San Juan	8	100	10	10	1410	1247	12
Tingloy	3	142	13	9	1465	672	54

cause more wide-spread detrimental impacts. The increase in frequencies and intensities of storms and typhoons for example, can cause more devastating effects on habitat complexity. **Nevertheless, the estimates made are still significant as it provides us lower-range projected losses in the VIP.**

Consequence of this habitat sensitivity to fisheries

To achieve the objectives of the vulnerability analyses it is necessary to determine the attributes of fisheries ecosystem, their ecosystem features and connectedness to the various habitats and resources and how the ecological and social economic systems interact. This component emphasizes on the ecological interactions and only introduces its links to the social systems as these social linkages and adaptive capacities are discussed by another group.

This approach (Table 19) first identifies and then quantifies the types of gear present and used in six municipality/city sites in the VIP, namely Mabini (Batangas), Verde Is. (Batangas City), Puerto Galera (Oriental Mindoro), Lubang (Occidental Mindoro), Looc (Occ. Mindoro), and Paluan (Occ. Mindoro). Where available, information on fisher population, types of fishing gears used (mainly artisanal and under the municipal fisheries category), number of fishers per gear type, catch rate, catch composition, seasonality of gear use, and fishing areas of the gears were collected.

Threat analyses

Standardizing semi-quantitative scores of human induced threats vis-à-vis fisheries and resource exploitation and other exacerbating impacts.

The vulnerability assessment utilizes the information gathered from the literature to identify the fisheries resources (target species, fishery stocks) that will be most affected (i.e., vulnerable vis-á-vis the prospective climate impacts) by extreme changes in the climate. Emphasis was placed upon knowledge of the critical life stages (e.g., larvae, juveniles, reproductive stages) of the species as well as some information on their catch rates and habitat conditions. It has been acknowledged that changes in the climate (e.g., rising sea surface temperature, increase in storm frequency, storm surges) would possibly introduce greatest impact upon larval, juvenile and reproductive stages of target species affecting distributional patterns (e.g., Munday et al. 2008). Target species may also be influenced by changes in the climate indirectly through habitat loss and fragmentation (e.g., coral loss through bleaching events, inundation of mangroves areas) affecting their recruitment, survivorship and abundance (Pratchet et al. 2008). The associated habitats of the target species were determined as this will allow further examination of the conditions of these habitats harboring the critical life stages. The presence of habitat types (e.g., seagrass beds, mangroves) that enhances the growth and survivorship and what drives the population dynamics of the species potentially will serve as a gauge or index as what would be vulnerable to climate change (e.g., increase in sea surface temperature, sea level rise).

Catch composition and dominant catches of the gears allows identification of the species targeted in the fisheries. In addition, the distribution of the target species can be assessed by determining the types of gear used in the area and the associated habitats of the species and gears. The gear types of the target species and their level of fishing effort will be concurrently assessed to incorporate the exacerbating effects of exploitation upon "sensitive" species and habitats. The vulnerability assessment also takes into account the dependence of the gears and therefore the fishers upon specific "sensitive" habitats in the fisheries. The gear types, their density, and their level of effort will be utilized to explore the vulnerabilities of the fisheries. This also initiates the interaction with or the link to socio-economic aspects of the assessment particularly highlighting the effects upon human well-being whereas the identified fishing areas of the gears will link to the habitat and biodiversity aspects of the assessment.

Vulnerabilities were first explored for the target species/taxa of each site by primarily considering the range of associated habitat types throughout the life cycle of the species that would be at risk to climate change impacts. Table 20 shows the target species/taxa of the various gear types of the 6 sites and their associated habitat types. Under this assessment, Lubang and Looc fisheries appear both to be more vulnerable compared to any other site. This was mainly due to the several target species and/or taxa from a range of gear types. Many of the target species showed varying

Table 19. Focus of the fisheries vulnerability assessment in the Verde Island Passage.

Target species and life history characterstics
***Spratelloides* (dulong)**: post-larval juveniles of this pelagic species are heavity harvested at nearshore areas including lagoons at known season This fishery is important in Mabini and adjacent areas.
Groupers: juveniles of some of these reef associated fish occur at mangroves and estuaries (i.e., ontogenetic habitat movement) at known season. Important in the live fish food fishery in Looc and Lubang.
Milkfish: juveniles of this species occur at estuaries. Important in the milkfish fry fishery in Occidental Mindoro.
Aquarium fish: these fish are highly associated with coral reefs. Important in the aquarium fishery in Verde Island and Occidental Mindoro.
Gear quantity, distribution, and dependence on habitats
Fishing grounds of varying habitat types with associated gears. High gear effort at more habitat types render the areas more sensitive and therefore vulnerable to climate change. Lubang showed the most number of gears and gear types variably distributed at different habitat types.

Table 20. Vulnerability assessment of the fisheries, based on the number of habitat types of the target species/taxa (including all types of habitat throughout the life cycle). Oceanographic and remote sensing (RS) information on the habitat attributes will result in functional weighting of the habitat scores vis-à-vis their importance to the vulnerability values.

Species/taxa	Caught by gear type	Habitat type						Number of habitat types	Vulnerability index
		reef	sand/ beach	mangrove	seagrass	estuarine creeks/rivers	pelagic		
Mabini, Batangas									
dulong (*Spratelloides*)	basnig (bag net), lambat	√				√	√	3	medium
dilis (*Engraulis*)	pandulong (gill net), scissor net	√				√	√	3	medium
alumahan (*Rastrelliger*)	lambat pante (gill net)						√	1	low
tambakol (*Katsuwonus*)							√	1	low
galunggong (*Decapterus*)	lambat pante (gill net) hayhay (surface long line)	√					√	2	low to medium
matambaka (*Selar*)	hayhay (surface long line) lambat pante (gill net)	√					√	2	low to medium
lapu-lapu (groupers)		√		possible		possible	√	4	medium to high
maya-maya (*Lutjanus*)	kawil (hook and line), pana	√		possible			√	2	low to medium
kanoping (*Lethrinus*)	(spear)	√			possible		√	2	low to medium
bisugo (nemipterids)		√	√				√	2	low to medium
tulingan (*Auxis*)	hayhay (surface long line)						√	1	low
pusit (*Sepioteuthis, Loligo*)	pamanos (squid jig)	√					√	2	low to medium
									low to medium
Verde Island, Batangas City									
angelfish (*Pomacanthus*)		√					√	2	low to medium
butterflyfish (*Chaetodontus*)	hand nets (barrier net)	√					√	2	low to medium
damselfish (*Chromis*)		√					√	2	low to medium
anthiinid (*Anthias*)		√					√	2	low to medium
lion fish (*Pterois*)		√					√	2	low to medium
lapu-lapu (groupers)	kawil (hook and line)	√					√	2	low to medium
manites (*Upeneus*)		√					√	2	low to medium
galunggong (*Decapterus*)	hayhay (long line)	√					√	2	low to medium
mulmol (*Scarus*)	pana (spear)	√					√	2	low to medium
labahita (*Naso*)		√					√	2	low to medium
pusit (*Sepioteuthis, Loligo*)	pamanos (squid jig)	√					√	2	low to medium
									low to medium
Puerto Galera, Oriental Mindoro									
galunggong (*Decapterus*)	lambat pante (gill net) kawil (hook and line)	√					√	2	low to medium
									low
tulingan (*Auxis*)	kawil (hook and line)						√	1	low
alumahan (*Rastrelliger*)							√	1	low to medium
labahita (*Naso*)	pana (spear)	√					√	2	low to medium
loro, mulmol (*Scarus*)		√					√	2	**low to medium**
Lubang, Occidental Mindoro									
galunggong (*Decapterus*)	basnig (bag net) kawil (hook and line)	√					√	2	low to medium
dilis (*Stolephorus*)	basnig (bag net), lambat (gill net)	√		√		√	√	4	medium to high
pusit (*Sepioteuthis, Loligo*)		√					√	2	low to medium
pagulpol (*Cypselurus*)	pante (gill net)						√	1	low
tangigue (*Makaira*)	lambat (gill net)						√	1	low
gulyasan (tuna)	lambat (gill net), kawil (hook and line)						√	1	low
maya-maya (*Lutjanus*)	kawil (hook and line), bubo (trap), pana (spear), lambat (gill net)			possible		possible		4	medium to high
lapu-lapu (groupers)		√			possible		√	5	high
labahita (*Naso*), rabbitfish				possible	√			4	medium to high
angelfish (*Pomacanthus*)	hand nets (w/ compressor)	√					√	2	low to medium
butterflyfish (*Chaetodontus*)	hand nets (w/ compressor)	√					√	2	low to medium
damselfish (*Chromis*)	hand nets (w/ compressor)	√					√	2	low to medium
anthiinid (*Anthias*)	hand nets (w/ compressor)	√					√	2	low to medium
bangus fry (*Chanos chanos*)	scoop nets	√		√			√	4	medium to high
									medium
Looc, Occidental Mindoro									
dilis (*Stolephorus*)	basnig (bag net), lambat	√		√		√	√	4	medium to high
talakitok (*Carangoides*)	pandilis (anchovies), gill	√					√	2	low to medium
pusit (*Sepioteuthis, Loligo*)	nets	√					√	2	low to medium
matambaka (*Selar*)	kawil (hook and line)	√					√	2	low to medium
lapu-lapu (live groupers)	kawil (hook and line), pana	√		possible	possible	possible	√	5	high
maya-maya (*Lutjanus*)	(spear)	√		possible			√	3	medium
angelfish (*Pomacanthus*)	hand nets (w/ compressor)	√					√	2	low to medium
butterflyfish (*Chaetodontus*)	hand nets (w/ compressor)	√					√	2	low to medium
damselfish (*Chromis*)	hand nets (w/ compressor)	√					√	2	low to medium
anthiinid (*Anthias*)	hand nets (w/ compressor)	√					√	2	low to medium
bangus fry (*Chanos chanos*)	scoop nets	√		√		√	√	4	medium to high
									medium

Table 20. (continued)

Species/taxa	Caught by gear type	Habitat type						Number of habitat types	Vulnerability index
		reef	sand/ beach	mangrove	seagrass	estuarine creeks/rivers	pelagic		
Paluan, Occidental Mindoro									
angelfish (*Pomacanthus*)	hand nets (w/ compressor)	√					√	2	low to medium
butterflyfish (*Chaetodontus*)	hand nets (w/ compressor)	√					√	2	low to medium
damselfish (*Chromis*)	hand nets (w/ compressor)	√					√	2	low to medium
anthiinid (*Anthias*)	hand nets (w/ compressor)	√					√	2	low to medium
galunggong (*Decapterus*)		√						2	low to medium
tulingan (*Auxis*)	basnig (bag net), kawil (hook and line)						√	1	low
dilis (*Stolephorus*)		√				√		3	medium
alamang (*Acetes*)	lambat (gill net)					√	√	2	low to medium
pagulpol (*Cypselurus*)							√	1	medium
lapu-lapu (groupers)									
maya-maya (snappers)	kawil (hook and line), pana (spear), bubo (trap	√		possible	possible	possible	√	5	high
labahita (*Naso*)									
									low to medium

associated habitat types such as pelagic anchovies, herrings and sardines that are known to also occur at estuaries. These sites also had fishers harvesting milkfish fry at estuaries and several grouper species with juveniles occurring at mangroves and seagrasses. Several site-attached and coral dependent reef fishes were also targeted for the aquarium fishery in Lubang, Looc, Paluan, and Verde. The types of life history trait renders these organisms susceptible to large changes in the patterns of climate (e.g., sea surface temperature anomalies, sea level rise, more frequent and more intensified storms).

Qualitative descriptions and overall assessment

The Verde Island Passage is found at the core of highest marine biodiversity and with huge human populations dependent upon the fisheries resources. Climate-related impacts therefore would have tremendous effects upon the coastal fisheries (subsistence or large-scale), livelihood, and economic development in the VIP. These impacts include increase in sea surface temperature (SST), sea level rise, increase in frequency and intensity of storms, changes in the variability of rainfall, and ocean acidification. As an example, increase in SST will result in loss in coral cover through bleaching events and in the long term will affect the habitat complexity of reefs that in turn will influence the settlement, recruitment, and survivorship of coral-dependent species. This consequently will reduce abundance and species diversity affecting the reef fish community structure. Warming will also modify behavior, timing of reproduction, reproductive output, larval period, survivorship of recruits and therefore recruitment failure, among others. For other nearshore habitats such as mangroves and seagrasses, seedling production, habitat fragmentation, decrease species diversity of associated organisms, and therefore affect high value fisheries associated to them. In addition, the exacerbating effects of anthropogenic factors such as overfishing, pollution, habitat modification, infrastructure, etc. are also seen to accelerate the impacts.

Fishing has been acknowledged to potentially exacerbate the effects of climate change upon the target species (Brander 2007). The varying gear types and high fishing effort in Mabini and Lubang (Table 20) would enhance the threats more than can be observed in the other sites except that effort data were not available for Looc and Paluan (Table 21). Some target species were harvested by more than one gear type which was observed in anchovies and herrings in Mabini and coral reef fishes (e.g., groupers) in Lubang and, additionally, with high fisher populations.

In some cases, overlapping of gears occur increasing competition between fishers amidst declining stocks in specific habitats. Table 22 shows the number of gears used on each habitat type in the 6 sites. Lubang showed the most number of gears in several habitat types suggesting high degree of dependence by fishers on the habitats for fisheries and therefore demonstrated immense potential climate change impacts. This could eventually displace a number of fishers and therefore affect economic conditions. Mabini followed closely whereas Verde and Puerto Galera were in the middle range. Lack of data did not permit assessment in Looc and Paluan although it appears that because of its proximity to Lubang, Looc likely show similar conditions. The level of fishing effort of the gear types further demonstrate the exacerbating effects thus the vulnerability of the fisheries in Lubang.

Table 23 shows the potential impacts of the fisheries in the VIP by climate change impacts. In an increasing sea surface temperature, most of the target species will be affected through disruption in timing of reproduction, decreased reproductive output, shorter larval duration, lower recruit survivorship, and recruitment failure leading to changes in fisheries productivity. Impact on critical habitats such as coral reefs, seagrasses, and

Table 21. Vulnerability assessment of the fisheries based on the number of gear types (and their level of fishing effort) of the target species/taxa.

Species/taxa	Caught by gear type	Number of gear types	Level of fishing effort	Vulnerability index
Mabini, Batangas				
dulong (*Spratelloides*)	basnig (bag net), lambat	3 (high)	medium	medium to high
dilis (*Engraulis*)	pandulong (gill net), scissor net	3 (high)	medium	medium to high
alumahan (*Rastrelliger*)	lambat pante (gill net)	1 (low)	medium	low to medium
tambakol (*Katsuwonus*)		1 (low)	medium	low to medium
galunggong (*Decapterus*)	lambat pante (gill net) hayhay (surface long line)	2 (medium)	medium	medium
matambaka (*Selar*)	hayhay (surface long line) lambat pante (gill net)	2 (medium)	medium	medium
lapu-lapu (groupers)		1 (low)	medium to high	medium
maya-maya (*Lutjanus*)	kawil (hook and line), pana	1 (low)	medium to high	medium
kanoping (*Lethrinus*)	(spear)	1 (low)	medium to high	medium
bisugo (nemipterids)		1 (low)	medium to high	medium
tulingan (*Auxis*)	hayhay (surface long line)	1 (low)	medium	low to medium
pusit (*Sepioteuthis, Loligo*)	pamanos (squid jig)	1 (low)	medium	low to medium
				medium
Verde Island, Batangas City				
angelfish (*Pomacanthus*)		1 (low)	high	medium
butterflyfish (*Chaetodontus*)		1 (low)	high	medium
damselfish (*Chromis*)	hand nets (barrier net)	1 (low)	high	medium
anthiinid (*Anthias*)		1 (low)	high	medium
lion fish (*Pterois*)		1 (low)	high	medium
lapu-lapu (groupers)	kawil (hook and line)	1 (low)	medium	low to medium
manites (*Upeneus*)		1 (low)	medium	low to medium
galunggong (*Decapterus*)	hayhay (long line)	1 (low)	medium	low to medium
alumahan (*Rastrelliger*)	lambat (gill net)	1 (low)	low to medium	low to medium
dalagang bukid (*Caesio*)				
mulmol (*Scarus*)	pana (spear)	1 (low)	low to medium	low to medium
labahita (*Naso*)		1 (low)	low to medium	low to medium
pusit (*Sepioteuthis, Loligo*)	pamanos (squid jig)	1 (low)	low to medium	low to medium
				low to medium
Puerto Galera, Oriental Mindoro				
galunggong (*Decapterus*)	lambat pante (gill net) kawil (hook and line)	2 (medium)		medium
tulingan (*Auxis*)	kawil (hook and line)	1 (low)	medium	low to medium
alumahan (*Rastrelliger*)		1 (low)		low to medium
labahita (*Naso*)	pana (spear)	1 (low)		low to medium
loro, mulmol (*Scarus*)		1 (low)	medium	low to medium
				low to medium
Lubang, Occidental Mindoro				
galunggong (*Decapterus*)	basnig (bag net) kawil (hook and line)	2 (medium)	medium to high	medium
dilis (*Stolephorus*)	basnig (bag net), lambat	2 (medium)	medium to high	medium to high
pusit (*Sepioteuthis, Loligo*)	(gill net)			medium
pagulpol (*Cypselurus*)	pante (gill net)	1 (low)	medium	low to medium
tangigue (*Makaira*)	lambat (gill net)	1 (low)	medium	low to medium
gulyasan (tuna)	lambat (gill net), kawil (hook and line)	2 (medium)	medium to high	medium
maya-maya (*Lutjanus*)	kawil (hook and line), bubo	1 (low)	high	medium
lapu-lapu (groupers)	(trap), pana (spear), lambat	3 (high)		high
labahita (*Naso*), rabbitfish	(gill net)	3 (high)		high
angelfish (*Pomacanthus*)	hand nets (w/ compressor)		medium	low to medium
butterflyfish (*Chaetodontus*)	hand nets (w/ compressor)		medium	low to medium
damselfish (*Chromis*)	hand nets (w/ compressor)	1 (low)	medium	low to medium
anthiinid (*Anthias*)	hand nets (w/ compressor)		medium	low to medium
bangus fry (*Chanos chanos*)	scoop nets		medium	low to medium
				medium
Looc, Occidental Mindoro				
dilis (*Stolephorus*)	basnig (bag net), lambat			
talakitok (*Carangoides*)	pandilis (anchovies), gill	3 (high)		
pusit (*Sepioteuthis, Loligo*)	nets			
matambaka (*Selar*)	kawil (hook and line)			
lapu-lapu (live groupers)	kawil (hook and line), pana	2 (medium)		
maya-maya (*Lutjanus*)	(spear)		no data	**?**
angelfish (*Pomacanthus*)	hand nets (w/ compressor)			
butterflyfish (*Chaetodontus*)	hand nets (w/ compressor)	1 (low)		
damselfish (*Chromis*)	hand nets (w/ compressor)			
anthiinid (*Anthias*)	hand nets (w/ compressor)			
bangus fry (*Chanos chanos*)	scoop nets	1 (low)		

Table 22. Vulnerability assessment of the fisheries based on number of gear types per habitat type.

Species/taxa	Caught by gear type	Habitat type: reef	sand/ beach	mangrove	seagrass	estuarine creeks/rivers	pelagic	Vulnerability index
Mabini, Batangas								
dulong (*Spratelloides*)	basnig (bag net), lambat					**1**		medium to high
dilis (*Engraulis*)	pandulong (gill net), scissor net							
alumahan (*Rastrelliger*)	lambat pante (gill net)						4	
tambakol (*Katsuwonus*)	lambat pante (gill net)							
galunggong (*Decapterus*)	hayhay (surface long line)	1						
matambaka (*Selar*)	hayhay (surface long line)							
lapu-lapu (groupers)	lambat pante (gill net)							
maya-maya (*Lutjanus*)	kawil (hook and line), pana (spear)	2						
kanoping (*Lethrinus*)	hayhay (surface long line)			1		1		
bisugo (nemipterids)	pamanos (squid jig)							
tulingan (*Auxis*)			1		1			
pusit (*Sepioteuthis, Loligo*)		1					1	
No. of gears per habitat		**4 (high)**	**1 (low)**	**1 (low)**	**1 (low)**	**2 (medium)**	**5 (high)**	
Level of fishing effort		**medium to high**	**low**	**low**	**low to medium**	**medium**	**medium to high**	
Verde Island, Batangas City								
angelfish (*Pomacanthus*)								medium
butterflyfish (*Chaetodontus*)								
damselfish (*Chromis*)	hand nets (barrier net)	1						
anthiinid (*Anthias*)								
lion fish (*Pterois*)		1						
lapu-lapu (groupers)	kawil (hook and line)	1						
manites (*Upeneus*)	hayhay (long line)							
galunggong (*Decapterus*)		1						
alumahan (*Rastrelliger*)	lambat (gill net)	1					**1**	
dalagang bukid (*Caesio*)		1					**1**	
mulmol (*Scarus*)	pana (spear)							
labahita (*Naso*)								
pusit (*Sepioteuthis, Loligo*)	pamanos (squid jig)							
No. of gears per habitat		**6 (high)**					**2 (medium)**	
Level of fishing effort		**medium**					**medium**	

Table 23. Matrix of prospective responses to climate change impacts highlighting the interacting effects between habitats and fisheries.

Climate change impact	Responses: seagrass	seaweeds	reef fish	mangroves	estuaries/ creeks/rivers	pelagic	groupers
increased sea surface temperature	can be approached similar to corals/diversity of associated organisms; associated fishereies, e.g., siganids, and high value invertebrate fisheries, reduced catch in some finfish but may have a shift to detritivores and omnivores	phenological characteristic disrupted; change in overall community structure; slower growth and lower diversity; low fecundity of species	reproductive output, timing, survivorship of recruits; recruitment lag/ failure; shorter larval duration; abundance of coral dependent species will be reduced following coral bleaching events and decreased structural complexity	decreased seedling production, survivorship and recruitment; lower recruitment regeneration; phenological characteristics disrupted; associated fisheries will be reduced for temperature dependent reproductive output	see mangroves and associated fisheries especially in relation to ontogenetic habitats shifts and how adjacent habitats can be seen in exacerbated/synergistic negative effects, overfishing, and habitat fragmentation/loss	shorter larval duration; decreases survivorship due to low food availability; alter reproductive periodicity and eventual recruitment survivorship leading changes in fisheries productivity	shorter larval duration; enhanced recruitment variability; recruitment will be affected following decreased structural complexity via coral bleaching ?; reproductive output and timing of reproduction will be affected, especially spawning aggregations
sea level rise	shallow species will be most sensitive to change and will be vulnerable; species found growing on the slopes can adjust to changing depth	can be well adapted to changes in sea levels (community level/change in community structure)		inundation of mangroves and associated species (fauna); reduce conditions for settlement availability as nursery grounds for other species; change in sedimentation dynamics; substrate erosion			
increase storm intensity and frequency ▪ storm paths/ tracks ▪ storm surge	disrupt recruitment events of associated faunal species; decreases survivorship	change in substrate composition leading to changes in algal community structure; burial and scouring	topographic complexity/ habitat refuge (composition, biomass, density); this can lead to reduced fisheries productivity	disrupt recruitment events of associated faunal species (e.g., groupers, snappers, jacks); decreases survivorship propagules dislodged prematurely; uprooting of mature trees along shoreline	decreases survivorship of recently recruited associated faunal species (e.g., groupers, snappers, sprats, anchovies, bangus fry)		affect recruitment due to loss of habitat availability for settlement (e.g., decresed structural complexity)
rainfall ▪ changes in salinity ▪ increased sedimentation	change in water quality will have changes in light requirements/availability	only a few species are stenohalines species that can survive burial and mortality	can lead to habitat modification and reduce diversity and abundance; this reduces fisheries production	have salinity regulatory function change in sedimentation dynamics	affect recruitment of associated faunal species; decreases their survivorship	nutrient increases may lead to blooms	
ocean acidification	will increase CO_2; may favor seagrass photosynthesis but may not happen if the system is already distressed						

mangroves will affect the aforementioned attributes of the associated fauna which include high value target species (e.g., siganids, groupers, snappers). For sea level rise, some habitats such as mangroves will be inundated that will reduce available areas for recruitment of associated fauna that have fisheries value. In coral reefs, species on shallower parts (e.g., reef flats) will be affected compared to those on reef slopes. Increase in frequency and intensity of storms can greatly affect recruitment of target species through reduction of suitable sites for recruitment and reduction in abundance and species diversity due to habitat loss and decreased habitat complexity. Increase rainfall may result in over supply of nutrients from the land and may trigger algal blooms or will lead to hypoxic conditions that may affect existing aquaculture or mariculture.

The fisheries that are most vulnerable are those involving fishes that need different habitats throughout their life stages. For example, Mabini and Lubang/Looc have grouper and snapper fisheries. These fishes make use of estuaries, mangroves, seagrasses, corals, and the pelagic realm during the different stages in their life.

Vulnerable areas vs. ecologically critical or sensitive areas

Aside from vulnerable areas which are seen in the context of vulnerability relative to the aspect of climate change, it is crucial to determine ecologically critical or sensitive areas (e.g., coral reefs, seagrasses, and mangrove areas) and other ecological functions (e.g., turtle nesting beaches, nursery and feeding areas of important fisheries and/or threatened species). This is important in complying with Philippine environmental laws as human activities (or at a scale of development such as over a 5 hectare area or a building higher than 4 floors) that are threatening these critical habitats shall require a mandatory full Environmental Impact Assessment (EIA). Considering that there are uncertainties and data gaps in predicting more specific vulnerabilities, this is another precautionary step to highlight the complementarity of vulnerability and adaptation insights.

Recommendations

Apart from the threats of global climate change, the marine resources in the Verde Island Passage are already in a tremendous amount of stress due to various human pressures. The VIP is a major fishing ground. Over-fishing and use of destructive fishing methods disrupts the normal functions of the coral reef ecosystem. They reduce populations of key reef organisms either by direct extraction of coral and reef fish species or by destruction of corals during fishing (Licuanan and Gomez 2000, Wilkinson 2004, Deocadez et al. 2009). The passage is also a major navigational and shipping lane, and is constantly under threat by oil spills and strandings. Similarly, it is also surrounded by various industries such as ports, oil refineries etc., which pollutes, increases nutrient influx and sedimentation in reef areas. Pollution, sedimentation, and nutrients affect the survival of coral communities either by smothering corals and preventing coral recruitment (McClanahan and Obura 1997) or by promoting growth of macro-algae and other invertebrates (McCook 1999, Nugues and Roberts 2003). Other pressures impacting the coral reefs in the VIP is tourism, mining, coastal settlement, and other land-based activities.

Adaptation mechanisms would require that the present CRM programs be more tightly integrated through establishing knowledge based communities. These would involve multiple stakeholders working together and the incipient MPA network in the VIP would be a good starting point. The various CRM working groups would also need to engage with each other through inter-LGU arrangement joint fisheries law enforcement teams (FLET) and bay management councils or VIP level alliances can be formed.

Improving management through good CRM governance processes where climate adaptation systems are mainstreamed is imperative. The fisheries ecosystem approach to management will need to be put in place as natural links to the present conservation efforts with the tourism industry. Reduction of prevailing threats such as illegal and destructive fishing, emerging pollution, and habitat degradation from urban and industrial development must also be addressed. Environmental concerns will not only marginalize fishers and their fishing grounds, exacerbate the impending climate change impacts but will jeopardize the future of our next generations.

Since the VIP is the area where the State of the Coast has been piloted in the province of Batangas, the opportunity to scale up these efforts and at the same integrate within an ICM approach is imperative. As mentioned earlier the research and development and extension arena would need to involve a monitoring and evaluation, response and feedback program that mainstreams climate change. Linking with the ICE CREAM program would be an immediate next step together with developing a cadre of local expertise from the various higher education institutions, would be an opportunity not to miss. Highly qualified expertise such those in the De La Salle University Brother Shields Marine Lab are available and are part of the ICE CREAM program.

Research and monitoring imperatives

There are considerable gaps in the fisheries profiling and the related targeted research and monitoring concerns. The priority interactive concerns of the ecological and social systems are necessary to be integrated into an adaptation plan with its adaptive management approach.

- Incorporating an adaptive management approach would mean that the overall management framework is integrated into an overarching context and governance process that will be able to provide timely interventions with the appropriate monitoring and evaluation plan.
- Fisheries profiling using the FISH BE (Fisheries and Bio-economic model) framework approach to link effort regulation, MPA, and pollution abatement, among others.
- Climate change enhanced research on target life history studies and monitoring to provide inputs to an ecosystem approach to fisheries management and evaluate exacerbating effects e.g., collaborate with the Department of Science and Technology (DOST) funded ICE CREAM (Integrated Coastal Enhancement: Coastal Research, Evaluation and Adaptive Management) program. An opportunity whereby the MPA network provides social network insights that also derives biophysical information from an integrated monitoring of governance, ecological and social and economic indicators.
- Determine Environmental Impact Assessment (EIA) priority areas which highlights mitigating impacts from coastal and marine development activities (e.g., foreshore and navigation) so as to determine an overall integrated coastal management approach to the VIP incorporating climate change and threatened species concerns. This should have a close link with the social and economic research imperatives, e.g., reducing threats from unplanned development trends and improving compliance through market and non-market based incentives.

- Results should be reported regularly, e.g., no longer than for every relevant period such as a monsoon, or as needed as when there is an impending catastrophic or disaster event. Also, the state of the coasts mandates required in EO 533 is another venue for reporting and feedback and to engage in adjustments and mainstreaming lessons learned into policies, ordinances, and action plans.
- Changes in shoreline positions can now be easily established due to the availability of satellite images. However, what the time series of images can define are only snapshots of changes. Information on possible magnitude of erosion due to a single or series of storms or the pace of a subsequent recovery can only be captured through monitoring and partly through systematic interviews of long-time coastal residents. The high variability of coastal systems in the VIP corridor requires localized studies. In areas with very narrow coastal plains such as in coral reef areas, images with resolution better than 30 meters are required and field surveys are vital.
- Since the sediments of beaches associated with coral reefs are biogenic in origin, identification of the type and their sources are also needed. Identification of the drivers of shoreline change requires both regional and site specific studies and retracing of climate, oceanographic, biologic, geologic, and land use changes.
- Due to the limited information available on the condition of seagrass beds around VIP, assessment on the impacts of climate change on this ecosystem is incomplete. Information on areas covered by seagrasses, demographic and recruitment-mortality will be most useful in projecting the impact of climate change in any given area
- Eutrophication was identified as an exacerbating factor to coastal habitat vulnerability. Delivery of nutrients from various land-based anthropogenic activities need to be identified in order to come up with appropriate land-use management options.
- Sediment and nutrient delivery are not necessarily locally-derived. Far-fetched sources, especially relevant during extreme precipitation and storm events, also need to be determined. This can be achieved using fine-scale particle tracking with multiple release points under different climate scenarios.
- The same particle-tracking, modified to suit specific species, can also be used to study connectivity within and from outside the VIP. This can be used as one of the tools in identifying areas that need to be protected from a regional point-of-view.
- Different extreme events were shown to affect the health of habitat and fisheries. However, currently lacking are on-the-ground measurements of recruitment failures due to episodic events.
- The philosophical and pragmatic question is which general type of reef system—the areas that are used to variability or the areas that have been always warm—are more susceptible to future climate change. There is a need to examine the species (seagrass, coral, coral-zooxanthallae symbiont) that have survived repetitive or extreme thermal anomaly and factor these in management and rehabilitation plans of coastal habitats.
- Other exacerbating events like crown-of-thorns break-out should also be documented.
- Ocean acidification trends and projections is a gap of special concern.

Scenarios for adaptation

Areas that suggest that adaptation measures are imperative shall be those which are crucial to marine biodiversity, the life histories of important fisheries species, and human well-being.

For biodiversity and fisheries, these areas would be high candidate sites for expanding sizes or establishing areas as marine protected areas (MPA). This will not only help in the conservation of existing flora and fauna but also in the replenishment of fisheries stocks by regulating fishing effort. In addition to MPA, it is imperative that adoption of access and use rights fisheries management interventions are put in place such as close and open seasons, gear regulations and effort controls combined with access incentives linked to stewardship e.g., reserves related to enhancement and sea ranching of highly valued invertebrates species.

For human well-being, these areas would also be sites which deliver multiple services to the community not only as source of livelihood but also provide protection from climate-related hazards.

Recommendations and next steps

The fisheries ecosystem approach to management will need to put in place as natural links to the present conservation efforts with the tourism industry. Environmental concerns will not only marginalize fishers and their fishing grounds, exacerbate the impending climate change impacts but will jeopardize the future of our next generations.

The following are key strategies that will support efforts in moving forward a strategic conservation plan that will harmonize with a sustainable fisheries management agenda for the VIP consistent with a SSS and the Priority Biodiversity Conservation in the Philippines (e.g., Ong et al. 2002).

Adaptation mechanisms would require that the present CRM programs are more tightly integrated through establishing knowledge-based communities.

- These would involve multiple stakeholders working together and the incipient MPA network in the Verde Island Passage (VIP) would be a good starting point. The various CRM working groups would also need to engage with each other through inter-LGU arrangement joint fisheries law enforcement teams (FLET) and bay management councils or VIP level alliances can be formed.
- Since the VIP is the area where the state of the coast has been piloted in the province of Batangas, the opportunity to scale up these efforts and at the same integrate within an ICM approach is imperative. As mentioned earlier, the research and development and extension areas would need a monitoring and evaluation program, and a response and feedback program that mainstreams climate change. Improving management effectiveness through MPA network complementation with fisheries management (e.g., grow-out of group fry and "dulong" in conjunction with other aquarium), and Lubang and invertebrate fishery (e.g., in areas with wide reef flats such as Lian and Calatagan areas, tourism certification and or link with tourism).
- Linking with the ICE CREAM program would be an immediate next step together with developing a cadre of local expertise from the various higher education institutions (HEI), would be an opportunity not to miss. Highly qualified on-site expertise such those in the De La Salle University Brother Shields Marine Lab are available and are part of the ICE CREAM program—VIP network establishment with UB and BSU for fisheries and Biodiversity monitoring; Provincial MPA municipal cluster networks can be established to provide a venue to establish joint enforcement, M&E and IEC teams wherein they have some ecological basis for their clustering e.g., adjacent boundaries and circulation connectivity.

Based on available literature on the interconnectivity of mangrove, seagrass and coral reef, protecting adjacent ecosystems may increase the resilience of these ecosystems to the impacts, including that of climate change.

- This phenomenon of interconnectivity resilience is exhibited by sites where all of the coastal habitats can be persistently found (i.e., in Calatagan, Batangas and San Juan, Batangas—also referred to as Batangas East—and in a lesser degree in Wawa-Paluan, Mindoro Occidental and Puerto Galera-Naujan, Oriental Mindoro).
- Moreover, the concept of interconnectivity resiliency has consequence on fisheries with fish that need different habitats throughout their life stages (such as snappers and groupers) being most vulnerable. For example, the existence of these targeted fisheries in Wawa-Paluan and Puerto Galera-Naujan is therefore partially buffered whereas those in Mabini and Lubang are more vulnerable. Measures must therefore be taken for habitat protection in Mabini and Lubang for the sustainability of the snapper and grouper fisheries in these sites.
- In sites that have shown significant adaptive capacity and at the same time in sites where the fisheries were found vulnerable, measures must be taken to reduce of prevailing threats such as illegal and destructive fishing, emerging pollution and habitat degradation from urban and industrial development.
- In addition, given that sea level will accelerate in the coming years and that storms are likely to increase in frequency and possibly strengthen, the natural buffers to sea level rise and impact of large waves, such as coral reefs and mangroves, should be protected and rehabilitated.
- Areas fronting the South China Sea and the Sibuyan Sea may have a relatively higher storm surge potential compared to those within the VIP. The wave models show that in particular the areas exhibiting large bottom orbital velocities are the coasts facing Tayabas Bay, the northern coast of Lubang and possibly the western coast of the Calatagan Peninsula.

Deforestation and extensive agriculture in the watersheds, long steep slopes, and presence of numerous faults, high seismicity, and volcanoes all promote a high sediment yield. These potential will be more intense during extreme weather events.

- In some areas, this high sediment yield has resulted to rapid accretion. However, it should be noted that this newly prograded lands, in addition to existing low lying areas inland—presently occupied by wetlands, fishponds, rice fields and coconut plantations, are evaluated to be the most vulnerable to marine inundation (e.g., areas such as Nasugbu and Balayan that experienced rapid accretion in recent years, are the most vulnerable to coastal inundation; a 1 meter rise of sea level will already result to inundated of about 175 ha in Nasugbu and 199 ha in Balayan).
- Instead of utilizing the newly prograded lands in the VIP for various development, these can instead be used by the LGUs and national agencies as buffers to erosion and action of large waves. Greenbelts, of the appropriate assemblage, can be established in these newly prograded lands. Wide mangrove

plains will also reduce the level of nutrients and sediments entering the sea and create nursery habitats for fisheries.

- Moreover, although the high sediment yield of watersheds has led to accretion, it is likely that it has played a large role in the degradation of coral reef ecosystems and in the decline of coastal and offshore fisheries. In the formulation of mitigation and adaptation measures, this link between the marine ecosystem and the watershed should be considered.

Watershed sediments ending at the coast leads to coastal degradation. This is further exacerbated by erosion along the coast caused about by human modifications such as inappropriate ports, quarrying, and removal of mangroves and seagrasses.

- Location of ports need not only take into consideration the economic development but should position the ports in such as way as not to impede longshore sediment drift. Moreover, we advocate constructing open ports which allow water to flow in between pilings.
- Stop stone mining. Give alternative livelihood (e.g., the river mouth and flanks of Abra de Ilog show erosion of ~150 m between 2001 and 2009. Pebble picking activities is most likely contributing to, if not the main cause, of the erosion west of the river mouth).
- There is a need to educate people from various strata of the functions of mangroves and coral reefs towards the protection of the beach, e.g., erosion of about 200 m occurred along the mouth of Kampungpong River in Batangas City. Removal of the mangrove, large constructions and expansions of piers along the coast of Batangas City are likely linked to the erosion.
- Development along the coasts and the plains should also consider the likely natural changes that can take place due to tectonics, volcanism and river dynamics (e.g., erosion along the Baco-Malaylay delta may have been triggered by liquefaction caused by the magnitude 7.1 earthquake on a segment of Lubang Fault, south of Verde Island on November 15, 1994).
- A lot of coastal developments (including planting of mangroves on seagrass beds) have been observed around Batangas that either removes seagrasses or constructs barriers that influence the natural hydrology within the coastal areas. The latter makes the seagrasses around VIP more vulnerable to eutrophication caused by impediment of the flow of water in these areas.

Early response and immediate management recommendations

- Seasonal regulation of dulong, milkfish fry and other fry fishery with very minimal fishing during peak occurrence (based on lunar periodicity). This will reduce fishing mortality at the early life stages.
- Establishment of fry-grow out schemes to enhance juvenile survivorship e.g., for grouper, bangus and high value invertebrates in conjunction with MPA buffer reserve area.
- Gear effort control at varying habitat types (e.g., live fish collectors, fish corral deployment); establish incentives for regulating effort through certification schemes and targeting stakeholders for capacity building.
- Stricter enforcement over illegal fishing practices (blastfishing, cyanide fishing, poaching) and capacity building for inter-hierarchical network enforcement teams and incentives for stewards and IEC for greater social pressures on “illegalistas”
- Increase sizes of protected areas including other habitat types (e.g., mangroves, seagrasses, lagoons). Aside from fishery benefits, this mechanism will ensure good conditions of protected areas, and therefore less sensitive to climate change. Identify areas for refugia and stock enhancement strategies.
- Alternative livelihood (other economic/job opportunities) to fishing to reduce fishing pressure and other supplemental livelihood support (e.g., training of invertebrate grow out on reserve areas)
- Proper zonation of use of coastal waters (fishery zone, MPA, aquaculture zone, industry zone) as this will lower sensitivity of habitats and therefore vulnerability and reduce conflicting uses with clearer guidelines, ordinances and incentives per zone that incorporates climate considerations (e.g., erosion, sea surface temperature, and siltation).

References

Allison E, Perry A, Badjeck MC, Adger N, Brown K, Conway D, Halls A, Pilling G, Reynolds J, Andrew N, Dulvy N. 2009. Vulnerability of national economies to the impacts of climate change on fisheries. Fish and Fisheries 10:173-196.

Alongi, DM. 2008. Mangrove forests: Resilience, protection from tsunamis, and responses to global climate change. Estuarine, Coastal and Shelf Science 76:1-13.

Arceo HO, Quibilan MCC, Alino PM, Licuanan WY, Lim G. 2001. Coral bleaching in the Philippines: coincident evidences of mesocale thermal anomalies. Bull. Mar. Sci. 69(2): 579-594.

Bernascek G. 1996. The role of fisheries in food security in the Philippines: A perspective study for the fisheries sector to the year 2010. Paper presented during the Second National Fisheries Policy Planning Conference, Cavite, Philippines.

Brander KM. 2007. Global fish production and climate change. Proceedings to the National Academy of Sciences. 104(50):19709-19714.

Brownman HI, Stergiou KI. 2004. Perspectives on ecosystem-based approaches to the management of marine resources. Mar. Ecol Prog. Ser. 274:269-303.

Buoyweather Hurricane and Typhoon Tracking. Updated 25 June 2009. Retrieved 25 June 2009 <http://storm.buoyweather.com/map/pacific/west>

Camargo SJ, Robertson AW, Gaffney SJ, Smyth P, Ghil M. 2007. Cluster Analysis of Typhoon Tracks. Part II: Large-Scale Circulation and ENSO. Journal of Climate 20:3654-3676.

Campbell, S.J. et al. 2009. Photosynthetic responses of seven tropical seagrasses to elevated seawater temperature. Journal of Experimental Marine Biology Ecology 330:455-468.

Carpenter K, Springer VG. 2005. The center of the center of marine shore fish biodiversity: the Philippine Islands. Env. Biol. Fish. 72:467-480.

Carpenter K, Abrar M, Aeby G, Aronson RA et al. 2008. One-third of the reef-building corals face elevated extinction risk from climate change and local impacts. Science 321:560-563.

Chavez FP, Ryan J, Lluch-Cota SE, Niquen MC. 2003. From anchovies to sardines and back: multidecadal change in the Pacific Ocean. Science 299:217-221.

Cheung WWL, Lam VWY, Sarmiento JL, Kearney K, Watson R, Pauly D. 2009. Projecting global marine biodiversity impacts under climate change scenarios. Fish and Fisheries.

City of Batangas. 2005. 2005–2014 Isla Verde CRM Plan.

Conservation International Philippines. 2009. Scaling up from MPAs to Seascapes: lessons learned from the Sulu-Sulawesi. Quezon City. p. 7.

Cooley, SR, Doney SC. 2009. Anticipating ocean acidification's economic consequences for commercial fisheries. Environ. Res. Lett. 4 (1 June 2009) doi:10.1088/1748-9326/4/2/024007.

Dahdouh-Guebas, F. et al. How effective were mangroves as a defense against the recent tsunami? Current Biology 15 (12):443-447.

Deocadez MP, Moleño EP, Arceo HO, Cabansag JP, Apurado JL, Mamauag SS, Villanoy CL, Aliño PM. 2009. Spatio-temporal patterns of juvenile and adult abundance and biomass of reef fishes in the Sulu Sea, Philippines. Proceedings of the 11th International Coral Reef Symposium, Ft. Lauderdale, Florida, 7-11 July 2008. Session number 22.860.

Duarte CM et al. 1997. Response of a mixed Philippines seagrass meadow to experimental burial. Marine Ecology Progress Series 147:285-294.

Engelhart SE et al. 2007. Mangrove pollen of Indonesia and its suitability as a sea-level indicator. Marine Geology 242 (2007):65–81.

Fujimoto K, Miyagi T, Kikuchi T. 1995. Formative and maintainable mechanisms of mangrove habitats in Micronesia and the Philippines. In: Kikuchi, T. (Ed), Rapis Sea Level Rise and Mangrove Habitat. Institute for Basin Ecosystem Studies, Gifu University, Japan, pp. 9-18.

Genito GE. et al. 2009. Baseline assessment of seagrass communities of Lubang Island, Occidental Mindoro. Conservation International, unpublished report.

Gilman E et al. 2006. Pacific Island Mangroves in a Changing Climate and Rising Sea. UNEP Regional Seas Reports and Studies No. 179. United Nations Environment Programme, Regional Seas Programme, Nairobi, KENYA, 59pp.

Gilman EL et al. 2008. Threats to mangroves from climate change and adaptation options. Aquatic Botany (2008), doi:10.1016/j.aquabot.2007.12.009.

Han W, Moore AM, Levin J, Zhang B, Arango HG, Curchitser E, Di Lorenzo E, Gordon AL, Lin J. 2008. Seasonal surface ocean circulation and dynamics in the Philippine archipelago region during 2004-2008. Dynamics of Atmospheres and Oceans 802:1-24.

Ho CH, Baik JJ, Kim JH, Gong DY, Sui CH. 2004. Interdecadal changes in summertime typhoon tracks. Journal of Climate17(9):1767-1776.

Hoegh-Guldberg O. 1999. Climate change, coral bleaching and the future of the worlds coral reefs. Marine Freshwater Research. 50:839-866.

Hoegh-Guldberg O, Mumby PJ, Hooten AJ, Steneck RS, Greenfield P, Gomez E, Harvell CD, Sale PF, Edwards AJ, Caldeira K, Knowlton N, Eakin CM, Iglesias-Prieto R, Muthiga N, Bradbury RH, Dubi A, Hatziolos ME. 2007. Coral reefs under rapid climate change and ocean acidification. Science 3129 (5857):1737-1742.

Hulme M, Sheard N. 1999. Climate Change Scenarios for the Philippines Climatic Research Unit, Norwich,UK, 6 pp.

Imamura F, Synolakis CE, Gica E, Titov V, Listanco E, Lee HJ. 1995. Field Survey of the 1994 Mindoro Island, Philippines Tsunami. Pageoph Vol. 144, No. 3/4: 875-890.

IPCC 2007. Climate Change 2007: The physical science basis. Summary for policymakers. Intergovernmental Panel on Climate Change, Geneva 18 p.

Japan Meterological Agency. RSMC Best Track Data. Updated 21 June 2009. Retrieved 21 June 2009 http://www.jma.go.jp/jma/jma-eng/jma-center/rsmc-hp-pub-eg/besttrack.html.

Lewis RR, Marshall MJ. 1997. Principles of successful restoration of shrimp aquaculture ponds back to mangrove forests. Programa/resumes de Marcuba '97, September 15/20, Palacio de Convenciones de La Habana, Cuba, 126pp.

Lewis RR. 2009. Methods and criteria for successful mangrove forest restoration. In: Perillo, G.E., Wolanski, E., Cahoon, D.R., Brinson, M.M. (Eds), Coastal Wetlands: An Integrated ecosystem approach. Elsevier, pp 787-800.

Licuanan WY, Alino PM, Campos WL, Castillo GB, Juinio-Menez MA. 2006. A decision support model for determining sizes of marine protected areas: biophysical considerations. Philipp Agric Scientist. 89(1):34-47.

Licuanan WY, Gomez ED. 2000. Philippine coral reefs, reef fishes and associated fisheries: Status and recommendations to improve their management. Global Coral Reef Monitoring Network. Australian Institute of Marine Science. 51 p.

Luther DA, Greenberg R. 2009. Mangroves: a global perspective on the evolution and conservation of their terrestrial vertebrates. Bioscience 59 (7):602-612.

McClanahan TR and Obura D. 1997. Sedimentation effects on shallow coral communities in Kenya. Journal of Experimental Marine Biology and Ecology. 209:103-122.

McCook LJ. 1999. Macroalgae, nutrients and phase shifts on coral reefs: Scientific issues and management consequences for the Great Barrier Reef. Coral Reefs 18:357-367.

McLeod E, Salm RV. 2006. Managing Mangroves for Resilience to Climate Change. IUCN, Gland, Switzerland. 64pp.

Munday PL, Jones G, Pratchett M, Williams A. 2008. Climate change and the future for coral reef fishes. Fish and Fisheries 9:261-285.

Municipality of Lian, Batangas. 2005. 2005–2014 Talim Bay CRM Plan.

National Hurricane Center. NOAA National Weather Service. Updated 03 Sep. 2009. Retrieved 04 Sep 2009, http://www.nhc.noaa.gov.

Nugues MM, Roberts CM. 2003. Partial mortality in massive reef corals as an indicator of sediment stress on coral reefs. Marine Pollution Bulletin. 46:314-323.

Ong PS, Afuang LE, Rosell-Ambal RG. 2002. Philippine biodiversity conservation priorities: a second iteration of the National Biodiversity Strategy and Action Plan. DENR-PAWB, CI–Philippines, UP-CIDS, and FPE. Quezon City. 113 p.

Perez RT et al. 1999. Climate change impacts and responses in the Philippines coastal sector. Climate Research 12:97-107.

Philippine Institute of Volcanology and Seismology. 1994. The 15 November 1994 Mindoro Earthquake-Report of Investigation. Phivolcs Special Report No. 2.

Pratchett M, 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, Esteban JMA. 2008. A review of mangrove rehabilitation in the Philippines: successes, failures and future prospects. Wetlands Ecology and Management 16 (3):173-253.

Provincial Government of Batangas and PEMSEA. 2008. State of the coasts of Batangas Province. Partnerships in Environmental Management for the Seas of East Asia (PEMSEA), Quezon City. 119 p.

Pullen J, Doyle JD, May P, Chavanne C, Flament P, Arnone RA. 2008. Monsoon surges trigger oceanic eddy formation and propagation in the lee of the Philippine Islands. Geophysical Research Letters 35, L07604, doi:10.1029/2007GL033109.

Roberts CM, McClean CJ, Veron JEN, Hawkins JP, Allen GR, McAllister DE, et al. 2002. Marine biodiversity hotspots and conservation priorities for tropical reefs. Science 295:1280-1284.

Samson MS, Rollon RN. 2008. Growth performance of mangroves at the enhancement sites: need to revisit forest management strategies. AMBIO 37(4):234-240.

Short FT, Neckles HA. 1999. The effects of global climate change on seagrasses. Aquatic Botany 63:169-196.

Snoussi M, Ouchani T, Niazi S. 2007. Vulnerability assessment of the impact of sea-level rise and flooding on the Moroccan coast: The case of the Mediterranean eastern zone. Estuarine, Coastal and Shelf Science 77 (2):206-213.

Stevenson NJ, Lewis III RR, Burbridge PR. 1999. Disused shrimp ponds and mangrove rehabilitation. In: Streever, W. (Ed.), An International Perspective on Wetland Rehabilitation. Kluwer, Netherlands, pp. 277-297.

Terrados et al. 1998. Changes in community structure and biomass of seagrass communities along gradients of siltation in SE Asia. Estuarine Coastal and Shelf Science 46:757-768.

Ticzon VS, Samaniego BR, Bejarano S, Idip D, David LT, Mumby PJ. 2008. Change in benthic community composition, in Ngaderrak Reef, Koror, Republic of Palau (2006 to 2008). A report submitted to the government of the Republic of Palau.

Tiquio MGJP, Cayabyab NM. 2008. Characterization of seagrass communities and associated-seaweeds in the Verde Island Passage Marine Biodiversity Conservation Corridor. Conservation International, unpublished report.

Vermaat JE, Thampanya U. 2006. Mangroves mitigate tsunami damage: A further response. Estuarine, Coastal and Shelf Science 69 (2006):1-3.

Ward JD, Metz WD. 2004. Mangrove Forests as Modifiers of the Impacts of Climate Change on High Islands and Atolls in the South Pacific: Mobilizing People and Governments to Act (ATOLLS). http://www.spcforests.org/Library/Mangroves/atolls/atolls.htm, August 30, 2009.

Wilkinson C (Ed.). 2004. Status of Coral Reefs of the World. Global Coral Reef Monitoring Network. Australian Institute of Marine Science, Townsville, Australia. Vol I. p. 235 – 276.

Wilson SK, Graham NAJ, Pratchett MS, Jones GP, Polunin NVC. 2006. Multiple disturbances and the global degradation of reefs: are reef fishes at risk or resilient? Global Change Biology 12:2220-2234.

Wilson SK, Dolman AM, Cheal AJ, Emslie MJ, Pratchett MS, Sweatman HPA. 2009. Maintenance of fish diversity on disturbed coral reefs. Coral Reefs 28:3-14.

WL | Delft Hydraulics, Delft3D-WAVE, User manual, release 3.03.

Ye Y et al. 2004. Does sea level rise influence propagule establishment, early growth and physiology of Kandelia candel *and* Bruguiera gymnorrhiza*? Journal of Experimental Marine Biology and Ecology 306:197-215.*

Yohe G, Malone E, Brenkert A, Schlesinger M, Meij H, Xing X, Lee D. 2006. A Synthetic Assessment of the Global Distribution of Vulnerability to Climate Change from the IPCC Perspective that Reflects Exposure and Adaptive Capacity. Palisades, New York: CIESIN (Center for International Earth Science Information Network), Columbia University. http://sedac.ciesin.columbia.edu/mva/ccv/.

Chapter 2: Human well-being and climate change in the Verde Island Passage: vulnerability assessment for adaptation

Rowena R. Boquiren[1], **Lead Integrator**

Contributing Authors: Annabelle Trinidad[1], Rina Rosales (consultant), Niva Gonzales (consultant)

[1] Conservation International–Philippines

Introduction

Climate change, gradually being experienced globally is adversely affecting the wellbeing of humanity. In the Philippines' Verde Island Passage Marine Biodiversity Conservation Corridor, now more popularly known as the center of the center of marine biodiversity, rising sea level and surface temperature, pronounced storminess and unpredictable rainfall patterns are disturbing people's food and livelihood security, water security, health security as well as cultural and options values.

The greatest concentration of marine species in the Indo-Malay-Philippine Archipelago is threatened by climate change as the human population, especially along the passage.

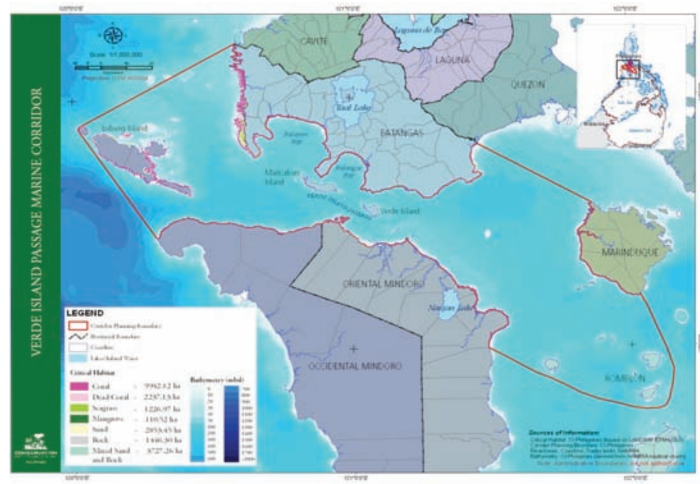


Figure 41. Geographic scope of the socioeconomic vulnerability assessment in the Verde Island Passage, municipalities abutting it, and coastal habitats found there.

Objective

As its first objective, a socio-economic team assessed the vulnerability and adaptive capacity of coastal communities in the Verde Island Passage to climate change. As a second objective the initiative had a methodological component which was to test appropriate approaches for engaging mandated agencies in the vulnerability assessment. To the extent that appropriate methodologies have yet to be developed for Philippine ecosystem situations, the socioeconomic aspect was addressed iteratively as a learning process, by demonstrating to local governance units and line agencies the steps in the vulnerability assessment.

The following specific objectives were addressed:

- identify impacts of climate change in the physical, biological, and socio-economic systems;
- describe responses of the biological/ecological and socio-economic systems;
- determine the vulnerability of these systems;
- provide management recommendations to address climate change impacts; and,
- identify knowledge gaps and research priorities.

Methodology

Climate change vulnerability of a particular area was defined as the amount of exposure and sensitivity less the capacity of the community to adapt. Exposure and sensitivity, defined below, are the recommended vulnerability assessment indicators of climate change impacts on human wellbeing.

Exposure

Exposure is defined as the types of valued assets that are at risk of being impacted by changes in climate. These assets include social assets (people, health, education), economic assets (property, infrastructure, and income), and ecological assets (natural resources and ecological services) (USAID 2009). The profile of foreshore areas would allow stakeholders to assess exposure appropriately. For this component, assets can be ranked in terms of their importance to local stakeholders and to the local and/or national economy.

Sensitivity

Sensitivity refers to the degree of likely damage of an asset if exposed to climate change. To assess the sensitivity of coastal assets exposed to climate change, the following questions may be considered (USAID 2009):

- How and to what degree were social, economic and ecological assets affected by past climate conditions and coastal hazard events?
- What specific characteristics make groups or systems sensitive?
- Was everyone equally impacted? If not, what were the differences between various individuals and groups?
- What is the sensitivity of "non-exposed" assets? For example, agriculture activities that take place away from the coast may rely on a highly exposed and sensitive coastal road or port for export. Losing this transportation asset could result in a loss in the value of the agricultural assets.

Adaptive capacity

Adaptive capacity is the most critical of the three dimensions because it shows a community's ability to manage and thereby reduce gross vulnerability. Hence, vulnerability is increased when adaptive capacities are minimal or not present.

Assessing the adaptive capacity of a place or sector helps in understanding why vulnerability exists in the first place. To reduce vulnerability, stakeholders must understand its root causes. These are much deeper societal issues than, for example, poorly constructed houses being located in areas of coastal erosion. Root causes might include poverty, insecure property rights, natural resource dependency, degraded resources, and weaknesses in institutions and political assets (Adger 1999). Adaptive capacity can be strengthened through policies that enhance social and economic equity, reduce poverty, improve natural resources and coastal management, increase public participation, generate useful and actionable information, and strengthen institutions.

For heuristic purposes, because vulnerability assessment methodology in the Philippine setting has not yet been developed, the team selected the following socioeconomic concerns in the Verde Island Passage project, using interdisciplinary perspectives to guide research methods:

- economic trends and livelihood sources (with focus on fisheries, tourism and foreshore development);
- health and food safety.

The vulnerability assessment process started with 1) knowing the climate change projection, 2) determination of exposure and sensitivity of a given region or locale to climate change, including the assessment of the health of coastal habitats and ecosystems, and 3) an assessment of adaptive capacity (capacity of society to cope with the expected or actual climate changes).

Participative and inter-agency collaborative methods were observed in the project. Iterative learning over nine months depended on accessed agency reports, roundtable discussions, interviews, focus groups discussions and workshops across varied lines of focus and expertise. Participative techniques engaged local government units (LGU) from the provincial and down to the municipal levels, stakeholders from coastal communities and non-governmental organizations in generating and systematizing information from the ground, to be linked with insights of academics, scientists and experts across disciplines in the physical, biological and social sciences.

The research process demonstrated what variables or data are to be accessed from agencies, generated from rapid site assessments and through inter-agency or multi-sectoral workshops to generate the baseline; how to customize climate change-sensitive instruments; what tools and measures can be creatively developed to facilitate vulnerability assessment; and in what aspects the help of support groups can be tapped for science-based disciplinal expertise and technical inputs.

Context analysis from the baseline as premise of the vulnerability assessment was first observed by the team: background on the sector, its importance, components/aspects and trends related to climate change impacts on the marine resources that the people experience. As a basis to the assessment, profiles were laid down, no matter how preliminary, as a flexible and opportunistic approach to data gathering in view of institutional gaps.

The vulnerability and resilience potentials of coastal communities were addressed next, followed by recommendations to management units. The novelty of climate change impacts in institutional mechanisms and in the public mind requires plans and policies to be scaled up beyond the normative and routine by being inter-linked and inter-agency driven in emphasizing the importance of human wellbeing along with marine biodiversity conservation.

Climate change effects on and of the people in the vulnerability assessment process are illustrated in a framework creatively designed by the team (Fig. 42). Extreme changes in climate affect marine habitats and species which then impact upon the economic uses of the marine waters and coasts as well as the livelihood and health of communities. Changes in sea surface temperature (SST), accelerated sea level rise (ASLR), storminess and unexpected precipitation patterns have effects on the fisheries, tourism and foreshore development trends that will damage or destroy investments if there are no climate change adaptation actions early enough. Beyond understanding the effects of climate change on the socioeconomic conditions of communities dependent on marine resources, the vulnerability assessment also included the exacerbating anthropogenic factors that affect the marine environment, represented by the back flows of arrows.

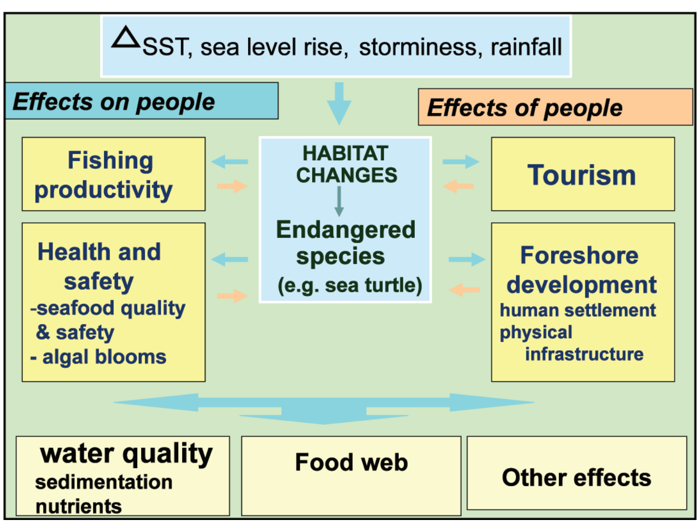


Fig. 42. Socioeconomic aspects in the vulnerability assessment of the Verde Island Passage.

Rising sea levels inundate wetlands and other low-lying lands, erode beaches, intensify flooding, and increase the salinity of rivers, bays, and groundwater tables, but some of these effects may be compounded by adaptation activities such as measures that people take to protect private property from rising sea level that may have adverse effects on the environment and on public uses of fish ports, beaches and waterways. Foreshore development, for instance, can bring in increasing investments for physical infrastructure such as sea walls or reclaimed areas in the short term, but in the longer term, these structures and human activities can damage mangrove ecosystems, fragment habitats, damage nutrient flows or cause destructive algal blooms which can aggravate climate change effects. Vulnerability assessment is therefore essentially related to disaster risk reduction and management.

More studies are needed to have appropriate guidelines for addressing adaptation. The vulnerability assessment exercise for Verde Island Passage is still exploratory but already significant for its methodological contributions.

Summary: methodology for socioeconomic vulnerability assessment

Fisheries

Characterization of the fisheries sector in Verde Island Passage (VIP) was done through literature review and analysis of fisheries statistics from the Bureau of Agricultural Statistics (BAS). Data from BAS was used to infer volume and value of production and number of fishers from three provinces in Verde Island Passage , namely: Batangas, Occidental Mindoro, and Oriental Mindoro. Finer scale data provided by technical reports allowed a more in-depth analysis for selected municipalities including: Mabini and Tingloy, for tuna fisheries (Soliman manuscript); Verde Island, Lubang, Looc and Paluan municipalities, for aquarium fishing (MAC and REEFcheck report); and Mabini, coral reef fisheries (MERF report). The compendium of PCAMRD on the impacts of El Niño on fisheries was compiled and used to supplement the literature review on increase in sea surface temperature.

A "perceptual survey" with 41 respondents and key informant interviews were conducted in the municipalities of Mabini, Bauan, Calatagan, Lian and Batangas City in April-May 2009 to determine how a sample of fishers perceive climate change. In particular, the following manifestations of climate change were validated: changes in frequency, occurrence, and magnitude of typhoons; changes in frequency, occurrence, and intensity of rainfall; sea level rise.

Tourism and foreshore development

The profile of the tourism sector and foreshore development status and trends was generated from previous studies, accessed data from government agencies in the VIP, interviews and a field survey in April to June 2009.

A climate change vulnerability assessment was conducted on July 22 to 24, 2009 participated in mostly by local government representatives from the coastal municipalities of the five provinces surrounding Verde Island Passage, namely Batangas, Mindoro Occidental, Mindoro Oriental, Marinduque, and Romblon. Resource persons from the natural and social sciences shared their initial assessments and frameworks for analysis on the potential impacts of climate change occurrences that are projected to occur. Climate change impacts include the following: increase in sea surface temperature, sea level rise, increased frequency and intensity of typhoons, changing rainfall patterns, and ocean acidification. Economic and social sectors that were assessed in terms of their vulnerability to such climate change occurrences include: fisheries, food safety and security, tourism and settlements/infrastructure in foreshore areas.

The framework for assessing the vulnerability of foreshore areas was applied by some of the participants coming from municipalities with significant infrastructure development in their respective foreshore areas, i.e., Balayan-Batangas, Calatagan-Batangas, Bauan-Batangas, Nasugbu-Batangas, Puerto Galera-Mindoro Oriental, and Naujan-Mindoro Oriental. Appendix A contains the list of participants for the foreshore area workshop group.

For the tourism sector, the framework for assessing the vulnerability was applied by some of the participants coming from municipalities with active tourism activities, i.e., Mabini-Batangas, Lian-Batangas, Tingloy-Batangas, Bauan-Batangas, Puerto Galera-Mindoro Oriental, and Calapan-Mindoro Oriental. Other municipalities with plans of increasing tourism in their areas also participated in the tourism workshop group.

Workshop objectives were provided as follows:

- Identify impacts of climate change in the physical, biological and socio-economic systems.
- Describe responses of the biological/ecological and socio-economic systems.
- Determine vulnerability of these systems.
- Provide management recommendations to address climate change impacts.
- Identify knowledge gaps, research priorities.

Health, food safety, and demographic trends

Accessed data from government agencies (National Statistical Board, National Statistics Office, Provincial/Municipal Planning and Development Offices of Batangas, Mindoro Oriental and Mindoro Occidental) were the sources for the demographic and health profile of the Passage, supplemented by information from the Batangas Provincial Disaster Coordinating Office.

Key informant interviews and focus group discussions were conducted in the municipalities of Mabini, Bauan, Calatagan, Lian and Batangas City in April-May 2009 to reconstruct health and food safety observations and experiences over the past 5-10 years and the local people's current knowledge on climate change.

A climate change vulnerability assessment was conducted on July 22 to 24, 2009:

- Identify the impacts of climate change on socio-economic systems and their resulting responses in the Verde Island Passage.
- Determine other impacts (natural or anthropogenic) that further contribute to the vulnerability of these systems.
- Provide recommendation for actions to address the impacts of climate change by increasing resilience, reducing vulnerability, increasing capacity for adaptation.
- Identify policy and knowledge gaps and research priorities.

Results and discussion

Profile of the Verde Island Passage and vulnerable socioeconomic situation

The Intergovernmental Panel on Climate Change in its 4th report detailed the impacts of climate change that affect human populations:

- Floods and droughts will be more frequent, and storms more intense.
- Water will be in shorter (and more erratic) supply.
- Sea level rise will result in salt water intrusion in coastal areas decreasing available freshwater.
- Water pollution will be worsened by higher water temperatures, increased precipitation, and longer dry periods.
- The likelihood of water borne diseases will increase.
- Aquatic ecosystems will suffer changes in water availability and related extinctions of species sensitive to water temperature and availability.

In addition to natural processes, threats to the rich but fragile environmental resources within and around the Verde Island Passage become more pronounced as population, conservation and natural resource management issues persist. Developments that respond to the escalating needs for income and food, industrialization and urbanization pose greater risks to the environment and to people's livelihood and health.

Biophysical setting

The Verde Island Passage extends about 100 km, from Lubang, Mindoro Occidental in the northwest, to the Romblon's island municipality of Corcuera in the southeast, and about 20 km across at its narrowest portion. The passage, a total of more than 494,700 hectares, is a special management area under the jurisdiction of five provinces: Batangas, Occidental Mindoro, Oriental Mindoro, Marinduque, and Romblon.

Warmer temperatures, diminished waters sources, and soil erosion results from a thinning forest cover while fish production is adversely affected by such changes as the loss of mangroves. Around the Verde Island Passage, the provinces of Batangas, Romblon and Marinduque have the least forest cover in relation to their respective land areas, with 4.46, 5.41, and 13.78% respectively (Forest Management Bureau or FMB 2003).

Low-lying and coastal communities as well as industries are exposed to hazards associated with strong typhoons and heavy rains. At least 51 barangays in 10 Batangas municipalities are more predisposed to flooding, erosion, siltation, and other damages brought by storms.

Biodiversity and ecosystem soundness are both threatened by the status and direction of development in the Verde Island Passage. Along with manufacturing, residential and institutional uses, fishing, farming, and tourism, the passage is an essential route for industrial and economic activities. Its waterways are some of the busiest in the Philippines, being used daily by oil and chemical carriers. Consequently, the shores of the province of Batangas are lined with shipyards, chemical and petrochemical plants, and oil refineries.

Other observed trends and facts on the socioeconomic situation in the Verde Island Passage are the following:

- Overfishing and the use of illegal fishing methods such as the use of sodium cyanide, explosives, and fine-meshed nets.
- Mangrove plantations are cut for other land uses that include fish farming. Calatagan's mangrove areas had been reduced to a mere 26.3 ha from 1 32.8 hectares in 1950 (Gonzales 2009).
- Agriculture is intensified, necessitating increased use of inorganic fertilizers and pesticides. Batangas itself has surpassed its capacity levels, with crop production activities utilizing marginal lands, including upland areas (Lusterio-Berja and Colson 2008).
- Forest cover has been diminished as this land has been converted to cultivation. Logging and extractive industries such as mining put entire forest ecosystems at risk.
- Forest patches and agricultural lands are cleared to make way for new human settlements and for profit-making ventures at various scales.
- Garbage and toxic effluents from settlements, industrial operations and intensified agricultural production contaminate the ground and water bodies through seepage and run off. Residuals from households and agriculture contribute to the pollution of Batangas Bay and Verde Passage (Arcenas 2008, in Gonzales 2009).
- Wastewater discharge from Batangas City's industries is estimated at almost 600 million liters per year, 98% of which come from the manufacturing, refinery and power industries (Gonzales 2009). Oil spills from ships are a constant threat given the numerous local and international ports and shipyards in Batangas province and the Verde Passage being a busy route for cargo and passenger vessels.
- Residential areas, including informal settlements,

expand especially in the lowland and coastal areas where commerce, industry and infrastructure are concentrated. Population congestion and mounting garbage expose people to diseases and other problems.

- More frequent algal blooms that are harmful to the health of marine resources and thus, of humans, are likely due to pollution of water bodies.
- Decline in fish catch has been attributed to the establishment of industries in the coastal areas.
- Industrial and vehicular emissions cause air pollution. In 2004, Batangas City had a one-year exposure level of 127 μg m^{-3} total suspended particulates which consist of dust, smoke, soot, and acid fumes usually produced by motor vehicles and fuel-burning facilities. Exceeding the acceptable level of 90 μg m^{-3}, the city's inhabitants are predisposed to cardiovascular and respiratory diseases (Lusterio-Berja and Colson 2008).

Demographic trends and the status of human health and safety

Climate change impacts in the Verde Island Passage may influence three factors that impact upon the state of human health: settlement expansion from fertility and migration, increased economic opportunities and urbanization. Baseline data on these factors are well established but have not been appropriately considered in terms of adaptation to climate change.

The five provinces (Table 24) flanking the Verde Island Passage consist of 32 municipalities and two cities which support 3,913,000 people (46.07% of the total 2007 population). In Batangas, Occidental Mindoro and Oriental Mindoro, more than 251 barangays (28%) serve as residence to 34% (557,710) of the population. In summary, from one third to almost a half of the total population of Verde Island Passage provinces are residents of coastal communities where the population size grows fastest.

Known coastal centers of commerce and industry in Batangas province such as Batangas City, Nasugbu, Taal, and Balayan had higher annual population growth rates than Batangas province as a whole. In 2000, a total of 67% of the region's population lived in urban areas where industries and commercial establishments were already concentrated (Lusterio-Berja and Colson 2008).

Although there are lower annual population growth rates for the provinces, growth rate in the municipalities of Looc and Lubang increased from 0.22% in 1995-2000, to 3.41% and 3.35% respectively in 2000-2007, higher than the national average of 2.3%. Puerto Galera's annual growth rate also increased from 2.56% to 3.45%. People from communities with less economic opportunities have migrated into areas with more options. Notably, Puerto Galera, Looc and Lubang are increasingly becoming attractive as tourist destinations, with the Lubang Island known for its wealth in fish resources (Occidental Mindoro PPDO 2009; Oriental Mindoro PPDO 2008).

Among the five provinces of the Verde Island Passage, Batangas is the most densely populated at 720 people km^2, which is higher than the 709 people km^2 for the entire Region IV-A Calabarzon (refers to Cavite, Laguna, Batangas and Rizal Zone). Calabarzon has the largest population and is the second most densely populated region in the country. It draws an influx of people because of the lucrative economic opportunities presented by its growing number of industries.

While industrialization draws people into the urban center, poverty continues to be a great challenge despite income derived from industries, tourism, agriculture and fisheries. A quarter to about half of the families in the Verde Island Passage provinces had incomes below the designated poverty and food thresholds in 2006. Batangas with 25.6% poverty lacked more than 12% in fish supply in terms of per capita consumption in 2004 (Batangas PPDO 2007). Oriental Mindoro and Occidental Mindoro slipped into becoming the 12th and 13th poorest provinces in the Philippines from being 32nd and 36th in 2000, and from being 28th and 19th in 2003. Romblon became the 25th poorest province in the country. A considerable section of the population are fisherfolks: more than 16,000 fishers in Batangas City and other Batangas towns beside the Verde Island Passage (year 2007), 15,535 municipal fishermen lived in Oriental Mindoro in 2008.

There are significant reproductive and other health concerns in the region. Mimaropa registered a total fertility rate of 5.0% in 2003, which was the highest in the country, as against Calabarzon's 3.2%, the lowest during the period. Although Batangas has an obvious advantage over the Mimaropa provinces in terms of economic position, health services and infrastructure, contraceptive prevalence in the province was only 41.77% (Batangas PPDO 2007) and 2007 crude birth rate (22.96) was even higher than those of Occidental and Oriental Mindoro (20.49 and 20.9 respectively). Batangas City itself had a crude birth rate of 21.23 and an infant mortality rate of 16.83 (Batangas City OCPDC 2007), which was more than double the provincial rate, and almost three and four times that of Occidental Mindoro and Oriental Mindoro respectively. Moreover, 8.2% of all children below 72 months old were considered malnourished because they weighed below normal low (BNL) and very low (BNVL).

Table 24. Population of municipalities and barangays along the Verde Island Passage (VIP).

Province/ municipality/ city	Population (2007) total	Population (2007) barangays along VIP	No. of barangays per mun/city	No. of barangays along VIP	Population density per sq km (2007)	Annual population growth rate % (2000-2007)
PHILIPPINES	88,574,614				295	2.04
Region IV-A (Calabarzon)	11,743,110				709	3.24
Batangas province	2,245,869				720	2.29
Balayan	79,407	20,873	48	11	730	2.33
Batangas City	295,231	65,774	105	18	1,043	2.46
Bauan	79,831	24,348	40	10	1,199	1.32
Calaca	64,966	19,191	40	8	648	1.46
Calatagan	51,544	34,433	25	16	460	1.87
Lemery	76,090	27,149	46	13	749	1.87
Lian	44,925	19,114	19	6	585	1.92
Lobo	37,798	18,589	26	10	196	1.51
Mabini	40,629	20,616	34	13	946	1.12
Nasugbu	113,926	29,488	42	7	433	2.37
San Juan	87,276	26,537	42	15	319	1.53
San Luis	29,645	10,091	26	6	757	1.34
San Pascual	57,200	18,942	29	3	1,637	2.14
Taal	51,459	4,825	42	1	1,729	2.36
Tingloy	18,548	18,548	15	15	572	1.19
Total population along the VIP	**1,128,475**	**358,518**	**579**	**152**		
Region IV-B (Mimaropa)	2,559,791				93	1.49
Occidental Mindoro	421,952				72	1.56
Abra de Ilog	25,152	10,117	9	3	47	1.89
Looc	11,310	10,317	9	8	85	3.41
Lubang	28,267	28,267	16	9	250	3.35
Paluan	13,718	4,191	12	2	24	2.01
Total population along the VIP	**78,447**	**52,892**	**46**	**22**		
Oriental Mindoro	735,769				169	1.06
Baco	34,127	7,526	27	6	141	1.71
City of Calapan	116,976	47,014	62	18	441	1.38
Gloria	40,561	12,166	27	8	176	0.66
Naujan	90,629	14,275	70	11	172	1.07
Pinamalayan	77,119	26,977	37	9	278	0.77
Pola	32,635	10,618	23	9	251	0.30
Puerto Galera	28,035	19,742	13	12	125	3.45
San Teodoro	15,039	7,982	8	4	41	1.19
Total population along the VIP	**435,121**	**146,300**	**267**	**77**		
Marinduque	229,636				241	0.76
Buenavista	21,018					
Gasan	33,772					
Mogpog	33,341					
Total population along the VIP	138,954					
% of total provincial population	**60.51%**					
Romblon	279,774				1	0.78
Banton	6,799					
Concepcion	4,166					
Coruera	10,883					
Total population of island municipalities along the VIP	21,848					
% of total provincial population	**7.81%**					

Total population of Batangas, Occ. Mindoro, and Or. Mindoro	**3,403,590**
Number of VIP municipalities and cities in the above	24 + 2
Total population of the 24 municipalities and 2 cities	**1,642,042**
Total population of VIP barangays in above	557,710 (34%)
Total population of non-VIP barangays in above	1,084,332 (66%)

Total number of barangays in the VIP municipalities and cities of Batangas, Occ. Mindoro, and Or. Mindoro	**892**
Number of VIP barangays	251 (28.14%)
Number of non-VIP barangays in the VIP municipalities and cities of the 3 provinces	641 (71.86%)

Source: Collated by SEPU for the Population, Health and Environment (PHE) network from materials and data availed through the Provincial Planning and Development Office (PPDO) of Batangas, Occidental, and Oriental Mindoro (acquired May-August 2009) and through the National Statistics Office (NSO) 2007 Census of Population.

Water supply and sanitation are health problems associated with poverty. As of 2007, 89% of families in Calabarzon had access to safe water while this was only 76% in Mimaropa. During the same year, 16% of the Batangas population did not have access to safe drinking water. Six percent of the families in Calabarzon and 20% of those in Mimaropa were without sanitary toilet facilities. The absence of safe water and sanitary toilet facilities are associated with diarrhea and other water and food-borne diseases.

In relation to climate change adaptation, the National Objectives for Health in the Philippines (NOH 2005-2010) does not specifically cite climate change as a cause of health problems, yet major causes of mortality currently are recognized as climate sensitive diseases: under-nutrition (3.7 million), diarrhea (1.8 million), and malaria (1.1 million). Acute or upper respiratory tract infection was the leading cause of morbidity in the provinces of Batangas, Occidental, and Oriental Mindoro (2007). Pneumonia was the top cause of mortality in Occidental Mindoro while it ranked fourth in Oriental Mindoro.

Whether because of extreme weather and high rainfall, eight out of 10 leading causes of illnesses are infectious. While most of these happen without being attributed to climate change, threats to human health and safety can demonstrate how vulnerability assessment in climate change adaptation can and must be pursued to avoid major epidemics.

Economic uses

A large portion of the Verde Island Passage population is employed near Batangas, where there are eight industrial parks including Cocochem Agro-Industrial Park and Tabangao Special Export Processing Zone, as well as 181 companies that are mostly situated in Batangas City and other coastal municipalities (Batangas PPDO 2007). Tourism also offers significant employment opportunities for coastal communities in resorts close to major dive sites. While commerce and industry provide big revenues, a substantial segment of the population depends on agriculture for sustenance. Fisheries remain a viable income and food source for many people who live immediately around the passage.

Discussion of the economic profile for the vulnerability assessment is confined only to fisheries, tourism, and foreshore development.

Fisheries

i. Fish production

One of the important steps in the Vulnerability Assessment was to estimate fisheries production attributable to the habitats of the Verde Island Passage (VIP) (Figure 43). Two sources of data were used for this purpose: a) Bureau of Agricultural Statistics (BAS) data set which provides for disaggregation of fisheries production on a provincial level, and b) LGU data which are presented in plans or in various published and unpublished reports. For the capture sector, all coastal municipalities of Batangas were included, assuming that their main fishing area is in the Verde Island Passage.

As for aquaculture, we only considered brackish water fishponds and seaweed production and expressly ignored the huge volume of production from Taal Lake. For Oriental Mindoro, we assumed all 14 coastal municipalities contribute to, and are fishing in, Verde Island Passage. For Occidental Mindoro, we only considered the four municipalities that include Paluan, Abra de Ilog, Lubang, and Looc and as such, provincial level production was divided equally by all 11 municipalities and multiplied by four in order to get appropriate attribution for these four.

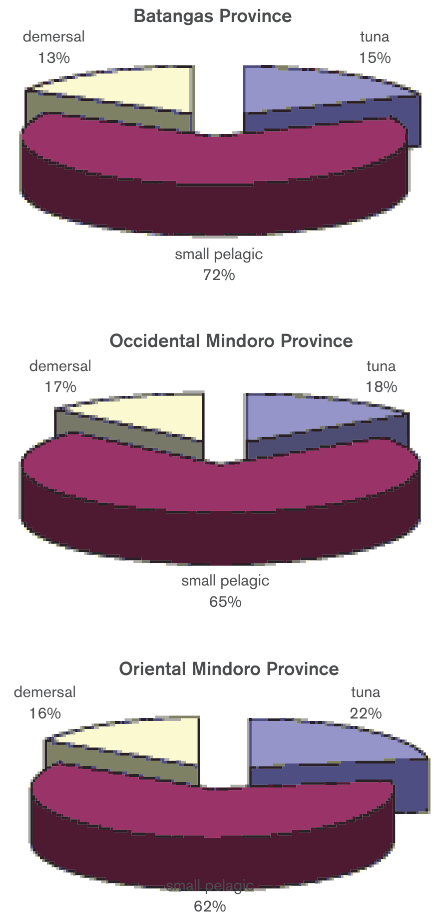


Fig. 43. Fisheries production by major species in Verde Island Passage.

Our estimates are shown in Tables 25-27 and indicate that Verde Island Passage contributes somewhere between 40-47 thousand MT per year with the province of Batangas contributing the most. The 6,000 MT average for Occidental Mindoro is already a weighted figure for the four municipalities, as explained, and so appear to be lower than BAS statistics. Another 4,000 MT was estimated to be from the aquaculture sector (bangus, prawns, and seaweeds). As for aquarium fishing, another activity studied, we assume that production was not recorded at both LGU and BAS levels.

Small pelagics are the most important species group caught in Verde Island Passage with Batangas alone contributing an average of 18,000 MT per year. The

Table 25. Marine fisheries production (thousand MT) from the commercial and municipal sectors estimated for Verde Island Passage from 2005-2007.

Province	2005	2006	2007
Batangas	20.10	27.80	26.40
Occidental Mindoro	5.93	6.29	6.76
Oriental Mindoro	13.30	13.20	13.90
Total	**39.33**	**47.29**	**47.06**

Source: Basic data from BAS 2007.

dominant small pelagic species include roundscad, anchovies, mackerel, and sardines while the tuna species caught include skipjack and yellowfin. Demersal species include slipmouths, threadfin bream, and squid. For the three provinces, the distribution of major species caught is similar, and in all cases small pelagics dominate the production total. This study found that tuna ranks second and demersals rank third, in all provinces. Soliman (manuscript) suggests that Mabini and Tingloy together contribute to about 2000 MT per year of tuna per year or more than half of the total Batangas production.

Table 26. Aquaculture production (thousand MT) from brackish water fishponds and seaweed farms estimated for Verde Island Passage from 2005-2007.

Province	2005	2006	2007
Fishponds			
Batangas	0.19	0.19	0.16
Occidental Mindoro	0.76	0.78	0.86
Oriental Mindoro	2.05	2.14	2.22
Total fishponds	3.00	3.11	3.24
Seaweeds			
Batangas	0.50	0.70	1.00
Occidental Mindoro	0.51	0.55	0.58
Oriental Mindoro	0.15	0.14	0.12
Total seaweeds	1.16	1.39	1.70

Table 27. Estimates for tuna, small pelagics and demersal fish catch (thousand MT) from the Verde Island Passage from 2005-2007.

Province	2005	2006	2007	3 year average
Tuna				
Batangas	3.24	4.42	3.75	3.80
Occidental Mindoro	0.98	1.15	1.34	1.16
Oriental Mindoro	3.06	2.97	2.94	2.99
Small Pelagics				
Batangas	14.26	19.99	18.81	17.69
Occidental Mindoro	3.83	4.14	4.40	4.12
Oriental Mindoro	8.10	8.10	8.74	8.31
Demersals				
Batangas	2.60	3.39	3.84	3.28
Occidental Mindoro	1.12	1.00	1.03	1.05
Oriental Mindoro	2.14	2.13	2.22	2.16

ii. Fishers and fishing units

We estimated a total of 12,000 municipal and commercial fishers were utilizing the fisheries resources of Verde Island Passage. It was not possible to disaggregate the numbers of commercial and municipal fishers to the major species group (tuna, small pelagics, and demersals) because both sectors were exploiting the same target species albeit using different gears or size/power of boats. The same observation on targeting similar species is echoed by Soliman in his manuscript on Mabini and Tingloy. However, we estimated the number of municipal and commercial fishers by extrapolating from available data. Data from Batangas Provincial Agriculturists Office suggested that there were approximately 550 commercial fishers, and another 400 deep sea fishers from Lubang municipality. We therefore used a conservative estimate of 2,000 commercial fishers out of the total 12,000.

We could not make any judgment on whether these numbers include aquarium fishers but we nevertheless indicated the numbers in Table 28.

Table 28. Number of commercial and municipal fishers per province including aquarium fishers (estimates from various sources).

Province	Commercial and municipal fishers	Aquarium fishers	Source
Batangas	9508		Rosales consultancy report for CI (2006)
Batangas City (Bgy Sn Andres, Verde Is.)		117	MAC Report, Reef Check Report
Occidental Mindoro	1300		MAC Report, Reef Check Report
Lubang	614	14	
Looc	258	14	
Paluan	420	20	
Oriental Mindoro	1477		Coastal resource profile of Oriental Mindoro
Total	**12200**	(estimate only) **250**	

iii. Aquarium fisheries

Aquarium fishing is prevalent in Verde Island (under the jurisdiction of Batangas City) Lubang, Looc, and Paluan and all of Occidental Mindoro. Studies on the aquarium trade indicate that aquarium fishing is also practiced in Lian and Calatagan (Figure 44).

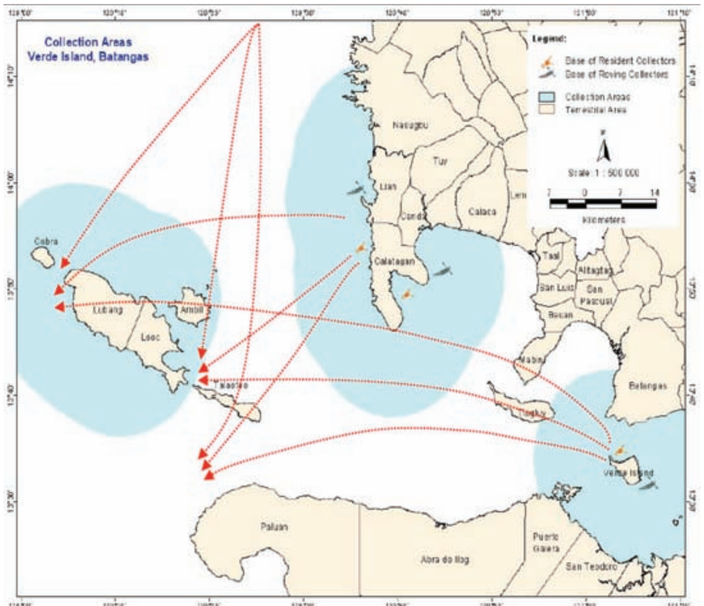


Fig. 44. Roving collection routes in the Verde Island Passage corridor.

A feature article that chronicles the lives and practices of aquarium fishers of Barangay San Andres in Verde Island has anecdotal details that indicate vulnerable marine resources and human communities in the passage (Lesaba 2009). In that community, 90% of the population (about 1200 people) is engaged in diving for tropical fish or aquaculture. They go to areas with good reefs and catch species such as yellow wrasse, sexline wrasse, longnose pupper, white fin lion, spot fin anthias. Occasionally, they catch "Majestic" which are priced at P800 to P1000 apiece. It is more of a way of life for the people of Barangay San Andres so they have to continuously adapt to local regulations and find some enterprising "sponsors" in other municipalities/ provinces.

Ironically, the practice is banned not only in Verde Island but also in the barangay which breeds aquarium fishers and this is the reason why the practice is exported to places such as Lubang and Looc in Occidental Mindoro (Figure 44). Conservation International has also commissioned the Marine Aquarium Council (MAC) and Reefcheck to investigate sustainability options for roving aquarium fishers in the Verde Island Passage.

The collection practice itself is dependent on good weather, especially for those who are "mano mano" (use hands or hand-based tools) divers or those who do not use any air-supplying device. Dives may last from 8 am until 2 pm every day until enough fish are assembled, i.e., about 500 to 1000 assorted tropical fish, after which the catch is brought to Tabangao en route to Manila. A comparison of average monthly incomes of: a) mano mano fisher; b) hookah collector (including crew), and c) trader indicate that the mano mano fisher earns an average of P4,600 per month compared to the hookah collector who earns P5,100. The trader earns the highest at P7,800 per month (MAC Report).

Despite the relatively low average monthly incomes, the income of mano mano fishers may be as high as P12,000 in some months, and hookah fishers as high as P19,000, presumably when catches are high and when the expensive species are caught.

Early analyses of the effects of El Niño on tuna fisheries in the Philippines point to minimal or no impacts on overall production. Barut (1999) argues that Philippine waters approximate that of the Western Tropical Pacific (WTP) where no warm water intrusion is bound to occur and even if it does, tuna is known to thermo-regulate. Further observations of U.S. tuna fleets support the claim that no change in production is expected in the WTP waters. Meanwhile, the Australian Bluefin Association observed an increase in tuna production, and an increase in small pelagics, especially in areas where upwelling occurs.

Recent climate change studies depict more of a downtrend in production and a shift in abundance at higher latitudes (Aaheim and Sygna 2000) and modeled changes for skipjack (Pratchett et al. 2008). Increased water temperature is forecast to result in changes to the distribution and abundance of tuna towards the Central Pacific and away from the Coral Triangle area. Moreover the impacts of increasing water temperature on habitats and incidence of storms and acidification threaten coastal habitats such as coral reefs. Lehodey (2000) agrees with the shift in spatial distribution and decline in abundance of fisheries, especially in the Pacific, but recognizes that some countries may in fact gain from this anticipated change.

iv. Small pelagics fisheries

The importance of the small pelagic fisheries sector in Verde Island Passage can be gleaned from production statistics. Annual average production of small pelagics (sardines, anchovies, round scads, and mackerels) total more than 30, 000 MT. In Batangas province, more than 70% of catch is small pelagics and in the two Mindoro provinces, more than 60% of catch is small pelagics. Both commercial and municipal fishers exploit the small pelagics fisheries.

Like tuna, small pelagics are observed to favor deeper, cooler waters during periods of drought or El Niño. In such cases, the movement of these fish to deeper waters may assist commercial fishing gears such as ringnets and Danish seines. In nearshore waters, competition among municipal fishers will intensify unless gear adaptation occurs.

v. Demersals
Total production of demersal fish (represented by threadfin bream, squid and slipmouths) has an annual average of 6,000 MT for Verde Island Passage. In percentage terms, it is similar to tuna which contributes somewhere between 10 and 15% of total production. In value terms, the demersal fishery has the highest value contribution at more than P400 million pesos, on average, compared to P372 million for small pelagics, and an even smaller value for tuna at P142 million a year. This can be explained by the higher prices obtained for demersal species.

It should be emphasized, however, that these estimates are based on available data from BAS and that BAS limits itself to the collection of statistics for the first 30 most important commercial species.

Demersal species are closely linked to habitat conditions, and more specifically to coral reefs. Climate change impacts may result in population declines due to loss of settlement habitat and erosion of habitat structural complexity, while increased ocean temperature will affect the physiological performance and behavior of coral reef fishes and cause shifts in recruitment patterns and reproduction. In extreme cases, we may see the extinction of small-range species.

vi. Coastal aquaculture (seaweeds and fishponds)
Production estimates for coastal aquaculture comprise about 3, 000 tons from brackish water fishponds and another 2, 000 MT from seaweeds. While not significant based on volume of production, seaweeds provide livelihoods to wives of fishers and other community members. Requiring relatively little capital and with huge returns, seaweed aquaculture is touted as a "poverty alleviation" tool by government.

In Calatagan, Batangas, Tambuyog (2005) analyzes the growth of, and issues related to, the seaweed industry. Seaweed farming was introduced in Calatagan in 1971 from Zamboanga. At time of writing, there were around 1, 200 seaweed cultivators dispersed over five of the 19 coastal barangays, mainly concentrated in three barangays: Barangay Uno, Dos, and Balitoc, but also in Barangay Gulod and Barangay Carretunan. The current numbers of seaweed farmers could not be confirmed, but reports indicate that the practice still exists.

The monthly income from seaweed farming would normally range from P8, 167 to P14, 672 assuming that there were no typhoons or disease outbreaks to adversely affect production. These figures are higher than the income from fishing, but as already mentioned, the cost of labor is not fully included as seaweed production is mainly a family enterprise. However, given that at least three production cycles can be completed in one year, seaweed farming appears to be highly profitable.

Seaweeds may be impacted by climate change due to increasing sea surface temperatures and declining water quality levels. Based on the observation by Monzales, seaweeds farmed using bottomset methods suffered almost unilaterally compared to those using a floating system. Likewise, water quality and the absence of pollutants provide an ideal environment for seaweeds.

Data obtained from the Calapan City Coastal Environmental Profile indicate that brackish water fishponds for bangus cover about one thousand hectares with annual production of 2,000 MT (2005 statistics). With a productivity of about 2 tons ha^{-1}, the estimated income per hectare of bangus fishpond is P200, 000 per hectare.

Tourism
Tourism in Verde Island Passage has traditionally been limited to a few areas and activities within the entire passage. Recreational activities are focused mainly on the area's natural attributes, many of which are marine-based. Increasing importance of tourism is the recent trend that climate change may most affect.

There is no comprehensive profile for the tourism sector that covers all areas within the Verde Island Passage. What is presented in this study are initial data sets on the tourism profile of the Passage from three sources, i.e., a) a start-up passage-wide profile from a workshop covering Lian, Mabini, Tingloy, Calatagan, San Teodoro, Bauan, Calapan and Puerto Galera—all tourism destination sites; b) information from a prior study confined to the Batangas side and with a detailed profile provided for only one municipality, Mabini (where scuba diving activities are concentrated); and c) supplemental focused primary research, also in Mabini, to generate updated information on the economic engagement of local communities.

This effort demonstrates how opportunistic data accessed from agencies and representative sites or case studies can be an appropriate approach when initiating a vulnerability assessment. The choice of focus area for the Verde Island Passage is only intended to show how profiles in general can be used as an initial step for assessing overall vulnerability of the tourism sector. The complete profile, and eventually the vulnerability assessment, will hopefully be undertaken more comprehensively by the local stakeholders in succeeding workshops.

i. Important tourist activities and destinations
A profile of the marine tourism sector summarized in Table 29 shows that diving is the most popular activity offered by resort owners. Puerto Galera and Mabini are the main destinations, although a significant number of dive spots are located in Tingloy as well. Lian is a major destination for swimmers and picnic goers, as reflected by the very large number of establishments for such purposes. January to May is the peak season for most recreational activities, however in some areas, tourism is experienced all year round.

Tourist traffic is high in Verde Island Passage, as reflected by the estimated number of divers, swimmers, and snorkelers. It would be beneficial to establish a more accurate figure for monitoring purposes. Nevertheless, the initial estimates are high enough to classify Verde Island Passage as a major tourist destination for coastal and marine recreational activities.

ii. Employment and revenues generated by tourism

Table 30 provides an indication of the employment generated by marine tourism. As expected, boat operators are very much in demand. These recreational boat operators were former fisherfolk, validating the statement that tourism complements conservation as the sector provides alternative livelihood for locals, providing opportunities to cease resource extractive or environmentally destructive activities.

The exact share or contribution of marine tourism to the total economy of Verde Island Passage could not be ascertained in this project. It was agreed that this has to be established with more data, and it would be beneficial to determine how important the sector is in providing income and employment to municipalities and provinces, and to the country as a whole.

Only Mabini was able to provide figures on estimated revenue generated in the diving industry, which appear to be highly significant to the local economy (Table 31). Annual resort revenues are estimated to be PhP 88 million, and the sector contributes to local employment valued at PhP 33 million and to local government's CRM revenues at PhP 1.3 million. This is a minimum

Table 29. Tourism profile in the Verde Island Passage, 2009.

Activities	Location	Number of establishments/ units	Season	Number of tourists per year	Annual revenues in PhP
Wind Surfing	Puerto Galera	1	non-peak: rainy season	no data	
Diving	Puerto Galera	50 +	all year round, except when there are typhoons	350	
	Mabini	34	Jan-May: high; Jun to Sep: low; Oct-Dec: medium	Mabini-Tingloy: 20,000-22,000 divers	4.2M from boat rentals; 88M from resorts; 1.2M unified divers' fees
	Bauan	5	Jan-May: high; Jun to Sep: low; Oct-Dec: medium	200/week during peak season	3900/day
	Tingloy	4	Jan-May: high; Jun to Sep: low; Oct-Dec: medium	Mabini-Tingloy: 20,000-22,000 divers	1M unified divers' fees
	Calatagan	1			
	San Teodoro	1			
Snorkeling	Bauan	2	Jan-May: high; Oct-Dec: medium	200/week	
	Puerto Galera			100,000	
Swimming	Lian	800	all year round; peak season during summer	50,000/day during peak season	
Boat Trips	Calatagan	1			
Kayaking	Puerto Galera	10 establishments; 100 units			
Jetski	Calatagan	1			
	Puerto Galera	10 establishments; 20 units			
	Calapan				
Wakeboarding	Calatagan	1	all year round		
Skim boarding	Puerto Galera				
Banana boat	Mabini				
	Puerto Galera	150			
	Calapan				

Source: Tourism Sector Workshop for the VA, Batangas City, 2009.

Table 30. Employment generated in the marine tourism sector, Verde Island Passage, 2009.

Activities	Employment generated	Type of employment
Wind Surfing		
Diving	boat rental; instructors; Puerto Galera: 345 boatmen (with membership in the association); 125 diving instructors; equipment rental Mabini: boat rental; van rental	skilled skilled
Snorkeling		
Swimming	boat operator; equipment rental	
Boat Trips	resort operation; boat rental; balsa rental; lifesaver rental; other small-scale entrepreneurship (sari-sari store, videoke rental, vending of souvenir items and backyard agricultural production)	managerial staff/helper
Kayaking	boat operation	skilled
Jetski		
Wakeboarding	Puerto Galera: 20 operators; equipment rental	skilled
Skim boarding		
Banana boat	kayak fare; boat operator	

Source: Tourism Sector Workshop for the VA, Batangas City, 2009.

Table 31. CRM revenues in Mabini, 2003 to 2008.

Year	Number of divers	Collected dive fees (PhP)
2003	2,225	225,000
2004	10,005	1,000,510
2005	16,778	1,677,750
2006		1,350,000
2007		1,130,300
2008		1,150,000
5-Year Average		**1,299,894**

Source: Municipal Environment and Natural Resources Office, Mabini, Batangas.

estimate, considering that real estate and income taxes are not included in these estimates. More importantly, other tourist expenses such as those for land and water transport, food on-site and other related expenses are also not included. Assuming a minimum amount of transport expense of PhP 500 and food expenses at PhP 500 per person, other tourist expenses could be in the amount of PhP 12 million for scuba divers alone.

In the case of the Batangas portion of the Passage, Tables 32 and 33 show that the types of tourist attractions available confirm marine-based tourism as an important attraction—with Nasugbu, Mabini, Tinglliy, and Lian being the coastal municipalities with the most natural attractions. Beach and dive resorts (195 and 36, respectively) were the most common tourist establishments with accommodations, among all tourism establishments, as of 2004.

Table 32. Tourist attractions in the Batangas portion of the Verde Passage MBCC, 2003 to 2004.

Municipality/ city	Tourist attractions						
	historical	cultural	religious	festivals	natural	ancestral house	Total
Batangas Study Area	10	9	2	5	23	19	**68**
Balayan	1	1		1		2	**5**
Bauan				1	1		**2**
Calaca	1			1		1	**3**
Calatagan	1						**1**
Lemery							
Lian					3		**3**
Mabini					5		**5**
Nasugbu					10		**10**
San Luis							
Taal	6	8	2	2		16	**34**
Tingloy	1				4		**5**
Tuy							

Source: Provincial Tourism Office, Batangas.

Table 33. Tourist accommodations in the Batangas portion of the Verde Passage, MBCC, 2003 to 2004.

Municipality/ city	Dive resort	Beach resort	Island resort	Golf club	Boat club	Hotel/restaurant/resort/lodge/ pension house/inn/apartelle/ convention-seminar center	Other accommodations	Total
Batangas Study Area	36	195	4	3	1	31	4	**274**
Balayan		9				6		**15**
Bauan	4	14				5		**23**
Calaca		30					3	**33**
Calatagan		7		1		5		**13**
Lemery		24				3		**27**
Lian		7				3		**10**
Mabini	26	65	1			6		**98**
Nasugbu	1	28	2	2	1	1	1	**36**
San Luis	3	5						**8**
Taal		5				2		**7**
Tingloy	2	1	1					**4**
Tuy								

Source: Provincial Tourism Office, Batangas.

Most of the resorts were located in Mabini, followed by Calaca and Nasugbu with peak occupancy during the months of March to May and towards the Christmas season from November to January.

The most common activity is scuba diving, narrowly concentrated within the municipalities of Mabini and Tingloy, and a few more dive sites and resorts in Verde Island (Table 34). Within the past two decades, Verde Passage has consistently been increasing its popularity as the premiere scuba diving destination in mainland Luzon. A significant number of scuba divers and marine recreationists have been flocking to the area, as reflected in the increasing revenues collected from diving entrance fees.

Verde Island is likewise being promoted as another diving destination in the area. Although no primary data is available, estimates have shown that a significant number of divers have been visiting dive sites over the past few years. These divers, however, are likely to be the same divers going to dive sites in Mabini-Tingloy and Puerto Galera. There is only one resort on the island, and most divers are billeted in tourism establishments elsewhere. In 2004, between 1,000 and 2,000 divers visited Verde Island.

Table 34. Estimated number of divers in Verde Island, CY 2004.

Source of information	Estimated total number of divers
Revenues from Bgy. San Agapito's divers' fees in PhP	1,800 six months of a year
Interview with Bgy. Chair of San Agustin Kanluran	260 to 1,040 divers a year
Dive Camp Resort	720 to 1200 divers a month during peak months

Source: Rosales, R. 2005. Report on the Establishment of User Fees for Scuba Diving in Verde Island.

iii. Case Study: Updates in the tourism profile of Mabini, Batangas

Mabini presents itself as a strategic location as far as the tourism sector is concerned. Scuba diving is a prominent activity in the area. The coral reefs of Mabini and Tingloy are favorite diving sites of both foreign and local divers who visit from Manila. At present, there are 39 dive sites scattered throughout the coastal waters of these two municipalities. Most sites (i.e., 23) are located in Tingloy, although tourist facilities are mostly in Mabini.

As mentioned above, most tourist resorts in Verde Island Passage are located in this municipality. Out of a total 24 resorts, 14 cater exclusively to divers, three are for beach goers and swimmers, and seven cater to both types of tourists (Table 35). Other types of water-based activities offered by resorts include kayaking, banana boats, pedal boats, snorkeling, island hopping and swimming. A few offer additional activities such as game fishing, surfing, water skiing, and jet skiing.

Table 35. Resorts in Mabini Municipality, by Barangay, 2009.

	Number of resorts			
Location	beach	dive	both	Total
San Jose			3	3
Ligaya	1	2	2	5
Solo		3	1	4
San Teodoro	2	4		6
Bagalangit		5	1	6
Total	**3**	**14**	**7**	**24**

Source: Field interviews, June 2009.

Capacity for visitors is around 1,061 persons at any point in time, based on the number of rooms available for occupancy and the maximum capacity per room (Table 36). The total does not include visitors who visit during the day but do not spend the night at resorts.

Table 36. Number of rooms and maximum capacity in Mabini, by Barangay, 2009.

Location	Room capacity	Maximum visitor capacity
San Jose	15	62
Ligaya	59	191
Solo	89	334
San Teodoro	85	243
Bagalangit	88	231
Total	**336**	**1,061**

Source: Field interviews, June 2009.

All resorts are located in the foreshore area of Mabini, with establishments ranging from a distance of less than one meter to 20 meters from the shoreline (Table 37). The big resorts are located in San Teodoro, while the smaller ones are in Ligaya. The other barangays have a mix of relatively large and relatively small resorts. The total area occupied by tourist resorts is 26,875 square meters.

Table 37. Area occupied by tourist resorts, Mabini, June 2009.

Location	Farthest distance from shore (m)	Nearest distance from shore (m)	Area occupied (sq m)
San Jose	10	< 1	1,800
Ligaya	5	5	1,900
Solo	20	5	3,625
San Teodoro	15	2.5	14,225
Bagalangit	10	5	5,325
Total			**26,875**

Source: Field interviews, June 2009.

Occupancy averages around 80 nights (1 night= 1 room occupied) per resort per year. The lowest occupancy registered at 13, while the highest was at 247. This translates to an average of PhP3.835 million per year, or PhP88.215 million in total revenues for all resorts in a year (Table 38). Annual revenues per resort ranged from a low of PhP104,400 to PhP36.386 million. Sixteen resorts had revenues above PhP one million.

Table 38. Occupancy and annual revenues, Mabini tourist resorts, June 2009.

Annual occupancy	
Average number of nights per resort	80
Total number of nights for Mabini	1,839
Annual revenues	
Average per resort, in PhP	3,835,422
Total for Mabini, in PhP	**88,214,695**

Source: Rosales, R. 2005. Report on the Establishment of User Fees for Scuba Diving in Verde Island.

Resorts employ a significant number of locals in their operations. There are around 342 locals working at 24 resorts, with an average of around 14 per resort (Table 39). Using certain assumptions on salaries paid by position, total employment was valued at PhP33.15 million annually, or an average of PhP1.381 million per resort. Employment thus represents approximately 38% of total annual revenues, or 36% of average annual revenues per resort. Other employment opportunities related to tourism are not yet reflected here. Employment in downstream industries may even be higher, such as provision of food on-site, land and water transportation to, from and within Mabini, souvenir making and selling and manufacture, trade and rental of equipment used in water-based recreational activities.

Table 39. Employment status in Mabini resorts, June 2009.

Resort employment by type	Number/amount
Administrative	113
Housekeeping	55
Kitchen	80
Landscaping	28
Garbage disposal	23
Divers/dive masters	40
Others	3
Total employment, 24 resorts	**342**
Average employment per resort	**14**
Total value of employment, 24 resorts, in PhP	**33,150,000**
Average value of employment per resort, in PhP	**1,381,250**

Source: Field interviews, June 2009.

Data on taxes paid by resorts to the local government office of Mabini were not available for this report. However, revenues collected from diving entrance fees have shown a significant increase since the time they was implemented in 2003 (Table 8). The entrance fee system was introduced in 2002 to provide funds for coastal resources management activities of the LGU. Divers are mandated to pay PhP100 for a weekend dive in Mabini and Tingloy coral reefs. The amount was based on a 2001 study that estimated the recreational value of scuba diving in the area. There was a revenue shortfall in 2006, but this was due to problems in collecting fees from divers, rather than a steep drop in the number of divers visiting Mabini. The Municipal Environmental and Natural Resources Office (MENRO) has since instituted changes intended to make collection methods more efficient. Using a five-year average between 2004 to 2008, close to 13,000 divers visited Mabini and Tingloy coral reefs annually, generating an estimated PhP1.3 million in annual CRM revenues.

Tourism is a sector with steadily increasing importance as a revenue source and employment opportunity in the Verde Island Passage. However, the regular repeat divers and marine recreationists who generate incomes will tend to sustain tourism costs only while the marine resources are in good condition, which makes assessments of vulnerability to climate change both urgent and important.

Foreshore development

As with tourism, profiling foreshore development in the Verde Island Passage was needed to carry out the vulnerability assessment as there was no available data base. Hence, the framework for assessing the vulnerability of foreshore areas was applied by some of the participants coming from municipalities with significant infrastructure development in their respective foreshore areas, i.e., Balayan-Batangas, Calatagan-Batangas, Bauan-Batangas, Nasugbu-Batangas, Puerto Galera-Mindoro Oriental, and Naujan-Mindoro Oriental.

To start from a profile of foreshore areas in the Verde Island Passage, participating municipalities in the workshop group indicated the length of their coastlines (presented in Table 40). Nasugbu and Calatagan have relatively long coastlines (60 and 48 km respectively), thus have larger areas for potential foreshore development than most of the other municipalities.

Table 40. Length of coastline, Verde Island Passage municipalities, 2009.

Location	Length
Calatagan	48 km
Puerto Galera	10 km
Bauan	4 to 5 km
Naujan	25 km
Nasugbu	60 km
Balayan	11 km

Source: Field interviews, June 2009.

Infrastructure development in foreshore areas has gone unabated throughout the years. The majority of coastal municipalities have roads that extend all the way to their foreshore areas, many of which are concrete (Table 41). Table 42 contains the number of municipalities that have allowed bridges to be constructed, mostly in municipalities with relatively little coastline.

Table 41. Roads in foreshore areas.

Location	Type/construction materials used	Length
Calatagan	3 rough, 4 concrete	
Puerto Galera	10 rough to concrete	10 km
Bauan	4 concrete	3 km
Naujan	rough	1 km
Nasugbu	concrete	500 km
Balayan		

Table 42. Bridges in foreshore areas.

Location	Type/construction materials used	Number
Calatagan	0	
Puerto Galera	3 concrete, 1 wooden	3
Bauan	concrete	3
Naujan	concrete, foot bridge	2
Nasugbu	0	
Balayan	0	

Settlements and other buildings abound in all coastal areas in Verde Island Passage (as shown in Tables 43, 44, and 45). Meanwhile, some portions have been used as public ports and docking areas for fishing boats (Tables 46 and 47). Only Calatagan has allotted a portion for the establishment of fishponds (Table 48). Accurate figures for most of these indicators could not be determined at the workshop, but there was a consensus that there were too many man-made establishments located in foreshore areas. The participants agreed that the very presence of all these settlements and buildings were exacerbating coastal erosion and pollution of their waters, thus already threatening resources even without the onset of climate change.

Table 43. Houses in foreshore areas.

Location	Type/construction materials used	Number
Calatagan	concrete and light materials	11 barangays
Puerto Galera	concrete and light materials	500
Bauan	concrete	12 barangays
Naujan	semi-concrete	200
Nasugbu	concrete to light	50
Balayan	concrete to light	2500

Table 44. Tourism establishments in foreshore areas.

Location	Type/construction materials used	Number
Calatagan	concrete	12
Puerto Galera	concrete, nipa	600
Bauan	concrete 10, 5 small scale	15
Naujan	nipa 3, concrete 2	5
Nasugbu	concrete 10, 5 small scale	15
Balayan	concrete 5, 25 small scale	30

Table 45. Other buildings in foreshore areas.

Location	Type/construction materials used	Number	Area occupied
Calatagan	seawall	7	
	lighthouse	1	
Puerto Galera	windbreaker	1	800 meters
	reclaimed area	2	100 m
			50 m
	lighthouse	2	
	post light		
Bauan	reclaimed area		2-3 ha
	seawall		
	chapel		
	barangay hall		
	day care center		
	basketball court		
	baywalk		
	multipurpose hall		
Naujan	seawall	1	
	stage	2	
	chapel	1	
	school	1	
	basketball court	2	
	shorelights		
	barangay hall		
Nasugbu	barangay hall		
	chapel		
	multipurpose hall		
	seawall		
Balayan	multipurpose hall	6	
	barangay hall	2	
	PCG detachment	1	
	baywalk		2 km
	seawall	1	

Table 46. Ports in foreshore areas.

Location	Type/construction materials used	Number
Calatagan	PPA	1
Puerto Galera	public	3
Bauan	private, 1 public	8
Naujan		
Nasugbu	public	2
Balayan		

Table 47. Docking facilities in foreshore areas.

Location	Number of boats docked	Area occupied
Calatagan	fishing boats, speedboats (10)	19 barangays
Puerto Galera	repair, dry docking; fishing, passenger and tourist boats	
Bauan	fishing and passenger boats	12 barangays
Naujan	fishing, passenger	10 barangays
Nasugbu	fishing	7 barangays
Balayan	fishing	11 barangays

Table 48. Fish ponds in foreshore areas.

Location	Number of fish ponds	Area occupied
Calatagan	18	250 ha
Puerto Galera	2 abandoned	2 ha
Bauan		
Naujan		
Nasugbu		
Balayan		

Table 49. Natural resources in foreshore areas.

Location	Resources available
Calatagan	mangroves beach
Puerto Galera	mangroves white sandy beaches beautiful bay
Bauan	beaches
Naujan	mangroves sandy beach delta hot springs
Nasugbu	coves mangroves beaches
Balayan	mangroves beaches delta

Meanwhile, natural resources could still be found in these foreshore areas. Most of the participants proudly claimed the existence of mangrove forests and sandy beaches, the latter being used often for local tourism and recreation. Table 49 contains a summary of natural resources found in these coastal municipalities, although details on area covered and species present could not be provided at the workshop proper.

The tables that detail the data to profile foreshore structures and facilities is very preliminary but has been included in the exercise (through inter-agency workshops) to show that the kinds of data suggested are neither well reported nor monitored, and will therefore require creative ways to generate this information. Lack of management mechanisms limits the ability to assess vulnerability. However, local government units can be encouraged to carry out inter-agency coordination in baselines and monitoring, which would allow a full vulnerability assessment in the future.

Vulnerability assessment of human well-being

Climate change impacts on the fisheries sector in the Verde Island Passage and the sector's responses

Climate change disrupts fisherfolk's livelihood when fish breeding and spawning seasons and habitats, fish runs and migration paths are altered. Starting with a profile of the fisheries sector, a two-step process was used to estimate the vulnerability of fishing activities to climate change.

The **first step** was to derive a Socio-Economic Vulnerability Index (SEVI) given a listing of parameters: i) incomes levels; ii) sectoral importance; iii) socio-cultural attachment to activity; iv) diversity of livelihood options; and, v) dependency of activity on coastal habitat.

- **Income levels:** Incomes are negatively affected by declining production levels, declining prices, and increased operational costs. Poverty threshold levels were used as benchmarks and income vulnerability was a measure of the possible divergence of income levels from this threshold. Annual per capita poverty thresholds estimated by the National Statistical Coordination Board (NSCB) for Batangas, Occidental Mindoro, and Oriental Mindoro were P16,615, P12,564, and P14,330, respectively, with income estimates for the municipal and commercial sectors summarized in Table 50.

Table 50. Average per capita incomes of commercial and municipal fishers, by province, based on fisheries production value, 2005-2007.

Province	Average income of commercial fishers (in thousand PhP)	Average income of municipal fishers (in thousand PhP)
Batangas	43.975	12.264
Occidental Mindoro	21.651	5.683
Oriental Mindoro	26.164	6.613

- **Sectoral importance:** relative to the contribution to production, food security, and employment generation, the sector is highly vulnerable when contribution to either of these parameters is high.
- **Socio-cultural attachment to activity:** when activity is not only economic but social as well; difficulty in shifting to an alternative is greater.
- **Diversity of livelihood option:** based on information culled from reports, this measured the extent to which the individual (and his/ her household) relied solely on fishing activity. If alternative livelihood options are meager, vulnerability is higher.
- **Dependency levels on coastal habitats:** not quantitatively measured in this study, but an opportunity to employ an in-depth analysis exists given data on species caught; where fishing activity occurs (in or near coastal habitats); and type of gear used.

Each parameter was given a rating of Low, Medium, or High based on the best available information, and converted numerically thereafter (1=low; 2=medium, and 3=high). For example, in the case of income vulnerability, the rating was HIGH if the estimated or perceived income was lower than the poverty threshold. Any intermediate scores such as Low to Medium or Medium to High were scored as a half point score, such that Low to Medium was given a score of 1.5, for example.

A simple average was then computed to derive a Socio-Economic Vulnerability Index (SEVI). The summary indices provide a general indication of vulnerabilities for the entire Verde Island Passage based on the parameters selected (Table 51).

Table 51. Summary socio-economic vulnerability index (SEVI) matrix for fisheries in the Verde Island Passage.

Type of fishing	Income levels	Sectoral importance	Social/cultural attachment to activity	Diversity of livelihood option	Dependency levels on coastal habitats	SEVI
Aquarium fishers	medium (2)	low (1)	high (3)	high (3)	high (3)	**medium to high (2.4)**
Municipal fishing: demersals, coral reef fish	high (3)	high (3)	low to medium (1.5)	low to medium (1.5)	high (3)	**medium to high (2.4)**
Commercial fishing: demersals, coral reef fish	low to medium (1.5)	high (3)	low to medium (1.5)	low to medium (1.5)	high (3)	**medium to high (2.1)**
Coastal aquaculture (seaweeds)	low to medium (1.5)	high (3)	medium to high (2.5)	medium to high (2.5)	medium to high (2.5)	**medium to high (2.4)**
Coastal aquaculture (ponds)	low (1)	medium to high (2.5)	low (1)	low (1)	high (3)	**low (1.7)**
Small pelagics fishing, municipal	high (3)	high (3)	low (1)	low (1)	medium to high	**medium (2.1)**
Small pelagics fishing, commercial	low (1)	high (3)	low (1)	low (1)	medium to high	**low (1.7)**
Tuna fisheries (municipal)	high (3)	high (3)	low (1)	low (1)	medium to high	**medium (2.1)**
Tuna fisheries (commercial)	low (1)	high (3)	low (1)	low (1)	medium to high	**low (1.7)**

From a purely socio-economic perspective, therefore, the most vulnerable fishing activities are aquarium fishing, municipal fishing for demersals and coral reef fish, and coastal aquaculture. Aquarium fishing is highly dependent on coastal habitats (coral reefs), is a community activity, and is practiced in communities with few livelihood options. These factors influenced the vulnerability ratings, despite the relatively high incomes (low income vulnerability) and minimal contribution to the economy. Municipal fishing for demersals and coral reef fish also rated high due to the low incomes of fishers (therefore, High vulnerability), high importance in terms of employment and food security, and high dependency on resource.

The **second step** was to arrive at the assessed impact of climate change on coastal habitats associated with particular kinds of fishing activities, to be used as a biophysical overlay. This was achieved through an assessment by experts on the status of fisheries based on accessed data, consultations and workshops. Scoring for the biophysical overlay followed the procedure to get the SEVI. The result was then averaged out with the SEVI to arrive at a Climate Change Vulnerability Index (CCVI) as in Table 52.

Table 52. Summary climate change vulnerability index (CCVI) matrix for fisheries in the Verde Island Passage.

Type of fishing	Climate change impact to associated coastal habitat	SEVI	CCVI
Aquarium fishers	3.0	2.4	2.7
Municipal fishing: demersals, coral reef fish	3.0	2.4	2.7
Commercial fishing: demersals, coral reef fish	3.0	2.1	2.6
Coastal aquaculture (seaweeds)	3.0	2.4	2.7
Coastal aquaculture (ponds)	2.5	1.7	2.1
Small pelagics fishing, municipal	2.5	2.1	2.3
Small pelagics fishing, commercial	2.5	1.7	2.1
Tuna fisheries (municipal)	2.5	2.1	2.3
Tuna fisheries (commercial)	2.5	1.7	2.1

Overall vulnerability assessment

Following the suggested methodology, the vulnerability of the fisheries sector was then assessed.

i. Aquarium fishing: HIGHLY VULNERABLE

Aquarium fishing was found to be HIGHLY VULNERABLE to climate change because income vulnerability ranged from Medium to High, there was high dependence of coral reef conditions and biodiversity of fish, which was in turn related to biophysical processes likely affected by increasing sea surface temperature. Income levels were also expected to be negatively impacted by increasing operational costs (e.g., travel to farther distances and inability to stay in the water for long hours especially during bad weather). Social attachment to activity was HIGH especially in the case of Barangay San Andres. It was also observed that in Barangays in Looc and Lubang where this is practiced, the communities are highly integrated. With respect to its sectoral importance, aquarium fishing has low vulnerability due to the small number of fishers involved and minimal impact on food security.

Assuming the most conservative income for the “mano mano” fisher, i.e., P4,600 per month, and further assuming that a household consists of five individuals including the fisher himself, the annual per capita income was estimated at P11,040, lower than the poverty threshold for all three provinces. If the incomes used were on the higher side, i.e., P12,000, the poverty threshold levels are attained for all provinces. For this paper, we assumed the more optimistic approach where, the vulnerability with respect to income was scored as MEDIUM, i.e., an average of the conservative estimate and the high-end estimate.

There was also HIGH vulnerability with respect to diversity of livelihood options due mainly to the relative isolation of the fishing communities (especially during typhoon months), and lack of opportunities in the trade and service sectors. This was more pronounced in the case of Verde Island and Looc, where farming opportunities are not as numerous as in Lubang.

ii. Tuna fisheries: VULNERABLE
At least 15% of fisheries production in all three provinces consisted of tuna (skipjack, yellowfin, and big eye). For the last three years from 2005 to 2007, the three provinces collectively caught, on average, 6,000 MT a year valued at P400 million pesos,. Data from BAS indicated that Batangas province earns about P180 million per year, consistent with the findings of Soliman (unpublished manuscript) that together, Mabini and Tingloy fisheries have a value of P172 million (including demersals).

Since both municipal and commercial sectors exploit the tuna fisheries, the disaggregation of volume and value was done by determining the percentage contribution of the two sectors to total production. In Verde Island Passage, the ratio of tuna catch is 1:4 with the municipal sector contributing 25% of production. In terms of value, the municipal sector earns about P32 million compared to P95 million for the commercial sector.

Municipal tuna fisheries were found to be more vulnerable to climate change than commercial fisheries (Table 6). Income from municipal fishers contributed to less than half of the poverty threshold especially in Mindoro—even assuming that municipal fishing exploited tuna, small pelagics and demersal fisheries.

Shifting of tuna aggregations to deeper waters will not bode well for the municipal sector and incomes are bound to decline even further as operational costs increase. The commercial sector will be better able to accommodate these changes in tuna behavior. Being a migratory species, tuna may not be directly influenced by habitat conditions; however, impacts on the food chain due to changing biophysical conditions, and generally, on food availability for tuna poses a larger potential issue.

Tuna is an important food fish and substantial numbers of people depend on tuna for livelihood; thus, it was found to be highly vulnerable in terms of its contribution to the economic sector. There was a lack of data to suggest that tuna fishing approximates a social activity or that tuna fishers are not engaged in other forms of livelihood but we assumed that vulnerability was low due to general engagement of fishers in other economic activities such as trade, services, and other seasonal employment (especially in Batangas province).

The SEVI for tuna was on the low side; however, when the climate change impacts were considered, the CCVI showed that tuna are mildly vulnerable due to potential changes in tuna behavior.

iii. Small pelagics: VULNERABLE
Due to its contribution to fisheries production in the Verde Island Passage and food security, the small pelagics fishery is highly vulnerable to climate change impacts. Incomes of municipal fishers may be taken as similar to that of tuna fisheries; thus, municipal fishers are vulnerable due to lower incomes.

Small pelagic fish are known to react to changes in temperature and this may well be happening in Verde Island Passage where temperatures have increased, on average, by about 4°C. As in tuna fisheries, we assume that this fishery does not constitute a social activity and that other forms of livelihood are gaining importance in the aggregation of household income. In Bauan, Batangas, for example, focus group discussion participants reported that currently only 50% of the community are fishers as opposed to 80-90% fifty years ago. This indicates the broadening of income sources in the province, which may not yet be true for the Mindoro provinces. As with tuna, the SEVI of small pelagics indicates a low socio-economic vulnerability; however, when coupled with climate change impacts, the CCVI shows a higher index.

iv. Demersals: VULNERABLE
Production trends in the demersal fishery mirror the pattern of exploitation. Demersal fisheries tend to be overexploited first and this is the case for the Verde Island Passage fisheries. Production levels are below 10,000 MT per year and the threat posed by climate change is high because of the high dependence of demersal species on coral reef and soft bottom communities.

As in the case of small pelagics, municipal fishers are more vulnerable than commercial fishers due to already low incomes but also due to their inability to adapt by changing gear or by mechanization. The assumptions pertaining to social activity and diversity of options are the same as for small pelagics and tuna.

v. Seaweeds: VULNERABLE
Seaweeds resulted in a Medium to HIGH SEVI due to its economic importance, its role as an alternative livelihood provider for women, and its dependence on water quality conditions. When climate change impacts are overlain on the socio economic vulnerability for seaweeds, the CCVI shows an increase due to the dependency of seaweed culture on water quality conditions and observations that an increase in sea surface temperature may have negative impacts on bottom farming of seaweeds.

vi. Fishponds: LOW VULNERABILITY
Fishponds are more vulnerable to coastal inundation and decrease in water especially during dry seasons;

thus, the CCVI was low. Its SEVI is also on the low side due to the relatively low income vulnerability associated with aquaculture and the availability of livelihood options for owners and employees of fishpond establishments.

Assessment of adaptive capacity
Integrated Coastal Management, or Coastal Resource Management, and conservation efforts have been started in the Verde Island Passage. An MPA Network covering nine LGUs has been formed in partnership with LGU, PGENRO, WWF and other sectors/groups. CI, WWF-Philippines, and the provincial government of Batangas signed a tri-partite memorandum of agreement that formalized the mechanics of cooperation among the organizations.

Collaborative efforts among the three signatories were enhanced through existing mechanisms (e.g., Strategic Environmental Management Plan and Batangas Integrated Environmental Council). Verde Island Passage marine conservation program is integrated in the SEMP. The eight municipalities and one city included in the MPA network are Bauan, Lobo, Calatagan, Balayan, Tingloy, Nasugbu, San Juan, Mabini and Batangas City. However, the stakeholders in Calatagan do not have an integrated coastal management policy for their municipality.

The MPA Network formation in the Verde Island Passage has exerted peer pressure on other municipalities to conserve their marine resources. An enforcement strategy has been institutionalized at the provincial and nine coastal areas in the formation of the Bantay Dagat Baywatch Network. This network is composed of eight municipalities and one city. There are 280 members and about 75% are active. Bantay Dagat network meets on a monthly basis. Encroachment of commercial fishers in municipal waters reduced since the MPA and Bantay Dagat network was formed. In 2008, 11 cases filed in court that reached a resolution.

All 25 MFARMCs are organized and there are 4 IFARMCs located in Balayan Bay, Batangas Bay, Taal Lake, and Tayabas Bay.

Climate change impacts on the tourism sector in the Verde Island Passage and the sector's responses

Natural coastal and marine resources for tourism activities that could potentially be effected include foreshore areas dedicated to tourism, coral reefs used for scuba diving and snorkeling, as well as hotels and lodging facilities. The framework for the vulnerability assessment is summarized in Figure 45, showing how biophysical impacts are related to socio-economic impacts in the tourism sector. As measures of exposure, hazards that pertain to the biophysical climate change indicators are storm frequency and/or intensity, increase in sea surface temperature causing coral bleaching, or accelerated sea level rise. Measures of sensitivity, meanwhile, are related to the type and status of reefs and numbers of tourists as reef-dependent activities attract the most tourists.

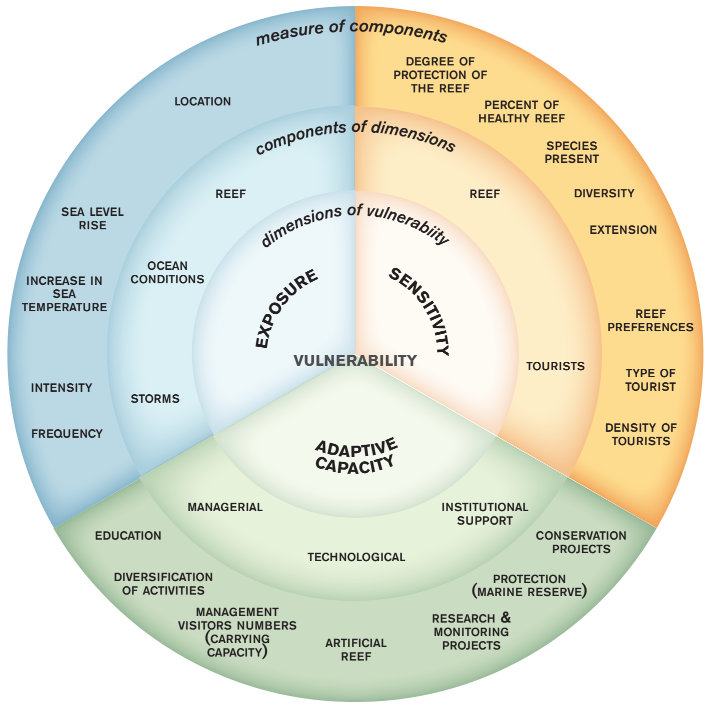


Fig. 45. Framework that was used to guide the vulnerability assessment.

For the assessment of the indicators that measure the different vulnerability components, a scoring system can be developed in collaboration with stakeholders, building on existing knowledge and data

With data from the created profile, the vulnerability assessment with inter-agency workshop participants concluded that the tourism industry is threatened by climate change as it can potentially destroy tourist-attracting natural resources. Coastal municipalities of Batangas, Lubang, and Puerto Galera will lose revenues and employment opportunities in such an event. Reef-dependent scuba diving and snorkeling are the activities that will be most greatly affected by the first two scenarios. In these cases, some recreational areas of the Verde Island Passage will be more vulnerable than others, i.e., scuba diving and snorkeling locations will be more negatively affected. In particular, the local economies of Mabini, Tingloy, Bauan, and Puerto Galera may suffer as climate change impacts increase.

On the other hand, the third scenario is projected to affect all tourism activities as tourists will obviously adjust their schedules and destination choices in places that have less potential of being hit by storms and extreme weather events. Should the third scenario occur, local income and employment will be negatively affected in all tourism sites. Following is a summary of potential responses indicated by the workshop participants.

Scenario A: increase in sea surface temperature (SST)
Increase in sea surface temperature causes coral bleaching, making the activity less attractive to divers and snorkelers
No effect on the other tourism activities

Scenario B: accelerated sea level rise (ASLR)
Causes poor turbidity, reduced photosynthesis and chlorophyll production/coral drowning
Less interest/appreciation for snorkelers
Divers will have to go deeper underwater to see the corals; will have to exert more effort and additional cost; will involve higher risk for divers
Positive impact: beneficial to some corals; will be undisturbed
No effect on the other tourism activities

Scenario C: increase in frequency and intensity of typhoons (STORMINESS)
Tourism facilities are damaged; additional construction costs for renovation and repair
Increase in unemployment and underemployment
Decreased livelihood opportunities
Less revenue collection
Destruction of the natural and man-made resources
No tourism activities in the presence of typhoons

Overall vulnerability assessment

Based on the above scenarios and the potential impacts on the tourism sector, the participants ranked the impacts and assigned scores to determine the overall vulnerability due to climate change. For each climate projection with high likelihood of occurrence, vulnerability was assessed in terms of exposure and sensitivity (1=Low, 2=Medium, 3=High). Table 53 provides a summary of the scores.

Table 53. Vulnerability assessment in the tourism sector, Verde Island Passage, 2009.

Activity/climate change impact	Sea surface temperature	Accelerated sea level rise	Storminess
Wind Surfing	1	1	3
Diving	3	3	3
Snorkeling	3	3	3
Swimming	1	2	3
Boat Trips	1	1	3
Kayaking	1	1	3
Jetski	1	1	3
Wakeboarding	1	1	3
Skim boarding	1	1	3
Banana boat	1	1	3

Reef-dependent tourism activities are clearly the most vulnerable, in contrast with those that are not dependent of reef condition.

Assessment of adaptive capacity

Methodology for the tourism sector was extended to the assessment of adaptive capacity. Participants ranked the capacities of the municipal and provincial levels of government, both of which have distinct mandates to manage the tourism sector of Verde Island Passage. Indicators were determined based on the participants' knowledge of management requirements to fulfill their mandates.

The Information, Education and Communication (IEC) indicator refers to production and distribution of information materials as well as workshops and general assemblies for information dissemination purposes. Policies refer to local ordinances, MOUs and environmental management plans formulated at the local level. Management bodies indicate the number of councils and organizations formed in addressing environmental issues related to the tourism sector. LGU and NGO partnerships reflect the number of active government agencies, private foundations and NGOs in environment-related programs, while stakeholder partnerships include people's organizations and local interest groups formed for the same purpose. Community involvement refers to environmental projects affecting tourism that involve community participation, e.g., giant clam seeding, MPA establishment, mangrove reforestation, abalone culture and coastal clean-ups.

Finally the last indicator is not specifically a management indicator; however it refers to the perceived resiliency and adaptive capacity of natural resources and ecosystems to climate change, based on their reported status and health. Using the rating scheme of 1=Low (High), 2=Medium, 3=High (Low) vulnerability (capacity), Table 54 contains the perceived adaptive capacity of VIP in responding to climate change impacts in the tourism sector.

Table 54. Adaptive capacity assessment in the tourism sector of the Verde Island Passage, 2009.

Management indicator	Status			Score	
	presence	absence	inadequate	municipal	provincial
IEC			x	2	2
Policies			x	2	2
Management body	x			2	2
LGU-NGO partnerships	x			1	1
Stakeholder partnerships/POs	x			2	2
Community involvement			x	3	2
Natural resources			x	2	2

Climate change impacts on the foreshore areas in Verde Island Passage and the sector's responses

Similar to the effects of climate change on the tourism sector, three climate change scenarios were discussed as potentially affecting foreshore areas, namely: increase in sea surface temperature, accelerated sea level rise, and increased frequency and intensity of typhoons (storminess). Participants believed that increase in sea surface temperature would not have any impact on man-made structures located in foreshore areas. Potentially heavy damages may arise when accelerated sea level rise and storminess occur. Many of these structures, particularly settlements and tourism facilities, are made of light materials that can easily be washed out or destroyed during strong storms. Accelerated sea level rise and storminess may cause severe damage to natural resources as well, particularly sandy beaches. These climate change scenarios could intensify coastal erosion, which is already happening due to the unabated infrastructure development in foreshore areas. Some municipalities have put up sea walls to prevent further damage to their coastline infrastructure facilities. Although these structures may prevent damages in the short-run, participants agreed that they could exacerbate coastal erosion, further damaging foreshore areas in the long-run. Table 55 summarizes the workshop discussions on potential impacts of climate change on foreshore areas of the Verde Island Passage.

Table 55. Climate change impacts on foreshore areas in the Verde Island Passage.

Climate change projection	Impacts on natural resources	Impacts on man-made structures
Increase in sea surface temperature	warming can cause coral bleaching and drowning	▪ none
Accelerated sea level rise (ASLR)	coastal erosion	▪ infrastructure damage; ▪ infrastructure and natural resources are highly exposed; ▪ materials and design of buildings and houses are not adapted to sea level rise; ▪ sea walls: barriers to sea level rise; ▪ foreshore area highly sensitive to ASLR, because of historical trends of foreshore development
Increased storm frequency and intensity	coastal erosion	▪ infrastructure damage ▪ infrastructure and natural resources are highly exposed ▪ materials and design of buildings and houses are not adapted to storm surges ▪ sea walls: exacerbate coastal erosion ▪ foreshore area highly sensitive to storm surges, because of historical trends of foreshore development ▪ deterioration of sea walls: debris get washed out, causing pollution ▪ transports seasonal waste from one coastal area to another; causes solid waste pollution on foreshore areas

Overall vulnerability assessment

Based on the above scenarios and the potential impacts on foreshore areas, the participants ranked the impacts and assigned scores to determine the overall vulnerability due to climate change. For each climate projection with high likelihood of occurrence, vulnerability was assessed in terms of exposure and sensitivity (1=Low, 2=Medium, 3=High). Table 56 provides a summary of the scores.

Table 56. Vulnerability assessment in foreshore areas of the Verde Island Passage, 2009.

Climate change impact	Coastal asset exposed	Exposure	Sensitivity
Sea surface temperature	none	0	0
Accelerated sea level rise	infrastructure	3	3
	mangroves	1	1
	beaches/coves	3	3
	delta	3	3
	hot springs	3	2
Storminess	infrastructure	3	3
	mangroves	2	1
	beaches/coves	3	3
	delta	3	3
	hot springs	2	3

In terms of adaptive capacity, participants ranked the capacities of the municipal, provincial and national levels of government in managing foreshore areas of Verde Island Passage as highly vulnerable. Indicators were determined based on the participants' knowledge of management requirements to fulfill their mandates. It was noted that municipal and provincial LGUs were not authorized to manage their foreshore areas, as this responsibility still rests with the national government. Granting of Foreshore Lease Agreements is still within the mandate of the Department of Environment and Natural Resources. Meanwhile, the Bureau of Fisheries and Aquatic Reforms, which in turn is under the Department of Agriculture, is the agency authorized to approve and issue Fishpond Lease Agreements, which may be located within foreshore areas of coastal municipalities.

Clearly, there is a lot of confusion and discord that can be created at the local level. As one participant of the workshop noted in plenary, management of both municipal lands and municipal waters has been devolved to LGUs, but foreshore area management is still within the mandate of national government. In effect, municipal and provincial LGUs consider themselves as having a very low adaptive capacity to climate change, simply because they do not have the mandate to carry out adaptation and mitigation plans in foreshore areas. Using the rating scheme of 1=Low (High), 2=Medium, 3=High (Low) vulnerability (capacity), Table 57 contains the perceived adaptive capacity of Verde Island Passage in responding to climate change impacts in foreshore areas.

Table 57. Adaptive capacity assessment in foreshore areas of the Verde Island Passage, 2009.

Capacity requirements	Municipal level	Provincial level	National level
IEC	3	3	3
Policy formulation and implementation	3	3	2
Management bodies	3	3	3
LGU-NGO partnerships	3	3	3
Community involvement	3	3	3
Disaster preparedness	3	3	3

Climate change impacts on the people's health and safety in Verde Island Passage and the sector's responses

Water- and vector-borne diseases, destruction of infrastructure in human settlements, loss of incomes, and even loss of lives, because of extreme weather events (sea surface temperature and storminess), flooding, and accelerated sea level rise, command large scale institutional response. Vulnerability assessment to aid adaptation is indeed expedient now.

USAID's Guidebook is a very useful reference in setting the scope of the assessment. The matrix below provides a summary of the threats affecting mariculture and affected freshwater resources as a source of income and food, human settlements, health, and conflict situations.

Following the guidebook, absent or incomplete baselines for the vulnerability assessment were first addressed in the project through appropriately prioritized agency data sources such as physical framework and development plans, socio-economic profiles, health reports, disaster records and infrastructure plans. These were accessed but re-read with a climate-sensitive perspective. Reconstructive data, based on experiences and observations, was separately done through interviews with technical staff with coastal residents. Multi-agency workshops for systematic consolidation and validation followed (Table 58).

Vulnerability assessment of health and safety

The climate change impacts from more frequent strong typhoons and the consequent intensified flooding, will potentially have large effects on livelihood and quality of life in settlements. (Note: vulnerability assessment of effects on livelihood is covered in the earlier sections.) Sea level rise is not yet seen by many people as a result of global warming/climate change. Unfortunately, effects

Table 58. Climate change threats to coastal communities.

Sector	Climate change impacts	Climate change threats
Mariculture	sea surface temperature increases; environmental changes e.g., salinity, precipitation levels, seasonality; changes in weather patterns and extreme weather events	▪ unpredictable changes in culture productivity; ▪ increase stress and vulnerability to pathogens and parasites in cultured organisms; ▪ overall decline in ocean productivity reduces supplies of wild fish used for fish meal for mariculture; ▪ reduce productivity and disrupted operations (loss of infrastructure and stock) due to extreme weather events; ▪ loss of income and investments
Freshwater resources	encroachment of saltwater into the water table, estuaries and coastal rivers; waves and storm surges reaching further inland; decreased precipitation	▪ saltwater intrusion of freshwater sources; ▪ increased saltwater intrusion, exacerbating water supply problems; ▪ contamination of water supply sources during flooding and coastal inundation; ▪ lack of potable water during extreme weather events
Human settlements	increasing coastal inundation; sea level rise raising water levels during storm surge; erosion, and extreme weather events	▪ more inland relocation; ▪ houses, buildings and infrastructure damage from increasing coastal storm intensity and flood exposure; ▪ reduced clearance under bridges;
Human health	changing weather patterns; extremely hot periods	▪ overtopping of coastal defense structures; ▪ degradation of natural coastal defense structures
Conflict	coastal land loss due to sea level rise	▪ injuries, illness, and loss of lives due to extreme weather events; ▪ malnutrition, water and food shortages during extreme events; ▪ heat stress from extremely hot periods; ▪ increased spread of vector-borne disease (dengue fever and malaria), waterborne diseases (diarrhea) and toxic algae (ciguatera) ▪ coastal land and resource scarcity or loss, and human migration; ▪ resource and water use conflicts due to scarcity; ▪ population migration to urban areas as ocean productivity and food availability declines and fishers are displaced; ▪ disruption of peace and order situation

Source: Adapted from the USAID *Guidebook for Development Planners: Adapting to Coastal Climate Change.*

on health and food safety are the least recognized. Hence, with the focus on human health and safety in the coastal environment, vulnerability indicators recommended include the following:

- flood-prone area;
- climate change effects on health and diseases that are water-, vector-, rodent- and food-borne as well as extreme temperature-related; and,
- climate change-ready physical infrastructure for disaster and risk management and ecosystem-based water supply system (distribution), drainage and sanitation.

i. Flood-prone area: VULNERABLE

A Flood-prone Index with scores from 1=Low, 2=Medium, 3=High vulnerability is a suggested tool. As a case study, flood prone areas in all municipalities on the Batangas side of the Verde Island Passage that host hundreds of thousands of people are categorized into the following:

- Category 1: Almost flooded as a result of heavy rains aggravated by high tide or rise in water level or nearby seas, lakes, rivers, etc.
- Category 2: Flooded only after several days of heavy and continuous rains with subsequent rise in water level or lakes, seas, dikes, rivers and canals
- Category 3: Flooded only after several days of exceptionally heavy or continuous rains.
- Category 4: Never experienced flood but present environmental condition in the area warrant LGU's concern on flood, flash flood, land slides and mud slides.
- Category 5: Residential areas, national and provincial road networks prone to landslide and mudslides.

This scale indicates vulnerability ranges from highest (Category 1) to lowest (Category 4 and 5). Table 59 summarizes the vulnerable population across all barangays, whether located in the interior sections or town center, as basis of Flood-prone Index A with scores from 1=Low, 2=Medium, 3=High vulnerability.

Flood-prone Index A was customized to rank municipalities where they are most vulnerable to flooding under Category 1 and 2 only (rains with subsequent rise in sea water level or near seas, dikes other waterways in coastal areas). The following among the province-wide Batangas side of the Verde Passage had the greatest number of communities and population exposed to floods aggravated by water level rise: Nasugbu (37 out of 42 barangays) and Calatagan (20 out of 25 barangays) with a vulnerability rating of 3 (high), followed by Lian (10 of 19), Bauan (16 out of 40) and Lemery (18 out of 46 barangays) with a rating of 2 (medium).

Focusing on only the coastal areas in these municipalities to emphasize marine adaptation to climate change, an adjusted Flood-prone Index B (only for the scaled down area) gives Calatagan and Tingloy (for its size) a score of 3 (Table 60). They are highly vulnerable to flooding where it is most likely to happen and where they have the greatest number of coastal barangays, although Calatagan, Nasugbu, Lemery and San Juan have the largest exposed population.

Testing the use of the Flood-prone Index in the rest of Verde Island Passage provinces would be beneficial to expand the vulnerability assessment.

Table 59. Vulnerable population in selected flood-prone municipalities, Batangas-wide.

Municipality	Category 1		Category 2		Category 3		Category 4		Category 5		Total population
	barangays	pop.	barangays	pop.	barangays	pop.	barangays	pop.	barangays	pop.	
Lemery	12	16,559	6	7,041	4	5,134	none	none	4	4,202	**32,936**
Lian	5	2,651	5	1,925	1	288	1	288	1	296	**5,448**
Balayan	13	18,501	3	23,032	8	21,463	4	6,218	none	none	**69,214**
Calatagan	5	10,206	15	25,819	none	none	1	1,581	none	none	**37,606**
Nasugbu	11	28,876	26	53,013	26	53,013	2	3,168	none	none	**85,057**
Bauan	3	5,032	13	21,530	none	none	1	491	none	none	**27,053**
Lobo	none	none	5	5,351	3	5,284	11	9,279	5	7,332	**27,246**
Tingloy	2	5,400	2	400	2	1,200	none	none	1	1000	**8,000**
Mabini	none	none	2	2,608	none	none	2	3,374	none	none	**5,982**
San Juan	none	none	8	15,557	8	14,707	18	27,719	none	none	**57,983**
Total	**51**	**87,225**	**85**	**156,276**	**26**	**48,076**	**40**	**52,118**	**11**	**12,830**	**35,525**

Note: number of flood-prone barangays across all categories is not cumulative.

Source: Provincial Disaster Coordinating Office, Batangas, 2009.

Table 60. Flood-prone index, coastal municipalities in Batangas.

Municipality	Total number of barangays	Number of barangays Cat. 1, 2	Percentage	Population vulnerable to flooding	Flood-prone index-A	Barangay along VIP	Percentage	Population along VIP	Flood-prone index-B
Balayan	48	16	33	41,533	1	11	22.91	20,873	1
Bauan	40	16	40	26,562	2	10	25.00	24,348	1
Calatagan	25	20	80	36,025	3	16	64.00	34,433	2-3
Lemery	46	18	39	23,600	2	13	28.26	27,149	1
Lian	19	10	52	4,576	2-3	6	31.58	19,114	1
Lobo	26	5	19	5,351	1	10	38.46	18,589	2
Mabini	34	2	6	2,608	1	13	38.24	20,616	2
Nasugbu	42	37	88	81,889	3	7	16.67	29,488	1
San Juan	42	8	19	15,557	1	15	35.71	26,537	2
Tingloy	15	4	26	5,800	1	15	100.00	18,548	3
Total population along the VIP	**579**					**152**	**26.25**	**358,518**	

ii. Climate change-related diseases and effects on health: VA for integration in the institutional framework

With exposure to flooding because of storminess and accelerated sea level rise or because of increased sea surface temperature, the presence or absence, magnitude and trending of the following direct effects on health are aspects that require inclusion in the climate change adaptation framework, policies, and plans for the sector:

- diseases that are temperature-related, water and food-borne, vector- and rodent-borne;
- effects of food and water shortages;
- extreme temperature-related health effects; and,
- mental, nutritional, infectious health effects.

Following the example of the Flood-prone Index, the impacts on health and safety can also be used with scores of 1=Low, 2=Medium, 3=High vulnerability to mainstream adaptation. Below are health implications of climate change that the vulnerability assessment can cover. (Regular health services and facilities do not suffice since those are commonly confined to maternal and child health care, control of diarrheal diseases, micronutrient supplementation, family planning, TB control program and cardiovascular disease.)

- Even if not yet experienced, sea level rise can lead to salt water intrusion in and pollution of the water supply. Pollution is aggravated by dumping of industrial and domestic waste and oil spills.
- Marine productivity decreases as sea surface temperature increases and thus results in unsafe and reduced food. Harmful algal blooms (ciguatera) occur. Algal blooms, though of non- toxic variety, have been observed for the first time in Balayan Bay in 2002. This is being aggravated by inorganic fertilizer run off and domestic waste dumping.
- There is increased spread of vector-borne disease (dengue fever and malaria) and waterborne diseases (diarrhea).
- Natural disasters cause injuries, illness, loss of life.
- Heat stress is experienced from extremely hot periods.
- Health and food service delivery is disrupted due to damage to infrastructures, roads and bridges. Malnutrition and food shortages during extreme events are experienced.
- There is increased emotional and psychological stress due to calamities and loss of livelihood.

As an added dimension, the assessment can be carried out according to geographic scope, population and temporal scale when dealing with infection and reduced access to basic services. Systematic documentation and monitoring of health and safety aspects, even if qualitatively, will guide responses in adaptation. These are the next steps to be pursued to complete the full vulnerability assessment.

iii. Climate change-ready physical infrastructure for disaster and risk management and ecosystem-based water supply system (distribution), drainage and sanitation

Safety issues generated by storminess and accelerated sea level rise as well as by increased sea surface temperature apply not only to the physical infrastructure for foreshore development but for coastal communities in general. Vulnerability to the destruction of physical infrastructure cited in Table 32 indicates direct effects on quality of life and can result in injuries, illness, loss of incomes and lives.

- Destruction of infrastructures, transport and utilities destabilizes the safe delivery of basic services such as food, water and health.
- Disaster and risk management plans are inadequate.
- There are no management plans for river-to-sea linkages for flows of water, nutrients, soils and species.
- The natural coastal defense structures such as mangroves that can serve as buffer against storm

surges have been converted into fishponds and other uses.

- Housing development is increasing in coastal areas (example is Nasugbu).
- The domestic water supply needs are being provided by existing water districts, municipal water system and barangay waterworks associations, with groundwater as the main source of potable water, however, extraction is not regulated.

These combined factors can explain weak water supply system, sanitation and drainage beyond physical infrastructure. Human settlements in coastal areas are commonly inhabited by fisherfolk in precarious economic existence, live in unplanned and temporary settlements, have limited access to clean water and sufficient nutrition, lack education, sanitation and adequate health-care provision, and lack social status. Also, the informal nature or remoteness of their settlements means that relief efforts are less likely to reach them. These situations are aggravated by the lack of public knowledge of the impacts of climate change and possible adaptation measures.

Overall vulnerability assessment

Based on the potential impacts of climate change, experts' advice based on the review of agency reports and inter-agency workshops, scores were assigned that reflect the overall vulnerability in health and safety. For each climate projection with high likelihood of occurrence, vulnerability was assessed in terms of exposure and sensitivity (1=Low, 2=Medium, 3=High). Table 61 provides a summary of the scores.

Assessment of adaptive capacity

Adaptive mechanisms in health and safety are present in relation to health services which are devolved to the LGU, as well as coastal resource management (discussion included in the fisheries sector), disaster response and solid waste management. These are positive investments that can steer programs in adaptation and even mitigation (Table 62).

Table 62. Assessment of the climate change adaptive capacity for health and safety for the Verde Island Passage, 2009.

Capacity requirements	Municipal level	Provincial level	National level
IEC	3	3	3
Policy formulation and implementation	2	2	3
Management bodies	2	2	2
LGU-NGO partnerships	3	3	2
Community involvement	3	3	3

To link concerns about climate change adaptation to health and safety impacts in the Verde Island Passage is a big challenge. As such adaptation is still being incorporated into governance: the goals, framework, strategy, and action plans are still being addressed by the government. The basic units of management are operational, but the demands of responding to climate change needs scaling up in strategies and operations.

A Provincial Disaster Coordinating Office (PACD) or a City Disaster Management Coordinating Council is expectedly a big challenge in all areas. Their disaster risk and management plans are still currently being formulated but the following programs that are functional include the organization of Barangay Disaster Coordinating Councils, formulation of contingency plans for different events at the municipality level, implementation and periodic updating on communities and populations in vulnerable areas and also on evacuation centers.

Table 61. Health and safety vulnerability assessment of the Verde Island Passage, 2009.

Indicators of VIP vulnerability	Vulnerability within 10 years	Vulnerability within 50 years
Flood-prone index (by area category)		
Category 1: Almost flooded as a result of heavy rains aggravated by high tide or rise in water level or nearby seas, lakes, rivers, etc.	high	high
Category 2: Flooded only after several days of heavy and continuous rains with subsequent rise in water level or lakes, seas, dikes, rivers and canals.	high	high
Category 3: Flooded only after several days of exceptionally heavy or continuous rains.	moderate to high	high
Category 4: Never experienced flood but present environmental condition in the area warrants LGU's concern on flood, flash flood, land slides and mudslides.	moderate to high	high
Category 5: Residential areas, national and provincial road networks prone to landslide and mudslides.	moderate to high	high
Health and disease Index (direct effect on health)		
▪ diseases that are temperature-related, water and food-borne, vector- and rodent-borne	moderate to high	high
▪ food and water shortages	low to moderate	moderate to high
▪ extreme temperature-related health effects	low	moderate to high
▪ mental, nutritional, other infectious health effects	low	low to moderate
CC-ready and ecosystem-based physical infrastructure (direct effect on health)		
▪ DRM physical infrastructure	moderate to high	high
▪ water supply system	low to moderate	high
▪ drainage system	moderate to high	high
▪ sanitation system	moderate to high	high

Solid waste management as mandated by R.A. 9003 has set up plans at all levels of the LGU through Solid Wastes Management Board with multi-sectoral representatives as members. There are also health service and social welfare agencies/ institutions/ assistance centers that work at all levels of governance, with programs and services such as formal and non-formal education, skills training, spiritual enrichment, social services, livelihood assistance, and cooperative development. The Fishery and Aquatic Resource Management Council (FARMC), Community Environment and Natural Resources Office, Protected Areas Management Board and Community-Based Forestry Management Board are key units mandated to manage and protect the environment. Meanwhile, community and household capacities and means in adapting to health emergencies need to be strengthened and enhanced. Disasters in recent events have tacitly demonstrated the impact of climate change and how adaptation is urgently warranted.

Conclusions and recommendations

Performing a vulnerability assessment and suggesting adaptation and mitigation strategies is not a one-time activity. All previous studies and guidebooks point to the need to treat this as an iterative process, involving as many stakeholders as possible. Baselines as starting point in vulnerability assessment have been crafted opportunistically in the research. Whether through accessed agency data sets or generated from participative methods, benchmarks that are expected from governance units revealed huge gaps that could provide concerned agencies with a sound basis for a comprehensive vulnerability assessment and planning adaptation measures.

In the course of profiling foreshore areas, for health and disaster as well as risk mitigation, it was noted that many of the issues are institutional in nature and can be resolved even without having to factor in climate change. As consensus, participants in the project recommended the following cross-cutting measures that may be implemented immediately at the LGU level to facilitate vulnerability assessments:

- Draft municipal profiles that are climate change smart and efficiently used, systematize baseline and M&E inclusive of CC.
- Establish a database system for use in synergy by mandated agencies.
- Review existing environmental policies and ordinances related to ecosystem-based adaptation goals, framework and strategies, have policy reforms and mechanisms for these (across household, community, institutional level).

Follow-up activities are best pursued immediately, to document and assess the process and lessons learned along the way. More importantly, the identified adaptation and mitigation options should be given priority in implementation by the stakeholders and partners if conclusions of the vulnerability assessment exercise indicate the area is highly vulnerable to climate change.

Scores of recommendations are presented to management units to address climate change impacts across sectors. Institutional problems and development issues are recognized as serious constraints that efforts in adaptation and mitigation have to overcome, as well as challenges such as competing directions in development; corruption; lack of political will; priorities in the use of public funds; destructive, unregulated use of natural resources (mining, over fishing, etc.); and conflicting laws or their non- or weak enforcement.

Fisheries

The exercise confirmed that climate change affects different types of fisheries as source of livelihood and domestic food in various ways but mostly negatively due to decline in production and productivity as well as shifting operational regimes. Virtually all types of capture fisheries in Verde Island Passage are vulnerable to climate change due to its direct impacts resulting from increase in sea surface temperature (small pelagics and seaweed culture) and indirect impacts on coastal habitats that provide nursery grounds for important fish and invertebrates.

Aquarium fishing is one of the more vulnerable sectors in the fishery because the reef fish are highly dependent on reef health. An aggravating factor is the general prohibition imposed by the LGUs on this activity due to its historical association with cyanide. Tuna fishing and fishing of small pelagics are vulnerable, particularly in the municipal sector which may not adapt immediately to changing operational regimes. Mechanization and changing gears is an option for adaptation but this may not be very prudent in the light of overfishing, and may negate efforts to rehabilitate coastal habitats. Maximum Sustainable Yield (MSY) or its best approximation should be estimated to enable informed decision making.

- Prepare most vulnerable fishing activities by training in alternative livelihood.
- Implement coastal habitat protection as short term but sustained adaptation methods.
- Gear adaptation or mechanization as pelagic fish shall move farther offshore **provided** that level of fishing effort does not exceed sustainable limits and that carrying capacity is first determined.
- Educate seaweed farmers on appropriate methods least impacted on by increase in sea surface temperature.
- Generate area based/site based data and improve catch statistics collection.
- Maintain logbooks or data collection at landing sites (specifically on areas fished) may contribute to the overall understanding of climate change impacts on fisheries, in particular, and to overall fisheries utilization, in general.
- Confirm, through focused research, impacts of increasing sea surface temperature and accelerated sea level rise on commercially important species.
- Diversify livelihoods of coastal communities.

Tourism sector

Policy and implementation mechanisms were identified, all of which could address climate change impacts but will bring in other benefits in pursuit of environmental management, such as the following:

- Strictly implement existing laws at both the national and municipal levels.
- Develop sustainable financing mechanisms, such as implementing user fees in other areas and covering recreational activities other than scuba diving.
- Strengthen existing organizations and management bodies.
- Increase technical expertise on survey and monitoring of underwater resources at the local level.

Recommendations that directly deal with climate change impacts were also provided by inter-agency workshop participants:

- Include CC adaptation strategies in all AIPs.
- Convene all major stakeholders of the tourism industry to formulate an adaptation plan in dealing with CC, to include resort owners, boat operators, and tourism-related associations.
- Provide incentives for community/PO to get their involvement and commitment.
- Develop reader-friendly information materials and multimedia IEC materials on climate change.

Foreshore development

Many of the management recommendations for foreshore area management deal with institutional changes within the current government set-up as well as completion of baseline and monitoring records. National government agencies are being asked to issue policies that will mandate LGUs to manage their respective foreshore areas. LGUs are recommending that foreshore area management be devolved to them, so that they can appropriately issue a moratorium on Foreshore Lease Agreements (FLA). Should management remain within the DENR, LGUs recommend stricter monitoring, shortening of FLA periods, and revocation of agreements for those that do not comply with the FLA conditions.

Following is a list of management recommendations being made for national government agencies. Recommendations specific to addressing climate change include the following:

- Implement adaptive building design to address accelerated sea level rise and storm surges.
- Allocate budget for addressing climate change impacts.
- Institutionalize Task Force on Climate Change at all levels of government.

Within the mandate of LGUs, a number of recommendations emerged that may address climate change impacts but can result in other benefits as well:

- All LGUs should create and designate MENRO.
- Implement mangrove reforestation.
- Translate policies, plans, etc. for action by barangay chairpersons.
- Strictly enforce the building code.
- Strengthen LGU-NGO partnerships.
- Include upland stakeholders in CRM planning and activities.

Specific to management of foreshore areas are as follows:

- Devolve FLA approval to LGUs, so the latter can issue moratorium on FLAs.
- DILG to mandate LGUs to manage foreshore areas.
- DENR should monitor FLAs.
- Revoke agreements between leases and government for non-compliance of terms.
- Shorten FLA term for foreshore areas that are titled.
- Encourage owners to undertake mangrove reforestation.
- Revoke titles of abandoned foreshore areas.
- Amend existing policies, resolutions, etc. to specify rules on foreshore areas.

In order to address foreshore area management more effectively, participants recommend undertaking research in the following areas:

- Complete physical inventory and socio-economic profile of foreshore areas.
- More research on coastal erosion.
- Complete inventory of environment-related policies.

Health and food safety

People's health an be compromised by abrupt changes in atmospheric temperature, accelerated sea level rise and saltwater intrusion into groundwater sources. Immediate negative impacts can occur to livelihood and income, food security, health, education, human settlement and housing.

- Have health and safety in the climate change adaptation framework and strategy of the lead mandated agency (DOH, LGU).

- Build up from local to national level a public policy to address demographic pressures on socio-economic and natural resources.
- LGUs to function as coordinative mechanism for climate change adaptation concerns: health and food security with coastal and marine-based resources; health and safety with water, settlement expansion, infrastructure.
- Plan for the current food and health security systems and infrastructure in anticipation of food scarcity and diseases brought about by climate changes.
- Increase human safety, have disaster risk reduction, have flood hazard mapping, disease control.
- Have a disease surveillance mechanism.
- Put in place plans and programs to provide for safe water especially in times of calamities.
- Use surface water instead of groundwater for both domestic and agricultural use.
- Regulate ground water extraction.
- Protect watersheds.
- Strictly enforce building code.
- Relocate coastal communities.
- Craft policy to declare the 100 meter zone from the highest tide as a no-development zone and off limits to human settlements.
- Manage domestic and industrial waste properly to pre-empt its aggravate role in climate change impacts.
- Set up measures to manage domestic wastes and agricultural run off have to be put in place to reduce the possibility of toxic algal blooms.

As an opportunity in iterative learning, the vulnerability assessment presented in this report certainly has a lot of room for improvement and refinement. Furthermore, there are quite substantial data requirements that are needed before a full assessment can be undertaken. Nevertheless, most if not all of the data requirements are possibly available at government and local offices, or can eventually be generated when data gathering is improved. Quick surveys can be conducted by stakeholders to secure some of the data requirements that are not available easily. Once it has been applied in the Verde Island Passage, the stakeholders should take note of which parts of the framework are useful and which ones can be improved. Only then can it be subjected to replication in other conservation corridors in the country.

References

A. Special Studies

Arias, J. 2009. Economic Vulnerability and Possible Adaptations to Coastal Erosion in San Fernando City, La Union, Philippines. EEPSEA, Singapore.

Bigano, Andrea, Hamilton, Jacqueline M. and Tol, Richard S. J., 2006. The Impact of Climate Change on Domestic and International Tourism: A Simulation Study, (June 1, 2006). FEEM Working Paper No. 86.2006; CMCC Research Paper No. 04.

Conservation International (CI). (n.d.) The Verde Island Passage Marine Biodiversity Conservation Corridor.

__________. (n.d.) Sulu-Sulawesi Seascape, Ensuring Living Seas for Generations. CI, Department of Environment and Natural Resources (DENR), and Haribon Foundation. (2007). Priority Sites for Conservation in the Philippines: Key Biodiversity Areas.

De la Paz, Ma. Corazon G. and Colson, Lisa. (October 2008). Population, Health, and Environment Issues in the Philippines: A Profile of the ARMM. Washington, D.C.: Population Reference Bureau. (PRB)

Ehmer, Philipp and Eric Heymann, April 2008. Climate Change and Tourism: Where Will the Journey Lead? Deutsche Bank Research, Frankfurt, Germany.

Gonzales, Minerva. July-August 2009 Report prepared for the CI Verde Island Passage Vulnerability Assessment.

Foundation of the Faculty of Science of the University of Lisbon, 2009. Climate Change and Tourism in Portugal: Potential Impacts and Adaptation Measures (CLITOP). Portuguese Science and Technology Foundation, Lisbon, Portugal.

Hamilton, J. And R. Tol, 2007 (?). The Impact of Climate Change on Tourism and Recreation. Centre for Marine and Climate Research, Hamburg University, Hamburg Germany. http://www.anilaodiving.com/divingservices.htm

Lusterio-Berja, Clarinda and Colson, Lisa. (October 2008). Population, Health, and Environment Issues in the Philippines: A Profile of the Calabarzon (Region 4-A). Washington, D.C.: PRB.

Moreno, Alvaro and Susanne Becken, 2009. "A climate change vulnerability assessment methodology for coastal tourism", Journal of Sustainable Tourism, 17:4,473 — 488.

Peeters, P. (undated) The Impact of Tourism on Climate Change. Centre for Sustainable Tourism and Transport, NHV University for Applied Sciences, Breda, Netherlands.

Munday, Philip L. 1,2 , Geoffrey P Jones 1,2 , Morgan S Pratchett 1 and Ashley J Williams 3

Climate change and the future for coral reef fishes. 1 ARC Centre of Excellence for Coral Reef Studies, James Cook University, Townsville, Qld 4811, Australia; 2 School of Marine and Tropical Biology, James Cook University, Townsville, Qld 4811, Australia; 3 Fishing and Fisheries Research Centre, School of Earth and Environmental Sciences, James Cook University, Townsville, Qld 4811, Australia . Fish and Fisheries 9(3): 261-285

Perez, R., L. Amadore and R. Feir, August 1999. Climate Change Impacts and Responses in the Philippines Coastal Sector. Climate Research, Vol. 12:97-107,1999.

Partnerships in Environmental Management for the Seas of East Asian (PEMSEA). (2009). State of the Coasts of Batangas Province.

Population Reference Bureau (PRB). (2006). Making the Link in the Philippines: Population Health and Environment. Washington, D.C.: PRB.

Sales RFM. Vulnerability and adaptation of coastal communities to climate variability and sea- level rise: Their implications for integrated coastal management in Cavite City, Philippines, Ocean and Coastal Management (2009), doi: 10.1016/j.ocecoamN.2009.04.007

Scantlebury, M. (undated). The Impact of Climate Change on Heritage Tourism in the Caribbean: A Case Study from Speightstown, Barbados, West Indies. International Journal of Climate Change: Impacts and Responses, Volume 1, Issue 2, Florida, USA.

Simmons, D. 2009. The Impact of Climate Change on Australian Tourism Destinations: Developing Adaptation and Response Strategies. Sustainable Tourism Cooperative Research Center (STCRC), Government of Australia.

Simpson, M.C., Gössling, S., Scott, D., Hall, C.M. and Gladin, E. (2008) Climate Change Adaptation and Mitigation in the Tourism Sector: Frameworks, Tools and Practices. UNEP, University of Oxford, UNWTO, WMO: Paris, France.

Tompkins et al. 2005—"Surviving Climate Change in Small Islands". In Simpson, M.C., Gössling, S., Scott, D., Hall, C.M. and Gladin, E. (2008) Climate Change Adaptation and Mitigation in the Tourism Sector: Frameworks, Tools and Practices. UNEP, University of Oxford, UNWTO, WMO: Paris, France.

United Nations World Tourism Organization (UNWTO), the United Nations Environment Programme (UNEP) and the World Meteorological Organization (WMO), October 2007. Davos Declaration on Climate Change and Tourism: Responding to Global Challenges. Second International Conference on Climate Change and Tourism, Davos, Switzerland.

United States Agency for International Development, 2009. Adapting to Coastal Climate Change: A Guidebook for Development Planners. Coastal Resources Center-University of Rhode Island and International Resources Group (IRG)-USAID, USA.

B. Accessed Official Government Agency Records

Baatangas City Office of the Planning and Development Coordinator (OCPDC). Batangas City Socioeconomic, Physical and Political Profile, CY 2007.

Batangas Provincial Health Office. 2007 and 2008 A1, A2 and A3 records accessed June 2009.

Batangas Provincial Planning and Development Office (PPDO). 2006 and 2007 Provincial Socio-Economic Profiles/Physical Framework Plans and other records accessed June 2009.

Bauan Municipal Planning and Development Office (MPDO). (2003). Bauan Comprehensive Land Use Plan and Zoning Ordinance.

Municipalities of Lubang and Looc, National Economic Development Authority Region IV, and Development Planning and Environmental Management, Inc. (n.d.). Lubang Island Sustainable Tourism Development Plan.

Morella, Cecil. (May 2007). Verde Island Passage: Centre of Centre of Marine Biodiversity.

Marinduque and Romblon. Accessed from NSO Quickstat websites on 27 July-03 August 2009.

Occidental Mindoro PPDO. 2007-2009 records accessed August 2009.

Oriental Mindoro PPDO. Briefing Kit for 2008 and other records accessed August 2009.

_________. (2009). Verde Island Passage Marine Biodiversity Conservation Corridor Management Plan.

National Statistical Coordinating Board (NSCB). (2008a). Philippine Statistical Yearbook 2008.

___________. (2008b). Philippine Poverty Statistics, 2006. Accessed from http://www.nscb.gov.ph/poverty/2006_05mar08, on 14 August 2009.

National Statistics Office (NSO). (2008). 2007 Census of Population. Accessed from http://www.census.gov.ph/data/pressrelease/ 2008/pr0830tx.html, on 20 July 2009.

_________. (2008). 2007 Census of Population, Annual Growth Rates Per Province. Accessed from http://www.census.gov.ph/data/sectordata/2007/province.pdf, on 03 September 2009.

_________. (2008). Families with access to safe water and sanitary toilet facilities per region. Accessed from http://www.census.gov.ph/data/sectordata/ap2007/tx.html and http://www.census.gov.ph/data/sectordata/2007/ ap0703.htm, on 03 September 2009.

__________. (2008). Quickstat on Batangas, Occidental Mindoro, Oriental Mindoro

C. Miscellaneous

Lesaba, M.E., 2009. Fishing for Pets. Philippine Daily Inquirer article, April 19, 2009.

Chapter 3: Recommendations for adapting to climate change impacts

Climate change has already altered the balance of the oceans with serious and irreversible consequences for marine ecosystems and the services they provide. The disruption of ecological functions and ecosystem services has severe impacts on the well-being of human communities, especially in coastal areas like the Verde Island Passage, where human dependencies on the oceans are high. Immediate and substantial actions need to be taken to increase the adaptive capacity of coastal marine ecosystems and the people that depend on them. Adapting to climate change is the only solution to ensure ecosystems and human societies can survive and maintain their well-being when exposed to climate change impacts. To decrease vulnerabilities of the Verde Island Passage to climate change, the following recommendations should be implemented.

Implement:

- municipal management strategies that are climate change-smart and efficiently used, and ecosystem monitoring and evaluation that address climate change.
- sustainable aquaculture practices that minimize the impacts to the natural ecosystems (e.g., low density finfish pens and chemical-free shrimp ponds).
- a review of existing local, regional, and national policies and ordinances focused on resource management and reform to include ecosystem-based adaptation, and enable new frameworks where necessary.
- guidelines and best practices for coastal and foreshore development planning that take into account the potential for increased storm activity, salt water intrusion, and other climate change impacts.

Regulate:

- artificial reef development, channel dredging, and seaweed farming through zoning activities.
- the establishment of better enforcement of illegal fishing activities including blast fishing, cyanide fishing, and shark fin fishing.
- use of sustainable fishing gear to minimize bycatch.

Instigate:

- use of newly propagated accretion from eroded uplands for mangroves as a buffer against coastal erosion and large waves.
- the improvement and retrofit of existing infrastructure to make sure they can sustain climate impacts.
- appropriate engineering of ports, quarries, and foreshore development so as to not impact long-shore sediment movement.
- use of best management practices for fishing on coral reefs, seagrass beds, and mangrove forests, and increased enforcement towards illegal and destructive practices (e.g., dynamite fishing and push nets).
- enforcement against deforestation and extensive agriculture in the watersheds that promote high sediment runoff, causing coral reef degradation and the decline of coastal and offshore fisheries.

Establish:

- Marine Protected Areas to reduce current impacts, preserve biodiversity, and sustain fisheries, increasing the resilience and adaptive capacity of marine ecosystems to sustain climate change impacts.
- climate-smart Marine Protected Areas that apply adaptive management approaches to address current and future climate change impacts.
- outreach programs to create awareness and engage communities on climate change and its impacts on marine resources.
- enforcement patrol and communication tools among wardens within the local Marine Protected Area network.

Protect:

- areas of critical life stages of vulnerable fisheries species, e.g., siganids, and critical biological communities, e.g., upwelling areas.
- natural mangrove, seagrass, and coral habitats that act as natural coastal defense mechanisms, reducing erosional processes and buffering storms and other extreme weather events.
- a variety of habitats including seagrass, seaweed, and mangroves as they support various life stages of multiple fisheries species.
- areas (e.g., Mabini, Puerto Galera), species (e.g., whale sharks), and ecosystems (e.g., mangroves, coral reefs) that sustain important tourism activities, providing income for local communities.

Diversify:

- livelihoods for coastal miners (e.g., pebble picking) to reduce coastal erosion and enable revenues to derive from sustainable practices.
- livelihoods, particularly for climate change-vulnerable activities such as aquarium fishing.
- gear use, adaptation, and mechanization within sustainable limits to facilitate fishing as fish move farther offshore.
- opportunities for solid waste and chemical disposal that favor the spread of disease, pollution, and burial of important coastal ecosystems (e.g., seagrass meadows and mangrove seedlings).

Chapter 4:
Outreach and communication strategy

Miledel C. Quibilan [1] **and Giuseppe Di Carlo** [2]**, Lead Integrators**

Contributing Authors: Michele Reyes (consultant)

[1] Marine Science Institute, College of Science, University of the Philippines–Diliman, Quezon City, Philippines
[2] Conservation International–USA

Executive summary

Conservation International (CI)–Philippines conducted a vulnerability assessment for the impacts of climate change on marine biodiversity and related human well-being in the Verde Island Passage. The project investigated possible ecological effects of climate change in the region to inform stakeholders and build local support for such impacts. Initial workshops were held in Batangas, Occidental Mindoro, and Oriental Mindoro in February and March of 2009. These workshops served as venues for stakeholders to present their views about the effects of climate change on their environment and livelihoods, and to make recommendations for adaptation and mitigation. This communication strategy is a product of those workshops, and contains the actions and activities proposed by the stakeholders to specifically address the identified impacts. The results were validated at the culminating workshop in July 2009 where priorities and strategies were also identified.

The development of a communications strategy is an important component of a climate change vulnerability assessment. The goal of this strategy is to assess how the outcomes of the vulnerability assessment will be adopted and mainstreamed to the appropriate audiences.

This document includes recommendations for communicating basic information about climate change, and results of the vulnerability assessment, to communities in the Verde Island Passage. The strategy is based on output from stakeholders, drawn from a series of workshops held in Mindoro and Batangas in February and March of this year and validated at the Vulnerability Assessment (VA) workshop in July.

At the preliminary workshops, strategy objectives identified by participants revolved around three central themes: awareness and engagement, action/implementation, and funding. The target audiences included were elected officials, civil society groups, students and law enforcers, among others. The products used to address these needs and reach the necessary audiences fell into four categories: multimedia, education/training programs, exposure/field trips, and legislation. The time frames of these strategies generally did not exceed the political terms of elected officials (1-3 years).

During the VA workshop, stakeholders validated the results of the initial workshops and proceeded to strategize and prioritize actions to be taken. For all three main objectives, a top-down approach was the choice of the majority, with elected/appointed officials being the first-priority target audience for awareness/engagement, action/implementation and funding activities.

This document integrates the results of the three stakeholders' workshops and the validation workshop. The strategies were directly developed by stakeholders and identify climate change adaptation measures that can be easily integrated into municipal/provincial plans. These measures could also be implemented at the local/municipal scale using local funds. Securing other sources of funding—beyond the local level—was identified as the next step in adaptation fundraising.

Introduction

This paper consolidates and summarizes the results of stakeholder consultation workshops, which were part of Conservation International–Philippines' project: "Vulnerability Assessment of Marine Biodiversity and related human well-being in the Verde Island Passage (VIP) to climate change". The first three workshops, held in February and early March of 2009, were aimed at formulating an outreach and communication strategy for the VIP region. Validation of output was then done during the Vulnerability Assessment workshop, held in Batangas in July. Results of the prioritization and strategy-formulation sessions are also presented in this document.

About the workshops

Preliminary workshops (February and March 2009)

Two-day consultation workshops were conducted by CI–Philippines in three locations: Oriental Mindoro on 2-4 February (72 participants from 7 municipalities and 1 city), Occidental Mindoro on 25-26 February (29 participants from 4 municipalities), and Batangas on 3-4 March (37 participants from 8 municipalities and 1 city).

During these workshops, a perception survey was done and participating stakeholders revealed what they knew about climate change.

A 4-P design (Earle et al. 2006) was then used for the workshop. Participants were divided into groups based on their positions or functions. Each group was then asked to:

- Identify key **problems** of local governments regarding understanding climate change and its impacts on marine biodiversity and related human-well being and formulate objectives for a communications strategy based on the area's needs and the problems identified.
- dentify **key audiences** for the communications strategy. Specific actions that could be taken by each target audience were also identified as well as the possible incentives each could get for its involvement in such an endeavor.
- Enumerate specific **products** to deliver the messages related to the problem statement to reach target audiences.
- Formulate practical **plans** of action to fulfill the objectives identified at the beginning of the workshop.

Vulnerability assessment workshop

The validation of the draft communications strategy was done during Workshop 3 of the Vulnerability Assessment workshop. Participants were divided by province and their task was threefold:

- Validate the draft strategy produced during three preliminary workshops.
- Prioritize audiences and actions.
- Formulate strategies to target the identified priority audiences and activities.

Results

Preliminary workshops

Stakeholders drew up objectives for the communications strategy, with most of the suggestions revolving around three central themes: awareness/ engagement, action/implementation, and funding. Their target audiences included, elected officials, civil society groups, students, law enforcers and others. The products that they chose to communicate with were various forms of media, education/training programs, exposure/field trips, and legislation. Political terms of incumbent officials defined the timelines for most of the proposed activities (1-3 years) and the suggested strategies did not move above the provincial level—in fact, most were proposed for implementation at the municipal level.

The draft strategy drawn from the results, demonstrated the existence of a basic understanding of climate change, based mostly on its effects rather than understating the concepts. Many people stated that climate change was the result of human activities such as burning and pollution. However, others identified it with changing/extreme weather patterns, sea level rise, scarcity of food and loss of freshwater. The fact that most stakeholders defined climate change in terms of how it affected them and their immediate environment, is important to determine a successful communications strategy.

Draft plans drawn up by the stakeholders also demonstrated an awareness of identifying gaps or "needs". They identified the need to disseminate information on climate change and the need for funding for climate change projects as their most serious issues.

Stakeholders' realistic attitude towards the adoption of a communications strategy was reflected in the timelines they drew up for implementation, which generally stayed within the three year term of incumbent local officials. It is important to note that the participants in the stakeholders' workshops were largely employees of the local government (Table 63). This group made up over 85% of the attendees of the preliminary workshops, so it should come as no surprise that timeline planning often depends on political election schedules.

Table 63. Breakdown of participants of the preliminary workshops.

Designation	Percent of total
PENRO/PG-ENRO/MENRO	13.27
MAO	11.22
PPDO/MPDC	19.39
SP / SB	16.33
Mayors	2.04
Fisheries/Aquatech	9.18
Agritech	2.04
Tourism	4.08
Other government officials	8.16
NGOs	8.16
FARMCs	6.12

The full results of each preliminary workshop were outlined in earlier documents.

Vulnerability assessment workshop

Natural and social scientists who attended the Vulnerability Assessment (VA) workshop provided data and analyses of the vulnerability of the Verde Island to climate change. The main goals of the communications strategy are to use the results of the Vulnerability Assessment to:

- mainstream priorities; and,
- deliver climate change messages to key audiences

For the validation and prioritization part of the workshop, results were as follows:

Workshop 3—Part 1 and 2: Validation and Prioritization

*items in italics were added by the stakeholders during the validation process

Objective 1: awareness and engagement

Public/Target audience	Priority: Or. Min.	Occ. Min.	Bat.	Mar. and Rom.	Product	Or. Min.	Occ. Min.	Bat.	Mar. and Rom.	Implementers
Elected officials and local government units	1	1	1	1	▪ capacity building (seminars/dialogues)	2	1	1	1	▪ Mayors ▪ SB ▪ Bishop, religious sector ▪ DENR ▪ DILG ▪ Department of Education ▪ MHO ▪ MFARMC ▪ MAO/MENRO ▪ MPDO ▪ Provincial - Municipal Information Office
					▪ production/distribution/ display of IEC materials	1	2	2	2	
Civil Society Groups	2	4	5	5	▪ information/education campaign	1	1	1	2	▪ NGOs ▪ Academia ▪ Local media
					▪ *training and capacity building*	3				
					▪ multi-sectoral meetings on CC	2	2	2	1	
Farmers and fishermen	4	2	2	2	▪ *information/education campaign and advocacy*	1				▪ LGU ▪ DA ▪ NGOs
					▪ capacity building (forums and seminars)	3	1	1		
					▪ regular FARMC meetings	2	2	2		▪ Religious groups
General public	5	5	4	4	▪ pastoral letter or sermon	1	3	x		
					▪ community outreach	3	2	1		
					▪ meetings and fellowships	4	4	2		
					▪ multimedia presentations	2	1			
Schools - principals and teachers - students	3	3	3	3	▪ meetings and seminars	1	1	1		▪ NGOs ▪ Department of Education ▪ LGUs ▪ DENR
					▪ multimedia presentations	2	3	3		
					▪ games	5	5	5		
					▪ field trips	4	4	4		
					▪ integration of CC in the school curriculum	3	2	2		

Objective 2: action and implementation

Public/Target audience	Or. Min.	Occ. Min.	Bat.	Mar. and Rom.	Product	Or. Min.	Occ. Min.	Bat.	Mar. and Rom.	Implementers and co-implementers
	Priority									
General Public	5	1	4	4	▪ law enforcement	▪	1	1	1	▪ LGUs ▪ Bantay Dagat
Schools	4	2	5	5	▪ mangrove rehabilitation projects	▪	1	1	1	▪ LGUs ▪ Rural Health Units
Business sector	2	3	1	7	▪ regulations concerning private sectors ▪ responsibilities to the community ▪ come up with incentive schemes for companies with positive cc-related operations ▪ waste management programs ▪ provide environmental friendly products for sale		1 3 2	1 3 2 4		▪ LGUs
General Public	3		6		▪ conduct capacity building activities ▪ barangay level planning activities ▪ provide environmental friendly products for sale	1 2	1 2 3	2 1		▪ LGU ▪ Business Sector ▪ Chamber of Commerce ▪ NGOs (ex. CI and Mindoro Biodiversity Foundation) ▪ DENR ▪ National Solid Waste Management
Community	3			3	▪ organize coastal barangay climate change programs ▪ partnership with ngos, private sectors ▪ coastal clean up	1 2 3	1 2 3	2 1 3		▪ LGU
Elected Officials	1		3	1	▪ approval/implementation of plans (i.e., disaster management plan) ▪ awarding of incentives to performing barangays ▪ enforcement of laws ▪ organization of a task force on cc ▪ issuance of executive orders, ordinances, etc ▪ monitoring and evaluation of plans implemented ▪ environmental scanning ▪ integration of climate change into the tourism program ▪ vulnerability assessment	3 6 5 2 1 4	5 9 6 1 4 8 2 7 3	5 9 7 2 1 8 3 6 4	5 9 7 1 6 8 3 4 2	▪ MAO ▪ MENRO ▪ MG ▪ LGU ▪ DILG ▪ LGUPGOM ▪ MPDO/ PPDO-RSED ▪ MG-Task Force ▪ Mindoro Biodiversity Foundation ▪ CI–Philippines ▪ Provincial governments
Local Government Units			2	2	▪ incentive schemes for positive practices in cc adaptation ▪ amend laws to accommodate climate change adaptation and mitigation ▪ declare climate awareness day ▪ enactment of ordinances/ resolutions regarding climate change ▪ enforcement of ordinances and approved easement areas ▪ zoning/rezoning		6 1 5 3 4 2	6 4 5 1 2 3		▪ Sanggunian ▪ National agencies ▪ DENR ▪ NGOs ▪ Municipal engineeri ▪ Congressman ▪ LCE ▪ MENRO ▪ PNP ▪ Coast Guard/ ▪ Bantay Dagat

Objective 2: action and implementation (continued)

Public/Target audience	Priority Or. Min.	Occ. Min.	Bat.	Mar. and Rom.	Product	Or. Min.	Occ. Min.	Bat.	Mar. and Rom.	Implementers and co-implementers
Military	6		7	8	▪ law enforcement			1		▪ LGUs
- NGOs and people's organizations	2		8	6	▪ assist in the dissemination of information on climate change	1	2	2		▪ LGUs
- National line agencies					▪ provide supplies and materials	3	3	3		
					▪ technical assistance	2	1	1		

Objective 3: funding

Public/Target audience	Priority Or. Min.	Occ. Min.	Bat.	Mar. and Rom.	Product	Or. Min.	Occ. Min.	Bat.	Mar. and Rom.	Implementers
LGUs	n/a	n/a	n/a	n/a	▪ Ordinances to provide government funding for climate change projects	1	1	1	1	▪ Policy makers
	n/a	n/a	n/a	n/a	▪ Partnerships with NGOs and the private sector	2	3	3	2	▪ Community
	n/a	n/a	n/a	n/a	▪ provide supplies and materials		4	5	3	▪ National Line Agencies
					▪ provide funding		2	2	4	
	n/a	n/a	n/a	n/a	▪ provide help with funding		5	4	5	▪ NGOs

Workshop 3—Part 3: Strategy Formulation

Oriental Mindoro

Awareness and engagement

Priority public:	Elected and appointed officials
Priority product:	Production and distribution of IEC materials
Strategy:	Preparation and distribution of IEC materials (flyers, comics, media blitz) by the local government unit from August to December

Action and implementation

Priority Public:	Elected officials
Priority Product:	Organization of a task force on climate change
Strategy:	Creation of provincial/municipal task force thru an EO 774 by the LCE August

Funding

Priority public:	Local government units
Priority product:	Ordinances to provide government funding for climate change projects
Strategy:	Formulation and adoption of investment plan by the Task Force by August to December

Occidental Mindoro

Awareness and engagement

Priority public:	Elected officials and Local government units
Priority products:	Capacity building and IEC
Strategy:	Local government unit climate change task force to gather info materials from expert organizations/agencies. Reproduce materials appropriate to the area of jurisdiction and invite resource persons

Action and implementation

Priority public:	General public
Priority product:	Law enforcement
Strategy:	Request experts to deliver lectures

Funding

Priority public:	Local government units
Priority product:	Ordinances to provide government funding for projects
Strategy:	Formulation and adoption of investment plan by the task force by August to December

Batangas

Awareness and engagement

Priority public:	Elected officials and local government units
Priority products:	Capacity building
Strategy:	1. Conduct one-on-one separate briefing for the Mayor and the members of the SB 2. Organized joint meeting with executive and legislative branch 3. Preparation of IEC materials, e.g., flyers, primer and electronic presentations

Action and Implementation

Priority public:	Business sector
Priority product:	Regulations concerning private sector's responsibilities to the community
Strategy:	Make sure that the corporate social responsibility of all the business sectors be part of the process in coming up with the climate change awareness program, through: a. capacity building b. distribution of IEC materials c. provision of incentives

Funding

Priority public:	Local government units
Priority product:	Ordinances to provide government funding for climate change projects
Strategy:	1. formulation and passing of ordinances concerning collection of fees 2. lobbying for a percentage out of the collection from fines and penalties to be allotted or allocated to climate change programs and projects 3. build transparent relationship with business sector and a percentage from the CSR fund be allotted to climate change programs and projects

Marinduque and Romblon

Awareness and Engagement

Priority public:	Elected officials and Local government units
Priority products:	Capacity building
Strategy:	1. coordination through the SB 2. include in the municipal SB agenda 3. conduct the actual capacity building

Action and Implementation

Priority public:	Elected officials
Priority product:	Organization of a task force on climate change
Strategy:	1. identification of climate change members 2. organizational meeting 3. creation of climate change task force through ordinance

Funding

Priority public:	Local government units
Priority product:	Ordinances to provide government funding for climate change projects
Strategy:	1. coordination with the SB 2. draft an ordinance 3. deliberation 4. public hearing

As seen above, over 85% of the people involved in the formulation of the draft strategy, work for the local government units. This group also made up the bulk of the participants of the VA workshop. Therefore, this may explain why the elected officials were identified as the priority target audience for all three objectives of the climate change communications strategy.

The prioritization of local officials for the communications strategy suggests that the majority of the stakeholders believe these people have the greatest capacity to impact (directly or indirectly) climate change perceptions in local communities. The results of the validation also suggest that the main focus of the strategy should be at the level of the municipal governments since the national government is generally not active in implementation, even though all management falls under national laws and policies. This reflects the fact that the Local Government Code of 1991 transferred many environment-related responsibilities of the national government to the local government units.

Second priority was given to fishermen and farmers for awareness building, likely due to the fact that they are the people most directly impacted by the effects of climate change. The business sector was considered an important target for the action/implementation objective. This reflects a common belief that government initiatives are not sufficient enough to complete environmental projects. This same attitude is apparent in the results for the third objective, which is to find funding for climate change projects. Although funding from within the local government units was prioritized, partnerships with NGOs and the business sector closely followed in importance. It appears that environmental projects are not prioritized for funding by local government units because their benefits are difficult to quantify. Local officials are also concerned that projects they fund will affect the number of votes that they receive at the next election. This makes them biased towards projects that have immediate, readily visible local benefits, such as health programs and infrastructure.

The strategies identified, addressed capacity building, behavior change and taking action. The product of greatest importance, was the municipal ordinance, which would then make climate change activities a legal mandate. There is also a clear top-down trend in the priorities and strategies identified in the workshops, with government officials as priority targets and the general public taking second priority.

Recommendations

Certain questions regarding prioritization were answered in the workshop, but further thought on the following points is recommended:

1. The need to be more specific.
The natural and social scientists present at the Vulnerability Assessment (VA) workshop provided information about climate change effects in the area, however there is a need for site-specific information. Not all parts of the VIP will be affected in the same way and so the information to be disseminated can be tailored for each area as needed with greater specificity.

2. Should the message to be delivered be positive or negative?
One thing to be considered will be whether to use positive messages or "scare" tactics in the strategy. The results of the workshop established quite clearly that what matters most to stakeholders in this region is how climate change will specifically affect them at the present time. Next, we need to determine how stakeholders perceive climate change, and how these perceptions may need to be changed to impact attitudes and behavior. Then a decision will have to be made between encouraging, coaxing, scaring or perhaps even enforcing the issue (i.e., imposing penalties) to effect those changes.

3. Do we use/improve material that already exists or develop new materials?
Discussions during and between the workshops suggest that most of the stakeholders believe adapting existing materials (i.e., translating existing materials on climate change into their local dialects) is preferable to creating new material. This is mostly because of funding constraints. It is also interesting to note that, although coming up with new laws and ordinances is prioritized in the strategy, some people actually believe it will be easier to find a way to integrate activities into existing plans and priority projects (i.e., solid waste management, disaster preparedness) than to come up with and implement new laws. The second part of the VA workshop has already initialized steps to integrate climate change into local government unit plans, and so the challenge will be to carry on from there.

4. Who will be responsible for implementing actions?
Again, as the majority of the people consulted work for the local government units, it is not strange that they recommend a top-down approach for the communications strategy. Some recommended the creation of a task force to concentrate on the problem. This kind of centralized approach should, however, be taken with caution. Other stakeholders (non-governmental) may have a different point of view of the problem and it is possible that a centralized approach by the local government will be one sided and bring up conflicts of interest. Climate change has effects that go beyond the municipal or even provincial level and it may be necessary to have outside help to understand how local activities can fit into the 'bigger picture'. This is already being attempted in the VIP, with municipal and provincial plans being integrated into the Verde Passage framework plan.

5. The need for evaluation and follow up
It is inevitable that some aspects of the strategy will work better than others or that some actions will work in certain areas and not elsewhere. Just as ecosystems can vary between locations and the effects of climate change are felt differently, the communications strategy may need to be flexible with regards to both content and implementation. Available funding may play some part in determining which areas, and people receive resources to conduct follow up measures. Regardless of approach and jurisdiction, there is a need for some provisions to ensure follow up of the communications process to guarantee that the proper messages reach the appropriate audiences. In addition, certain criteria will be drawn up to quantify changes in behavior or to determine the overall effectiveness of the strategy. The strategy should then be modified and adapted where it is not perceived to be effective.

References

Earle S, Margit A, MacDowell M, and D Lerda (Eds.), 2006. Designing a communications strategy: the 4-P workshop. Global communications for Conservation International. 112 pp.

Conservation International (CI)

Mission

Building upon a strong foundation of science, partnership and field demonstration, CI empowers societies to responsibly and sustainably care for nature, our global biodiversity, for the well-being of humanity.

Vision

We imagine a healthy prosperous world in which societies are forever committed to caring for and valuing nature, our global biodiversity, for the long-term benefit of people and all life on Earth.

CONSERVATION INTERNATIONAL