Port Honduras Marine Reserve

Climate Change Adaptation Plan

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Introduction

In Belize, with the current environment of increasing sea surface temperatures, ocean acidification and tropical storm intensity, managing for climate change has become a fundamental necessity for marine protected area managers. Whilst climate change adaptation strategies are not yet fully integrated into national governance, at the global scale it is recognized that protected areas play a critical role in the maintenance of ecosystems services - a role that will become increasingly important as climate change impacts increase. Belize is highlighted as an area highly vulnerable to climate change impacts. It is becoming increasingly important to understand and integrate climate change adaptation into protected area management, with the identification of strategies that can assist in maintaining the viability of Belize's marine ecosystems in their continued role in assisting Belize to mitigate the predicted impacts of climate change.

This report is the output of an assessment of Port Honduras Marine Reserve, the first to be conducted following the ***Guidelines for Integrating Climate Change Adaptation Strategies into Management Plans,*** and is facilitated by The Nature Conservancy, MAREA and the Toledo Institute for Development and Environment. The Climate Change Adaptation Plan is based on a series of six targets, selected for their perceived vulnerability to climate change. It develops a 'hypothesis of change' for those targets and nested targets, in terms of climate change, and identifies specific climate-change associated threats. Based on this, a series of objectives and strategies were developed to assist TIDE in adapting for climate change in their management of Port Honduras Marine Reserve.

Climate Change Adaptation Targets

Conservation Targets
- *Coral Reef Communities*
- *Littoral forest / sandy beaches / mangrove*
- *Commercial and Recreational Species*

Vulnerable Communities
- *Monkey River* and *Punta Negra*

Key Socio Economic Activities
- *Commercial Fishing*
- *Tourism*

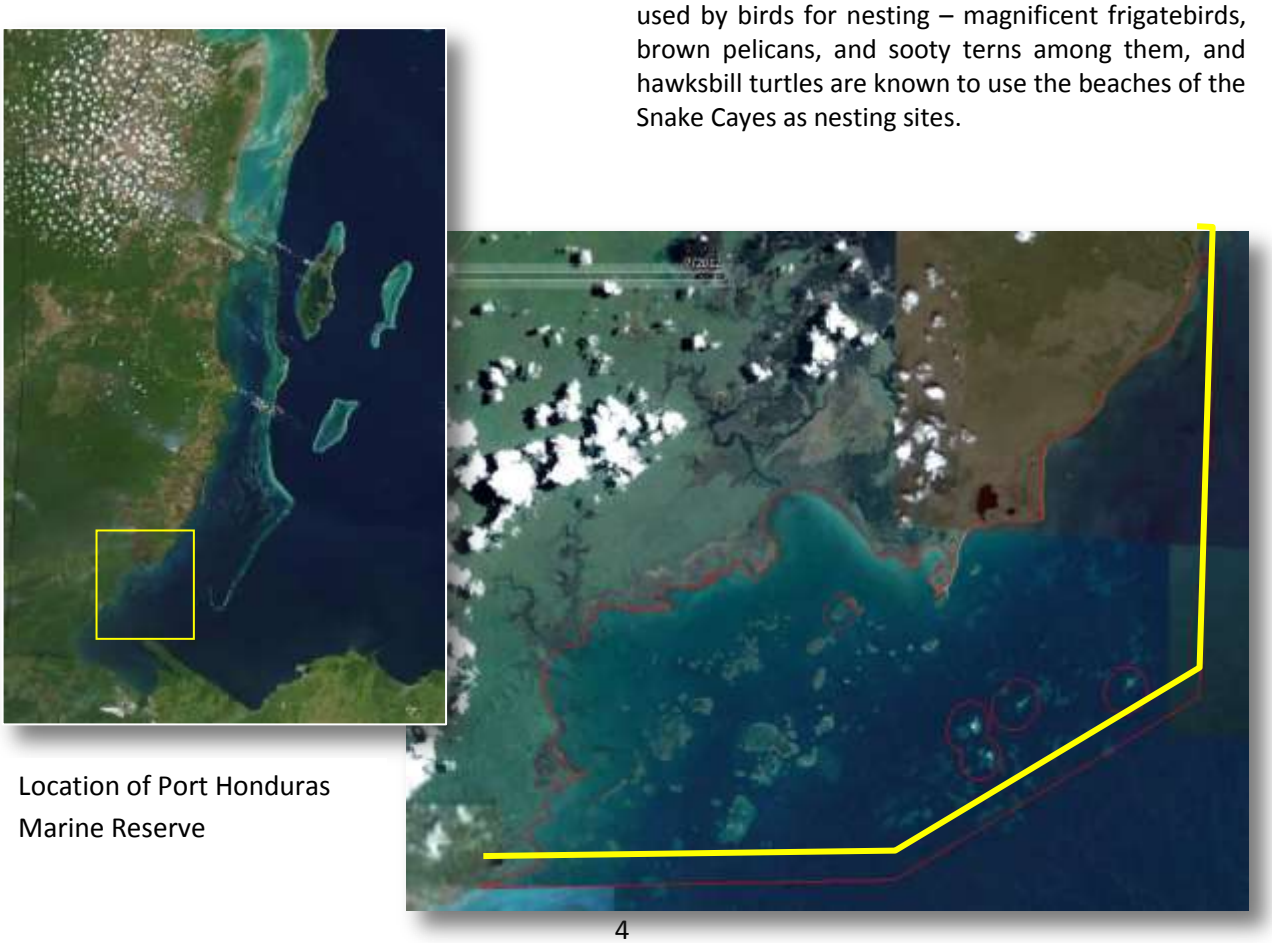
Context

Port Honduras Marine Reserve, in the southern coastal waters of Belize, is a semi-estuarine system that stretches from Monkey River to beyond Rio Grande, and extending approximately 8 kilometres out to sea. Established in 2000, it contains a diverse set of ecosystems – coastal and tidal wetlands, coral reef, extensive sea-grass and mangrove, and is an important resource for local fishermen. The Marine Reserve, first established for its role in maintaining the viability of local populations of the West Indian manatee, has also been highlighted for its value as a fish nursery area.

The extensive sea-grass beds surrounding many of the cayes of Port Honduras Marine Reserve provide critical nursery habitat for many commercial and non-commercial marine species, and important feeding grounds for the West Indian manatee. In the waters surrounding the Snake Cayes, near-shore fringing reefs provide habitat for the sponges, reef fish, crustaceans and other marine organisms that bring the reefs alive and support local livelihoods, both tourism and fishing. These mid-lagoonal reefs are unique in Belize, with characteristics of both inshore reef and offshore barrier reef environments.

The coral reefs of Port Honduras Marine Reserve underwent extensive bleaching in 1998, losing up to 40% of coral cover, but have since recovered. Their ability to recover rapidly after bleaching, and to thrive in the turbid waters of Port Honduras, with its rapidly changing salinities, suggests that they may be particularly resilient to the predicted effects of climate change.

Fringing mangroves provide important habitats for fish nurseries, particularly adjacent to the 138 cayes lying within the boundaries of the Marine Reserve, the majority of which remain undeveloped. Some are used by birds for nesting – magnificent frigatebirds, brown pelicans, and sooty terns among them, and hawksbill turtles are known to use the beaches of the Snake Cayes as nesting sites.



Location of Port Honduras Marine Reserve

Mangroves also fringe the coastline, providing important ecosystem functions, including the provision of high levels of organic input to the system, the filtering of water as it enters the Marine Reserve, as well as being an important habitat for prop root communities. The mangrove prop roots are also important in protecting the shoreline from erosion, particularly with the predicted rise in sea-levels and increasing intensity of storms.

The area also supports fifteen species of international concern, including four rated as Critically Endangered – staghorn and elkhorn corals (*Acropora cervicornis and A. palmata*), the goliath grouper (*Epinephelus itajara*), and the hawksbill turtle (*Eretmochelys imbricate*). Extensive surveys of these habitats have revealed a rich matrix of ecosystems, supporting the high biodiversity of the coral reef within the Marine Reserve.

The Conservation Zone is only non-extractive recreational activities permitted (snorkelling, diving, swimming, kayaking), and covers 4% of the reserve. The Preservation Zone makes up the final 1% of the reserve, with entrance restricted to researchers only (with a permit), or emergency access.

The Port Honduras area has only limited human settlement on its shores, concentrated primarily in Punta Gorda, the district capital. Cattle Landing lies on the northern edge of Punta Gorda and the much smaller coastal communities of Punta Negra and Monkey River. The predominant use of the coastal waters has traditionally been fishing, with a shift to tourism as Toledo has developed recognition as a tourism destination.

Key Characteristics

- Mid-lagoonal reefs, with characteristics of both inshore reef and offshore barrier reef environments - unique in Belize
- Extensive sea-grass beds filter and settle out sediments and nutrients - critical for maintaining the health of the barrier reef further offshore
- Supports local traditional fishing industry
- Important tourism and recreational resource
- Important goliath grouper habitat

1.0 Site Resilience Assessment

1.1 The Commercial Fisheries Sector

The non-mechanised, traditional capture fishery of Port Honduras Marine Reserve is focused on Caribbean spiny lobster (*Panulirus argus*), queen conch (*Strombus gigas*) and finfish - primarily lane snapper (*Lutjanus synagris*). An estimated seventy fishers are considered to use the Marine Reserve on a regular basis (Climate Change Adaptation Planning workshop, 2012), based from the coastal communities of Punta Gorda, Monkey River and Punta Negra, accessing the area using skiffs with outboards, or paddled canoes (dories) (Padilla et al., 2010). At the national level, the conch and lobster fisheries represent over 90% of total capture fisheries production (Ministry of Agriculture and Fisheries, 2009). Whilst there are no updated figures, the total value of the PHMR fishery in 2004 / 2005 has been estimated at BZ$889,906.00, with lobster the most productive sector, generating an estimated BZ$506,638.00 per year (Coleman & Diamond 2005).

Lobster: The lobster fishery is the most economically productive within PHMR, contributing 57% of the total value of the PHMR fishery (Coleman & Diamond 2005), with lobster caught using traps, shades and by free diving, primarily on the deep-water banks associated with the Snake Cayes. The average number of lobster observed in PHMR gradually increased between 2003 and 2009, and more rapidly in 2011. Size class assessment also points to good recruitment, with an increased number of juveniles, suggesting Port Honduras is fulfilling its role as a source for stocks in the Gulf of Honduras.

Conch: Conch is fished by free diving, with effort generally concentrated at the start of the conch season. The average number of conch observed in PHMR gradually increased between 2004 and 2008, but has shown a more recent decline between 2008 and 2011, with 2011 surveys suggesting that many sites were devoid of conch altogether, with severely reduced recovery rates when compared with 2010 data. The lack of significant difference between densities in the No Take and General Use Zones suggests that the no take zones may be too small, and / or the area is being fished illegally.

Finfish: Historically, lane snapper (*Lutjanus synagris*) has been, and still is, the most abundant fish species extracted (Coleman & Diamond 2005; Climate Change Adaptation Planning workshop, 2012), and is targeted using fish traps and hand lines (and previously gill nets, before they were banned within the protected area). Mutton and silk snapper, snook, dog snapper and goliath grouper also listed among the top ten targeted species.

Direct threats to the viability of commercial species, and therefore the fishing industry, have been identified as the low income in local stakeholder fishing communities, and the traditional dependence on fishing, coupled with the increase in number of fishermen. Poor fishing practices and illegal fishing (fishing out of season, harvesting of undersized product, use of gill nets, and nocturnal fishing within no-take zones), both as local incursions and transboundary incursions into the protected area, reduce the viability of the fish stocks, and the small size of the no take zones for spill-over effect reduces the effectiveness in their function as a replenishment tool for the fisheries industry. This is exacerbated by increasing fishing pressure and market demand from Jamaica and other CARICOM nations, and Guatemala and Honduras, as well as ecosystem

impacts - the reduced coral reef health (partially as a result of reduced herbivorous fish populations), and regime shifts and disruption of the trophic structure.

1.2 The Tourism Sector

The proximity of the scenic reef and cayes to the mainland places Port Honduras Marine Reserve in an excellent position as a tourism destination. Port Honduras Marine Reserve attracts primarily day visitors, providing employment opportunities for local guides and tourism developments on the mainland. In addition to visitors from Belize, the Marine Reserve also receives visitors from the neighboring countries of Guatemala and Honduras, particularly during the Easter holiday.Tourism and recreation is currently considered low impact in the Marine Reserve when compared with similar nearby locations such as Sapodilla Cayes Marine Reserve and Placencia. Two cruise ships carrying between 20 and 85 passengers currently visit the cayes within the protected area on a regular basis with landings off West Snake Caye (PHMR Management Plan, 2011).

For the stakeholder communities of Port Honduras Marine Reserve (Monkey River, Punta Negra and Punta Gorda), tourism has been important in relieving some of the pressures of decreased fisheries resources and supplementing family incomes. There have been a number of TIDE initiatives to assist fishermen in moving into sport fishing or general tourism, though tourism levels in Toledo are not yet sufficient to support a large number of trained guides). The tourism value of the marine protected area is based on the presence of a number of important marine resources:

Healthy Reefs: Coral reefs are an important ecosystem within PHMR, with a rich diversity providing habitat and feeding areas to reef organisms, supporting many endangered species and providing shoreline protection, as well as enhancing tourism. The coral of PHMR rates as **FAIR** (TIDE, 2011), with an average percent live coral cover across sites increasing from less than 7% in 2003 to over 14% in 2009, indicating a natural resilience (Foster / TIDE, 2009), indicative of potential resilience in the face of climate change.

Key Resilience Features of reefs in Port Honduras Marine Reserve

- High adaptability to rapidly changing salinity and turbid water conditions - corals thriving close to shore, in shallow water
- Corals show rapid and widespread recovery from coral bleaching, with increasing coral cover

Divers and snorkelers are attracted to the fringing reefs such as those around Frenchman's Range to Moho Caye, South Snake Caye and West Snake Caye, New Haven and Punta Ycacos Lagoon (Avila et al., 2005). Visibility however is sometimes poor due to the large amount of freshwater/sediment input from the watersheds during high rainfall.

Sandy Beaches: Swimming, sunbathing and general relaxation are common activities enjoyed by both local residents and tourists within PHMR, with the majority of these activities taking place on the cayes. Fourteen of the cayes in Port Honduras Marine Reserve have higher elevation areas suitable for on-land visitation. Attractive beach areas are accessible on West Snake Caye (the most frequently visited, with over 190 feet of shifting beach), Abalone Caye, South Snake Caye, and Moho Caye. .

Sport Fishing Species: Catch and release or tag and release fishing of target species (tarpon, bonefish, permit and snook), is an important resource for the area, generating an estimated annual profit of US$237,359 in 2005 (Coleman & Diamond 2005) PHMR is now regarded as one of the prime fly fishing sites where the 'grand slam' can be achieved, and the area has healthy stocks of targeted species In 2005, a number of fishers had been able to switch completely to sport fishing guiding, though by 2009, many were returning to fishing to supplement their incomes (Padilla Plaza & Ferguson, 2010).

Aesthetic Beauty and Wildlife: People are attracted to the area for its aesthetic beauty, the abundant bird life and the nesting colonies of frigatebirds, herons, white ibis, pelican and brown boobies at Bird Caye, and the potential to see West Indian manatees. Kayaking is popular within the Marine Reserve, focused on the Snake Cayes, and the close proximity to, and marina facilities in Punta Gorda and Placencia Village, and Rio Dulce in Guatemala, also makes the area a popular sailing destination for private sail boats.

Threats to the tourism industry include increased visitor impacts on the reef through poor snorkeling and diving practices, and poor boat practices. These, however, are overshadowed by the impacts of climate change, with the increasing frequency of coral bleaching, disease and reduced coral health. Monitoring of the area has also shown a reduction in the abundance of colourful reef fish and sharks, essential for ensuring visitor satisfaction, with the heavy extraction of these species in the adjacent seascape, particularly in neighbouring waters of Guatemala and Honduras.

1.3 Ecosystem Services

Port Honduras Marine Reserve is considered of national importance for the services it provides, particularly as the key link between the coastal and marine ecosystems and the terrestrial protected areas and upland watersheds of the landscape / seascape of the Maya Mountain Marine Corridor (MMMC). The Marine Reserve supports the commercial and sport fishing industries by enhancing finfish, conch and lobster populations, contributing towards the long-term sustainability of these activities. The extensive seagrass beds act as nursery areas for commercially important marine species and as adult habitat and feeding areas. The complex root systems of mangroves also provide an ideal nursery habitat for juvenile fish and invertebrate species, and mangroves have been shown to significantly increase the survivorship of juvenile reef fish (Mumby et al., 2004). Additionally, these coastal ecosystems provide protective buffer services for the Southern Belize Reef Complex (including the Sapodilla Cayes Marine Reserve) by filtering out sediment and agrochemicals from terrestrial sources.

Port Honduras Marine Reserve plays a critical role for the buffer communities of Punta Gorda, Punta Negra and Monkey River, and the Toledo District as a whole, with intact mangroves along the coastline providing protection against storms and hurricanes and reducing the impact of the waves on the coastline. They reduce storm surge inundation of seawater and the potential physical damage to houses and other infrastructure during storm events. Furthermore, mangroves limit the daily erosion that would otherwise occur as a result of the natural flow of the seawater and tides along the coastline. They also reduce the flow of land-based nutrients, sediment and pollution into the sea (Valiela et al. 2001).

2.0 Community Vulnerability

2.1 Introduction

As part of climate change adaptation planning for Port Honduras Marine Reserve, a rapid assessment was completed of community vulnerability, examining three vulnerability factors:

- ***Exposure:*** the extent to which a community comes into contact with climate events or specific climate impacts
- ***Sensitivity:*** the degree to which a community is negatively affected by changes in climate
- ***Adaptive Capacity:*** adaptive capacity (the potential or capability of a community to adjust to impacts of changing climate, and to minimize, cope with and recover from the consequences of changes

2.2 Stakeholder Communities

97% of users of Port Honduras Marine Reserve have been identified as originating from Monkey River, Punta Negra or Punta Gorda (MMAS, 2010). All three communities use the Marine Reserve as their primary use area, either for fishing or tour guiding, with Laughing Bird Caye National Park and Sapodilla Cayes Marine Reserve providing a second, much smaller focus for activities – predominantly based on tourism (Table 1).

Two of the communities (Monkey River and Punta Negra) lie directly on the boundary of the protected area and are heavily focused on marine resource use. As such, they have the greatest impact on the Marine Reserve and its resources, and will be the most impacted by the predicted climate change impacts.

Community	Population	Primary Occupations	PHMR*
Monkey River (100)[1]	200	Fishers, farmers, tourism (including fly fishing)	63%
Punta Negra (16)	18	Fishers, farmers, tourism	57%
Punta Gorda (2,932)	5,205	Fishers, tour guides. District administrative centre	8%

(…)[1] - Number of households surveyed (MMAS, 2010)
*% households surveyed per community that use Port Honduras Marine Reserve

Table 1: Community Stakeholders of Port Honduras Marine Reserve

Of the three communities, Punta Gorda is considered the most resilient to climate change, with its location on higher land, the greater income diversification and the limited dependence on marine resources, and is therefore not included in this summary. Whilst Monkey River and Punta Negra are both low lying and therefore at high risk of inundation, Monkey River is considered the least resilient, with the greatest dependence on marine resources. The residents of the small community of Punta Negra show greater adaptability, with less resistance to the idea of relocation - many already migrating permanently to Punta Gorda or to other inland communities, and several of those remaining having occupations based in Punta Gorda.

Monkey River is located at the mouth of the river with the same name, and was once a thriving port with a population of over a thousand. It has declined to current population of approximately 200, with a heavy dependence on commercial fishing, sport fishing and natural history tourism. Many community members have more than one occupation to supplement the family income, with 63.3% of households engaged in commercial fishing, and 52% in tourism activities (MMAS, 2010). Part of the community's ability to diversify into tourism lies in its proximity to Placencia, one of Belize's primary tourism centres. However, the limited infrastructure, and only recent establishment of 24 hour electricity and community water system have inhibited Monkey River itself from supporting larger-scale tourism within the community.

Monkey River was largely destroyed by Hurricane Iris in 2001, with up to 98% of the houses showing structural damage (NEMO, 2001). The village was then hit again in 2009 by an earthquake, with damage to 27 houses. Whilst some people moved to Punta Gorda or Independence following these disasters, there is a strong tie to the location, and the majority of people living there are reluctant to relocate.

Exposure: The extent to which Monkey River comes into contact with climate events or specific climate impacts

- Despite being in a lower risk hurricane belt, Monkey River is exposed to hurricanes, and was badly impacted by Hurricane Iris in 2001
- With its location on an east-facing coastline, coastal erosion is already reducing village land facing the sea, with a recent rate of erosion of 16 ft of foreshore per year, thought to be partly as a result of altered river dynamics, with upstream water extraction for agriculture
- Access is affected during and after storm events, and will become increasingly difficult with increasing sea level rise
- Increasing intensity of storms threatens fishing infrastructure (boats, traps, nets)
- Increased sea temperature is leading to coral bleaching, increased disease and increased coral mortality, affecting the health of the reef ecosystem
- increased intensity of tropical storms with increased mechanical damage to reef, increased sediment load from watersheds and sediment impacts on reef

Sensitivity: The degree to which Monkey River is negatively affected by changes in climate

- The community is located on the coast on land less than 1m and faces inundation from sea level rise in the long term, with the high probability of relocation
- Saltwater intrusion of ground water will reduce water security and affect current and future agriculture
- Decreasing rainfall predictions will lead to reduced water security, and reduced ability to diversify from fishing into agricultural alternatives
- Declining reef health as a result of ocean acidification and sea temperature rise will have future impacts on the fishing and tourism industries, the two primary income sources for the community

Adaptive Capacity: **The potential or capability of Monkey River to adjust to impacts of changing climate, and to minimize, cope with and recover from the consequences of changes**

- Monkey River was identified as one of the coastal communities with a more diversified income base (MMAS, 2010), increasing the capacity of its inhabitants to adapt to climate change
- Income diversification into tourism still places a heavy reliance on the state of the marine resources
- Majority of adults (86%) have minimal education, leaving school on completion of primary level (MMAS, 2010), reducing options for diversification.
- However, many of the young adults are attending high school or college in Punta Gorda

Punta Negra is located directly on the coastline of Port Honduras Marine Reserve, and is accessible only by water. It is not connected to the national road network or electricity system, nor does it have a community potable water system. Hurricane Iris affected the community in 2001, with 95% of the buildings estimated to have been structurally damaged (NEMO, 2001), reinforcing the exposed location and vulnerability of this community to tropical storm events.

With the lack of amenities, educational opportunities and jobs, there has also been a migration of families to more accessible communities, and many people have established second homes in Punta Gorda. This has resulted in the community shrinking from an estimated 40 households to 4 over the past twenty years. Punta Negra is a focal community of TIDE activities, receiving input in terms of skills training / capacity building, providing skills that have enabled community members to seek jobs outside the community.

Exposure: The extent to which Punta Negra comes into contact with climate events or specific climate impacts

- Despite being in a lower risk hurricane belt, Punta Negra is exposed to hurricanes, and was badly impacted by Hurricane Iris in 2001
- Increasing intensity of storms threatens fishing infrastructure (boats, traps, nets)
- Increased sea temperature is leading to coral bleaching, increased disease and increased coral mortality, affecting the health of the reef ecosystem
- increased intensity of tropical storms with increased mechanical damage to reef, increased sediment load from watersheds and sediment impacts on reef

Sensitivity: The degree to which Punta Negra is negatively affected by changes in climate

- The community is located directly on the coast and faces inundation from increasing sea level in the long term, with 100% of the community living less than 1m above sea level
- Decreasing rainfall predictions will reduce water security. This will be exacerbated by salt water intrusion of ground water with increasing sea level
- Declining reef health as a result of ocean acidification and sea temperature rise will have future impacts on the fishing and tourism industries, the two primary income sources for the community

Adaptive Capacity

The potential or capability of Punta Negra to adjust to impacts of changing climate, and to minimize, cope with and recover from the consequences of changes

- Punta Negra is a focal community of TIDE activities, receiving input in terms of skills training / capacity building.
- The majority of adults (over 70%) have minimal education, leaving school on completion of primary level (MMAS, 2010) reducing options for income diversification
- Those who are not fishermen generally are employed or have businesses and second residences in Punta Gorda
- Families in the community are slowly relocating to Punta Gorda or adjacent communities, for improved education opportunities, work and / or access to amenities (24hr electricity and water)

2.3 Conclusions

Of the three communities, Monkey River stands out as being the most vulnerable, due partly to the attitudes within the community. Whilst the physical location of both Punta Negra and Monkey River on the vulnerable, low lying coastline is similar, Punta Negra residents are more adaptable with in dealing with the issues facing them, diversifying their income base through opportunities offered by their proximity to Punta Gorda. Many families have already started the process of relocation, with only four households still remaining of the twenty or so when Port Honduras Marine Reserve was first established.

In comparison, Monkey River has a population primarily dependent on the marine resources, either through fishing or tourism, or both. Despite being hit by natural disasters twice in recent years (with Hurricane Iris and the more recent earthquake), despite increasing awareness of climate change through TIDE, and despite fighting an ongoing battle against coastal erosion there are few people considering relocating inland. This reluctance to adapt makes Monkey River more vulnerable in the long term.

Conservation strategies focused on assisting communities to adapt should therefore prioritise Monkey River, followed by Punta Negra. These may be overlooked in more national-level initiatives. Punta Gorda, however, should receive climate change adaptation support from central Government in the medium and long term.

Monkey River

Monkey River (Collins, 2004)

Punta Negra (Collins, 2004)

3.0 Planning for Climate Change

3.1 Introduction

The Climate Change Adaptation Plan is based on the outputs of a two-day workshop, held over the 28th / 29th June, 2012, with 34 participants drawn from different stakeholder sectors and communities. The workshop was designed to develop a fully participatory Climate Change Adaptation Strategy (CCAS) according to the "*Guidelines for Integrating Climate Change Adaptation Strategies into Protected Areas Management Plans*" to serve as an annex to the Port of Honduras Protected Area Management Plan. and followed the series of steps laid out in the manual:

- Situation Analysis
- Prioritizing identified threats
- Defining objectives
- Developing and Prioritizing Adaptation Strategies

3.2 Situation Analysis

It is important to start the climate change adaptation planning process with an understanding of the implications of climate change in both the land and the seascape context, and how these will impact the natural resources at national and site level (Table 2)

Table 2: Predicted Climate Change Impacts

Impact	Current Status – 50 years	100 yrs
Sea level rise	▪ Increased global average sea level rise rate of 1.8mm per year from 1961 – 2003 (IPCC, 2007). Current average increase in sea level rise in the Mesoamerican region is estimated at 3.1mm per year (IPCC, 2007).	▪ Predicted increase of between 0.6m and 1.0m over next 100 years, though could be higher (up to 3.3m), dependent on the rate of melt of ice sheets (Simpson et al., 2009)
Sea surface temperature rise	▪ Water temperature has increased by 0.74˚C between 1906 and 2005 ▪ Current levels of increase are estimated at 0.4˚C per decade (Simpson et al., 2009)	▪ Predicted regional increase of temperature by up to 5˚C by 2080, with the greatest warming being experienced in the north-west Caribbean (incl. Belize) (WWF, 2009).
Increased intensity of storms	▪ Increased storms from 1999 onwards, with annual fluctuations. More storms during La Nina, fewer El Nino. Stronger storms >Cat 4 / 5	

Table 2: Predicted Climate Change Impacts		
Impact	**Current Status – 50 years**	**100 yrs**
Ocean acidification	▪ Atmospheric CO_2 concentration has increased from 280 parts per million (ppm) in 1880 to 385 ppm in 2008 - 35% increase in hydrogen (Simpson et al., 2009). ▪ 48% of all atmospheric CO_2 resulting from burning of fossil fuels has been taken up by the ocean (Hartley, 2010) ***25 – 50 years*** ▪ Predicted atmospheric CO_2 levels of 450 by 2040 (Simpson et al., 2009) ▪ Predicted 30% decrease in pH ▪ Predicted decrease in calcification rate by 20 - 50% by 2050	▪ Decrease of between 0.3 and 0.5 units by 2100 (Hartley et. al. 2010). ▪ Some experts predict a 35% reduction in coral growth by 2100 (Simpson et al., 2009)
Decreased Precipitation	▪ Mean monthly rainfall over Belize has decreased at an average rate of 3.1mm ▪ per decade since 1960 (NCSP/UNDP) ***25 – 50 years*** ▪ Predicted ecological shifts up the altitudinal gradient of the Maya Mountains Massif may remove the quasi-cloud forest, and the catchment functionality important for maintaining rivers in dry season in the south of Belize, and providing nutrients to the reef environment. ▪ Increased concentration and seasonality of agrochemical delivery	▪ Predicted decrease in precipitation of 9% by 2099 (IPCC, 2007), with significant fluctuations, attributed to El Niño ▪ Some models predict a decrease of as much as 22% (IPCC 2007)
Air Temperature	▪ Mean annual temperature has increased in Belize by 0.45°C since 1960, an average rate of 0.10°C per decade. ▪ Average number of 'hot' days per year in Belize (days exceeding 10% higher than current average temperature) has increased by 18.3% between 1960 and 2003 (NCSP/UNDP).	▪ Predicted mean annual temperature increase is 3.5° by 2099 (UNDP, 2009).

With this information, it is possible to develop a "Hypothesis of Change" for the climate change adaptation targets considered important for Port Honduras Marine Reserve and the role it plays in providing ecosystem services for the stakeholder communities.

Hypothesis of Change: Coral Reef Ecosystems	
Impact	**Hypothesis of Change**
Increased sea surface temperature	▪ Increased coral bleaching and eventual loss of ecosystem functionality. ▪ Increased coral disease. ▪ Possible impacts from new invasive species and algal blooms. ▪ A shift towards more tolerant species and symbiont types, and more opportunistic species, with reduced diversity. ▪ May alter localized current patterns and therefore larval dispersion.
Sea level rise	▪ Coral reefs may be able to keep up with sea level rise, barring other impacts and dependent on rate of sea level rise. ▪ Change in dispersal / recruitment routes / sources. ▪ Potential loss of deeper corals, shift in distribution, as light availability decreases. ▪ Increased sedimentation and reduced light availability due to shore erosion.
Increased frequency and intensity of storms	▪ Increased mechanical damage to corals. ▪ Increased sedimentation, particularly from watersheds following high rainfall and storm damage to riparian belts. ▪ Removal of macro algae, resulting in more available substrate for recruitment. ▪ Fragmentation of coral – dispersal and colonization
Ocean acidification	▪ Decreases in coral calcification rates, growth rates and structural strength. ▪ Weakening of reef matrix.

Hypothesis of Change: Littoral Forest / Sandy Beaches / Mangrove	
Impact	**Hypothesis of Change**
Sea-level rise	▪ The cayes may become inundated ▪ Salt intrusion of water table may alter terrestrial vegetation cover, with changes in species presence / diversity. ▪ Potential loss of low-lying crocodile and turtle nesting beaches ▪ Reduction of functional, available fish nursery mangrove habitat
Increased Storm Frequency	▪ Removal of some or all natural vegetation with less time for regeneration between storms - change in forest structure / reduced species diversity. ▪ Increased erosion, loss of part or entire cayes, changes in beaches. ▪ Arrival of opportunistic species. ▪ Impacts on bird colonies (nesting / roosting) ▪ Reduction of functional, available fish nursery mangrove habitat
Decreased Precipitation	▪ Reduction of freshwater lens, affecting carbon uptake and photosynthesis by plants. ▪ Changes in species composition - more salt tolerant species. ▪ Potential loss of savanna vegetation to poorly vegetated hypersaline flats
Air Temperature	▪ Potential change in species composition favouring more heat tolerant species. ▪ Higher air temperature could cause more arid conditions – drier soils ▪ Changes in sex ratio of sea turtles with increase in incubation temperature

Hypothesis of Change: Commercial Species	
Impact	**Hypothesis of Change**
Sea surface temperature rise	▪ Conch: Temperature may affect spawning. ▪ Lobster: Possible effects on larval and adult lobsters and reproduction. ▪ Loss of critical habitat . ▪ Possible impacts from new invasive species and algal blooms. ▪ Disease may become more prevalent. ▪ Changes in currents and larval dispersal
Sea level rise	▪ Conch: range shift in range or habitat loss linked to changes in critical habitat. ▪ Snapper / grouper / lobster: Shift in range / habitat loss of both adult and juvenile lobster – linked to inundation of mangrove, shift in seagrass distribution, changes in coral reef.
Increased frequency and intensity of storms	▪ Habitat destruction and increased sedimentation . ▪ Possible impacts on larval dispersal / survival (potential for wider dispersal of larvae).
Ocean acidification (lobster / conch)	▪ Habitat loss (impacts on reef). ▪ Impacts on larval viability and adult growth rates . ▪ Weakening shell structures. ▪ Possible increase in seagrass productivity.
Decreased Precipitation	▪ Potential for changes in salinity impacting larval dispersal. ▪ Lobster migration patterns and times may change with changing salinity.

Hypothesis of Change: Vulnerable Communities	
Impact	**Hypothesis of Change**
Sea surface temperature rise	▪ Reduction in commercial marine resources – lobster, conch, snapper, as they move deeper into cooler water, or with changes in connectivity and / or ecosystem health ▪ Reduction in health of reef, resulting in reduced tourism ▪ Increased poverty with decreasing returns from fishing and tourism
Sea level rise	▪ Inundation of low-lying areas – would include much of Monkey River and Punta Negra ▪ Salt contamination of freshwater aquifers, reducing water availability for household consumption and agricultural activities ▪ Increased erosion of coastal shorelines
Increased intensity of storms	▪ Increased potential for storm surge and flooding of communities ▪ Increased potential for reduced access to communities during and after storm events ▪ Increased erosion of coastal shorelines ▪ Increased infrastructural damage to structures (houses and community buildings) in communities ▪ Increased frequency of damage / destruction of fishing equipment (traps, nets etc.) and boats ▪ Increased contamination of potable drinking water supplies ▪ Increased sedimentation of river and associated agrochemical contamination
Ocean acidification	▪ Reduction in lobster and conch productivity, with related reduction in catch and income
Decreased Precipitation	▪ Reduced potable water availability

Hypothesis of Change: Key Socio-Economic Activities – Commercial Fishing and Tourism	
Impact	**Hypothesis of Change**
Sea surface temperature rise	▪ Reduction in commercial marine resources – lobster, conch, snapper, as they move deeper into cooler water, or with changes in connectivity and / or ecosystem health, reducing income for commercial fishing industry ▪ Reduction in health of reef, resulting in reduced tourism
Sea level rise	▪ Inundation of low-lying areas – potential reduction in mangrove extent, and related reduction in key nursery areas for commercial species (though mangrove may be able to adapt by moving in-land
Increased intensity of storms	▪ Increased frequency of damage / destruction of fishing equipment (traps, nets etc.) and boats ▪ Increased frequency of damage / destruction of tourism infrastructure (hotels, mooring buoys, signage etc.) and boats ▪ Increased sedimentation and associated agrochemical contamination impacts on reef, reducing reef health ▪ Increased mechanical damage to reef, reducing tourism potential
Ocean acidification	▪ Reduction in lobster and conch productivity, with related reduction in catch and income ▪ Reduced coral health, reducing tourism potential of reef

3.3 Cross Cutting Priority Threats	**Coral Reef Communities**	**Littoral Forest / Sandy Beaches / Mangrove**	**Commercial Species**	**Vulnerable Communities**	**Commercial Fishing**
Climate change impacts and adaptation measures are exacerbated by limited enforcement effectiveness					
Local, national and international climate adaptation politics..including de-reservation, issuing of permits for fishing, dredging etc.					
Increase in people abandoning terrestrial livelihoods and turning to fishing / People relying on the sea as an extra source of income or leaving other job or farming/cattle rearing to fish.					
Diversification resulting in increased fishing pressure across a wider range of species that impact coral reef health.					
Tourism increasing to unsustainable levels in the PHMR as a result of degradation in other popular tourist areas					
Erosion of beaches in Monkey River					
Using different fishing techniques (eg. deep sea fishing) / Change from normal species fished to other types of species (fishing deep sea fish).					
Possible loss of mangrove, littoral forest and sandy beaches as a result of increase sea level rise.					
Reduced availability of marine resources with increased sea surface temperature					
Increased damage to infrastructure					
Increase in air temperature will affect the sex ratio of sea turtles					
Tourism developments on the cayes and coastline will potentially face the need to reinforce shorelines and create landfill, or relocate, as sea level rises					
Less fresh water available for villagers					

3.4 Cross Cutting Objectives	Coral Reef Communities	Littoral Forest / Sandy Beaches / Mangrove	Commercial Species	Vulnerable Communities	Commercial Fishing
By 2020, 100% of tourism activities and services follow well defined and accepted best practices standards					
By 2018, at least 75% of fishermen consider they have ownership of PHMR and are integrated into decision making, stewardship and surveillance and enforcement					
By 2018, mangrove coverage in PHMR will be increased by 10% based on 2011 mangrove baseline results, and maintains viable littoral forest and sandy beaches.					
By 2014, 50% of fishermen will have access to training and funding opportunities to diversify into sustainable alternatives, with integration in project planning and implementation					
By 2015, collaboration between fishermen of Port Honduras Marine Reserve will be strengthened to be able to lobby successfully at local and national level					
By 2050, at least 75% of Toledo's non-fishing population has access to viable, high-value, environmentally sustainable livelihoods besides the fishing industry.					
By 2020, effectively managed, sustainable fisheries diversification initiatives are in place that target both traditional and new target species					
By 2020, income sources will have been diversified for 25% of commercial fishers through the creation of new economic opportunities					
By 2020, Fisheries Department and TIDE will identify and improve at least three responsible and effective fishing techniques, in collaboration with PHMR fishers					
By 2015, Fisheries Dept and TIDE will have identified two finfish species with potential for sustainable, commercial extraction					
By 2016, a sustainable tourism plan will have been developed for Port Honduras Marine Reserve, integrating climate change adaptations					
By 2012, mechanisms will be in place to ensure maintenance of the shoreline in its current (2012) position for the community of Monkey River.					
By 2028, sea turtle sex ratio will have increased by 30% from the 2013 baseline results in PHMR					
By 2013, 100% of villagers from Punta Negra, Monkey River have a sustainable water supply considered resilient for at least 25yrs					
By 2017, infrastructure in Punta Negra, Monkey River is strengthened to be more resilient to storm damage in line with recommended hurricane building codes					

3.5 Prioritised Strategies per Target and Objective				
Target	**Objective**	**Strategy**	**Priority**	**Priority Threat**
Coral Reef Communities	By 2020, effectively managed, sustainable fisheries diversification initiatives are in place that target both traditional and new target species	Monitor each identified species using both fisheries dependent and independent surveys	1	Diversification resulting in increased fishing pressure across a wider range of species that impact coral reef health.
	By 2020, 100% of tourism activities and services follow well defined and accepted best practices standards	Educate tour operators and tourists regarding best practices and impacts of malpractice to encourage responsible tourism	1	Tourism increasing to unsustainable levels in the PHMR as a result of degradation in other popular tourist areas
		Provide incentives for tour operators to abide by established best practices regulations	2	
	By 2016, a sustainable tourism plan has been developed for Port Honduras Marine Reserve, integrating climate change adaptations	Establish a grassroots tourism program to increase community involvement in the management of tourism in PHMR by 2015	2	Tourism developments on the cayes and coastline will potentially face the need to reinforce shorelines and create landfill, or relocate, as sea level rises
Littoral Forest / Sandy Beaches / Mangroves	By 2018, mangrove coverage in PHMR will be increased by 10% based on 2011 mangrove baseline results, and maintains viable littoral forest and sandy beaches.	Enforce existing mangrove legislation by 2015 to decrease mangrove loss along coastline	1	Tourism developments on the cayes and coastline will potentially face the need to reinforce shorelines and create landfill, or relocate, as sea level rises
		Develop an on-going education and outreach program to promote stewardship for mangroves, sandy beaches and littoral forest	1	
		By 2016 establish reforestation program to increase mangrove by 10% of existing coverage and maintain littoral forest and sandy beaches	2	
	By 2028, sea turtle sex ratio will have increased by 30% from the 2013 baseline results in PHMR	Develop a turtle monitoring program by 2015 to protect nesting areas	2	Increase in air temperature will affect the sex ratio of sea turtles

Target	Objective	Strategy	Priority	Threat
Commercial Species	By 2020, Fisheries Department and TIDE will identify and improve at least three responsible and effective fishing techniques, in collaboration with PHMR fishers	Establish regulations to discontinue the use of destructive fishing techniques within PHMR.	1	Using different fishing techniques (eg. deep sea fishing) without informed guidelines in place
		Assess present fishing techniques used by PHMR fishers and identify both sustainable and destructive fishing techniques	2	
		Consult with stakeholders (fishers, TIDE, FiD) to share information on findings about the assessment of fishing techniques.	2	
Commercial Fishing	By 2018, at least 75% of fishermen consider they have ownership of PHMR and are integrated into decision making, stewardship and surveillance and enforcement	Strengthen representation with at least one fishermen, elected by fishing stakeholders, to both TIDE Board of Directors and PHMR Board	2	Climate change impacts and adaptation measures are exacerbated by limited enforcement effectiveness
		Build capacity of PHMR stakeholders for management and staff positions for PHMR and TIDE	2	
		Strengthen managed access committee to the point where it can give the final approval on resource management decisions eg. research permits, licenses	2	
		Involve fishermen in activities at all levels – boat drivers, community researchers	2	
	By 2014, 50% of fishermen will have access to training and funding opportunities to diversify into or improve sustainable alternatives, with integration in project planning and implementation	Strengthen initiatives assisting fisherman and farmers in Toledo for diversification and improved marketing	2	Reduced availability of marine resources with increased sea surface temperature
		Support return to traditional small-scale, family support agricultural schemes for fishermen for supplementing fishing income	2	
		Assist fishermen in strengthening marketing of marine products and mechanisms of increasing market value	2	Reduced availability of marine resources with increased sea surface temperature

Target	Objective	Strategy	Priority	Threat
Commercial Fishing	By 2014, 50% of fishermen will have access to training and funding opportunities to diversify into or improve sustainable alternatives, with integration in project planning and implementation	Invest in education of fisher's children, to ensure they have employment opportunities beyond fishing	2	
	By 2015, collaboration between fishermen of Port Honduras Marine Reserve will have been strengthened to be able to lobby successfully at local and national level	Develop a public relations / communication programme to be implemented by fisherman group leaders, to increase awareness and collaboration among fishermen	2	Local, national and international climate adaptation politics
Vulnerable Communities	By 2013, 100% of villagers from Punta Negra and Monkey River have a sustainable water supply considered resilient for at least 25yrs	Implementation and reinforcement of water conservation and awareness campaign in Punta Negra and Monkey River by 2014.	2	Reduced availability of Fresh Water
	By 2012, mechanisms will be in place to ensure maintenance of the shoreline in its current (2012) position for the community of Monkey River.	Complete an assessment of impacts and causes of erosion in Monkey River by July 2015	1	Erosion of Beaches in Monkey river

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Annex: Strategies per Target and Objective				
Target	**Objective**	**Strategy**	**Priority**	**Priority Threat**
Coral Reef Communities	By 2020, effectively managed, sustainable fisheries diversification are in place that target both traditional and new target species	Monitor each identified species using both fisheries dependent and independent surveys	1	Diversification resulting in increased fishing pressure across a wider initiatives range of species that impact coral reef health.
		Identify and assess the commercial viability and environmental sustainability of species not currently being exploited and establish optimal yield	3	
		Develop high value markets for these species, including lionfish	3	
		Establish and enforce quotas set at the optimal yield	4	
	By 2020, 100% of tourism activities and services follow well defined and accepted best practices standards	Educate tour operators and tourists regarding best practices and impacts of malpractice to encourage responsible tourism	1	Tourism increasing to unsustainable levels in the PHMR as a result of degradation in other popular tourist areas
		Provide incentives for tour operators to abide by established best practices regulations	2	
		Establish site specific regulations and enforce all regulations regarding best practices (including tourists reporting malpractice)	3	
	By 2050, at least 75% of Toledo's non-fishing population has access to viable, high-value, environmentally sustainable livelihoods besides the fishing industry	Build capacity for value-added enterprise including business planning, marketing, developing skills, access to capital and markets.	3	Increase in people moving from terrestrial livelihoods and turning to fishing
		Provide sex education in all primary schools in the Toledo District.	3	
		Monitor socio-economic and demographic changes with emphasis people entering the fishing industry.	4	

Prioritised Strategies per Target and Objective				
Target	**Objective**	**Strategy**	**Priority**	**Priority Threat**
Coral Reef Communities	By 2050, at least 75% of Toledo's non-fishing population has access to viable, high-value, environmentally sustainable livelihoods besides the fishing industry	Build capacity for sustainable agriculture including agroforestry.	4	Increase in people moving from terrestrial livelihoods and turning to fishing
		Provide family planning services to entire Toledo population with emphasis on youth.	4	
		Limit immigration.	5	
Littoral Forest / Sandy Beaches / Mangroves	By 2018, mangrove coverage in PHMR will be increased by 10% based on 2011 mangrove baseline results, and maintains viable littoral forest and sandy beaches.	Enforce existing mangrove legislation by 2015 to decrease mangrove loss along coastline	1	Tourism developments on the cayes and coastline will potentially face the need to reinforce shorelines and create landfill, or relocate, as sea level rises
		Develop an on-going education and outreach program to promote stewardship for mangroves, sandy beaches and littoral forest	1	
		By 2016 establish reforestation program to increase mangrove by 10% of existing coverage and maintain littoral forest and sandy beaches	2	
	By 2028, sea turtle sex ratio will have increased by 30% from the 2013 baseline results in PHMR	Develop a turtle monitoring program by 2015 to protect nesting areas	2	Increase in air temperature will affect the sex ratio of sea turtles
		Establish a nest management program by 2014 to ensure an on-going reproductive population	3	
		Establish a captive breeding population by 2020	5	
	By 2016, a sustainable tourism plan has been developed for Port Honduras Marine Reserve, integrating climate change adaptations	Establish a grassroots tourism program to increase community involvement in the management of tourism in PHMR by 2015	2	Tourism developments on the cayes / coastline will potentially face the need to reinforce shorelines and create landfill, or relocate, as sea level rises
		Identify gaps and integrate mandatory guidelines for sustainable tourism by 2018	4	
		Promote ecotourism to diversify economic opportunities by 2018	4	

Prioritised Strategies per Target and Objective				
Target	**Objective**	**Strategy**	**Priority**	**Threat**
Commercial Species	By 2020, Fisheries Department and TIDE will identify and improve at least three responsible and effective fishing techniques, in collaboration with PHMR fishers	Establish regulations to discontinue the use of destructive fishing techniques within PHMR.	1	Using different fishing techniques (eg. deep sea fishing) without informed guidelines in place
		Assess present fishing techniques used by PHMR fishers and identify both sustainable and destructive fishing techniques	2	
		Consult with stakeholders (fishers, TIDE, FiD) to share information on findings about the assessment of fishing techniques.	2	
		Implement a trial period of 2 years whereby by baseline data is collected and impacts assessed	5	
	By 2020, income sources will have been diversified for 25% of commercial fishers through the creation of new economic opportunities	Promote sustainable farming practices such as proper irrigation, crop planting cycle, back yard farming, in house farming	3	People relying on the sea as an extra source of income or leaving farming/cattle rearing to fish.
		Promote craft making for buffering communities of PHMR.	4	
		Promote and facilitate livestock (pig and chicken rearing)	4	
		Promote and facilitate production of honey for buffering communities of PHMR.	5	
		Promote and facilitate sustainable aquaculture (tilapia)	5	
		Promote and facilitate seaweed farming	5	
		Promote and facilitate sea cucumber faming	5	

Prioritised Strategies per Target and Objective				
Target	**Objective**	**Strategy**	**Priority**	**Threat**
Commercial Species	By 2015, Fisheries Dept and TIDE will have identified two finfish species with potential for sustainable, commercial extraction	Conduct consultations in buffering communities to identify two new potential commercial finfish species	3	Change from normal species fished to other types of species (fishing deep sea fish) without sustainable guidelines in place
		Determine the population status of two new potential commercial finfish species	3	
		Tap into a market for the species	3	
		Determine sustainable practices for extraction of these species (quotas)	5	
Commercial Fishing	By 2018, at least 75% of fishermen consider they have ownership of PHMR and are integrated into decision making, stewardship and surveillance and enforcement	Strengthen representation with at least one fishermen, elected by fishing stakeholders, to both TIDE Board of Directors and PHMR Board	2	Climate change impacts and adaptation measures are exacerbated by limited enforcement effectiveness
		Build capacity of PHMR stakeholders for management and staff positions for PHMR and TIDE	2	
		Strengthen managed access committee to the point where it can give the final approval on resource management decisions eg. research permits, licenses	2	
		Involve fishermen in activities at all levels – boat drivers, community researchers	2	
		Implement a pilot surveillance and enforcement initiative by PHMR fishermen, with investment in and engagement of fishermen for assisting with surveillance and enforcement activities in PHMR , (with stipend)	3	

Prioritised Strategies per Target and Objective				
Target	**Objective**	**Strategy**	**Priority**	**Threat**
Commercial Fishing	By 2014, 50% of fishermen will have access to training and funding opportunities to diversify into or improve sustainable alternatives, with integration in project planning and implementation	Strengthen initiatives assisting fisherman and farmers in Toledo for diversification and improved marketing	2	Reduced availability of marine resources with increased sea surface temperature
		Support return to traditional small-scale, family support agricultural schemes for fishermen for supplementing fishing income	2	
		Assist fishermen in strengthening marketing of marine products and mechanisms of increasing market value	2	
		Invest in education of fisher's children, to ensure they have employment opportunities beyond fishing	2	
		Strengthen support of cooperative initiatives for diversification into mari-culture and marketing of product	3	
	By 2015, collaboration between fishermen of Port Honduras Marine Reserve will have been strengthened to be able to lobby successfully at local and national level	Develop a public relations / communication programme to be implemented by fisherman group leaders, to increase awareness and collaboration among fishermen	2	Local, national and international climate adaptation politics
		Identify different fisherman groups and group leaders, and mechanisms for engaging leaders to participate in collaborative meeting	3	
		Identify mechanisms such as a regular radio slot to provide fishermen with a forum for informing and discussion	3	
Vulnerable Communities	By 2013, 100% of villagers in Punta Negra and Monkey River have a sustainable water supply considered resilient for at least 25yrs	Implementation and reinforcement of water conservation and awareness campaign in Punta Negra and Monkey River by 2014.	2	Reduced availability of fresh water
		A 25% increase in effectiveness of watershed management by 2015.	3	
		Improve management of existing water supply systems in terms of consistent supply and quality; desalinization	3	

Prioritised Strategies per Target and Objective				
Target	**Objective**	**Strategy**	**Priority**	**Threat**
Vulnerable Communities	By 2013, 100% of villagers in Punta Negra and Monkey River have a sustainable water supply considered resilient for at least 25yrs	Ensure consistent water supply and quality for Punta Negra, and Monkey River by 2015.	3	Reduced availability of fresh water
		Install reverse osmosis	2	
		Implementing and enforcing policies that protect and regulate water use	5	
	By 2012, mechanisms will be in place to ensure maintenance of the shoreline in its current (2012) position for the community of Monkey River.	Complete an assessment of impacts and causes of erosion in Monkey River by July 2015	1	Erosion of beaches in Monkey river
		Implementation of barriers for erosion control in Monkey River by 2013.	3	
		Implement plan to relocate the community	5	
	By 2017, infrastructure in Punta Negra, Monkey River and Cattle Landing is strengthened to be more resilient to storm damage in line with recommended hurricane building codes	Implement education program in PN,MR, CL to address best practices in accordance with building code regulations	5	Increased tropical storm damage to infrastructure