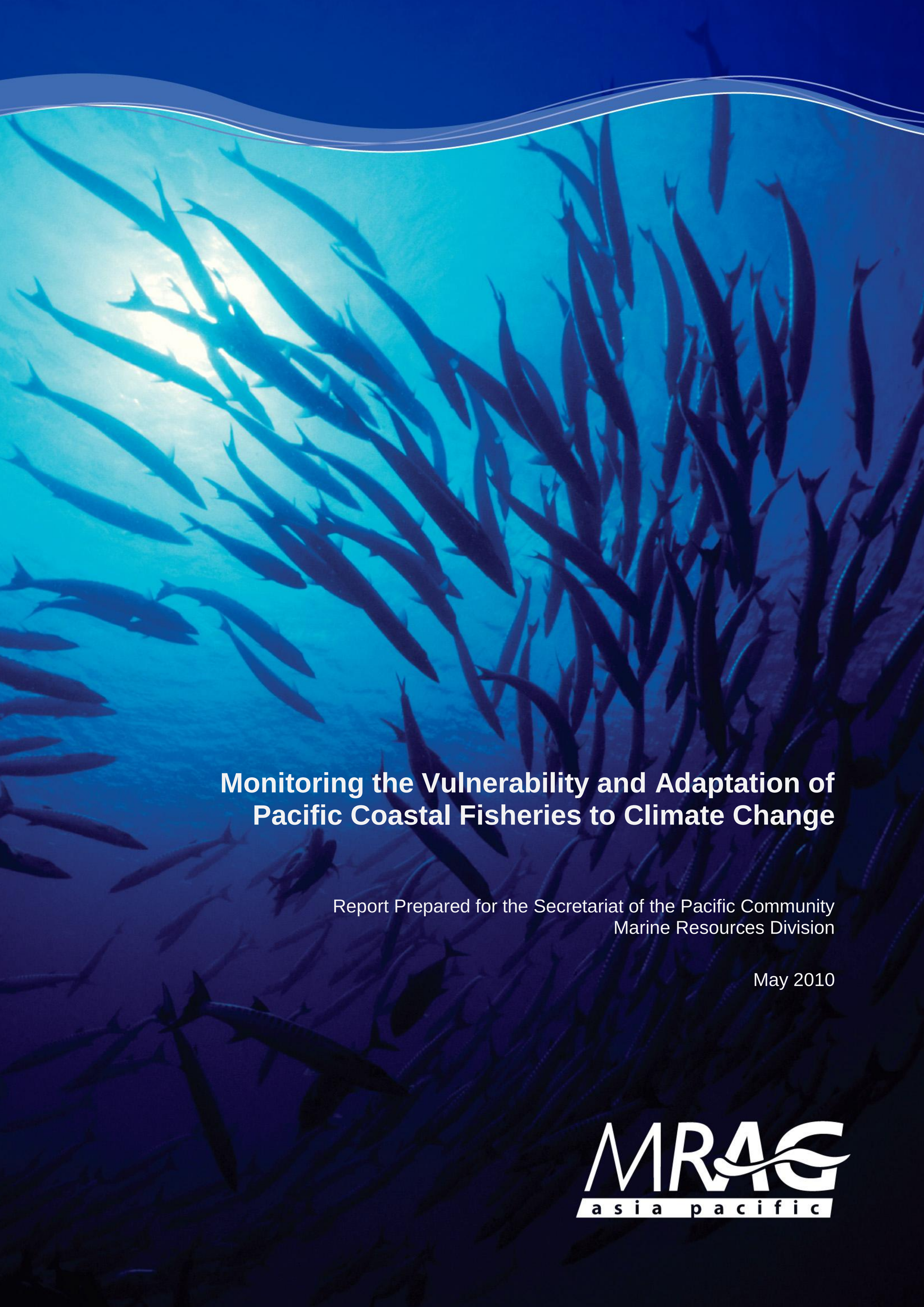

Monitoring the Vulnerability and Adaptation of Pacific Coastal Fisheries to Climate Change

Report Prepared for the Secretariat of the Pacific Community
Marine Resources Division

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Table of Contents

Executive summary

Growing evidence suggests that climate change is having more substantial and rapid effects on marine communities than terrestrial ones. Climate change is predicted to have significant impacts on the distribution and abundance of fisheries resources, and is an issue for global food security. For regions where there is significant reliance of fisheries resources for food and/or income, understanding the potential impacts of climate change, and assessing whether potential impacts are realised is a critical issue. It is all the more important for Pacific Island countries and territories (PICTs) because many have a very high reliance on seafood as a source of protein, and modelling identifies that they are projected to have reduced seafood production as a result of climate change.

This study looked at issues surrounding the information required to monitor the impacts of climate change on coastal fisheries in the Pacific. Specifically, this study addressed the following objectives:

- A review of literature and consultation with experts in the field to identify the information needed to monitor climate change impacts on coastal fisheries.
- Identification of organisations and individuals already working in this field in the Pacific Islands.
- Recommended priorities for data collection and analysis to be initiated by the project.
- Identification of locations and partners for field testing, with a view to developing sustainable arrangements after the end of the project.

Four main sources of information were used: literature reviews of both published and 'grey' literature; project surveys; in country consultations, principally in New Caledonia, Samoa and Fiji; and a 4-day workshop of regional experts held in Noumea during April 2010.

This study highlighted a number of challenges associated with monitoring the impacts of climate change in the Pacific region, most notably challenges associated with the need to understand large scale processes (e.g. oceanographic processes) and how these influence a range of biological and ecological processes at smaller scales, challenges associated with monitoring the impacts of fisheries as a nexus between biological/ecological systems and social/economic systems, and challenges associated with the biological, ecological, geological and socio-economic diversity of the region.

Climate change may lead to a number of physical stressors to the marine environment, which in turn may result in a range of biological/ecological responses affecting coastal fisheries. The main potential physical (sea surface temperature, currents, stratification and upwelling; ocean acidification; sea level rise; ultra violet radiation; rainfall patterns) and biological/ecological (phytoplankton and primary production; zooplankton and larval supply; changes in species ranges and abundances; changes to habitats that support fisheries production; calcification rates of reef organisms; physiological responses of organisms to climate change; timing of life history events) variables affected by climate change were identified and reveiwed for their possible relevance and utility in monitoring the impacts on coastal fisheries.

Despite the challenges highlighted above, this study identified a considerable number of monitoring methodologies and pre-existing studies/programs that could inform a region-wide approach to monitoring the impact of climate change on coastal fisheries. The latter category were grouped according to their biophysical monitoring objective – namely oceanographic and water quality, habitat assessment and monitoring, fisheries resource assessment and fisheries monitoring – and relevant current programs summarised.

Based on the outcomes above, options for consideration in the design of a future monitoring program are presented. These include conceptual approaches to monitoring, considerations for designing the monitoring program, collation of baseline information, choosing monitoring locations, choosing indicators and survey monitoring and design.

Finally, the main data gaps between the information currently being collected in the region and that required to monitor the impacts of climate change on coastal fisheries are identified.

List of abbreviations and acronyms

AIMS	Australian Institute of Marine Science
ASEAN	Association of Southeast Asian Nations
ASTER	Advanced Spaceborne Thermal Emission and Reflection Radiometer
AusAid	Australian Agency for International Development
BACIPS (method)	Before After Control Ipact Paired Series
BMR	Palau Bureau of Marine Resources
CDMP	Coral Disease Monitoring Program
CSPOD	Canada South Pacific Ocean Development Programme
CITES	Convention on International Trade in Endangered Species
CSP	Conservation Society of Pohnpei
CORIS	NOAA's Coral Reef Information System
CRAG	Coral Reef Advisory Group (American Samoa)
(NOAA) CRCP	NOAA's Coral Reef Conservation Program
CRIOBE	Le Centre de Recherches Insulaires et Observatoire de l'Environnement de Polynésie Française (The Center for Research Islanders and Environment Observatory of French Polynesia)
CREIOS	Coral Reef Ecosystem Integrated Observing System
CRISP	Coral Reef Initiative for the South Pacific
CTI	Coral Triangle Initiative
DAFOR (scale)	Dominant, Abundant, Frequent, Occasional, Rare
DAWR	Guam Division of Aquatic and Wildlife Resources
DMWR	American Samoa Department of Marine and Wildlife
DOI	US Department of Interior
EMAP	Environmental Monitoring and Assessment Program
FLMMA	Fijian Locally-Managed Marine Area Network
GCRMN	Global Coral Reef Monitoring Network
IFRECOR-NC	French Initiative for Coral Reefs in New Caledonia
IRD	Institut de Recherche pour le Dévelopement
JCU	James Cook University
LMMA	Locally-Managed Marine Area Network
(NOAA) MARAMP	Mariana Archipelago Reef Assessment and Monitoring Program
NOAA	National Oceanic and Atmospheric Administration
NOAA CCMA-BB	NOAA Center for Coastal Monitoring and Assessment – Biogeography
NGO	Non-Government Organisation
NMFS	National Marine Fisheries Service (USA)
NRAS	Natural Resources Assessment Surveys
PARC	Palmyra Atoll Research Consortium
PaReFiCo	Pacific Reef Fish Collaboration
PI-CPP	Pacific Islands Climate Prediction Project
PICRC	Palau International Coral Reef Center
PICT	Pacific Island Countries and Territories
PIFSC-CRED	NOAA Pacific Islands Fisheries Science Centre – Coral Reef Ecosystem Division
PI-GOOS	Pacific Islands Global Ocean Observing System
PRIA	US Pacific Remote Island Area
RAMP (surveys)	Rapid Assessment of Marine Pollution
REA	Rapid Ecological Assessment

ROCR-NC	Réseau d'observation des Récifs Coralliens (Long-term Monitoring Program of New Caledonian Coral Reefs)
SFD	Samoa Fisheries Division
SCRMN	Solomon Islands Coral Reef Monitoring Network
SOPAC	Pacific Islands Applied Geoscience Commission
SPC	Secretariat of the Pacific Community
SPSLCMP	South Pacific Sea Level and Climate Monitoring Project
SPICE	Southwest Pacific Ocean Circulation and Climate Experiment
SPREP	Secretariat for the Pacific Regional Environment Program
SST	Sea Surface Temperature
TMP	Territorial Monitoring Program
TNC	The Nature Conservancy
UNEP-WCMC	United Nations Environment Programme – World Conservation Monitoring Centre
UNC	University of New Caledonia
UQ	University of Queensland (Australia)
USFWS	United States Fish and Wildlife Service
USP	University of the South Pacific
UVC	Underwater Visual Census
WCS	Wildlife Conservation Society
WMAs	Wildlife Management Areas
WoE	Weight of Evidence (approach)
WWF	World Wildlife Fund

List of tables

Introduction

Growing evidence suggests that climate change is having more substantial and rapid effects on marine communities than terrestrial ones (Richardson and Poloczanska, 2008). Climate change is predicted to have significant impacts on the distribution and abundance of fisheries resources, and is an issue for global food security. For regions where there is significant reliance of fisheries resources for food and/or income, understanding the potential impacts of climate change, and assessing whether potential impacts are realised is a critical issue. It is all the more important for Pacific Island countries and territories (PICTs) because many have a very high reliance on seafood as a source of protein, and modelling identifies that they are projected to have reduced seafood production as a result of climate change.

While recent climate change modelling suggests that global primary production in the ocean will increase by 0.7% to 8.1% by 2050, this is accompanied by a projected global redistribution of primary production and fisheries production (Sarmiento et al., 2004; Cheung et al., 2008; 2009). It should be recognised that there are significant uncertainties with respect to modelling potential climate change impacts, but nonetheless recent modelling suggests significant impacts in the tropical Pacific. By 2050, catch potential in the tropical Pacific is projected to decrease by up to 42% from the 2005 level (Cheung et al., 2009). Climate change will potentially necessitate a more precautionary approach to coastal fisheries management in the tropical Pacific (Johnson and Welsh, 2010).

The focus of this report is the impacts of climate change on fisheries rather than the impacts of climate change on the biodiversity and functioning of coral reefs in general. That said, the link between ecosystem structure and function and fisheries production is not ignored. Specifically this report addresses the following objectives:

- A review of literature and consultation with experts in the field to identify the information needed to monitor climate change impacts on coastal fisheries.
- Identification of organisations and individuals already working in this field in the Pacific Islands.
- Recommended priorities for data collection and analysis to be initiated by the project.
- Identification of locations and partners for field testing, with a view to developing sustainable arrangements after the end of the project.

Methods

This study was conducted between February and May 2010. Four main sources of information were used:

1. Literature search

Scientific and 'grey' literature relevant to the question of monitoring the impacts of climate change on coastal fisheries in the Pacific was reviewed. The outcomes of the reveiw are largely summarised in the 'monitoring the impacts of climate change on coastal fisheries' section below.

2. Project survey

A survey seeking information on existing monitoring activities and approaches was sent to PICTs in February/March 2010. The information generated by the survey has been incorporated into the 'existing monitoring of climate change impacts' section below.

3. In country consultations

Visits were made by Associate Professor Daryl McPhee to New Caledonia, Fiji and Samoa in February/March 2010 to interview a range of researchers and agency representatives that preliminary research indicated were best placed to know what monitoring initiatives potentially relevant to climate change were being undertaken in their country or elsewhere in the Pacific. A full list of people contacted in person is provided in Annex 1.

While the focus was on identifying longer-term monitoring programs, this assessment was also extended to including relevant studies in the Pacific, including one-off studies, which may provide suitable baseline information at varying points in time from which monitoring may detect long term changes. Work undertaken directly by SPC was not included in the analysis.

Monitoring programs and studies identified were categorised as: oceanographic and water quality, marine habitats, fisheries resources (finfish and invertebrates) and fisheries.

4. Project workshop

A 4-day workshop of regional experts was held in Noumea in April 2010 to discuss current monitoring programs underway in PICTs, data necessary to monitor the vulnerability and adaptation of coastal fisheries to climate change, and potential monitoring methodologies. Attendees at the workshop are listed at Annex 2.

Monitoring the Impacts of Climate Change on Coastal Fisheries

The Challenge of Climate Change Monitoring

The potential impacts of climate change are complex. There is a need to understand large scale processes (e.g. oceanographic processes) and how these influence a range of biological and ecological processes at smaller scales. Resolving the effect of climate change on fished populations is further complicated because climate change affects a multitude of environmental factors that may affect various processes at different levels of biological organisation (Harley et al., 2006; Lehodey et al., 2006). For example, even if the effect of changes in an environmental factor on the physiology of an organism is known, it will be difficult to evaluate the outcome of this organism-level physiological response at the population or ecosystem level, even in relatively simple ecosystems (MacKenzie and Kőster, 2004). Overall, climate change has the potential to result in “regime shift” whereby the entire marine system is altered from its current state (Brierley and Kingsford, 2009). How a fisher (or group of fishers) responds to changes in abundance and availability of a species is also not simple and is influenced by cultural, historic, and technological factors.

Attempting to detect and monitor the impacts of climate change on fisheries is all the more challenging because fisheries represent a nexus between biological/ecological systems and social/economic systems. Thus, a broader range of values need to be potentially considered (including indicators) than if the questions being posed was of ecological interest only (e.g. abundance of a species of butterfly fish). The effects of climate change and fisheries interact, such that climate may cause failure in a fishery management scheme but that fishery exploitation may also disrupt the ability of a resource population to withstand, or adjust to, climate change (Planque et al., 2010).

The Pacific region is large and is biologically, ecologically, geologically and culturally diverse. Across the Pacific, there are a number of specific challenges to coastal fisheries management that are also critical in the context of monitoring to detect the impacts of climate change. These include:

- Coastal and marine environments contribute to the livelihoods of people in the Pacific who are widely dispersed and often live in remote locations;
- Gathering information on their livelihood activities is very difficult in terms of logistics and costs;
- Utilisation of the coastal and marine environments involves hundreds of different species of which the biology and ecology of many is still poorly understood;
- Legislation is complicated by the existence of customary tenure and resource use and access rights; and
- General lack of human and financial capacity by management and regulatory authorities, relative to the large areas and challenges.

The long-term nature of monitoring required also poses a challenge in terms of providing continuity of activities and the necessary support, including funding support beyond the usual three to five year window. At short time scales (e.g. less than 10 years) any anthropogenic component of climate change adds only a small increment to change compared with normal climate variability (Brander, 2010). However given the long term nature of possible impacts, the frequency of monitoring activities need not be annual.

Biophysical stressors to coastal fisheries related to climate change

Climate change may result in a number of physical stressors to the marine environment such as changes in sea surface temperature and sea level rise. These physical factors may then lead to a number of biological and ecological responses including changes to primary productivity and changes to species ranges. This section provides an overview of the main physical and biological/ecological factors considered to be important from the perspective of coastal fisheries in PICTs, and consequently those most likely to be important in monitoring the impacts of climate change.

Physical Stressors

It is critical to understand how physical climate signals propagate, and what processes lead to ecosystem changes. On a broad scale, ocean conditions in the Pacific are driven by basin-scale atmospheric pressure systems and their associated winds. Superimposed on this are local conditions that may also influence coastal fisheries. The following section outlines some of the most likely physical impacts associated with climate change.

Sea Surface Temperature, Currents, Stratification and Upwelling

The most intuitively obvious impact of climate change is an increase in sea surface temperature and this drives a number of other significant oceanographic factors including surface currents, upwelling and stratification. A challenge for coastal fisheries management is that general circulation models do not resolve fine-scale oceanographic processes that can be important for coastal productivity and coastal fisheries production (Brown *et al.*, 2010). Although there are exceptions (both higher and lower), typical coral reef fish larval dispersal is at the scale of 10-100 km (Cowan et al., 2006).

Ocean Acidification

Ocean acidification is a predictable consequence of rising atmospheric CO_2 levels and does not suffer from uncertainties associated with climate change forecasting. Absorption by the sea surface of atmospheric CO_2, reduced pH and lower calcium carbonate ($CaCO_3$) saturation in surface waters are well verified from models, surveys, and time series data (e.g. Calderia and Wickett, 2003; Feely et al., 2004; Orr et al., 2005; Doney et al. 2009). These changes can obviously lead to impacts on animals such as corals and calcareous algae that build calcareous skeletons. Calcification of most organisms is linearly related to the carbonate ion concentration in seawater (Langdon et al. 2000). Ocean acidification is considered essentially irreversible over the next century (Poloczanska et al., 2007).

Sea Level Rise

In addition to the obvious physical impact of sea level rise for many low lying Pacific nations and territories, increasing water depth may also impact coastal habitats by reducing light availability which is important for seagrass and corals (Short and Neckles, 1999). The effects of sea level rise may be in part mitigated by the local migration of habitats into what becomes more suitable habitat. For instance seagrass beds being found more shoreward than their current locations. Whether this can occur or not is partly dependent on the rate of sea level rise and a range of local factors (e.g. sedimentation rates).

Ultra Violet Radiation

Ultra violet radiation (UVR) is known to have detrimental effects on marine organisms. While climate models predict that the ozone layer will recover and thicken throughout the twenty-first century, it has been suggested that climate change will slow the recovery of the ozone layer by up to 20 years (see Poloczanska et al., 2007). There are however significant uncertainties regarding the magnitude and significance of any impacts.

Rainfall Patterns

Changes to the pattern of rainfall is a consideration for high islands in the Pacific and particularly areas where catchments deliver freshwater as riverine input to the coastal zone. It is likely that the average annual rainfall will be reduced in the Pacific (particularly the western Pacific) as a result of climate change effects. In parts of PNG at least, subsistence fisheries such as those in the Gulf of Papua and the Sepik region are dependent on estuarine species (e.g. barramundi *Lates calcarifer*, threadfins and "croakers" (Family Scienidae)) whose life cycles and year class strengths are related directly to the timing and volume of freshwater input to the marine environment (e.g. Staunton-Smith et al., 2004).

Changes to the pattern of rainfall will also potentially influence seagrass and inshore corals adjacent to sources of riverine input. Run-off alters the turbidity of nearshore waters. Prolonged elevated turbidity can result in large scale seagrass die-off (e.g. Preen et al., 1995), however if climate change does result in reduced rainfall, it will result in more exposure to ultraviolet radiation in particular which may have physiological impacts on corals and seagrass.

Biological and Ecological Factors

Phytoplankton and Primary Production

Primary production plays a fundamental role in the structuring of marine food webs. Under a climate change regime, the spatial and temporal pattern of primary production is predicted to alter, as well as a number of factors related to the structure of the phytoplankton assemblage itself. Monitoring of phytoplankton is identified as a sensitive early warning for climate-driven perturbations to marine ecosystems (Hallegraeff, 2010). Specifically focussing on coastal fisheries, it is plausible that climate induced changes to primary production and the phytoplankton assemblage will have a significant impact. This however should be tempered with the knowledge that within the coastal region primary production is heavily dependent on benthic (e.g. macrophytes and benthic microalgae) rather than pelagic primary production (Brown et al., 2010).

Phytoplankton in the tropics is nutrient limited and an understanding of the response of the assemblage to climate has been gained from the various studies that have examined responses to ENSO. In response to warmer surface waters phytoplankton biomass and growth will generally decline (e.g. Behrenfeld et al., 2006; Doney, 2006). This change is principally as a result of increased stratification of the ocean resulting in a reduction of nutrients being available in the photic zone. In coastal regions local changes may also result in response to changes in the volume and timing of rainfall, however these changes may still be significant from the perspective of coastal fisheries.

Climate change is also predicted to result in changes to the structure of the phytoplankton assemblage. There is predicted to be increased dominance in the assemblage by forms better able to cope with low nutrients such as smaller nano and pico-plankton which have higher surface area to volume ratios of their cells (Hallegraeff, 2010). A reduced availability of silica is predicted to reduce the abundance of diatoms in the assemblage (Goffart et al., 2002). Hallegraeff (2010) predicts an increase in the range of harmful algal bloom (HAB) species as well as an increasing prevalence of ciguatera in more temperate waters.

Zooplankton and Larval Supply

Changes in primary production would also result in changes to the zooplankton assemblage. The zooplankton assemblage includes larvae of fished species of finfish and invertebrates as well as other animals that are a food source for finfish in particular. During their larval stages, all fish consume zooplankton and many adult fish remain partly or wholly planktivorous during their life cycle. Synchrony between the peak in plankton abundance and the arrival of fish larvae in the plankton is considered important for the survival of fish larvae.

Hays et al. (2005) and Mackas and Beugrand (2010) consider zooplankton to be sentinels of climate change for a number of reasons. First, unlike many other marine species the majority of zooplankton species are not commercially exploited, Second, most species are short lived and so population size is less influenced by the persistence of individuals from previous years (year class strength) leading to a tight coupling between environmental change and plankton dynamics. Third, plankton can show dramatic changes in distribution because they are free floating and can respond easily to changes in temperature and oceanic current systems by expanding and contracting their ranges.

However within the Pacific (including Australia) there is limited time series information on zooplankton and limited research on the biology and ecology of most zooplankton forms (including coastal). This lack of information contrasts with other parts of the world, where no fewer than 30 countries including small or developing nations (e.g. Namibia, Peru, Estonia, Faroe Islands) have time series data on zooplankton dynamics spanning more than 15 years (Poloczanska et al., 2005).

Changes in Species Ranges and Abundances

Predicted and realised changes in species ranges as a result of climate change are relatively well studied. The ranges of a number of species have been observed to, or are predicted to move towards the poles in each hemisphere, while the range of others is predicted or observed to contract. In particular, some zooplankton groups have exhibited significant and rapid range shifts (Hays et al., 2005). For example, warm temperate copepod communities have expanded their range more than 1,000 km poleward over the last fifty years, while cooler water copepod assemblages have retracted further poleward (Beaugrand et al., 2002; Poloczanska et al., 2007).

Poleward shifts in the distribution over the last century of fish in the North Atlantic and the North Sea are well documented (e.g. Beare et al., 2004; Byrkjedal et al., 2004; Perry et al., 2005; Rose 2005 a and b). Changes in the distribution of various marine invertebrates are also well documented (e.g. Barry et al.,1995; Sagarin et al., 1999; Zacherl et al., 2003; Simkanin et al., 2005). There has been less work undertaken in the southern hemisphere that has examined range shifts of marine organism and with more variable results. Figuera and Booth (2010) identify that on the Australian temperate east coast, less severe cool water events in winter allow a number of more tropical species to persist. Stuart-Smith et al. (2010) identified only limited shifts in Tasmanian temperate reef assemblages (fish, invertebrates and macroalgae) which was contrary to predictions.

Given that range shifts are from the warmer to cooler waters, this effect of climate change may not be as significant in tropical regions such as the Pacific as it is in temperate regions. It is plausible though that longitudinal shifts in the range of some species may occur in tropical waters as the distribution of warmer waters within an ocean basin may be altered.

In terms of the abundance of species it is clearly plausible that the abundance of finfish and large invertebrates will be altered as a result of climate change impacts. However the abundances of various species may not respond identically, with a key consideration being whether a species is a habitat/foraging specialist that relies directly on a resource that is potentially impacted significantly by climate change (e.g. corallivores) that are dependent on live coral), or whether the species is a generalist. Although a large number of species typically constitute the catch in coastal fisheries, it is generally a small suite of common species that make up the catch. Many of these abundance species can be considered habitat foraging generalists. Stuart-Smith et al. (2010) identified that the majority of species with changing abundances in response to increasing SST possessed lower to mid range abundances, whereas highly abundant species showed no significant response.

Changes to Habitats that Support Fisheries Production

There are three main types of habitats that support coastal fisheries production in the Pacific – coral reefs, seagrass and mangroves. The relative importance of these habitats varies across the region, although coral reefs are generally the most important. An important consideration is that in regions where these high value habitats occur in combination, a number of fish species may use a variety of habitats and this is critical for fisheries production (and fish assemblages as a whole). Within the current context, it is important because simply monitoring coral reef habitats (regardless of the resolution) may not give a full understanding of impacts of climate change on the life history of species including those important for food security in the Pacific.

The linkage between these various habitats is well documented (e.g. Dorenbosch et al., 2006; Aguilar-Perera and Appeldoorn 2008; Verweji et al., 2008; Luo et al., 2009; Nakamura et al., 2009; Jones et al., 2010; Mateo et al., 2010). Within the Pacific, Wantiez and Kulbicke (2009) examined fish utilisation of coral reef, mangrove and bare sediment in St Vincent Bay (New Caledonia). They found that a large number of species including a number of fisheries significance utilised a variety of habitats. For example, members of the Families Holocentridae, Carangidae, Lutjanidae, Mullidae, Acanthuridae and Siganidae used mangroves as nurseries while adults utilised coral reefs. Coral reef, seagrass and mangrove habitats and the potential impacts of climate change are discussed in turn.

Coral Reefs

Coral reefs are susceptible to a number of impacts associated with climate change including increased SST and ocean acidification. Increases in SST correlate strongly with coral bleaching events and the frequency and severity of bleaching events is predicted to increase (Harvell, et al., 2002; Donner et al., 2005; Wilkinson 2008). Coral reefs in Micronesia and western Polynesia are considered particularly vulnerable to coral bleaching (Donner et al., 2005). Increased thermal stress is also implicated in the prevalence of various coral diseases, however a diverse range of biotic and abiotic stresses are potentially responsible and a significant amount of uncertainty exists (e.g. Arnoson and Precht, 2001; Sussman, 2008; Zvuloni et al., 2008; Mydlarz et al., 2010). Declines in coral cover as a result of disease and bleaching can have drastic effects on the entire coral reef ecosystem (Aronson and Precht, 2001; Jones et al., 2004; Graham et al., 2006). Ocean acidification is also a key climate induced impacts on habitat and is discussed later in this report.

Bleaching of corals principally in response to increased water temperature has been extensively studied and the mechanism that causes it (ejection of symbiotic algae from coral tissue) are well understood (see Hoegh-Guldberg, 1999). Bleaching events are not spatially homogenous even in areas subjected to uniformly high SST. There can be fine-scale spatial variation in bleaching related to other factors such as other physical factors including UVR levels and water mixing as well as the taxonomic composition of the coral assemblage (Selig et al., 2010; Yee and Barron, 2010). These fine scale patterns however are difficult to predict (Yee and Barron, 2010). The degree to which various coral can adapt and acclimatise to increased temperature is a significant area of ongoing long-term research (e.g. Baker et al., 2004; Grotolli et al., 2006).

The level of mortality of corals and the rate of recovery of corals can be variable. If a bleaching event is mild and short-lived, recovery may be in weeks and months. If the bleaching event is severe and the stressful temperatures persist for weeks, mortality may reach 100% (Poloczanska et al., 2005). In terms of recovery, Lovell and Sykes (2008) after a large scale bleaching event in Fiji identified substantial (although variable) recovery to pre-bleaching levels within five years in many areas. Recovery was considered to be facilitated by connectivity with areas of corals that persisted in areas subjected to less thermal stress and that many of the reefs were remote from highly populated land masses and large scale industrial pollution.

Coral reefs form a structurally diverse habitat that supports fish and invertebrates (e.g. Jones et al., 2004; Graham et al., 2006; Wilson et al., 2006). This structural diversity is a critical factor to consider from a fisheries perspective. While it is recognised that many coral reef fish are highly specialised and reliant on coral (e.g. species of chaetodons) (Wilson et al., 2006; Pratchett et al., 2008), the effect of coral loss on other fish species including those of fisheries significance is less clear. It is postulated that many species including a number that are of fisheries significance are associated with structural complexity *per se* rather than coral specifically. This is not downplaying the importance of corals, but it serves to highlight the importance of structural complexity (habitat heterogeneity) and also the importance from the perspective of coastal fisheries of understanding the spatial scale of heterogeneity that is important for the major fished species. A combination of disturbances, for example a bleaching event followed by severe storms that damage the reef structure may be more significant from a fisheries perspective than either disturbance in isolation.

Seagrass

The distribution of seagrass species across Pacific Islands has been assessed by Ellison (2009). Within the Pacific Island region, seagrass species richness is highest in Papua New Guinea, Vanuatu, Federated States of Micronesia, and New Caledonia. Seagrass is absent in the Cook Islands, Niue and Wallis and Futuna and is only represented by a single species in the Marshall Islands, French Polynesia, Kiribati and Tuvalu. Seagrass are considered sensitive to a number of potential climate induced changes including sea level rise, turbidity, ocean acidification and SST (Short and Neckles, 1999). Unlike corals, ocean acidification is predicted to increase productivity (Invers et al., 1997; Zimmerman et al., 1997). However, changes to turbidity and sedimentation patterns from changes to rainfall may limit the depth to which seagrass can grow. Altered seagrass depth distribution in Chesapeake Bay was the key indicator when run-off impacts caused changes in light penetration and consequently affected the seagrass assemblage (Dennison et al., 1993). Sea level rise may also limit the depth at which seagrass may grow, but may be compensated for by seagrass being able to colonise and persist in more shoreward location.

Seagrass is also sensitive to increased water temperature. Tropical species of seagrasses generally increase their photosynthesis at elevated temperatures. However, temperatures rising above the normal upper limit of 35^0C can inhibit carbon production in plants because high temperatures bring about increased respiration and photosynthetic enzyme breakdown (Ralph, 1998). Light requirements for carbon production are also greater at higher temperatures because of increased compensation irradiance (Bulthuis, 1987).

Some seagrass species are less tolerant of increased temperate than others. Campbell et al. (2006) investigated the photosynthetic responses of seven tropical seagrass species to elevated seawater temperature. Three species were identified as being intolerant to ecologically relevant exposure to thermal stress – *Halophila ovalis*, *Syringodium isoetifolium* and *Zostera capricorni*. The former two species are widespread in Pacific Islands, whereas the last species has only been recorded from Vanuatu (Ellison, 2009).

Mangroves

Mangroves are an important habitat in a number of Pacific Islands, in particular Papua New Guinea, Solomon Islands, New Caledonia, Federated States of Micronesia, Palau and Fiji. Mangroves are absent or largely absent from the Northern Marianas Islands, Marshall Islands, Vanuatu, Niue, Cook Islands, Wallis and Futuna and French Polynesia (Ellison, 2009).

Gilman et al. (2008) reviewed the potential impacts of climate change on mangroves and identified that mangroves are potentially susceptible to multiple stresses including sea level rise, increased temperature and atmospheric CO_2 levels, and altered rainfall pattern. In response to rising sea level, mangroves are expected to retreat landward to maintain their preferred position in the intertidal zone, and lateral expansions to other suitable locations may also occur. Depending on local conditions and the rate of sea level rise, this retreat may result in a reduction in the area of mangroves, or even local extinctions; however little net change may occur if the rate of colonisation of new areas is equivalent to losses sustained from the current seaward edge.

Increased surface temperature is expected to affect mangroves by: changing species composition; changing phenological patterns (e.g., timing of flowering and fruiting); increasing mangrove productivity where temperature does not exceed an upper threshold; and expanding mangrove ranges to higher latitudes where range is limited by temperature, but is not limited by other factors, including a supply of propagules and suitable physiographic conditions (Field, 1995; Ellison, 2009).

Changes in precipitation patterns are expected to affect mangrove growth and spatial distribution (Field, 1995; Eslami-Andargoli et al., 2009). Based primarily on links observed between mangrove habitat condition and rainfall trends (Field, 1995; Duke et al., 1998), decreased rainfall and increased evaporation will increase salinity, decrease net primary productivity, growth and seedling survival, alter competition between mangrove species, decreasing the diversity of mangrove assemblages. As soil salinity increases, mangrove trees will have increased tissue salt levels and concomitant decreased water availability, which reduces productivity (Field, 1995).

Unlike seagrass, mangroves will respond directly to atmospheric CO_2 levels rather than dissolved levels. It is likely that mangrove productivity will respond positively to increased CO_2 levels however there are uncertainties regarding the response and in particular how the response will differ across species and other physical parameters such as salinity. Ball et al. (1997) showed that doubled CO2 had little effect on mangrove growth rates in hypersaline areas. The greatest effect may be under low salinity conditions. Elevated CO_2 conditions may enhance the growth of mangroves when carbon gain is limited by evaporative demand at the leaves but not when it is limited by salinity at the roots. There is no evidence that elevated CO_2 will increase the range of salinities in which mangrove species can grow. The conclusion is that whatever growth enhancement may occur at salinities near the limits of tolerance of a species, it is unlikely to have a significant effect on ecological patterns (Ball et al., 1997).

Calcification Rates of Reef Organisms

As already identified, an effect of climate change is predicted to be an increase CO_2 and a decrease in pH leading to ocean acidification which has the potential to result in profound changes to tropical marine systems through decreasing calcification rates of organisms including reef building organisms. While there has been significant focus on the impacts of ocean acidification on coral, other calcareous reef forms such as the green algae *Halimeda* spp., the various encrusting coralline algae and molluscs will all be potentially impacted.

In response to ocean acidification, Hoegh-Guldberg et al. (2007) identifies three possible responses of corals and these are also generally relevant to other calcifying organisms. First, the most direct response is a decreased linear extension rate and skeletal density of coral colonies. Second, corals may maintain their physical extension or growth rate by reducing skeletal density. However, erosion could be promoted by the activities of grazing animals such as parrotfish, which prefer to remove carbonates from lower-density substrates or storm events. Third, corals may maintain both skeletal growth and density under reduced carbonate saturation by investing greater energy in calcification. A likely side effect of this strategy is the diversion of resources from other essential processes, such as reproduction.

The phytoplankton assemblage is differentially susceptible to increased ocean CO_2 levels that are predicted to occur as a result of climate change. Increased CO_2 levels can increase photosynthesis however there is significant uncertainty regarding the magnitude of this increase. For example, Beardall and Raven (2004) identified that doubling CO_2 levels only increases photosynthesis by 10% whereas Schippers et al. (2004) identified an increase of up to 40%. Ocean acidification can also reduce the calcification rates in calcified forms of phytoplankton (e.g. coccolithophores), however the limited amount of research on this has resulted in variable conclusions (Doney et al., 2009). Similar to phytoplankton, ocean acidification will also affect calcareous forms of zooplankton (e.g. pteropods and foraminiferans) (Doney et al., 2009).

Physiological Responses of Organisms to Climate Change

With the exception of mammals, marine animals are ectotherms and as such ambient temperature influences metabolic rate which influences a number of behavioural and life-history traits. The concentration of CO_2 in sea water can also influence physiological responses in organisms, in addition to calcification rates in calcified organisms. However, marine finfish are considered to be less likely to be significantly affected by the predicted increase in CO_2 and decrease in pH than invertebrates (Feely et al., 2004).

Life history traits such as size (and in some cases age) at first maturity, longevity and fecundity decrease with increasing temperature (Mora and Ospina, 2001; Wanless et al., 2004; Harvey, 2009). These changes can reduce the productivity of fished populations and make them more susceptible to fishing pressure. Climate induced changes on these factors may also interact with fishing induced changes, particular when fisheries target specific size classes (typically larger fish).

Overall, changes to life history traits is potentially a key issue for coastal fisheries, and one which a fisheries managers or communities may be able to adapt directly to with respect to altering levels of fishing effort.

Timing of Life History Events (Phenology)

Phenology refers to the timing of events in an individual’s or population’s life history (e.g. timing of reproduction). Water temperature and day length are principal triggers or correlates for the timing of biological events such as breeding and migration, and flowering and seed generation in marine plants (Poloczanska et al., 2005). While the synchronous mass spawning of coral reef invertebrates is well documented (e.g. Babcock et al., 1986), however the physiological and evolutionary mechanisms that underlie the timing of reproduction is unclear; thus it is difficult to speculate on the consequences of any changes in spawning time (Poloczanska et al., 2005).

Existing Monitoring for Climate Change Impacts

Most environmental field data are typically collected at relatively local scales and cannot provide suitable information to comprehend large scale perturbations such as climate change. They are also generally collected over relatively short timeframes and may use a variety of methods to assess similar types of habitats or assemblages (e.g. coral reef fishes). There can be very good reasons why methods used in studies may differ across a region including: differing levels of expertise and resources available, different reasons for undertaking monitoring, and regional differences in habitats or assemblages that are recognised overall as similar. The latter may necessitate a different intensity of surveying to obtain a sufficient statistical power to detect a difference, even when the effect size is the same.

This section provides an overview of methodologies, manuals and toolkits for monitoring the impacts of climate change currently available in the Pacific region, as well as specific programs and studies already in place that could inform a region-wide monitoring framework. The latter group have been divided based on their biophysical monitoring objective, namely oceanographic and water quality, habitat assessment and monitoring, fisheries resource assessment and monitoring and fisheries monitoring and assessment. Given the large number of relevant studies identified, these have been presented as a summary table. Additional information is presented in associated Annexes.

Existing monitoring manuals and toolkits

Within the peer-reviewed literature, there are no publications which document how monitoring for climate change impacts should be undertaken and no specific case studies that document the outcomes from monitoring activities specifically focussed on detecting climate change impacts. Nonetheless there a number of guidelines and manuals that document monitoring procedures with a focus on community monitoring of marine environments and fisheries resources in the Pacific region. Key examples include the following which are described briefly:

- Climate Witness Community Toolkit – WWF South Pacific Programme.
    - While not specific to fisheries or the marine environment, this toolkit outlines training approaches that can inform community monitoring with a focus on detecting climate change impacts. It is the result of a process undertaken first in Fiji (Kabara).
- Methods for Ecological Monitoring of Coral Reefs (Hill and Wilkinson, 2004).
    - This compendium of methods contains those known to be in common use for coral reef monitoring or were provided by coral reef resource managers and researchers from around the world. This manual is known to be extensively used.
- (Draft) Manual for Mangrove Monitoring in the Pacific Islands Region (Ellison, 2010).
    - Mangroves are found in all PICTs with the exception of Wallis and Futuna and the Cook Islands. Extensive and diverse mangrove assemblages occur in the western Pacific (e.g. PNG, Solomon Islands, New Caledonia, Fiji, Federated States of Micronesia, Guam, Palau and Vanuatu). This manual focuses on describing practical and low cost qualitative methods for assessing mangrove extent, community structure, status and health.
- Socioeconomic Manual for Coral Reef Management (Bunce et al., 2000).
    - This manual is intended to help reef managers understand the steps in a socioeconomic assessment, and provide practical guidelines on how to conduct baseline socioeconomic assessments of coral reef stakeholders. The main users of this manual will be coral reef managers in developing nations. The manual is arranged around four themes representing the data collection and analysis process: preparatory activities, planning and reconnaissance, field data collection and final data analysis.
- A Global Protocol for Assessment and Monitoring of Coral Bleaching (Oliver et al., 2004).
    - This protocol aims to provide a simple yet considered set of procedures to document the spatial distribution, timing and severity of large scale bleaching events; determine the factors (in addition to increased temperatures) that determine susceptibility to bleaching and subsequent mortality; develop a better understanding of current and emerging management practices may help reefs be resilient in the face of increasing sea temperatures; and raise awareness of the extent and urgency of coral bleaching as a threat to coral reefs and the ecosystem goods and services that they may provide.
- Standard Operating Procedures for Repeated Measures of Process and State Variables of Coral Reef Environments (van Woesik et al., 2009).
    - The Coral Reef Targeted Research and Capacity Building for Management (CRTR) Program is an international initiative designed to improve the knowledge base to help sustain the world’s coral reefs for the future. Documented in the manual are operating procedures grouped around six thematic areas for targeted investigations which were defined in consultation with managers and scientists around the world during the design of the CRTR Program. The themes serve as the technical foundation for the program and are defined as follows:
        - Coral bleaching and local ecological factors
        - Coral disease
        - Coral reef connectivity and large scale ecological processes

   - Coral reef restoration and remediation
   - Remote sensing
   - Modelling and decision support

- Seagrass-Watch: Manual for Mapping & Monitoring Seagrass Resources by Community (citizen) volunteers (McKenzie et al., 2003).
  - This manual provides a step by step guide and outlines initially the monitoring process and how to map seagrass using a variety of approaches. The methods are applicable across a wide geographic range. The manual also provides an inventory of (low cost) equipment that can be used to assess seagrass assemblages.

Existing Monitoring Programs and Studies

Oceanographic and Water Quality

Oceanographic monitoring initiatives have potential relevance for coastal fisheries and climate change even if they have not been undertaken specifically for those purposes. They provide an approach for detecting and monitoring physical parameters linked to climate change.

The main agencies that have undertaken work in the Pacific are IRD, SOPAC and NOAA; with support from a range of other agencies including CSIRO and various universities. The oceanographic projects identified are summarised in Table 1 below with further detail provided at Annex 3.

Table 1 Oceanographic monitoring programs and studies of potential relevance for detecting climate change impacts on coastal fisheries resources in the Pacific.

Project No	Title	Country and Location	Lead Organisation	Brief Overview	References
1.	Southwest Pacific Ocean Circulation and Climate Experiment (SPICE).	New Caledonia, Solomon Islands, PNG (in part)	IRD	Broadly, the project aims to understand the Southwest Pacific role in climate and the local oceanic environment influences.	Ganachaud *et al.* (2007) Link to SPICE Website
2.	Ocean Coastal Monitoring Buoys	Cook Islands (Penrhyn and Manihiki Lagoons)	SOPAC	Deployed loggers that measure a range of parameters including air temperature, sea temperature, salinity, wind speed and direction, pressure, dissolved O_2, pH and chlorophyll a.	-
3.	South Pacific Sea Level and Climate Change Monitoring Project	Cook Islands, Fiji, Kiribati, Marshall Islands, Nauru, PNG, Solomon Islands, Tonga, Tuvalu, Vanuatu and American Samoa.	SOPAC	Involves the deployment of Sea Level Fine Resolution Acoustic Measuring Equipment (Seaframe) at monitoring stations on wharfs that focus on collecting information on sea level change, but which also collect additional information.	Link to Project Website
4.	Coral Reef Ecosystem Integrated Observing System (CREIOS)	American Samoa, Guam, Commonwealth of the Northern Mariana Islands, U.S. Pacific Remote Island Territories. Global for SST.	NOAA	CREIOS is a program that combines various monitoring platforms to measure and record ocean temperatures, salinity, wind and wave energy, tides, currents, available UV-B, and PAR. The system includes Coral Reef Watch Satellite Monitoring which is continuous monitoring of sea surface temperature at global scales as an early warning tool to detect potential coral bleaching events.	Link to CREIOS Website
5	Monitoring Sea-Surface Temperature in the Southwest Pacific	Southwest Pacific	GCRMN	A network of temperature loggers has been established within the Global Coral Reef Monitoring Network's (GCRMN) Southwest Pacific Node to collect long-term data on temperature relationships with coral bleaching.	Morris and Mackay (2008)
6.	In-situ Sea Surface Temperature Logger Program Review and Recommendations	Fiji	CRISP	This report includes a ten year (1987-1997) sea surface temperature dataset and assesses the data in the context of coral bleaching events.	

7.	Moorea Coral Reef Long-term Ecological Research Project	French Polynesia	University of California	This project commenced in 2004 and is an interdisciplinary, landscape-scale program whose goal is to advance understanding of key mechanisms that modulate ecosystem processes and community structure of coral reefs. It contains a significant component of oceanographic and water quality.	Website: http://mcr.lternet.edu/
8	Environmental Monitoring and Assessment Program (EMAP)	Guam	Guam Environmental Protection Agency	Biennial sampling of multiple parameters around the island – See Table 13 at ATTACHMENT D	Burdick et al. (2008)
9	South Pacific Sea Level and Climate Monitoring Project	PICTs	SOPAC	Initiated in 1991. Has established a network of high resolution monitoring stations throughout the Pacific. Long-term goal to "Provide an accurate long term record of sea levels in the South Pacific for partner countries and the international scientific community, that enables them to respond to and manage related impacts"	Link to Website
10	Pacific Islands Global Ocean Observing System (PI-GOOS)		SPREP	A regional initiative to develop capacity in operational oceanography in the Pacific region. The primary focus is to work within an integrated framework that systemically acquires oceanographic and marine data, and disseminates as useful information in response to the needs of government, scientific research and the public, to address marine related issues.	Link to Website
11	Pacific Islands – Climate Prediction Project (PI-CPP)		Australian Bureau of Meteorology (funded by AusAid)	The project has four parts: 1) To develop and install PC-based climate prediction software; 2) To train NMS personnel in the use of the climate prediction software and the establishment of a climate prediction service; 3) To facilitate linkages between National Meteorological Services staff and clients making climate sensitive decisions; and 4) To train clients in the effective use of prediction information.	Link to Website
12	Biennial Surveys by NOAA research vessel(s)	United States Pacific Remote Island Areas (PRIA)[1]	NOAA PIFSC-CRED & USFWS	Monitoring concentrated on 3 functional and structural components of coral reef ecosystems: marine water quality and oceanographic conditions, benthic habitats and coral reef-associated fauna. Oceanographic data collected during these surveys is shown in Table 8 at ATTACHMENT A.	Miller *et al.* (2008)

[1]The US PRIA includes seven islands, atolls and reefs in the Central Pacific that are under the jurisdiction of the United States. Baker, Howland and Jarvis islands, Johnston Atoll, Palmyra Atoll (part-owned by the Nature Conservancy), and Kingman Reef and Wake Island.

13	Biennial Research Cruises	Guam	NOAA PIFSC-CRED	Monitoring of: 1) conductivity, temperature, depth, dissolved oxygen, and chlorophyll to a depth of 500 m using deepwater conductivity, temperature and depth (CTD) sensors; 2) temperature, salinity, and temperature at multiple sites using shallow-water CTDs; 3) chlorophyll and nutrients (nitrate, nitrite, silicate, phosphate) concurrent with the deep and shallow-water CTDs; 4) temperature at 0.5 m using two SST buoys; and 5) temperature at depths between 0.5 and 30 m using three subsurface temperature recorders.	Burdick et al. (2008)
14	Monthly water quality monitoring of marine waters around Palau.	Palau	Environmental Quality Protection Board of Palau (EQPB)	Turbidity, pH, salinity, dissolved oxygen, fecal coliform and temperature are collected monthly at 40 permanent sites.	Marino et al. (2008)
15	Biennial Research Cruises	American Samoa	NOAA PIFSC-CRED	Carried out in conjunction with research cruises and surveys of US PRIA – similar oceanographic data collected (See Table 10 at ATTACHMENT B)	Aeby et al. (2008)
16	Coastal water quality monitoring	American Samoa	ASEPA and NPAS	Commenced concentrated monitoring and assessment of coastal water quality in 2004 to document coastal water and coral reef condition. Methods follow US EPA Environmental Monitoring and Assessment Program.	Aeby et al. (2008)
17	Solomon Islands Coral Reef Monitoring Network (SCRMN)	Solomon Islands	WWF	Two temperature loggers have been deployed on two SCRMN sites in Gizo - Njari and Kennedy. It is believed some problems have been encountered in the maintenance and retention of some of this equipment.	Kere and Solomon Islands Coral Reef Monitoring Network (2008)

Habitat Assessment and Monitoring

Habitat mapping can be undertaken at many different scales using several methods and the activities identified reflect this. The majority of habitat assessment and monitoring undertaken has focussed on coral reef habitat with a significant focus on comparing differences inside and outside marine protected areas (however defined). Due to the fact that coral reef monitoring surveys generally record a range of data on habitat and associated fisheries resources. To reduce duplication, some studies noted below are not specifically referred to again in the following section for monitoring of reef associated fisheries resources, however, a degree of overlap may be applicable. Habitat projects identified are outlined in Table 2 below with further detail provided at Annex 4.

Table 2 Habitat assessment and monitoring programs and studies of potential relevance for detecting climate change impacts on fisheries resources and fisheries in the Pacific.

Project No	Title	Country and Location	Lead Organisation	Brief Overview	References
1.	Seagrass-Watch Program	Federated States of Micronesia , Fiji, New Caledonia, Palau, Papua New Guinea and the Solomon Islands	Fisheries Queensland	Seagrass-Watch is a non-destructive seagrass assessment and monitoring program. Key parameters assessed include the species composition, extent of seagrass beds and their above ground seagrass cover.	Link to Website
2.	Millennium Coral Reef Mapping Project	Cook Islands, Solomon Islands (in part), Kiribati, New Caledonia, American Samoa, Tokelau, Tuvalu, Vanuatu)	University of South Florida with Pacific component lead by IRD.	The project is a global assessment of the extent and diversity of coral reef habitat which includes assessment of a number of countries in the Pacific.	Andréfouët et al. (2005)
3.	Global Coral Disease Database	Global	UNEP-WCMC and NOAA NMFS.	This is a collaboration between UNEP-WCMC and NOAA NMFS that collates information on the global distribution of coral diseases to contribute to the understanding of coral disease prevalence.	Link to Website
4.	Ecological coral reef surveys	US PRIA	USFWS and NOAA PIFSC-CRED in collaboration with University of Hawaii's Joint Institute for Marine and Atmospheric Research.	Biennial research cruises to monitor the ecosystems of the US PRIA undertaken since 2001. Surveys include reef habitats and associated fish and invertebrate assemblages (including coral reef fisheries resources). An outline of data collection activities in the US PRIA is provided at Table 9 at ATTACHMENT A. Cruise reports for surveys undertaken 2005-2007 are available at: http://www.pifsc.noaa.gov/library/cruise.php	Miller et al. (2008)

5.	Ecological coral reef surveys	Federated States of Micronesia (FSM)	FSM MRD and EPA state depts., national NGOs, SPREP, TNC, US Peace Corps, PICRC and NOAA PIFSC-CRED	FSM's 4 states are at different stages of development and implementation of coral reef monitoring programs, with some well established programs commencing in 1994. Ongoing coordination from Palau International Coral Reef Centre (PICRC) and NOAA is provided to support the first regionally coordinated monitoring program within Micronesia. Table 12 at ATTACHMENT C provides an outline of monitoring activities in FSM.	George et al. (2008) GCRMN Contact: Eugene Joseph, Conservation Society of Pohnpei (CSP) Email: csp@mail.fm
6	Coral Reef Monitoring	Guam	Guam Coral Reef Initiative Coordinating Committee	Several monitoring, assessment and research activities have been conducted in Guam since 2004. These include gathering data on benthic habitat, water quality, biological communities associated with coral reefs (e.g. Fish and Invertebrates) and socio-economic information. A full list of ongoing studies related to Guam's reefs is provided in Table 13 at ATTACHMENT D.	Burdick et al. (2008) and Goldberg et al. (2008) GCRMN Contact: Sebastian R. Marino (PICRC) Email: smarino@picrc.org
7	Rapid Ecological Assessments (REAs)	Guam	NOAA-MARAMP	Island-wide REAs were undertaken in 2003, 2005, 2007, with repeated surveys of the same sites in after 2003.	Burdick et al. (2008)
8	Marshall Islands Natural Resources Assessment Surveys (NRAS)	Marshall Islands	NRAS-Conservation	A series of studies at various locations in the Marshall Islands that have examined benthic habitats (coral and algae). A complete outline of monitoring and assessment activities in the Marshall Islands and associated sampling methods are provided in Tables 14 and 15 at ATTACHMENT E.	Berger et al. (2008) Contact: Sebastian R. Marino (PICRC), GCRMN Coordinator Micronesia and American Samoa Email: smarino@picrc.org
9	Rongelap Atoll Long-term Reef Monitoring Program	Marshall Islands	Maria Beger (The University of Queensland) and Zoe Richards (James Cook University)	Initiated in December 2006. Key objective to document trends in the coral reef community during resettlement of the atoll (See Table 16 at ATTACHMENT E for detailed objectives) Collects quantitative data for fishes, mobile invertebrates, benthic cover, live coral cover and diversity along with limited climatic and oceanographic data.	Berger et al. (2008)

10	Coral reef monitoring program	Palau	Palau International Coral Reef Centre (PICRC)	Nation-wide coral reef monitoring program for Palau launched in 2001. Currently 21 permanent monitoring sites. Table 17 at ATTACHMENT F provides an outline of monitoring and assessment activities in Palau.	Marino et al. (2008) GCRMN Coordinator: Yimnang Golbuu (PICRC) Email: ygolbuu@picrc.org
11	Habitat mapping	Palau	NOAA CCMA-BB[2]	NOAA released habitat maps covering 2,450km2 of nearshore marine habitats in Palau in 2007	Marino et al. (2008)
12	Coral reef monitoring and assessment	PNG	The Nature Conservancy (TNC)(Kimbe Bay – West New Britain), James Cook University (JCU) (Kimbe Bay), Wildlife Conservation Society (WCS)(Kavieng & Manus Is.), Wetlands International Oceania (Madang), WWF (Madang)	NGO's operating monitoring programs associated with established LMMA's in Kimbe Bay, Kavieng, Manus Island and Madang. Annual monitoring by JCU and TNC began in Kimbe Bay in 1996. Kimbe Bay program supported by TNC, USAID and David and Lucile Packard Foundation. REA's have been conducted to assess biodiversity (focusing on corals, reef fishes (including spawning aggregation sites), mangrove forests, seagrass beds and cetaceans).	Chin et al. (2008) Green et al. (2007) Contact: Alison Green, TNC Email: agreen@tnc.org
13	Long term monitoring of fringing coral reefs subject to sediment stress in PNG.	PNG	Hydrobiology Pty Ltd AIMS Lihir Management Company	Fringing reefs in Lihir group of islands in PNG monitored from 1994 to 2002 using video and photographic transects to record relative cover of major benthic life-forms.	Flynn et al. (2006) Contact Email: adrian.flynn@hydrobiology.biz
14	Atlas of Southeast Papua New Guinea coral reefs	PNG (part)	L'Institut de recherche pour le développement (IRD)		Andréfouët et al. (2006)
15	Coral reef surveys	Solomon Islands	Solomon Islands Coral Reef Monitoring Network managed by WWF	Five permanent locations established in 2004 – 4 in western province and 1 in Isabel Province. Methods used in surveys follow the modified GCRMN survey methodology – point intercept method (using X frames) for substrate and UVC for fish along same belt transect (50m).	Kere and Solomon Islands Coral Reef Monitoring Network (2008) Contact Email: nzkere@solomon.com.sb

[2] NOAA – Center for Coastal Monitoring and Assessment – Biogeography Branch

16	Coral reef monitoring	Vanuatu	Reef Check Vanuatu's Coral Reef Monitoring Network coordinated by Vanuatu Fisheries Department. Supported by AusAid and Peace Corps Volunteer Services	Systematic monitoring began in 2001. Now monitoring 57 sites in 11 regions throughout the islands. Follow Reef Check methodology with addition of additional species targeted by local fishers.	Raubani (2007) GCRMN Contact: Jason Raubani, Vanuatu Fisheries Email: 3jraudinbani@gmail.com
17	Fiji Coral Reef Monitoring Network Assessment of hard coral cover from 1999-2007	Fiji	USP	A long term monitoring program using the Reef Check and FCRMN Point Intercept Transect (PIT) methodologies that spanned several major bleaching events.	Lovell and Sykes (2008) Contact: Helen Sykes, GCRMN Country Coordinator Email: helen@marineecologyfiji.com & Edward Lovell, USP Email: lovell_e@usp.ac.fj
18	CRISP's Southwest Pacific Node	Melanesia (Solomon Islands, Vanuatu & Fiji)	USP, Fiji (funded through CRISP)	Monitoring commenced in 1991 and provides a temporal trend of coral diversity and cover including recovery from bleaching and crown of thorns outbreaks.	http://www.crisponline.net/
19	CRISP's Polynesia Mana Network	French Polynesia, Cook Islands, Wallis and Futuna, Kiribati, Tokelau, Tonga, Tuvalu and Niue. (Pitcairn Islands recently added to the network)	CRIOBE (funded through CRISP)	Monitoring commenced in 1991 and provides a temporal trend of coral diversity and cover including recovery from bleaching and crown of thorns outbreaks. Permanent monitoring sites established in Kiribati, Tokelau and Niue in 2005.	http://www.crisponline.net/ Contact: Caroline Vieux, SPREP Email: CarolineV@sprep.org
20	Territorial Monitoring Program (TMP)	American Samoa	Dept of Marine and Wildlife Resources (DMWR)	The TMP has monitored 11 sites annually since the program commenced in 2005. Replicate 50m transects laid along 8-10m contour at each site. Line intercept method to record benthic cover at each ½m. Bleaching monitored in two back-reef lagoon pools from 2003. A number of additional monitoring and research activities have been established in American Samoa - Table 11 at ATTACHMENT B provides an overview of all current monitoring activities in American Samoa, including those outside the TMP.	Craig et al. (2005), Aeby et al. (2008) GCRMN Contact: Chris Hawkins, Coral Reef Advisory Group and Coral Reef Initiative American Samoa Email: amsamoacrag@yahoo.com

21	Reef Assessment and Monitoring Program	American Samoa	NOAA PIFSC-CRED	Recorded benthic data on each island in AS biannually since 2002. 62 sites in total in 2006. 2x25m transects at 12-15m depth at each site, using point intercept method to record benthic cover. Coral disease prevalence is also recorded along with quantitative algal monitoring.	Aeby et al. (2008)
22	Coral Disease Monitoring Program	American Samoa	Dept of Marine and Wildlife Resources (DMWR)	This program monitors seven sites around Tutuila annually, with two 25-m tapes laid on depth contours at 5-18 m, with most at 6-10 m. Data collection began in 2004. Benthic categories are recorded with the point-intercept technique. Similar transects were conducted in the Ofu back reef pools in 2005 and on six sites on reef slopes around Ofu-Olosega in 2006 (Aeby et al., 2006).	Aeby et al. (2008)
23	Protected Marine Areas surveillance program	French Polynesia	CRIOBE	This program uses the BACIPS method (Before After Control Impact Paired Series) to determine the effectiveness of marine protected areas. The surveys commenced in 2004 and are undertaken twice yearly.	Email: criobe@mail.pf

Fisheries Resource Assessment

This section focuses on monitoring programs and studies that provide assessment of fisheries resources *in situ*. Fisheries resources include finfish and various invertebrates. Information collected may also include information on non-fisheries resources (e.g. non-fisheries finfish observed during UVC). As well as the specific monitoring programs identified in Table 3, a number of specific studies of fisheries resources have been undertaken which provide information that could be used as a baseline for monitoring programs. This includes studies in the Solomon Islands (Lincoln-Smith et al., 2006); Fiji (De Mazières, 2008) and New Caledonia (Wantiez and Kulbicki, 2009)

Fisheries resources monitoring projects identified in the Pacific Ocean are outlined in Table 3 below, with additional detail provided in Annex 5.

Table 3 Fisheries resources assessment and monitoring programs and studies of potential relevance for detecting climate change impacts on fisheries resources and fisheries in the Pacific.

Project No	Title	Country and Location	Lead Organisation	Brief Overview	References
1.	Overlap of shorefishes assemblages between mangroves, soft bottoms and coral reefs within a lagoon seascape, New Caledonia	New Caledonia (St Vincents Bay)	University of New Caledonia/IRD	This study provides detailed information on the utilisation by the fish assemblage of a number of inter-linked marine habitats with a lagoonal environment.	Wantiez and Kulbicki (2009)
2.	Spatial distribution of reef fish communities: An investigation of the Coral Coast, Fiji Islands.	Fiji (Coral Coast)	USP	While not specifically a monitoring program, the main goal of this research was to determine and to model the spatial distribution of reef fish communities of the Coral Coast, Fiji based on the habitat types and through a geostatistical approach.	De Mazières (2008)
3.	Pacific Reef Fish Collaboration (PaReFiCo)	Hawaii, the northern Line Islands, Fiji, American Samoa, Solomon Islands, and Wallis and Futuna	Dalhousie University	The Pacific Reef Fish Collaboration (PaReFiCo) is an initiative among reef biologists to assess human impacts on reef fish communities across the Pacific	PaReFiCo website Email: reeffish@dal.ca
4.	Marshall Islands Natural Resources Assessment Surveys (NRAS)	Marshall Islands	NRAS-Conservation	A series of studies at various locations in the Marshall Islands that examined fish and invertebrate resources.	NRAS-Conservation
5.	Moorea Coral Reef Long-term Ecological Research Project	French Polynesia	University of California	This project commenced in 2004 and is an interdisciplinary, landscape-scale program whose goal is to advance understanding of key mechanisms that modulate ecosystem processes and community structure of coral reefs.	http://mcr.lternet.edu/ Email: Russell Schmidt schmitt@lifesci.ucsb.edu
6	Effects of marine reserves on abundance and sizes of valuable tropical invertebrates	Solomon Islands		To detect effects of marine reserves on the size and abundance of giant clam, topshell and several species of holothurians (beche de mer).	Lincoln-Smith et al. (2006) Email Marcus.LincolnSmith@cardno.com.au
7.	Long-term Monitoring of New Caledonian Coral Reefs (ROCR-NC)	New Caledonia	University of New Caledonia	The ROCR-NC (Réseau d'observation des Récifs Coralliens) program involves annual surveys of long-term reef sites in New	

				Caledonia.	
8	Underwater Visual Census	American Samoa	DMWR	Extensive underwater visual surveys have been conducted for reef associated fish and invertebrate species throughout the territory in 1996, 2002 and 2004. NOAA PIFSC-CRED continues to carry out similar surveys on a biannual basis.	(Green 2002, Schroeder, unpublished data)[3]
9	Atoll Assessments	Marshall Islands	Secretariat of the Pacific Community (SPC)	Four atolls, Ailuk, Likiep, Majuro and Arno, were assessed by scientists from the SPC to determine the abundance and distribution of commercial fish and invertebrate species. Simultaneous assessments of reef health and substrate composition undertaken.	Berger et al. (2008)
10	Underwater Visual Census (UVC)	Solomon Islands (Western Province)	WWF GCRMN Surveys	UVC of every fish seen within 5x50m belt transect up to 5m above. Fish size and abundance are recorded at species level for important reef fish families such as Haemullidae, Labridae, Lethrinidae, Lutjanidae, Mullidae, Scaridae, Serranidae and Carangidae. Fish abundance recorded at family level for reef indicator species such as Pomacentridae, Pomacanthidae, Caesonidae, Acanthuridae, Balistidae, Ostracidae and Diodontidae.	Kere (2008) GCRMN Contact: Nelly Kere, WWF Solomon Islands Email: nzkere@solomon.com.sb
11	Reef Check Vanuatu	Vanuatu	Vanuatu Fisheries Dept	Target species of coral fish surveyed at 57 sites across Vanuatu on an annual basis.	Raubani (2007)
12	Community monitoring at Marow (Emau Island)	Vanuatu		This is a community based monitoring program that includes the broad assessment of substrate cover.	Dumas et al. (2009) Contact: Eric Clua ericc@spc.int
13	Fisheries	Tuvalu	Fisheries Dept Tuvalu Some support now being provided to Tuvalu through CRISP.	(Unverified) Monitoring of some fisheries and coastal erosion indicators but capacity for more detailed monitoring of reef resources is lacking. This is despite training being provided in GCRMN and Reef Check level monitoring in previous years.	Sulu et al. (2002) GCRMN Contact: Tupulaga Poulasi, Dept of Fisheries Email: etuati.ptauia@gmail.com

[3] Information/data/maps provided by ReefBase (http://www.reefbase.org)

Fisheries Monitoring and Assessment

Fisheries assessments refer to assessment of catch, consumption or sale. All countries in the Pacific collect general census information that is off varying quality. There is also a significant degree of variation in the level of specific focus given to collecting fisheries information within different countries, most often due to capacity or resource constraints within national fisheries management departments. Specific fisheries assessment and monitoring projects identified in the Pacific are outlined in Table 4 below, with additional detail provided in Annex 6.

Table 4 Fisheries assessment and monitoring programs and studies of potential relevance for detecting climate change impacts on fisheries resources and fisheries in the Pacific.

Project No	Title	Country and Location	Lead Organisation	Brief Overview	References
1.	Trends in Reef Fish Population and Associated Fishery after Three Millennia of Resource Utilization and a Century of Socio-Economic Changes in American Samoa	American Samoa (Tutuila and Manoa)	American Samoa Department of Marine and Wildlife Resources	This paper identifies and summarises shore-based data from roving catch and effort data collection done in Tutuila and Manoa, a market survey in Tutuila and boat-based data from intercept interviews at the main dock in Tutuila.	Sabater and Carroll (2009)
2.	CITES Trade Information	Fiji, PNG, Palau, Solomon Islands, Samoa, all French and American territories.	CITES	CITES collects information on the export of listed species from member countries.	http://www.cites.org/
3	Fisheries monitoring in Palau	Palau	Bureau of Marine Resources (BMR)	Market sales reports based on price categories instead of individual fish species. Market information has varied in the past with 30-85% coverage. BMR data collection program tracks exports with all exporters required to report on name, number and weight of all fish and invertebrates and other organisms being exported by air. Market data is collected to track sales to hotels, restaurants.	Marino et al. (2008)
4	Market-based analysis	FSM	Conservation Society of Pohnpei (CSP)	Market based analysis (in 2006) in conjunction with ongoing ecosystem assessment efforts in order to determine condition of Pohnpei's reef fisheries.	George et al. (2008)
5	Unmonitored aquarium fish trade	Marshall Islands		Collection and export of live aquarium fish is reportedly unregulated and unmonitored by local authorities.	Berger et al. (2008)
6	Creel Surveys of artisanal fishers	Nauru	Nauru Fisheries and Marine Resources Authority (NFMRA)	Creel surveys of local artisanal and subsistence fishers have been undertaken (at an unknown frequency) in Nauru since 1995 using catch/effort logsheet forms developed in consultation	Personal Communication with NFMRA (2010).

				with SPC (see ATTACHMENT F). It is understood SPC intends to host a workshop in June 2010 to harmonise the forms used in creel surveys throughout different Pacific Island countries.	
7	Creel Surveys	Guam	Division of Aquatic and Wildlife Resources (DAWR)	Regular creel surveys are undertaken to monitor artisanal fisher catches, catch composition, catch per unit effort and other fishery indicators.	Burdick et al. (2008)
8	Fijian Local Marine Managed Area Network (FLMMA)	Fiji	Environment Unit, Institute of Applied Science (IAS), University of the South Pacific (USP)	A community based monitoring program based on detailed logbook information.	Morris and Mackay (2008) Contact: Bale Tamata, Fellow, IAS-USP Email: tamata_b@usp.ac.fj
9	Socio-economic	PNG	Vieux, C.	Workshop Socio-economic assessement of Sunalailai community, in part, to gain a better understanding of local marine resource use patterns.	Vieux (2008)
10	Fisheries Monitoring in Samoa	Samoa	Samoa Fisheries Division (SFD)	A dedicated government resourced program including on-going market surveys, surveys of roadside stalls and periodic household surveys. Provides data on catch composition, size and volume of catches.	Personal communication with SFD (2010)
11	Creel surveys	American Samoa	American Samoa DMWR	Surveys to document actual species and quantities of fish extracted from reefs at fish landing points. Artisinal bottomfish catches have been monitored since 1982.	
12	Lobster Survey	American Samoa	Department of Marine and Wildlife Resources	Survey of artisanal lobster fishery in American Samoa undertaken in 2003	Coutures, (2003)
13	Socio-economic Assessment of Coral reefs	American Samoa	Spurgeon et al.	Comprehensive economic valuation of American Samoa's coral reefs.	Spurgeon et al. (2004)
14	Socio-economic Assessment of Coral reef resources	American Samoa	American Samoa Coral Reef Advisory Group	2006 economic valuation of American Samoa's coral reef resources	Jacobs Inc., MRAG Americas, NIWAR and Prof N. Polunin.

Future Monitoring Options

The impacts of climate change are complex. Given this *a priori* complexity it is relevant to ask whether effort and expenditure should be invested in monitoring activities or whether "action" should simply be taken. While monitoring in isolation is of only limited value, it is critical when embedded within an adaptive management framework.

Monitoring is necessary to identify whether an impact is occurring, whether any existing approaches to ameliorate impacts are being successful and if so why, or why not. If the approaches are not successful then monitoring can inform changes to mitigation approaches which have a higher likelihood of success.

This section outlines a conceptual framework for monitoring the impacts of climate change on coastal fisheris in the Pacific, together with possible indicators to guide data collection and potential partners and locations for field testing.

Conceptual Approaches to Monitoring

There are three main types of monitoring that are applicable for detecting the impacts of climate change. The first is a "weight of evidence" (WoE) approach where available data from multiple sources is used (Weed, 2005). The WoE approach does not require that data is collected using standardised methodologies. A WoE can be beneficial when it is necessary to integrate disparate information that is collected using very different methodologies to address a broad question. The question of climate change impacts on coastal fisheries fits this description. A WoE approach however, can be open to multiple interpretations, however there are approaches available to assist in making more rigorous interpretation (reviewed in Weed, 2005). A WoE cannot by itself demonstrate causative effects of one variable on another.

The second approach is "surveillance monitoring". This approach involves both qualitative or semi-quantitative techniques and frequently the application of rapid assessment tools. Surveying is often un-replicated and reference sites may be lacking which in ecology hinders the ability to separate causation from correlation and like the WoE approach, surveillance monitoring can be open to multiple interpretations. The third approach is "effects monitoring" which is fully quantitative with sufficient replication and spatial and temporal controls to eliminate as many confounding factors as possible. Effects monitoring if properly designed is far less ambiguous than either WoE or surveillance monitoring. Coupled with manipulative experiments, effects monitoring can allow for identification of causation.

There is a gradient of both cost and expertise required between the three approaches. WoE is the lowest cost approach and is most amenable to community involvement. In contrast, effects monitoring is high cost and is best undertaken by highly trained professionals (scientists). Effects monitoring does not always lend itself to community participation, however if community members are well trained and supervised (e.g. Lincoln-Smith et al., 2006) then effective community involvement can be achieved.

Given the complex nature of climate change impacts, the diversity of data that is relevant, together with the difficulty and cost of effects monitoring, a WoE approach is the most appropriate overall approach. However, specific projects and programs focussed on both surveillance monitoring and effects monitoring can provide critical information to inform a WoE approach. Effects monitoring is best undertaken in Pacific Island nations where research infrastructure and capacity is high.

Considerations for Designing the Monitoring Program

Where possible, monitoring initiatives should be undertaken as partof an integrated program, but it is also recognised this may not be feasible. That said, as long as it can be justified, it is not a necessary requirement to monitor the same variables in the same way across the monitoring locations chosen. For instance, the monitoring of the seagrass assemblage may be important in one PICT, but not others.

The main steps in designing the monitor program include:

- Establishing baseline information from previous and existing work.
- Using the information together with other considerations to choose which PICTs monitoring should be focussed on.

- Develop a conceptual (qualitative) model to explain the linkages between the various key parameters and fisheries production.
- Identifying key indicators.
- Design surveying/sampling, using baseline information to define significant changes and inform aspects of the survey design (e.g. stratification and replication).
- Establish potential responses to significant changes and how they will be implemented (beyond the scope of this report).

Collation of Baseline Information

This report has documented that while research and data gaps are present, there has been a significant amount of work undertaken in the Pacific, particularly with respect to habitat and associated fisheries resource assessment for coral reefs. This report has identified the main sources of information that can be used to establish baseline information. Although there are overlaps, baseline information can be divided into that associated with oceanography, habitat, fisheries resources and fisheries. Using the available information to establish baselines in PICTs was beyond the scope of this report.

Choosing Monitoring Locations

The Pacific region is obviously large and diverse. Key areas of diversity specifically related to climate change and coastal fisheries include:

- the regional diversity of habitats at a number of different scales;
- the diversity of the nature and magnitude of existing impacts;
- variation in the vulnerability of the natural system to climate change;
- variation in the vulnerability of coastal communities to climate change impacts; and
- variation in the capacity and infrastructure to undertake monitoring and assessment.

This diversity needs to be considered in choosing monitoring locations[4], together with the existence of suitable information to establish a baseline. In terms of existing baseline information only, three PICTs standout as being significant: New Caledonia, French Polynesia and Fiji. Additionally a high level of information is also available from Samoa (particularly fisheries information) and American Samoa.

Ideally, locations should be chosen to reflect both atolls and high islands as this potentially encompasses both habitat diversity and variations in vulnerability. Locations where capacity and infrastructure to undertake monitoring in the short term is low should be avoided unless an outside agency can be mobilised with a high degree of self-sufficiency. There is a significant advantage in locating any additional monitoring in locations where effective monitoring and assessment has been previously undertaken. This is because if monitoring and assessment has been undertaken in an area, there is therefore local capacity to do it, or it is feasible for remote research agencies to do it (e.g. NOAA); and there is potentially existing information from which to create a baseline to compare future monitoring with.

Choosing the number of monitoring locations is also an important issue. For a given amount of financial investment there is frequently a requirement to balance having a large number of monitoring locations to demonstrate the broad spatial nature of an impact, with ensuring sufficient surveying is undertaken in each location to detect the contrast of interest. This consideration is particularly important when effects monitoring is undertaken. In the first instance, it is generally recommended to select a smaller number of locations and expand the number over time. In the current example, a potential approach is to choose two PICTs that are principally atolls and two that are high islands.

For monitoring of habitats and fisheries resources within the chosen location (PICT), monitoring sites can be chosen that have a gradient of potentially impacts from heavily fished to lightly fished. Establishing some monitoring initiatives in marine managed areas is important to potentially remove the

[4] In this instance monitoring locations refers to a PICT.

confounding effect of fishing. However, it should be recognised that a number of marine managed areas are periodically opened to fishing and as such may not be true reference areas, although they may still represent a contrast of fishing effort levels. If monitoring is focussed in extremely remote locations where human impacts are considered to be very low, then interpreting results with respect to coastal fisheries may be problematic. Nonetheless, very remote areas can potentially be effective reference/control locations. Such sites may include the Pacific Remote Island Areas (PRIA) of the United States, which are surveyed biennially by specialised scientists from NOAA PIFSC-CRED and USFWS.

Conceptual Model

Conceptual models are frequently used to understand complex biological, ecological and physical interactions. They will be particularly useful in understanding the interactions of the various potential climate change impacts and to inform monitoring, and in particular to assist monitoring in being informative with respect to the specific questions being posed. In the current context, constructing a conceptual model should begin by identifying key species (or groups) in the harvest and working backwards to indentify components of the habitat and the relevant scales, key biological issues, and relevant oceanographic factors.

Indicators

Indicators can include direct measures of physical variables that may lead to impacts on flora and fauna assemblages, and/or measures of change in those assemblages. It is almost always not feasible to monitor all components of an ecosystem and as such it is common to monitor indicator species or groups of species (e.g. functional groups). Broadly, there are a number of criteria to consider when choosing indicators and these criteria include:

- The indicator should respond directly to the disturbance and be specifically related to the monitoring question posed;
- As far as possible, the indicator should not be confounded by other factors;
- The indicator should have relatively little natural variation, or the level of variation is reasonably well known;
- The indicator should be relatively easy to monitor;
- The response of the indicator to the disturbance should be rapid;

Specifically related to choosing indicator species, Hilty and Merenlender (2000) identify a number of criteria (Table 5). In the current instance, these criteria represent a guide only.

As clearly demonstrated in this report, climate change potentially introduces multiple stressors to the marine environment and these stressors can potentially elicit a number of direct or indirect biological and ecological responses. Further, a climate change stressor may interact cumulatively with other climate change stressors, or other stressors (e.g. fishing) to elicit a biological or ecological response. Table 6 identifies the key physical stressors arising from climate change, the rationale for considering them, the challenges of using then in monitoring and the capacity to monitor in the Pacific, and summarises the type of indicator broadly applicable.

Table 7 identifies the key potential biological and ecological responses that may be elicited from the potential stressors identified in Table 6 and the rationale for considering them, the challenges of using them in monitoring and the capacity to monitor in the Pacific. Table 7 also summarises the type of indicator broadly applicable.

Table 5 Suggested criteria and key attributes for choosing indicator species (modified from Hilty and Merenlender, 2000).

Suggested Criteria	Key Attributes
Baseline Information	
Clear Taxonomy	Taxonomic Status Clear
Biology and Life History Studied	Information on key parameters is available
Tolerance Levels Known	Tolerance levels to a disturbance are known
Correlations to Ecosystem Changes Established	Known response to disturbance
Locational Information	
Cosmopolitan Distribution	Wide distribution, not migratory
Limited Mobility	Sessile, sedentary or site attached
Niche and Life-history Characteristics	
Early Warning and functional Over the Range of Stress	Reproduction rate high, small body size,
Trends Detectable	Reproduction rate high, small body size, low or medium trophic level
Low Population Variability	Low population fluctuations
Specialist	Food/habitat specialist
Ease to Assess	Easy to find and measure
Other	
Societal Importance	Economically valuable or intrinsically important (e.g. threatened species)

Table 6 Physical factors affected by climate change and an overview of potential indicators, and the rationale, challenges and regional capacity for undertaking relevant monitoring.

Physical Factors Affected By Climate Change	Rationale for Monitoring	Challenges for Monitoring	Regional Capacity for Monitoring	Potential Indicators	Potential Principal Partners
Sea Surface Temperature, Currents and Stratification	Direct physical result of climate change that provides the basis of a number of biological/ecological responses. There is currently broad-scale Pacific wide monitoring of SST. In addition to this broad-scale information, SST in the coastal zone is also a potentially important parameter.	For coastal fisheries, examination of smaller scale oceanographic factors may be required. Limited scope for community involvement, however the community could be involved in upkeep of equipment.	High in French and American territories but very limited elsewhere. However, global monitoring of SST is undertaken and data is freely available. Collected at local scale in some select areas by NGOs leading monitoring programs associated with LMMAs	SST maxima and variation at a number, current speeds and directions.	NOAA, IRD, SOPAC
Changes to rainfall pattern	Rainfall Influences the life-history of a number of harvested species in some PICTs, and salinity and turbidity also influences the depth distribution of corals and seagrass in some areas.	Nil for changes in rainfall.	High. Information is also important for national water security and agricultural production.	Timing and volume of rainfall, salinity and turbidity.	Various Met Bureau's, IRD, Pacific Islands Climate Prediction Project (PI-CPP)
Ocean Acidification and calcification rates.	Largely un-confounded by other variables. Identified as a critical issue for marine environments during this century and beyond.	Further research on how some taxa are likely to adapt to. Some intra-specific variation in calcification rates due to exposure but can be overcome in any field experiments with an appropriate experimental design. Additional lab experiments may be necessary to refine and better understand relationships between calcification rates, water chemistry and other factors.	High in a number of countries including French and American territories and Fiji.	pH levels, calcification rates of various organisms (e.g. *Halimeda*).	JCU, NOAA, SOPAC, CRIOBE
Sea level rise	Independent of fisheries, this is a key variable for many low-lying PICTs. It is potentially important for the distribution of mangroves, seagrass and corals	Nil	High for the physical component of sea level rise. Where existing ecological monitoring of habitat is being undertaken, there is limited additional work required.	Rate of sea-level change and response of indicator taxa.	NOAA, IRD, SOPAC (.The South Pacific Sea Level and Climate Monitoring Project (SPSLCMP))

Table 7 Identification of biological/ecological responses to climate change and an overview of potential indicators, and the rationale, challenges and regional capacity for undertaking relevant monitoring.

Biological/Ecological Responses	Rationale for Monitoring	Challenges for Monitoring	Regional Capacity for Monitoring	Potential Indicators	Potential Partners
Changes to the Pattern of Primary Production in the Phytoplankton Assemblage	The base of the food chain so exerts a profound influence on food chains, particularly pelagic food chains.	Coastal environments also have a high reliance on benthic primary productions systems, so changes in plankton primary production may be less important for fisheries production compared with pelagic environments. Broad scale (e.g. basin wide) monitoring may not be sufficient for detecting changes at smaller scales which may be important for coastal fisheries.	Remote sensing capacity is available in New Caledonia and the American territories and can provide basin wide information. Capacity to deploy loggers to collect fine-scale information in a number of PICTs is feasible and has been undertaken previously (e.g. Cook Islands).	Distribution of chlorophyll a in space and time.	NOAA, IRD, Regional universities (JCU, UQ, USP, Uni of Hawaii)
Changes in the structure of zooplankton assemblages	Identified as an important sentinel of climate change. First, unlike many other marine species the majority of zooplankton species are not commercially exploited. Second, most species are short lived and so population size is less influenced by the persistence of individuals from previous years (year class strength) leading to a tight coupling between environmental change and plankton dynamics. Third, plankton can show dramatic changes in distribution because they are free floating and can respond easily to changes in temperature and oceanic current systems by expanding and contracting their ranges.	Capacity and expertise – compared to other faunal assemblages in the Pacific region there is little work examining coastal plankton. Insufficient information on natural variation to design a robust monitoring program exists at the present time.	Expertise across the region is low. Significant research and investment in scientific capacity would be necessary, although relevant research projects leading to developing a statistically robust monitoring program may be undertaken over time.	Changes in relative abundance of indicator species, and biomass as a whole.	Unknown
Coral Cover	Coral cover can be influenced by a number of factors, but in particular coral	Nil, however research gaps exist in explaining fine scale patterns of bleaching, recovery dynamics, and	High. Remote sensing expertise is available which can be utilised (with	Changes in coral cover, reef rugosity, changes in coral	NOAA, IRD, CRIOBE, UNC, USP. NGOs

Biological/Ecological Responses	Rationale for Monitoring	Challenges for Monitoring	Regional Capacity for Monitoring	Potential Indicators	Potential Partners
	bleaching. Coral bleaching is directly linked to SST in combination with changes to prevailing winds and UVR. Results in significant reduction in coral cover which can potentially influence fisheries production.	variation in responses of individual coral taxa. Depending on the target species in the fishery, coral cover may not be a universal indicator of fisheries health. Monitoring will need to focus on scales that are relevant to fisheries (probably multiple scales on a given reef complex).	appropriate ground truthing) to monitor coral cover at a landscape scale. Basic programs that assess coral cover are implemented throughout most of the Pacific region. More detailed programs also exist in a number of locations (e.g. French Polynesia, American Samoa and New Caledonia).	composition. Ratio of live coral cover to algae.	with specialist expertise (eg. Universities, TNC, WWF)
Prevalence of Coral Disease	Together with coral bleaching, coral disease can result in significant reductions in live coral cover.	There are a number of diseases and significant uncertainties regarding the biology of the diseases and the responses of corals to the pathogens. While variables related to climate change may influence the prevalence of the disease, the causative relationships may be complex. Depending on the target species in the fishery and the magnitude of the disturbance, coral disease prevalence may not be a universal indicator of fisheries health.	There is capacity and a level of coordination as witnessed by the Global Coral Disease Database. This database also provides identification keys for detecting disease which could be applied as part of coral monitoring in general. Some on-ground capacity building would most likely be required.	Disease name, coral genus affected, number of diseased corals (prevalence of coral disease), coral mortality estimate.	UNEP-WCMC
Dynamics of Seagrass Beds	Seagrass makes an important direct and indirect contribution to fisheries production in a number of PICTS. Seagrass is directly impacted by a number of physical variables influenced by climate change.	Continuity of the existing SeagrassWatch program.	High in a number of PICTS where seagrass is an important component of the coastal environment. An existing community based protocol is available and is used in the Pacific region.	Extent, condition and species composition of seagrass beds. Prevalence in seagrass meadows of the two widespread species in the Pacific (*Halophila ovalis* and *Syringodium isoetifolium*) identified as being relatively intolerant to temperature increases.	Fisheries Queensland and existing Seagrass Watch groups in the Pacific.
Dynamics of Mangrove	Mangroves make an important direct and indirect	Community desire to monitor mangroves in relevant PICTs is	Monitoring of mangrove forests is not a technically difficult	Extent, condition and species	SPREP, IRD

Biological/Ecological Responses	Rationale for Monitoring	Challenges for Monitoring	Regional Capacity for Monitoring	Potential Indicators	Potential Partners
Forests	contribution to fisheries production in a number of PICTS. They are also used directly for other purposes. Mangrove forests are directly impacted by a number of physical variables influenced by climate change, in particular sea level rise.	currently unknown.	issue and could be undertaken by community members with training. SPREP has prepared a (draft) guide which could be used as the basis for implementing monitoring if required.	composition of mangrove forests	
Range Changes of Finfish and Benthic Plants and Animals	Range shifts are a well documented response to climate change. Shifts of invasive species may have wide reaching ecological consequences.	Range shifts are likely to be less important in tropical areas compared to temperate areas as shifts are documented to be poleward. Communities may have little motivation for systematic searches to detect the presence of species that are not of economic or cultural importance.	Some information may be collected during fisheries surveys in the region. In locations where scientific capacity is high then scope to undertake monitoring and review information against historical information exists, and has been identified in this report is being undertaken to some degree. There is an existing initiative (PAREFICO) which has among its aims the detection of range changes.	Species distributions, indicator species, catch composition in coastal fisheries.	PAREFICO, UNC,
Fish Physiology	Temperature driven changes to metabolic functions in fish directly result in changes to key life history parameters. These changes may necessitate changes to management of targeted species, as the level of harvest that is sustainable may be reduced.	Changes in life history parameters in fish can also be influenced by size selective harvesting. This potentially confounding factor would need to be considered in the design of monitoring.	Highly variable across the region. With sufficient support, there is scope to expand existing market monitoring in Samoa to encompass additional biological monitoring.	Size distribution of harvested indicator species, size at maturity and fecundity of indicator species	Samoa Division of Fisheries, American Samoa Dept of Marine and Wildlife Resources (Upon completion of research station)
Timing of life-history events	Climate change can alter the timing of life history events such as spawning periods.	Information gaps on the current spawning period for many harvested species.	Variable	Commencement and duration of spawning period.	UNC, Samoa Division of Fisheries

Biological/Ecological Responses	Rationale for Monitoring	Challenges for Monitoring	Regional Capacity for Monitoring	Potential Indicators	Potential Partners
Abundance of fish and large invertebrates	There is a clear need to monitor the resource base that fisheries production is dependent upon.	Potentially Influenced by a number of factors associated with, but also independent of climate change.	Variable	Abundance and mean size of indicator species and functional groups	UNC, CRIOBE, NOAA.
Fisheries Production	Key variable with respect to food security – the end point. Provides a reality check that any trends that are detected in other monitored variables are meaningful in terms of food security. Improved fisheries monitoring has flow-on benefits to PICTs as long as there are processes in place that allow monitoring information to inform management.	Confounded to the extent that it is not possible to attribute a climate change affect from monitoring fisheries production. Nonetheless, information on fisheries production potentially adds to the “weight of evidence” that a climate induced change may or may not be occurring.	Variable. Well developed monitoring programs are in place in a number of PICTs including American Samoa, Samoa and Fiji and Guam.	Overall species composition, proportion of indicator species or functional groups in catches, size distribution, overall harvest levels.	FLMMA, Samoa Division of Fisheries, Guam Division of Aquatic and Wildlife Resources

Survey Monitoring and Design

Survey monitoring and design should be informed by baseline information. Additionally existing monitoring programs should be utilised or built upon and regard should be given for what approaches are effective in a given PICT and whether or not there appropriate representative monitoring sites are already established, for example in a similar group of islands in a neighbouring country. For example, community based fisheries monitoring through logbook programs is established and very effective in Fiji, while centralised fisheries monitoring through market surveys is established and very effective in Samoa. Both yield information at a resolution that can be incorporated into climate change monitoring. In a number of instances it is not necessary for SPC to implement monitoring, but rather incorporate existing monitoring information into a WoE approach. Examples of this include information on SST. This report is not in a position to provide a detailed survey design, however the report indentifies a number of key initiatives that should be undertaken and for which there is expertise and capacity.

In terms of habitat monitoring and fisheries resource monitoring, remote sensing offers a key solution that can implemented virtually anywhere in the Pacific, without having the expertise based in the PICT's of interest. Remote sensing should be a key plank of survey monitor and significant expertise exists within IRD and NOAA in particular. Relevant field work to ground truth remote sensing should be undertaken. As well as IRD and NOAA, there is significant expertise within CRIOBE, the University of New Caledonia and the University of the South Pacific. Further, existing initiatives such as the LMMA network and those already established by SPC can provide a vehicle for integrating community monitoring initiatives and socio-economic data into climate change monitoring. Oceanographic monitoring can be integrated with habitat monitoring and fisheries resource monitoring. Key expertise in the region exists with IRD, NOAA and SOPAC. Additionally, it would be highly beneficial to implement additionally oceanographic modelling at a smaller spatial scales.

Data Gaps

This report has identified a number of data gaps in relation to coastal fisheries and climate change. Key data gaps identified include the following:

- In relation to oceanographic processes, there is only limited available information on processes at smaller spatial scales (e.g. tens of kilometres) of relevance to coastal fisheries resources. Existing capacity exists in parts of the Pacific (e.g. New Caledonia) to address this with specific research and monitoring initiatives.
- A lack of information on coastal zooplankton dynamics. There has been limited work on coastal plankton in the Pacific in general.
- Varying susceptibility (including spatial differences) of coral species to bleaching and coral disease, and recovery dynamics following disturbances. This is a long-term research challenge.
- Understanding of the spatial scales of disturbance to coral reef habitat that are important for the key harvested species in a chosen fishery. Continued remote sensing work together with ground truthing is a critical research initiative to address this gap.
- Understanding the broader significance of changes to the timing of reproduction in harvested species, corals and flowering/seed setting in aquatic macrophytes.
- Catch composition, harvest levels and length-frequency of the fisheries catch (particular non-commercial fisheries) in a number of PICTs. While information in some countries is adequate, there is scope for improvement and also scope for introducing effective (but feasible) monitoring programs in PICTS where programs are ineffective or lacking appropriate resolution and/or coverage.

References

Aeby, G., Aletto, S.C., Anderson, P., Carroll, B., DiDonato, E., DiDonato, G., Farmer, V., Fenner, D., Gove, J., Gulick, S., Houk, P., Lundblad, E., Nadon, M., Riolo, F., Sabater, M., Schroeder, R., Smith, E., Speicher, M., Tuitele, C., Tagarino, A., Vaitautolu, S., Vaoli, E., Vargas-Angel, B., Vroom, P. (2008) The State of Coral Reef Ecosystems of American Samoa. NOAA Technical Memorandum. 307-351.

Aguilar-Perera, A. and Appeldoorn, R.S. (2008) Spatial distribution of marine fishes along a cross-shelf gradient containing a continuum of mangrove – seagrass - coral reefs off southwestern Puerto Rico. *Estuarine, Coastal and Shelf Science.* 76:378-394.

Andréfouët, S., Chauvin, C., Kranenburg, C., Muller-Karger, F., Noordeloos, M. (2006) *Atlas of Southeast Papua New Guinea Coral Reefs.* IRD, Noumea. New Caledonia.

Andréfouët, S., Kranenburg, C., Chauvin, C., Torres-Pulliza, D., Vigliola, L., Noordeloos, M., Muller-Karger, F. (2007) *The Status of the Millennium Coral Reef Mapping for Pacific Ocean islands*. GeoHabs 2007, Nouméa, New Caledonia.

Arnoson, R.B. and Precht, W.F. (2001) White-band disease and the changing face of Caribbean reefs. *Hydrobiologia* 460: 25-38.

Babcock, R.C., Bull, G.D., Harrison, P.L., Heyward, A.J., Oliver, J.K., Wallace, C.C. and Willis, B.L. (1986) Synchronous spawning of 105 scleractinian coral species on the Great Barrier Reef. *Marine Biology* 90: 379-394.

Baker, A.C., Starger, C.J., McClanahan, T.R., and Glynn, P.W. (2004) Corals' adaptive response to climate change. *Nature*: 430:741.

Ball, M.C., Cochrane, M.J., Rawason, H.M. (1997) Growth and water use of the mangroves *Rhizophora apiculata* and *R. stylosa* in response to salinity and humidity under ambient and elevated concentration of atmospheric CO_2. *Plant Cell Environment* 20:1158–1166.

Barry, J.P., Baxter, C.H., Sagarin, R.D. and Gilman S.E. (1995) Climate-related, long-term faunal changes in a California rocky intertidal community. *Science* 267: 672-675.

Beare, D.J., Burns, F., Greig, A., Jones, E.G., Peach, K., Kienzle, M., McKenzie, E. And Reid, D.G. (2004) Long-term increases in prevalence of North Sea fishes having southern biogeographic affinities. *Marine Ecology Progress Series.* 284: 269-278.

Beardall, J. And Raven, J.A. (2004) the potential effects of global climate change on microalgal photosynthesis, growth and ecology. *Botanica Marina* 41: 113-123.

Beaugrand, G., Reid, P.C., Ibanez, F., Lindley, J.A. and Edwards, M. (2002) Reorganisation of North Atlantic marine copepod biodiversity and climate. *Science* 296: 1692-1694.

Behrenfeld, M.J., O'Malley, R.T., Siegel, D.A., McClain, C.R., Sarmiento, J.L., Feldman, G.C., Milligan, A.J., Falkowski, P.G., Letelier, R.M. and Boss, E.S. (2006) Climate-driven trends in contemporary ocean productivity. *Nature.* 752-755.

Beger, M., D. Jacobson, S. Pinca, Z. Richards, D. Hess, F. Harriss, C. Page, E. Peterson and N. Baker , 2008 , The State of Coral Reef Ecosystems of the Republic of the Marshall Islands. pp. 387-418 . In: J.E. Waddell and A.M. Clarke (eds.), The State of Coral Reef Ecosystems of the United States and Pacific Freely Associated States: 2008. NOAA Technical Memorandum NOS NCCOS 73. NOAA/ NCCOS Center for Coastal Monitoring and Assessment's Biogeography Team. Silver Spring, MD. 569 pp.

Brainard, R., J. Maragos, R. Schroeder, J. Kenyon, P. Vroom, S. Godwin, R. Hoeke, G. Aeby, R. Moffitt, M. Lammers, J. Gove, M.Timmers, S. Holzwarth, and S. Kolinski , 2005 , The State of Coral Reef Ecosystems of the Pacific Remote Island Areas. . p.338-372 in Waddell, J. (ed.), 2005. The State of Coral Reef Ecosystems of the United States and Pacific Freely Associated States: 2005. NOAA Technical Memorandum NOS NCCOS 11. NOAA/NCCOS Center for Coastal Monitoring and Assessment's Biogeography Team. Silver Spring, MD. 522 pp.

Brander, K. (2010) Impacts of climate change. *Journal of Marine Systems.* 79: 389-402.

Brierley, A.S. and Kingsford, M.J. (2009) Impacts of climate change on marine organisms and ecosystems. *Current Biology* 19: R602-R614.

Brown, C.J., Fulton, E.A., Hobday, A.J., Matear, R.J., Possingham, H.P., Bulma, C., Christensen, V., Forrest, R.E., Gehrke, P.C., Gribble, N.A., Griffiths, S.P., Lozano-Montes, H., Martin, J.M., Metcalf, S., Okey, T.A., Watson, R. and Richardson, A.J. (2010) Effcets of climate-driven primary production change on marine food webs: implications for fisheries and conservation. *Global Change Biology.* 1194-1212.

Bulthius, D.A. (1987) Effects of temperature on the photosynthesis and growth of seagrass. *Aquatic Botany* 27: 27-40.

Bunce L.L., Townsley, P., Pomeroy, R.S. and Pollnac, R.B. (2000) *Socio-economic Manual for Coral Reef Management*. Australian Institute of Marine Science, Townsville.

Burdick, D., V. Brown, J. Asher, M. Gawel, L. Goldman, A. Hall, J. Kenyon, T. Leberer, E. Lundblad, J. Mcllwain, J. Miller, D. Minton, M. Nadon, N. Pioppi, L. Raymundo, B. Richards, R. Schroeder, P. Schupp, E. Smith and B. Zgliczynski (2008) The State of Coral Reef Ecosystems of Guam. pp. 465-510 . In: J.E. Waddell and A.M. Clarke (eds.), The State of Coral Reef Ecosystems of the United States and Pacific Freely Associated States: 2008. NOAA Technical Memorandum NOS NCCOS 73. NOAA/ NCCOS Center for Coastal Monitoring and Assessment's Biogeography Team. Silver Spring, MD. 569 pp.

Byrkjedal, I., Godo, O.R. and Heino, M. (2004) Northward range extensions of some mesopelagic fished in the Northeastern Atlantic. *Sarsia*. 89: 484-489.

Caldeira, K. and Wickett, M.E. (2003) Anthropogenic carbon and ocean pH. *Nature* 425: 365.

Campbell, S.J., McKenzie, L.J. and Kerville, S.P. (2006) Photosynthetic responses of seven tropical seagrasses to elevated seawater temperature. *Journal of Experimental Marine Biology and Ecology.* 330:445-468.

Chateau, O. And Wantiez, L. (2005) Comparison of coral reef communities between two fished and one protected reefs in New Caledonia South Lagoon Marine Park. *Cybium* 29(2): 159-174.

Cheung, W.W.L., Lam, V.W.Y., Sarimento, J.L., Kearney, K., Watson, R., Zeller, D. and Pauly, D. (2008) Application of macroecological theory to predict effects of climate change on global fisheries potential. *Marine Ecology Progress Series*. 365: 187–197.

Cheung, W.W.L., Lam, V.W.Y., Sarimento, J.L., Kearney, K., Watson, R., Zeller, D. and Pauly, D. (2009) Projecting global marine biodiversity impacts under climate change scenarios. *Fish and Fisheries* 10: 235–251.

Cheung, W.W.L., Lam, V.W.Y., Sarimento, J.L., Kearney, K., Watson, R., Zeller, D. and Pauly, D. (2010) Large-scale redistribution of maximum fisheries catch potential in the global ocean under climate change. *Global Change Biology*. 16:24–35.

Chin, A., H. Sweatman, S. Forbes, H. Perks, R. Walker, G. Jones, D. Williamson, R. Evans, F. Hartley,S. Armstrong, H. Malcolm, G. Edgar , 2008 , Status of the Coral Reefs in Australia and Papua New Guinea: 2008 . In: Wilkinson, C. (ed.). Status of Coral Reefs of the World: 2008. Global Coral Reef Monitoring Network and Reef and Rainforest Research Center, Townsville, Australia. p159-176

Clua, E., Chenet, A. & Dupre, C. (October 2009) CRISP Consolidated Report 2008-2009. CRISP Coordinating Unit.

Coutures, E. (2003) The biology and artisanal fishery of lobsters of American Samoa. Department of Marine and Wildlife Resources Report Series 102, Government of American Samoa . Pago Pago, American Samoa. 22pp.

Cowan, R.K., Paris, C.B. and Srinivasan, A. (2006) Scaling of connectivity in marine populations. *Science* 311: 522-537.

Craig, P., G. DiDonato, D. Fenner, and C. Hawkins (2005) The State of Coral Reef Ecosystems of American Samoa. . p.312-337 in Waddell, J. (ed.), 2005. The State of Coral Reef Ecosystems of the United States and Pacific Freely Associated States: 2005. NOAA Technical Memorandum NOS NCCOS 11. NOAA/NCCOS Center for Coastal Monitoring and Assessment’s Biogeography Team. Silver Spring, MD. 522 pp.

Császár, N.B.M., Ralph P.J., Frankham, R., Berkelmans, R., van Oppen M.J.H. (2010) Estimating the Potential for Adaptation of Corals to Climate Warming. *PLoS ONE* 5(3): e9751. doi:10.1371/journal.pone.0009751.

De Mazières, J. (2009) *Spatial distribution of reef fish communities: An investigation of the Coral Coast, Fiji Islands*. University of the South Pacific, Masters Thesis.

Dennison, W.C., Orth, R.J., Moore, K.A., Stevenson, J.C., Carter, V., Kollar, S., Bergstrom, P.W. and Batiuk, R.A. (1993) Assessing water quality with submersed aquatic vegetation: Habitat requirements as barometers of Chesapeake Bay health. *Bioscience.* 43: 86-94.

Doney, S.C. (2006) Plankton in a warmer world. *Nature*. 444: 695-696.

Doney, S.C., Fabry, V.J., Feely, R.A. and Kleypas, J.A. (2009) Ocean Acidification: The Other CO_2 problem. *Annual Review of Marine Science* 1: 169-192.

Donner, S.D., Skirving, W.J., Little, C.M., Oppenheimer, M. And Hoegh-Guldberg, O. (2005) Global assessment of coral bleaching and required rates of adaptation under climate change. *Global Change Biology.* 11: 2251-2265.

Dorenbosch, M., Grol, M.G.G., Nagelkerken, G. and van der Velde, G. (2006) Seagrass beds and mangroves as potential nurseries for the threatened Indo-Pacific humphead wrasse, *Cheilinus undulatus* and Caribbean rainbow parrotfish, *Scarus guacamaia*. *Biological Conservation* 129(2): 277-282.

Duke, N.C., Ball, M.C., Ellison, J.C. (1998) Factors influencing biodiversity and distributional gradients in mangroves. *Global Ecology and Biogeography* 7: 27–47.

Dumas, P., Jimenez, H. And Leopold, M. (2009) *Training in community-based monitoring techniques in Emau Island, North Efate, Vanuatu*. CRISP Final Report.

Ellison, J.C. (2009) Wetlands of the Pacific Island region. *Wetlands Ecology and Management* 17: 169-206.

Ellison, J.C. (2010) (Draft) *Manual for Mangrove Monitoring in the Pacific Islands Region*. A report prepared for SPREP.

Eslami-Andargoli, L., Dale, P., Sipe, N. and Chaseling, J. (2009) Mangrove expansion and rainfall patterns in Moreton Bay, Southeast Queensland, Australia. *Estuarine, Coastal and Shelf Science.* 85(2): 292-298.

Feely, R.A., Sabine, C.L., Lee, K., Berelson, W., Kleypas, J., Fabry, V.J. and Millero, F.J. (2004) Impact of anthropogenic CO_2 on the $CaCO_3$ system in the oceans. *Science* 305: 362-366.

Fenner, D., M. Speicher, S. Gulick, G. Aeby. S.C. Aletto, P. Anderson, B. Carroll, E. DiDonato, G. DiDonato, V. Farmer, D. Fenner, J, Gove, S. Gulick, P. Houk, E. Lundblad, M. Nadon, F. Riolo, M. Sabater, R. Schroeder, E. Smith, M. Speicher, C. Tuitele, A. Tagarino, S. Vaitautolu, E. caoli, B. Vargas-Angel, P. Vroom, p. Brown, E. Buchan, A. Hall, J. Helyer, S. Heron, J. Kenyon, R. Oram, B. Richards, K.S. Saili, T. Work and B. Zgliczynski , 2008 , The State of Coral Reef Ecosystems of American Samoa. pp. 307-351 . In: J.E. Waddell and A.M. Clarke (eds.), The State of Coral Reef Ecosystems of the United States and Pacific Freely Associated States: 2008. NOAA Technical Memorandum NOS NCCOS 73. NOAA/NCCOS Center for Coastal Monitoring and Assessment's Biogeography Team. Silver Spring, MD. 569 pp. Information/data/maps provided by ReefBase (http://www.reefbase.org)

Field, C. (1995) Impacts of expected climate change on mangroves. *Hydrobiologia* 295: 75–81.

Figueira, W.F. and Booth, D.J. (2010) Increasing ocean temperatures allow tropical fishes to survive overwinter in temperate waters. *Global Change Biology*. 16: 506-516.

Flynn, A., S. Rotmann and C. Sigere (2006) Long-term Monitoring of Coral Reefs Subject to Sediment Stress in Papua New Guinea. Proceedings of 10th International Coral Reef Symposium, Okinawa, Japan. June 28-July 2, 2004. 38-42 pp

Ganachaud, A., Kessler, W., Wijffels, S., Ridgway, K., Cai, W., Holbrook, N., Bowen, M., Sutton, P., Qiu, B., Timmermann, A., Roemmich, D., Sprintall, J., Cravatte, S., Gourdeau, L. And Aung, T. (2007) Southwest Pacific Ocean Circulation and Climate Experiment. Part I Scientific Background. NOAA OAR Special Report/International CLIVAR Office, CLIVAR Publication Series 111.

George, A., M. Luckymis, S. Palik, K. Adams, E. Joseph, D. Mathias, S. Malakai, M.R. Nakayama, C. Graham, K. Rikim, A. Marcus, J. Albert, V. Fread, M. Hasurmai, C. Fillmed, W. Kostka, A. Takesy, T. Leberer and S. Slingsby, 2008. The State of Coral Reef Ecosystems of the Federated States of Micronesia. pp.419-436 In: J.E. Waddell and A.M. Clarke (eds.), The State of Coral Reef Ecosystems of the United States and Pacific Freely Associated States: 2008. NOAA Technical Memorandum NOS NCCOS 73. NOAA/NCCOS Center for Coastal Monitoring and Assessment's Biogeography Team. Silver Spring, MD. 569 pp. Information/data/maps provided by ReefBase (http://www.reefbase.org)

Gilman, E.L., Ellison, J., Duke, N.C. and field, C. (2008) Threats to mangroves from climate change and adaptation options: A review. *Aquatic Botany.* 89: 237-250.

Goffart, A., Hecq, J.H., and Legendre, L. (2002) Changes in the development of the winter-spring phytoplankton bloom in the Bay of Calvi (northern Mediterranean) over the last two decades. *Marine Ecology Progress Series.* 236: 45-60.

Goldberg, J., K. Adams, J. Albert, J. Asher, P. Brown, V. Brown, D. Burdick, B. Carroll, P. Craig, D. Fenner, C. Fillmed, V. Fread, M. Gawel, A. George, Y. Golbuu, L. Goldman, C. Graham, A. Hall, M. Hasurmai, L. Jacob, D. Jacobson, E. Joseph, J. Kenyon, W. Kostka, T. Leberer, M. Luckymis, E. Lundblad, S. Malakai, J. Maragos, A. Marcus, S. Marino, D. Mathias, J. Mcilwain, J. Miller, D. Minton, M. Nadon, S. Palik, N. Pioppi, L. Raymundo, B. Richards, M. Sabater, R. Schroeder, P. Schupp, E. Smith, T. Zgliczynski and B. Zgliczynski, 2008. Status of Coral Reef Resources in Micronesia and American Samoa: 2008 In: Wilkinson, C. (ed.). Status of Coral Reefs of the World: 2008. Global Coral Reef Monitoring Network and Reef and Rainforest Research Center, Townsville, Australia. p199-212.

Green, A. (2002) Status of coral reefs on the main volcanic islands of American Samoa: A resurvey of long term monitoring sites (benthic communities, fish communities, and key macroinvertebrates). A report prepared for the Department of Marine and Wildlife Resources, Pago Pago, American Samoa. 96799.

Green, A., Lokani, P., Sheppard, S., Almany, J., Keu, S., Aitsi, J., Warku Karvon, J., Hamilton, R & Lipsett-Moore, G. (2007) Scientific Design of a Resilient Network of Marine Protected Areas, Kimbe Bay, West New Britain, Papua New Guinea. TNC Pacific Island Countries, Report No 2/07.

Hays, G.C., Richardson, A.J. and Robinson, C. (2005) Climate change and marine plankton. *Trends in Ecology and Evolution*. 20(6): 337-344.

Graham, N.A.J., Wilson, S.K., Jennings, S. And Polunin, N.V.C., Bijoux, J.P. and Robinson, J. (2006) Dynamic fragility of oceanic coral reef ecosystems. Proceedings of the National Academy of Sciences USA. 103: 8425-8429.

Grand, S. (1985) The importance of the lagoon fishery in French Polynesia. Proceedings of the Fifth International Coral Reef Symposium 5:495-500

Grottoli, A.G., Rodrigues, L.J. and Palardy, J.E. (2006) Heterotrophic plasticity and resilience in bleached corals. Nature. 440:1186–1189.

Hallegraeff, G.M. (2010) Ocean climate change, phytoplankton community responses, and harmful algal blooms: A formidable predictive challenge. Journal of Phycology. 46: 220-235.

Harley, C.D.G., Hughes, A.R., Hultgren, K.M., Miner, B.G., Sorte, C.J.B., Thornber, C.S., Rodriguez, L.F. (2006) The impacts of climate change in coastal marine systems. Ecology Letters. 9: 228-241.

Harvell, C.D., Mitchell, C.E., Ward, J.R., Altizier, S., Dobson, A.P., Ostfield, R.S. and Samuel, M.D. (2002) Climate warming and disease risks for terrestrial and marine biota. Science 296: 2158-2162.

Harvey, C.J. (2009) Effects of temperature change on demersal fishes in the California Current: a bioenergetics approach. Canadian Journal of Fisheries and Aquatic Science. 66(9): 1449-1461.

Hill, J. and Wilkinson, C. (2004) Methods For Ecological Monitoring Of Coral Reefs: A Resource For Managers. Version 1. Australian Institute of Marine Science (AIMS), Townsville, Australia. 117 p.

Hilty, J. and Merenlender, A. (2000) Faunal indicator taxa selection for monitoring ecosystem health. Biological Conservation 92: 185-197.

Hoegh-Guldberg, O. (1999) Coral bleaching, climate change and the future of the world's coral reefs. *Marine and Freshwater Research* 50: 839-866.

Hoegh-Guldberg, O., Mumby, P.J., Hooten, A.J., Steneck, R.S., Greenfield, P., Gomez, E., Harvell, C.D., Sale, P.F., Edwards, A.J., Caldeira, K., Knowlton, N., Eakin, C.M., Iglesias-Prieto, R., Muthiga, N., Bradbury, R.H., Dubi, A. and Hatziolos, M.E. (2007) Coral reefs under rapid climate change and ocean acidification. *Science.* 318(5857): 1737-1742.

Invers, O., Romero, J. and Pérez, M. (1997) Effects of pH on seagrass photosynthesis, a laboratory and field assessment. *Aquatic Botany* 59: 185-194.

Jennings, S. And Polunin, N.V.C. (1995) Comparative size and composition of yield from six Fijian reef fisheries. *Journal of Fish Biology* 46: 28-46.

Johnson, J.E. And Welsh, D.J. (2010) Marine Fisheries Management in a Changing Climate: A Review of Vulnerability and Future Options. *Reviews in Fisheries Science* 18(1): 106-124.

Jones, D.L., Walter, J.F., Brooks, E.N., Serafy, J.E. (2010) Connectivity through ontogeny: fish population linkages among mangroves and coral reef habitats. *Marine Ecology Progress Series* 401: 245-258.

Jones, G.P., McCormick, M.I., Srinivisan, M. And Eagle, J.V. (2004) coral decline threatens fish biodiversity in marine reserves. *Proceedings of the National Academy of Sciences USA.* 101: 8251-8253.

Kere, N. (2008) Solomon Islands (Western Province) Coral Reef Monitoring Report for 2006 – 2007. WWF Solomon Islands Country Programme

Labrosse, P., Letourneur, Y., Kulbicki, M. and Paddon, J.R. (2000) Fish stock assessment of the northern New Caledonian lagoons: 3 – Fishing pressure, potential yields and impact on management options. *Aquatic Living Resources* 13(2): 91-98.

Langdon, C., Takahashi, T., Sweeney, C., Chipman, D. Goddard, J., Marubini, F., Aceves, H., Barnett, H. and Atkinson, M.J. (2000) Effect of calcium carbonate saturation state on the calcification rate of an experimental coral reef. *Global Biogeochemical Cycles.* 14: 639-654.

Lehodey, P., Alheit, J., Barange, M., Baumgartner, T., Beugrand, G., Drinkwater, K., Fromentin, J.M. (2006) Climate variability, fish, and fisheries. *Journal of Climate.* 19: 5009-5030.

Lincoln-Smith, M.P., Pitt, K.A., Bell, J.D. and Mapstone, B.D. (2006) Using impact assessment methods to determine the effects of a marine reserve on abundances and sizes of valuable tropical invertebrates. *Canadian Journal of Fisheries and Aquatic Sciences.* 63(6): 1251-1266.

LMMA Network (2007) LMMA Annual Report: Toward a New Vision.

Lovell, E., H. Sykes, M. Deiye, L. Wantiez, C. Garrigue, S. Virly, J. Samuelu, A. Solofa, T. Poulasi, K. Pakoa, A. Sabetian, D. Afzal, A. Hughes and R. Sulu , 2004 , Status of Coral Reefs in the South West Pacific: Fiji, Nauru, New Caledonia, Samoa, Solomon Islands, Tuvalu and Vanuatu. . p: 337-362 . in C. Wilkinson (ed.). Status of coral reefs of the world: 2004. Volume 2. Australian Institute of Marine Science, Townsville, Queensland, Australia. 557 p.

Lovell, E.R. and Sykes, H. (2008) Rapid Recovery from Bleaching Events – Fiji Coral Reef Monitoring Network Assessment of Hard Coral Cover from 1999-2007. *11th International Coral Reef Symposium, Ft Lauderdale, Florida. 7-11 July 2008.*

Luo, J.G., Serafy, J.E., Sponaugle, S., Teare, P.B., Kieckbusch, D. (2009) Movement of grey snapper *Lutjanus griseus* among subtropical seagrass, mangrove and coral reef habitats. *Marine Ecology Progress Series* 380: 255-269.

Mackas, D. And Beaugrand, G. (2010) Comparisons of zooplankton time series. *Journal of Marine Systems.* 79: 286-304.

MacKenzie, B.R. and Kőster, F.W. (2004) Fish production and climate: sprat in the Baltic Sea. *Ecology* 85: 784-794.

Marino, S., Bauman, A., Miles, J., Kitalong, A., Bukurou, A., Mersai, C., Verheij, E., Olkeriil, J., Basilius, K., Colin, P., Patris, S., Victor, S., Andrew, W,, Miles, J. and Golbuu, Y. 2008. State of Coral Reef Ecosystems in Palau. In: J.E. Waddell and A.M. Clarke (eds.), The State of Coral Reef Ecosystems of the United States and Pacific Freely Associated States: 2008. NOAA Technical Memorandum NOS

NCCOS 73. NOAA/NCCOS Center for Coastal Monitoring and Assessment's Biogeography Team. Silver Spring, MD. 569 pp. Information/data/maps provided by ReefBase (http://www.reefbase.org)

Mateo, M.I., Durbin, E.G., Appeldorn, R.S., Adams, A.J., Juanes, F., Kingsley, R. Swart, P.and Durant, D. (2010) Role of mangroves as nurseries for French grunt *Haemulon flavolineatum* and schoolmaster *Lutjanus apodus* assessed by otolith elemental fingerprints. *Marine Ecology Progress Series* 402: 197-212.

McKenzie, L.J., Campbell, S.J. & Roder, C.A. (2003) *Seagrass-Watch: Manual for Mapping and Monitoring Seagrass Resources by Community (citizen) Volunteers*. 2nd Edition. (QFS, NFC, Cairns) 100pp.

Miller, J., J, Maragos, R. Brainard, J. Asher, B. Vargas-Ángel, J. Kenyon, R. Schroeder, B. Richards, M. Nadon, P. Vroom, A. Hall, E. Keenan, M. Timmers, J. Gove, E. Smith, J. Weiss, E. Lundblad, Scott Ferguson, F. Lichhowski and J. Rooney , 2008 , The State of Coral Reef Ecosystems of the Pacific Remote Island Areas. pp. 353-386 . In: J.E. Waddell and A.M. Clarke (eds.), The State of Coral Reef Ecosystems of the United States and Pacific Freely Associated States: 2008. NOAA Technical Memorandum NOS NCCOS 73. NOAA/NCCOS Center for Coastal Monitoring and Assessment's Biogeography Team. Silver Spring, MD. 569 pp.

Miller, I. and H. Sweatman (eds.) , 2004 , Status Of Coral Reefs In Australia And Papua New Guinea In 2004. . p: 303-336 . in C. Wilkinson (ed.). Status of coral reefs of the world: 2004. Volume 2. Australian Institute of Marine Science, Townsville, Queensland, Australia. 557 p.

Mora, C. And Ospina, A.F. (2001) Tolerance to high temperatures and potential impact of sea warming in reef fishes of Gorgona Island (tropical eastern Pacific). *Marine Biology* 139: 756-769.

Morris, C. and Mackay, K. (eds.) , 2008 , Status of the Coral Reefs in the South West Pacific: Fiji, New Caledonia, Samoa, Solomon Islands, Tuvalu and Vanuatu . In: Wilkinson, C. (ed.). Status of Coral Reefs of the World: 2008. Global Coral Reef Monitoring Network and Reef and Rainforest Research Center, Townsville, Australia. p177-188.

Morize, E. (1985) Study of a small scale fishery in the Atoll of Tikehau (Tuamotu Archipelago, French Polynesia). *Proceedings of the Fifth International Coral Reef Symposium*. 5: 501-506.

Mydlarz, L.D., McGinty, E.S. and Harvell, C.D. (2010) What are the physiological and immunological responses of coral to climate warming and disease? *The Journal of Experimental Biology* 213:934-945.

Nakamura, Y., Horinouchi, M., Sano, M. And Shibuno, T. (2009) The effects of distance from coral reefs on seagrass nursery use by 5 emperor fishes at the southern Ryukyu Islands, Japan. *Fisheries Science* 75(6): 1401-1408.

Oliver, J, Marshall PA, Setiasih N, and L Hansen (2004) *A Global Protocol for Assessment and Monitoring of Coral Bleaching*. WorldFish Center and WWF Indonesia, Jakarta, Indonesia.

Orr, J.C., Fabry, V.J., Aumont, O., Bopp, L., Doney, S.C., Feely, R.A. (et al) (2005) Anthropogenic ocean acidification over the twenty-first century and its impacts on calcifying organisms. *Nature* 437: 681-687.

Perry, A.L., Low, P.J., Ellis, J.R. and Reynolds, J.D. (2005) Climate change and distributional shifts in marine fishes. *Science* 308: 1912-1915.

Pinca S., Beger M., Peterson E., Richards Z. and Reeves E. (2002) Coral reef biodiversity community-based assessment and conservation planning in the Marshall Islands: baseline surveys, capacity building and natural protection and management of coral reefs of the atoll of Rongelap. RALgov public report.

Pinca, S., Beger, M., Jacobson, D. and Keju, T., 2005 , The State of Coral Reef Ecosystems of the Marshall Islands . pp. 373-386. In: J. Waddell (ed.), The State of Coral Reef Ecosystems of the United States and Pacific Freely Associated States: 2005. NOAA Technical Memorandum NOS NCCOS 11. NOAA/NCCOS Center for Coastal Monitoring and Assessment's Biogeography Team. Silver Spring, MD. 522 pp.

Planque, B., Fromentin, J.M., Phileppe, C. Drinkwater, K.F., Jennings, S., Perry, R.I. and Kifani, S. (2010) How does fishing alter marine populations and ecosystems sensitivity to climate? *Journal of Marine Systems* 79(3-4): 403-417.

Poloczanska, E.S., Babcock, R.C., Butler, A., Hobday, A.J., Hoegh-Guldberg, O., Kunz, T.J., Matear, R., Milton, D.A., Okey, T.A. and Richardson, A.J. (2007) Climate change and Australian marine life. *Oceanography and Marine Biology: an Annual Review* 45: 407-478.

Pratchett, M.S., Munday, P.L., Wilson, S.K., Graham, N.A.J., Cinner, J.E., Bellwood, D.R., Jones, G.P., Polunin, N.V.C and McClanahan, T.R. (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.

Preen, A.R., Long, W.J.L. and Coles, R.G. (1995) Flood and cyclone related loss, and partial recovery, of more than 1,000 km^2 of seagrass in Hervey Bay, Queensland, Australia. *Aquatic Botany.* 52: 1-20.

Ralph, P.J. (1998) Photosynthetic response of laboratory-cultured *Halophila ovalis* to thermal stress. *Marine Ecology Progress Series* 171: 123-130.

Raubani, J. (2007). The Status of Coral Reefs in Vanuatu 2007. Ministry of Agriculture, Quarantine, Forestry and Fisheries

Richardson A.J. and Poloczanska E.S. (2008) Under-resourced, under threat. *Science* 320: 1294–1295.

Rose, G.A. (2005a) On distributional responses of North Atlantic fish to climate change. *ICES Journal of Marine Science.* 62: 1360-1374.

Rose, G.A. (2005b) Capelin (*Mallotus villosus*) distribution and climate: a sea ‘canary’ for marine ecosystem change. *ICES Journal of Marine Science.* 62: 1360-1374.

Sabater, M.G. and Carroll, B. P. (2009) Trends in reef fish population and associated fishery after three millennia of resource utilization and a century of socio-economic changes in American Samoa. *Reviews in Fisheries Science*: 17(3): 318-335.

Sagarin, R.D., Barry, J.P., Gilman, S.E. and Baxter, C.H. (1999) Climate-related change in an intertidal community over short and long time scales. *Ecological Monographs* 69: 465-490.

Sarmiento, J. L., Slater, R., Barber, R., Bopp, L., Doney, S.C., Hirst, A.C., Kleypas, J., Matear, R., Mikolajewicz, U., Monfray, P., Soldatov, V., Spall, S.A. and Stouffer, R. (2004) Response of ocean ecosystems to climate change. *Global Biogeochemical Cycles.* 18: GB3003, doi:10.1029/2003GB002134.

Selig, E.R., Casey, K.S. and Bruno, J.F. (2010) New insights into global patterns of ocean temperature anomalies: implications for coral reef health and management. *Global Ecology and Biogeography*. 19: 397-411.

Schippers, P., Lŭrling, M. And Scheffer, M. (2004) Increase of atmospheric CO_2 promotes phytoplankton productivity. *Ecology Letters* 7: 446-451.

Short, F.T. and Neckles, H.A. (1999) The effects of global climate change on seagrasses. *Aquatic Botany*. 63: 169-196.

Simkanin, C., Power, A., Myers, A., McGrath, D., southward, A.J., Miezkowska, N., Leaper, R. and O’Riordon, R. (2005) Using historical data to detect temporal changes in the abundances of intertidal species on Irish shores. *Journal of Marine Biological Association of the United Kingdom*. 85: 1329-1340.

Spurgeon, J.P.G., T. Roxburgh, S. O’ Gorman, R. Lindley, D. Ramsey, N. Polunin, and S. Clamp., 2004 Economic Valuation of Coral Reefs and Adjacent Habitats in American Samoa. A report to the American Samoa Department of Commerce. 109 pp.

Staunton-Smith, J., Robins, J.B., Mayer, D.G., Sellin, M.J. and Halliday, I.A. (2004) Does the quantity and timing of fresh water flowing into a dry tropical estuary affect year-class strength of barramundi (*Lates calcarifer*)? *Marine and Freshwater Research* 55(8): 787–797.

Stuart-Smith, R.D., Barrett, N.S., Stevenson, D.G. and Edgar, G.J. (2010) Stability in temperate reef communities over a decadal time scale despite concurrent ocean warming. *Global Change Biology.* 16: 122-134.

Sulu, R., R. Cumming, L. Wantiez, L. Kumar, A. Mulipola, M. Lober, S. Sauni, T. Poulasi and K. Pakoa , 2002 , Status of Coral Reefs in the Southwest Pacific Region to 2002: Fiji, Nauru, New Caledonia, Samoa, Solomon Islands, Tuvalu and Vanuatu. . In: C.R. Wilkinson (ed.), Status of coral reefs of the world:2002. GCRMN Report, Australian Institute of Marine Science, Townsville. Chapter 10, pp 181-201.

Sussman, M., Willis, B.L., Victor, S. and Bourne, D.G. (2008) Coral pathogens identified for white syndrome (WS) epizootics in the Indo-Pacific. *PLoS ONE* 3(6): e2393. doi:10.1371/journal.pone.0002393

van Woesik R.J., Gilner, J. and Hooten, A. (2009) *Standard Operating Procedures for Repeated Measures of Process and State Variables of Coral Reef Environments.* University of Queensland publication, pp 35.

Verweji, M.C., Nagelkerken, I., Hans, I., Ruseler, S.M. and Mason, P.R.D. (2008) Seagrass nurseries contribute to coral reef fish populations. *Limnology and Oceanography* 53(4): 1540-1547.

Vieux, C., (2005) Establishment of a coral reef Monitoring Program in Niue, May 26 th June 13 th 2005. Information/data/maps provided by ReefBase (http://www.reefbase.org)

Vieux, C. (2008) Preliminary socio-economic monitoring (Sem-Pasifika): assessment of Sinalailai area, Papua-New-Guinea. CRISP. Information/data/maps provided by ReefBase (http://www.reefbase.org)

Wanless, S., Wright, P.J., Harris, M.P. and Elston, D.A. (2004) Evidence for decrease in size of lesser sandeels *Ammodytes marinus* in a North Sea aggregation over a 30-yr period. *Marine Ecology Progress Series.* 279: 237-246.

Wantiez, L. and Chauvet, C. (2003) First data on community structure and trophic networks of Uvea coral reef fish assemblage (Wallis and Futuna, South Pacific Ocean). *Cybium* 17(2): 83-100.

Wantiez, L. and Kulbicki, M. (2009) Overlap of shorefishes assemblages between mangroves, soft bottoms and coral reefs within a lagoon seascape, New Caledonia. *8th Indo-Pacific Fish Conference and Australian Society for Fish Biology Conference and Workshop*.

Weed, D.L. (2005) Weight of evidence: A Review of Concept and Methods. *Risk Analysis* 25(6): 1545-1557.

Wilkinson, C.R. (2008) *Status of Coral Reefs of the World 2008.* Global Coral Reef Monitoring Network and Australian Institute of Marine Science, Townsville (Australia).

Wilson, S.K., Graham, N.A.J., Pratchett, M.S., Jones, G.P. and Polunin, N.V.C. (2006) Major disturbances and the global degradation of coral reefs: are reef fishes at risk or resilient? *Global Change Biology.* 12: 2220-2234.

Wright, A. and Richards, A.H. (1985) A multispecies fishery associated with coral reefs in the Tigak Islands, Papua New Guinea. *Asian Marine Biology*. 2:69-84.

Yee, S.H. and Barron, M.G. (2010) Predicting coral bleaching in response to environmental stressors using 8 years of global-scale data. *Environmental Monitoring and Assessment* 161: 423-438.

Zacherl, D., Gaines, S.D., Lonhart, S.I. (2003) The limits of biogeographical distributions: insights from the northward range expansion of the marine snail *Kelletia kelletii* (Forbes, 1852). *Journal of Biogeography* 30: 913-924.

Zimmerman, R.C., Korhs, D.G., Steller, D.L. and Alberte, R.S. (1997) Impacts of CO_2 enrichment on productivity and light requirements of eelgrass. *Plant Physiology* 115: 599-607.

Zvuloni, A., Artzy-Randrup, Y., Stone, L., Kramarsky-Winter, E., Barkan, R. Loya, Y. (2009) Spatio-temporal transmission patterns of black-band disease in a coral community. *PLoS ONE* 4(4): e4993. doi:10.1371/journal.pone.0004993.

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WORKSHOP: VULNERABILITY AND ADAPTATION OF COASTAL FISHERIES TO CLIMATE CHANGE: MONITORING INDICATORS AND SURVEY DESIGN FOR IMPLEMENTATION IN THE PACIFIC

(Noumea, New Caledonia, 19-22 April 2010)

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Annex 3: Oceanographic data collection programs and studies identified in the Pacific Ocean.

1. Southwest Pacific Ocean Circulation and Climate Experiment (SPICE).

This project which is lead by IRD is a large multi-agency project involving CSIRO, NOAA, Legos, PI-GOOS, University of Hawaii, Scripps Institute of Oceanography and USP. The goal of SPICE is to observe, model and understand the role of the Southwest Pacific ocean circulation in: (a) the large-scale, low- frequency modulation of climate from the Tasman Sea to the equator, and (b) the generation of local climate signatures whose diagnosis will aid regional sustainable development.

The objectives of the project are: 1) Analysis of the southwest Pacific role in global coupled models; 2) Development of an observational program to survey air-sea fluxes and currents in the Coral, Solomon, and Tasman Seas, and their inflows and outflows, with special attention to the strong boundary currents and jets; 3) Combination of these observations with focused modelling efforts to devise a sustained monitoring program to adequately sample the time variability of the currents and their heat and mass transports; and 4) Using remotely and locally sampled meteorological fields, and the ocean analysis, determination of the air-sea heat and freshwater fluxes and water mass transformations that occur in the region, and their effects on the local and global climate.

The experiment involves cruises and the deployment of gliders[5]. Research work also extends into Australia and New Zealand.

2. Ocean Coastal Monitoring Buoys

Buoys were deployed in 2005 at Penrhyn and Manihiki Lagoons (Cook Islands) that measure a range of parameters including air temperature, sea temperature, salinity, wind speed and direction, pressure, dissolved O_2, pH and chlorophyll a.

3. South Pacific Sea Level and Climate Change Monitoring Project

The primary goal is to generate an accurate record of variance in long-term sea level for the South Pacific and to establish methods to make these data readily available and usable by Pacific Island countries. All of the stations, with the exception of the one located at Pohnpei (Federated States of Micronesia), which was established in December 2001, have been operational since October 1994. Data reports are available on a monthly basis and in addition consolidated six-monthly reports are available. In additional to measuring sea level – air and water temperatures, wind speed, wind direction and atmospheric pressure is also measured. The project is funded by AusAid.

4. NOAA Coral Reef Ecosystem Integrated Observing System (CREIOS)

CREIOS includes long-term ecological monitoring which is integrated with the physical oceanographic data that is collected. Various monitoring platforms to measure and record ocean temperatures, salinity, wind and wave energy, tides, currents, available UV-B, and PAR. The system includes Coral Reef Watch Satellite Monitoring which is continuous monitoring of sea surface temperature at global scales as an early warning tool to detect potential coral bleaching events.

5. In-situ Sea Surface Temperature Logger Program Review and Recommendations

While this report is mostly focussed on identifying and explaining how to collect data on sea surface temperature, it does include a long term sea surface temperature dataset and assesses the data in the context of coral bleaching events. Sea surface temperature data from the Fiji Islands from 1987 to 1997 is presented. The data was obtained by the Hadley Centre Global Sea Ice and SST UK Met Office and contains SST observations gathered from a combination of data including in-situ and advanced high resolution radiometer (AVHRR) observations.

6. Moorea Coral Reef Long-term Ecological Research Project

The MCR LTER was established in 2004 by the United States National Science Foundation (NSF) and is a partnership between the University of California and California State University. The project is an

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[5] Autonomous underwater vehicles that use battery powered hydraulic pumps to vary their volume in order to generate the buoyancy changes that power their forward gliding

interdisciplinary, landscape-scale program whose goal is to advance understanding of key mechanisms that modulate ecosystem processes and community structure of coral reefs. The project aims to:

- document long-term (decadal length and longer) trends in reef biota and abiotic forcing functions;
- undertake observations and experiments to explore processes and events affecting the reef structure, function and dynamics; and,
- develop a suite of quantitative models to synthesize and generalize results.

Surveying undertaken includes water chemistry measurements taken two to four times per year at six stations in French Polynesia. Measurements include: sedimentation rate, CTD (conductivity, temperature and depth) nutrients, chlorophyll a, particulate organic carbon and nitrogen, dissolved organic carbon, dissolved inorganic carbon, water column primary production, and abundance of bacteria. It is understood that a similar program was started in Wallis and Futuna in 1999.

The oceanographic and water quality information is integrated with ecological data collected and this data is discussed in the relevant sections of this report.

7. Biennial Surveys in United States Pacific Remote Island Areas (PRIA)

Since 2000, NOAA PIFSC-CRED and the USFWS have sponsored biennial cruises to monitor the ecosystems of the PRIA. Except at Palmyra and Wake, virtually all monitoring and assessment activities conducted in the PRIA have been done by scientists from the USFWS and PIFSC-CRED, working in collaboration with the University of Hawaii's Joint Institute for Marine and Atmospheric Research. Cruise reports for 2005-2007[6] with appendices that include preliminary data analyses can be accessed at http://www.pifsc.noaa.gov/library/cruise.php[7]

Biota and habitat monitoring, data collection and analyses, and summaries of published studies concentrate on three functional and structural components of coral reef ecosystems: marine water quality and oceanographic conditions, benthic habitats and coral reef-associated fauna. Oceanographic data collected during these surveys is shown in Table 8 ATTACHMENT A.

8. Guam

Efforts to obtain water quality data relevant to coral reef management have increased in recent years, with biennial sampling of multiple parameters around the island occurring with Guam EPA's Environmental Monitoring and Assessment Program (EMAP). EMAP sampling was carried out in 2005 and 2006[8].

Measurements of chlorophyll and nutrient concentrations, conductivity temperature and depth, were obtained during the 2003, 2005 and 2007 MARAMP expeditions at numerous sites around the island. A list of MARAMP water quality and oceanographic data collecting activities is provided in Table 13 at ATTACHMENT D with detailed methods described at http://www.nmfs.hawaii.edu/cred [9]

9. Palau

The Environmental Quality Protection Board of Palau (EQPB) conducts monthly water quality monitoring of marine waters around most of Palau. Turbidity, pH, salinity, dissolved oxygen, fecal coliform and temperature are collected monthly at 40 permanent sites. Sampling sites were selected because they are either a popular recreational site or in close proximity to a sewage substation. Results from the monitoring program are added to a database that dates back to 1992[10].

10. Water Quality data collection in American Samoa

Table 10 at ATTACHMENT B provides an overview of oceanographic data currently being collected within the EEZ of American Samoa.

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[6] (Timmers et al., 2006; Vroom et al., 2006b; Schroeder et al., 2006; Ferguson et al., 2006; Ferguson et al., 2007) In: Miller et al. (2008)
[7] Miller et al. (2008)
[8] Burdick et al. (2008)
[9] Ibid, Burdick et al. (2008)
[10] Marino et al. (2008)

Coastal Water Quality Sampling:

In 2004, the American Samoa Environmental Protection Agency (ASEPA) in collaboration with local environmental resource agencies and federal partners such as the National Park of American Samoa (NPAS), began concentrated monitoring and assessment efforts to document coastal water and coral reef condition in order to protect and enhance aquatic life and human health. Methods and approach followed the U.S. Environmental Protection Agency's (EPA) Environmental Monitoring and Assessment Program[11].

Within the Territory's coastal region (up to one-quarter mile out from the coast), 50 randomly selected sites were sampled for a standard suite of parameters. In addition to a standard hydrographic profile, grab samples of water at the surface, middle, and bottom of the water column were processed and analyzed for standard nutrients (TN, TP, ammonium, nitrate/nitrite, phosphate), chl a, and suspended solids. Where possible, sediments were collected with a modified Van Veen grab and analyzed for grain size, total organic carbon, organics, and metals. Fish were also collected at those stations and analyzed for tissue contaminants. Field methods employed for this work are detailed in a U.S. EPA publication (2001)[12].

11. Monitoring Sea-Surface Temperature in the Southwest Pacific

A network of temperature loggers has been established within the Global Coral Reef Monitoring Network's (GCRMN) Southwest Pacific Node to collect long-term data on temperature relationships with coral bleaching. Monitoring has attempted to correlate sea surface temperatures and the extent of coral bleaching events in Fiji from 1999 to 2007. The longest periods with consecutive days of temperatures over 29oC were during the years 2000, 2002 and 2005 which corresponded with the years where fully bleached and partly bleached corals were observed (2000, 2001, 2002 and 2006)[13].

12. The Solomon Islands – Solomon Islands Coral Reef Monitoring Network (SCRMN) - WWF

Two temperature loggers have been deployed on two SCRMN sites in Gizo, Njari and Kennedy. The two loggers were activated on August 2006. The Njari logger was placed on a star picket at a depth of 10m and the Kennedy logger on the base of a mooring buoy at the same depth. These temperature loggers record sea temperature every two hours[14].

[11] Aeby et al. (2008)
[12] Ibid, Aeby et al. (2008)
[13] Morris and Mackay (2008)
[14] Kere (2008)

Annex 4: Habitat monitoring programs and studies identified in the Pacific Ocean

1. Seagrass-Watch Program

Seagrass-Watch is a global scientific, non-destructive, seagrass assessment and monitoring program. It is a community based monitoring program developed and implemented by Fisheries Queensland. Seagrass-Watch aims to raise awareness on the condition and trend of nearshore seagrass ecosystems and provide an early warning of major coastal environment changes. The goals of the program are:

- To educate the wider community on the importance of seagrass resources;
- To raise awareness of coastal management issues;
- To build the capacity of local stakeholders in the use of standardised scientific methodologies;
- To conduct long-term monitoring of seagrass & coastal habitat condition
- To provide an early warning system of coastal environment changes for management; and,
- To support conservation measures which ensure the long-term resilience of seagrass ecosystems.

The program involves assessing the species composition, extent of seagrass beds and their above ground seagrass cover. Other parameters (e.g. epiphytic algal cover) may also be recorded.

Within the Pacific region there are monitoring locations in the Federated States of Micronesia (Pohnpei and Kosrae), Fiji (Rotuma, Kawaci, Nadroga Navosa and Kabara Island), New Caledonia (Anse Vata), Palua (Koror), Papua New Guinea (Madang, Motepore and Kaiveng) and the Solomon Islands (Gizo).

Vanuatu is also believed to have commenced mapping seagrass beds in certain areas[15].

2. Millenium Coral Reef Mapping Project

The aim of the project was to utilise a consistent dataset of high resolution images (30 metre) multispectral Landsat 7 images acquired between 1999 and 2003 to characterise, map and estimate the extent of coral reef habitat in the main coral reef provinces including within the Pacific region. Remote sensing approaches can give a reef or a country wide overview of habitat and it forms an appropriate baseline.

3. Global Coral Disease Database

This project is a collaboration between UNEP-WCMC and NOAA NMFS that collates information on the global distribution of coral diseases to contribute to the understanding of coral disease prevalence. It is plausible that the prevalence of coral disease is linked directly or indirectly with a range of anthropogenic impacts.

MICRONESIA

4. United States Pacific Remote Island Areas (PRIA) – Ecological coral reef surveys

NOAA PIFSC-CRED and the USFWS have sponsored biennial cruises to monitor the ecosystems of the PRIA since 2001. Except at Palmyra and Wake, virtually all monitoring and assessment activities conducted in the PRIA have been done by scientists from the USFWS and PIFSC-CRED, working in collaboration with the University of Hawaii's Joint Institute for Marine and Atmospheric Research. Cruise reports for 2005-2007[16] with appendices that include preliminary data analyses can be accessed at http://www.pifsc.noaa.gov/library/cruise.php[17]

[15] Morris and Mackay (2008)
[16] (Timmers et al., 2006; Vroom et al., 2006b; Schroeder et al., 2006; Ferguson et al., 2006; Ferguson et al., 2007) In: Miller et al. (2008)
[17] Information/data/maps provided by ReefBase (http://www.reefbase.org)

Protocols used in the PRIA are similar or identical to those used during Pacific Rapid Assessment of Marine Pollution (RAMP) surveys of U.S. jurisdictions throughout the Pacific, allowing direct comparison of results that have been obtained using the same methods and, in many cases, by the same scientists. The Pacific-wide scope of this monitoring program, using similar protocols in the Hawaiian Archipelago, the Mariana Archipelago, American Samoa and the PRIA provides scientists with a wealth of integrated ecosystem observations that can be compared and contrasted with information across the Pacific region.

In addition to the above, the Palmyra Atoll Research Consortium has initiated a variety of ecosystem research projects at the recently established Palmyra research facility. In particular, SIO conducted detailed ecological surveys at the five northern Line Islands in August-September 2005, including Palmyra and Kingman, and followed up with additional surveys at Palmyra in 2006. In August and September 2007, SIO sponsored another expedition to Kingman involving microbe, coral, fish and algal surveys at multiple depths (5 m, 10 m, 20 m) at 15 fore reef sites and at more than 50 sites in other major habitats (back reef, pinnacle, reef pool).

USFWS and NOAA purchased and have made available IKONOS imagery that is used as base layers for habitat analyses (mapping).

The NOAA Coral Reef Conservation Program supported moderate-depth multibeam mapping surveys in the PRIA during Pacific RAMP cruises in 2006 and 2007. Submersible dives and multibeam surveys in deeper waters were also conducted around Jarvis Island, Kingman Reef and Palmyra Atoll by the Hawaii Undersea Research Laboratory of the University of Hawaii with support from NOAA as documented at http://www.noaanews.noaa.gov/stories2005/s2487.htm

Corals[18]:

Several techniques have been used since 2000 by PIFSC-CRED and USFWS to assess and monitor coral biodiversity, distribution, abundance, population structure, and condition in the PRIAs including the U.S. Phoenix Islands (Howland and Baker); U.S. Line Islands (Jarvis Island, Johnston Atoll, Palmyra Atoll, and Kingman Reef); and American Samoa (Rose Atoll). These techniques include towed-diver surveys each averaging about 2 km in length, rapid ecological assessments (REA) each covering between 1,000-5,000 m^2 per site, photo-quadrat/video surveys at permanently marked 50-100 m transects, and recruitment studies at three of the islands/atolls.

In 2002, recruitment plates were attached to the base of Coral Reef Early Warning System moorings in the Palmyra Atoll and Kingman Reef (Figure 12.13) lagoons and to a subsurface ocean data platform at Baker Island to assess larval recruitment by calcareous organisms. Their deployment in physical association with the instrumented moorings will enable coupling of biological data with physical data collected by the instruments. Biennial collections and deployments of these plates will address levels of larval recruitment as well as spatial and temporal differences among the sampled areas.

Algal surveys[19]:

During the 2006 Pacific RAMP surveys, quantitative algal monitoring continued with 15 sites surveyed in the Phoenix Islands (six at Howland, nine at Baker), 35 sites surveyed in the U.S. Line Islands (nine at Jarvis, 12 at Palmyra, 14 at Kingman) and 18 sites surveyed at Johnston Atoll. Quantitative algal sampling began for the first time at Wake Island with 14 sites surveyed in 2005, of which 12 sites were resurveyed in 2007.

A joint effort between PIFSC-CRED and the Bishop Museum is addressing algal biodiversity at many of the PRIA, basedon PIFSC-CRED collections and other surveys (Tsuda et al. in review; Table 11.11). For Howland and Baker Islands, 85% of species reported are new records for these locations. For Jarvis Island and Kingman Reef (analyses underway) 100% of the species are new, since no algal collections from these geographic locations have been described in past literature. Algal collections from Palmyra, Johnston, and Wake remain frozen at PIFSC-CRED and are awaiting critical taxonomic analyses.

5. The Federated States of Micronesia – Ecological coral reef monitoring activities

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[18] Brainard et al. (2005)
[19] Miller et al. (2008)

Each state in the FSM has two government regulatory agencies that manage coral reef ecosystems, namely, Marine Resources Divisions (MRD) and Environmental Protection Agency's (EPA). The local non-governmental organizations (NGOs) focused on coral reef conservation in each state, including Yap Community Action Program (YapCAP), Chuuk Conservation Society (CCS), Conservation Society of Pohnpei (CSP) and Kosrae Conservation and Safety Organization (KCSO), also work with government agencies and local communities to protect and monitor coral reef resources. Regional organizations such as the Secretariat of the Pacific Region Environmental Programme (SPREP) and The Nature Conservancy (TNC) offer technical and financial assistance for reef-related programs. Additionally, U.S. Peace Corps volunteers in the FSM assist local counterparts in government agencies, NGOs and local communities as part of the Natural Resource Conservation and Development program[20].

The four states of the FSM are at different stages of development and implementation of coral reef monitoring programs. Some individual monitoring efforts have been in effect since 1994 (See Table 12 at ATTACHMENT C), but recently the FSM have started to develop and implement a more standardized monitoring programs across the country[21]. On-going coordination efforts between the Palau International Coral Reef Center and NOAA will continue to support the first regionally-coordinated monitoring program within Micronesia[22].

From 2005 to 2007, the Palau International Coral Reef Centre (PICRC) and the National Oceanic and Atmospheric Administration's (NOAA) Coral Reef Conservation Program sponsored annual coral reef ecosystem monitoring workshops to build monitoring capability within Micronesia.

This monitoring program has been an international collaboration supported by NOAA, PICRC, the FSM Government, the Japanese International Cooperation Agency, the Marine Resources Pacific Consortium, TNC, government regulatory agencies and NGOs of Micronesia.

Some FSM shallow-water coral reef and associated benthic habitats have been mapped but only off major towns. Coastal resource inventories and atlases have been prepared for Pohnpei, Yap, Kosrae, and Moen Island in Chuuk Lagoon. The College of Micronesia-FSM has staff trained in marine resource assessment and monitoring and works with the Environmental and Marine Resource agencies to monitor FSM reefs. There is regional cooperation under the Marine Resources Pacific Consortium (MAREPAC) and funded by the U.S. Dept. of the Interior to increase local and regional capacity for assessment and monitoring. Monitoring activities in the FSM are summarised in Table 12 at ATTCHMENT C.

6. Guam – Ecological coral reef monitoring activities

Several monitoring, assessment, and research activities have been conducted on Guam since 2004. These activities measure several aspects of Guam's reef community that are important to coral reef management, including benthic habitat, water quality, biological communities associated with coral reefs (e.g., fishes and macroinvertebrates) and socioeconomic information. A comprehensive list of all recent or ongoing studies related to Guam's coral reefs is provided in Table 13 at ATTACHMENT D[23].

NOAA-MARAMP have carried out island wide rapid ecological assessments (research cruises) in 2003, 2005 and 2007 (NOAA PIFSC-CRED; http://www.nmfs.hawaii.edu/cred). The science teams for the Guam leg of MARAMP cruises have included staff from the NOAA Pacific Islands Fisheries Science Center (PIFSC) Coral Reef Ecosystem Division (PIFSC-CRED), the NOAA Pacific Islands Regional Office, Guam DAWR, the National Park Service (NPS) and the UOGML. Most of the ecological and oceanographic assessments conducted during the 2003 expedition were repeated at the same sites in later years[24].

The Guam Coral Reef Initiative Coordinating Committee has been established with numerous partners and is implementing projects to reduce the threats to Guam's coral reefs including outreach campaigns, MPA enforcement, and the development of a comprehensive monitoring strategy. Major public works,

[20] George et al. (2008)
[21] Ibid, George et al. (2008)
[22] Goldberg et al. (2008)
[23] Burdick et al. (2008)
[24] Ibid, Burdick et al. (2008)

including the extension of sewage outfalls and the closing of Ordot dump are also being undertaken to reduce reef stresses[25].

7. Republic of the Marshall Islands – Natural Resources Assessment Surveys (NRAS)

Although there are few consistent monitoring activities ongoing throughout the Marshall Islands, a number of programs have performed assessments at targeted locations in the RMI. Much of the repetitive work is conducted at Majuro Atoll, where a large proportion of the population resides. A number of assessments have been performed at the remote atolls as well. These activities are summarized in Table 14 at ATTACHMENT E[26].

The Marshall Islands NRAS are intended to serve as baseline data for managers and scientists to aid in the establishment of Marine Protected Areas. Reef habitats at Likiep (2001), Bikini (2002), Rongelap (2002-2003), Mili (2003), Namu (2004), Majuro (2004) and Ailuk (2006) have been surveyed. The surveys use benthic line intercept transects based on the AIMS-ASEAN methodology and specific quadrat based sampling focused on algae (See Table 15 at ATTACHMENT E for further detail on survey methodology).

Rongelap Atoll Long-term Reef Monitoring Program (2006-present):

In December 2006, the initial phase of a long-term monitoring program in Rongelap was completed. Led by M. Beger and Z. Richards and funded by National Oceanic and Atmospheric Administration (NOAA), the British Petroleum Conservation Leadership Programme (http://conservation.bp.com/projects/700204_proj.asp), CMI, The University of Queensland,

James Cook University, MIMRA and the Australian Patrolboat program, the project has established permanent monitoring sites in the vicinity of Rongelap Island and in more remote parts of the atoll. The program's objectives include documenting trends in the reef community during resettlement of the atoll as detailed in Table 16 provided at ATTACHMENT E. Rongelap represents one of the few reefs in the world still in excellent condition and this project is intended to provide unique insight into the patterns and processes of both natural and disturbed coral reef ecosystems where very little is known about how a reef in natural equilibrium responds to human impacts. This project will be one of the first to proactively monitor ecosystem changes and provide data that can be considered during the establishment and implementation of marine reserves[27]. The Rongelap long-term reef monitoring program collects quantitative data for fishes, mobile invertebrates, benthic cover, and live coral cover and diversity. In addition, this program will collect some limited climatic and oceanographic data to enable the development of a realistic circulation model for atoll to simulate larval transport and remotely sensed imagery from the ASTER sensor was used to create a bathymetric model of the atoll[28].

In addition to the outer island surveys on Rongelap, Bikini, Ailininae, Mili, Arno, Namu and Likiep scientists at the College of the Marshall Islands (CMI) have been paying close attention to local ecosystem indicators in the capital atoll of Majuro (i.e., bleaching, coral and coralline algal disease, COTS outbreaks, and pollution associated changes in macroalgae). Permanently-marked transects are being installed in transitional sites to photographically monitor long-term changes. One of these sites has been extensively photo-mapped (over a 15 x 130 m area) to closely monitor the incidence of coral disease. In addition, a project involving manta tows over several km of leeward shore on Majuro is planned to map the distribution and abundance of schooling food fish species (i.e., rabbitfish, parrotfish, and surgeonfish)[29].

8. Palau

A multi-level effort by different government and non-government agencies contributes to the general understanding of coral reef ecosystems and marine life in Palau. The Palau International Coral Reef Center (PICRC) launched a nationwide coral reef monitoring program for Palau in 2001. The objectives of the program are to: (1) establish permanent monitoring sites; (2) determine status of Palau's reefs; (3) assess changes to the benthic and fish communities at each site over time; and (4) examine the recovery process from the 1997-1998 bleaching event at each site. This program consists of a rapid

[25] Goldberg et al. (2008)
[26] Beger et al. (2008)
[27] Ibid, Beger et al. 2008
[28] Ibid, Beger et al 2008
[29] Pinca et al. (2005)

assessment of reef habitats using the spot check method and a detailed monitoring survey of benthic organisms, fish size and abundance, and coral recruitment[30].

Coral ecosystem monitoring by the PICRC began in 2001 and has continued to the present. It started with the establishment of 14 permanent monitoring sites in 2001. Two more sites were added in 2002 and five were added in 2005. Currently, there are 21 permanent monitoring sites. Video transects are utilized to survey benthic habitats (Golbuu et al., 2005; Golbuu et al., 2007a; Golbuu et al., 2007b) and five 50 x 5 m belt transects are used for fish surveys (Golbuu et al., 2005). Coral recruitment surveys were also conducted using 0.30 x 10 m belt transects (Golbuu et al., 2005; Golbuu et al., 2007a; Golbuu et al, 2007b)[31]. Table 17 provided at ATTACHMENT F provides an outline of monitoring and assessment activities in Palau.

In November 2007, NOAA's CCMA-BB released benthic habitat maps covering 2,450 km2 of nearshore marine habitats in Palau. Access to the source imagery and various map products is available at: http://ccma.nos.noaa.gov/products/biogeography/palau/welcome.html [32].

MELANESIA

9. Papua New Guinea – Data gathering activities

Research and monitoring capacity in PNG is relatively low with most programs run by NGOs; such that there are few long term datasets for PNG reefs. Some monitoring data are available from independent sources. There are also few MPAs in PNG and awareness and support for marine resource management is mostly limited to areas where NGOs have active programs such as in Kimbe Bay, Kavieng, Manus and Madang[33].

Annual reef monitoring by James Cook University (JCU) and The Nature Conservancy (TNC) began in the Kimbe Bay region (New Britain Province) in 1996[34]. This and the Madang program are the only two long-term reef monitoring programs in PNG[35]. Information about research and management in Kimbe Bay can be found at: http://www.nature.org/wherewework/asiapacific/papuanewguinea/work/art6726.html;

The Wildlife Conservation Society (WCS) PNG Marine Program monitors 3 'tambu' sites (customary fishing areas) within New Ireland Province that were established in 2006 and are establishing new tambu areas with partner communities, which also participate in monitoring 6 areas through the PNG LMMA Network. From 2006–2008 data were collected at 6 sites[36].

The WCS is monitoring sites at Andra and Ahus islands 5 km off the north coast of Manus Island.

Madang has 4 Wildlife Management Areas (WMAs) established with local communities at Tab, Sinub, Tabad and Laugum islands. These WMAs cover 1085 ha of coral reef, mangrove, seagrass and open sea habitat. Monitoring around Madang has been conducted since the mid 1990s: by the Christensen Research Institute (CRI) until 1996 and then by Wetlands International-Oceania. WWF are currently working in Madang.

More information on LMMAs in PNG may be viewed at: http://www.lmmanetwork.org/Site_Page.cfm?PageID=42

Fringing coral reefs in the Lihir Group of islands in Papua New Guinea were monitored from 1994 to 2002 using video and photographic transects to record relative cover of major benthic life-forms[37].

[30] Marino et al. (2008)
[31] In: Marino et al (2008)
[32] Ibid, Marino et al. (2008)
[33] Chin et al. (2008)
[34] Ibid, Chin et al. (2008)
[35] Miller and Sweatman (2004)
[36] Ibid, Miller and Sweatman (2004)
[37] Flynn et al. (2006)

10. The Solomon Islands

A national coral reef monitoring network was established in 2003 through the support of the David & Lucile Packard Foundation. In June 2004, The Nature Conservancy (TNC) collaborated with a range of community, government, and NGO partners to conduct broad scale rapid ecological assessment of the biodiversity and status of the marine ecosystems of Solomon Islands[38].

The Solomon Islands Coral Reef Monitoring Network (SICRMN) implemented and administered by WWF, established five permanent monitoring locations in 2004; four in the Western Province (Ghizo Island, Munda, Tetepare, Marovo) and one in Ysabel Province (Arnavon Islands). At each location four stations were identified (separate reefs) and at each of these stations two sites (representative of the reef habitat) were selected within which two depth profiles (5m and 10m) were surveyed. On each depth profile four 50m transects were laid and surveyed along reef slopes[39].

The methods used in this study follow the modifications of the standard GCRMN survey methodology. The point intercept method was used for substrates and the Underwater Visual Census (UVC) for fish. Fish and substrate composition were recorded on the same belt transect[40].

A modified point based method was employed for the substrate survey. The substrate data was collected using a cross (X) with 35cm long arms at a 90^0 angle placed at every 1m interval along a 50m transect. Substrate readings were taken at each point of the X (4 points) and directly beneath the centre of the X (1 point). Therefore, a total of five points were collected every metre on each 50m transect (4 transects) totalling 1000 points per depth profile or 2000 points per site. Substrate composition along the transects was recorded according to the Australian Institute of Marine Studies (AIMS) life form categories, which have been adopted by the Global Coral Reef Monitoring Network (GCRMN) as a standardised form of substrate collection (Hughes et al., 2005)[41].

11. Vanuatu

Vanuatu's systematic coral reef monitoring programme began in 2001 through funding assistance from the Canada South Pacific Ocean Development (CSPOD) Programme. Prior to this, monitoring was conducted on an ad hoc basis. Since the commencement of the programme, two permanent sites have been established on the island of Efate where monitoring has been conducted twice a year. In 2004, several other monitoring sites were established on Efate, and the islands of Epi and Espiritu Santo. In total, 57 sites in 11 regions throughout the islands have been surveyed by the Reef Check Programme coordinated by the Vanuatu Coral Reef Monitoring Network to identify and confirm current threats to Vanuatu's reefs[42].

In 2003 and 2004, the Vanuatu Fisheries Department modified the Reef Check methodology which had been used since 2001, to include other species important to fisheries that were not in the original indicator species list. In 2005, due to a lack of financial support from the Government to continue the monitoring programme Reef Check Vanuatu was founded and established (with the assistance of the Peace Corps Office in Port Vila) under the administration and management of the Fisheries Department. Financial assistance was provided by the Australian Agency for International Development (AusAID). Reef Check Vanuatu aims to function as a not-for-profit organization focusing mainly on monitoring, management and conservation of coral reefs in close collaboration with other stakeholders. Reef Check Vanuatu has worked closely with the Peace Corps Volunteer Services and through their network has expanded the monitoring programme to other provinces in Vanuatu (including Torba and Tafea).

12. Fiji Coral Reef Monitoring Network Assessment of hard coral cover from 1999-2007

The work described in this paper is a consolidation of GCRMN reports within the context of monitoring coral recovery from significant bleaching events.

Sites were fringing reef slopes close to shore, or patch reefs facing deeper water, and surveys were carried out between 5 and 20m depth. Data was contributed by many organisations, including scientists, tourism operators, non-governmental organisations and community members. All surveys utilised point

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[38] Lovell et al. (2004)
[39] Kere (2008)
[40] Ibid, Kere (2008)
[41] Hughes et al., 2005 IN: Kere (2008)
[42] Raubani (2007)

intercept transects from which the percentage of hard coral cover was applied for regional comparisons over-time. Benthic data was generally recorded as coral life-form categories.

POLYNESIA

13. American Samoa

American Samoa has a long history of coral research and monitoring activities. For example, the Aua Transect is the oldest known coral reef transect still being surveyed, and the second oldest monitoring program in the world (Green et al., 1997; Green, 2002); Fagatele Bay has been monitored for over 20 years (Green et al., 1999). However, there has not been an integrated monitoring program established in the Territory to determine overall coral reef ecosystem status and trends. A working group was created in 2003 to establish such a program, with the American Samoa Coastal Management Program (ASCMP) supporting the initial funding of a Territorial coral reef monitoring coordinator to lead this effort. In addition, the Department of Marine and Wildlife Resources (DMWR) has begun to develop an agency-oriented program of long-term coral reef monitoring, and has hired a coral reef monitoring ecologist. The first year of monitoring was set to begin in January 2005[43]. Table 11 provided at ATTACHMENT B provides an overview of current monitoring activities in American Samoa.

Monitoring of Biological Populations and Oceanographic Processes:

In February-March 2002 and February 2004, the NOAA's Pacific Island Fisheries Science Center, Coral Reef Ecosystem Division (PIFSC-CRED) conducted comprehensive, multidisciplinary assessments of the coral reef ecosystems around Rose Atoll and Tutuila, Aunuu, Tau, Ofu, Olosega, and Swains Islands. Spatial and temporal monitoring of biological populations (fish, coral, algae, macro-invertebrates) and oceanographic processes (current, temperature/salinity profiles, bio-acoustic surveys) were conducted to document natural conditions and to detect possible human impacts to these ecosystems. Detailed bathymetric maps were completed for Tutuila and the Manua Islands. Results of these studies will be included in the next reporting effort[44].

Bishop Museum Introduced Marine Species Survey:

A survey of marine organisms (macroinvertebrates, benthic macroalgae, fish) was conducted in Pago Pago Harbor, Fagatele Bay National Marine Sanctuary, the National Park on Tutuila Island, and other core sites to detect introduced marine species (Coles et al., 2003).

DMWR's Territorial Monitoring Program (TMP):

The American Samoa Department of Marine Wildlife Resources (DMWR) Territorial Monitoring Program monitors eleven sites annually: ten on the reef slope around Tutuila and one on Aunuu. Data collection began in 2005. At each non-reef flat site, four 50-m tapes are laid along the 8-10 m depth contour. Benthic cover is recorded in functional categories under a point at each half meter, with coral life form and species recorded where possible (Whaylen and Fenner, 2006; Fenner and Carroll, unpub. data).

Two transect tapes were laid per site on reef flats at the 11 sites starting in 2007. Coral rapid assessment dives are carried out at each of the 11 sites with a 60-minute roving dive ascending from the base of the reef slope (usually about 20 m depth) to the reef crest. Estimates of the abundance of all coral species encountered are recorded in the DAFOR scale (dominant, abundant, frequent, occasional, rare).

Bleaching has been monitored by the DMWR-Territorial Monitoring Program (TMP) in two back reef lagoon pools on Tutuila from December 2003 to the present (2008). The percentage of colony surface with signs of bleaching of staghorn corals (three species of *Acropora*, typically susceptible to bleaching) in two back reef lagoon pools on Tutuila (Airport and Alofau) were estimated based on hour-long timed swims every 2-4 weeks, beginning in December 2003. This monitoring has provided an early warning of past bleaching events and real-time data on the cause of bleaching[45].

DMWR's Key Reef Species Program:

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[43] Craig et al. (2005)
[44] Ibid, Craig et al. (2005)
[45] Aeby et al. (2008)

This program conducts annual monitoring at 24 permanent sites around Tutuila. The benthic assemblage is recorded from four replicate 30 m benthic transects at 10 meters depth using an underwater video taken 0.5 m from the bottom. Fifty frames are grabbed from each transect and benthic cover is identified to functional categories at 12 randomly assigned points per frame (Sabater and Tofaeono, 2006).

Reef Assessment and Monitoring Program of the Coral Reef Ecosystem Division (PIFSC-CRED):

This program records benthic data on each island in American Samoa biannually, starting in 2002 and with increasing numbers of sites over the years (a total of 62 sites in 2006). At each site, two 25-m tapes are laid at 12-15 m depth, and benthic cover recorded using the point-intercept method (Brainard et al., in review). Coral disease prevalence was also recorded based on a methodology developed, tested and implemented in the NWHI by G. Aeby (Friedlander et al., 2005).

Quantitative algal monitoring continued during 2006 in an effort led by PIFSC-CRED and supported by several partner agencies in American Samoa. Twenty-two sites were surveyed around Tututila, 18 sites were surveyed around the Manua islands, 10 sites were surveyed at Rose Atoll and eight sites were surveyed at Swains Island. Continued use of the algal monitoring protocol established in 2003 (Preskitt et al., 2004) assured uniformity of data sets for statistical analyses.

Benthic Habitat Mapping:

NOAA's Center for Coastal Monitoring and Assessment, Biogeography Team (CCMA-BT) initiated a nearshore benthic habitat mapping program in Guam, American Samoa and the Commonwealth of the Northern Mariana Islands in 2003. IKONOS satellite imagery was purchased from Space Imaging, Inc. for all three jurisdictions and used to delineate habitat polygons in a geographic information system (GIS).

The project, which was completed in 2004, mapped 71.5 km^2 of nearshore habitat in the islands and produced a series of 45 maps that are currently being distributed via a print atlas, CD-ROM, and on-line at http://biogeo.nos.noaa.gov/products/us_pac_terr/. A summary map (Figure 11.17), where polygons have been aggregated into major habitat categories, depicts the geographical distribution of reefs and other types of benthic habitats in American Samoa (NOAA, 2005)[46].

Reef flat algae:

Periodically, algal blooms occur in front of Olosega Village in Manua. In May 2006, in order to determine the sources of nutrients to the lagoons of Ofu and Olosega islands, a research team led by Virginia Garrison, U.S. Geological Survey, examined the nutrient content of the two most common species of seaweed (Halimeda sp. and Dictyosphaeria versluysii) that occur on the reef flats in front of each village and compared the findings from those sites with a relatively pristine lagoon/reef flat. Benthic cover at each of the three sites was determined using the point-intercept method. Algal species were analyzed for nitrogen isotopes 14N and 15N and δ13C.

Algae Survey:

A study was conducted in 2003 to inventory the algae of American Samoa (Skelton, 2003). The study surveyed 26 sites on Tutuila, Anuu, Ofu, and Olesega and documented the presence of 237 species of algae and two species of seagrass in the Territory.

Coral Disease Surveys:

Two disease studies were completed in American Samoa between 2002 and 2004. The first was a broad disease survey around Tutuila and the Manu'a Islands (Work and Rameyer, 2002). The second survey was recently led by Dr. Greta Aeby (Aeby and Work, in prep.) with the intent of linking coral disease to water quality there as well as to wider-Pacific coral disease distributions.

Coral Disease Monitoring Program (CDMP):

This program monitors seven sites around Tutuila annually, with two 25-m tapes laid on depth contours at 5-18 m, with most at 6-10 m. Data collection began in 2004. Benthic categories are recorded with the point-intercept technique. Similar transects were conducted in the Ofu back reef pools in 2005 and on six sites on reef slopes around Ofu-Olosega in 2006 (Aeby et al., 2006).

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[46] Craig et al. (2005)

Research Station:

The American Samoa Government has recently completed a facility plan for a marine laboratory. This plan is comprehensive, and includes detailed cost estimates for construction, operation, and maintenance, as well as recommendations for site selection. In addition, a conceptual rendition of the lab has been completed by a Hawaii-based architect and a business/marketing plan has been developed in partnership with the Small Business Development Center at the American Samoa Community College.

14. Coral Reef Initiative for the South Pacific (CRISP) - Polynesia Mana

Since January 2005, "Polynesia Mana" has been part of the french regional initiative in the Pacific region called CRISP (Coral Reef Initiative for the South Pacific) and is funded through this program for 3 years. These funds will be spent in training and purchasing equipment for fishery and/or environment departments in each country of the node. At the end of the program, it is intended that each country will be self-sufficient in performing every stages of coral reef monitoring from data collection to data analysis and storage. Staff will also be trained to assist communities with MPA monitoring. Through this program, additional funding will also be sought to develop more detailed monitoring activities performed by scientists[47].

Five long-term monitoring sites were set up in Niue in 2005[48]. Field trips were also undertaken to Tokelau and Kiribati to establish monitoring sites in 2005[49].

CRISP also funds supporting technical research projects, with recent studies published on indicator identifi cation (Leopold 2007[50]), improved perception of coral habitat characteristics (Roelfsema 2007[51]), the relationship between fi sh within a habitat (Saladrau 2008[52]; De Mazières 2008) and the relationship between fish populations belonging to different habitats (Swarup 2008)[53].

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[47] Vieux (2005)
[48] Vieux (2005)
[49] Vieux C. (2006a, 2006b, 2006c). Establishment of a coral reef monitoring program in Tokelau, Niue and Kiribati. CRISP mission reports, 34 pp. In: Clua et al. (2009)
[50] Leopold M. (2007). Social and ecological indicators for coral reef fisheries assessment. Report, 15 pp. In: Clua et al. (2009)
[51] Roelfsema C. (2007). Cost effective mapping of tropical benthic habitats: A study into integrated field and/or remote sensing approaches. Report, 18 pp. In: Clua et al. (2009)
[52] Saladrau W. (2008). Examination of the relationship between coral reef fish habitats at Navutulevu (Fiji). CRISP report, 43 pp. In: Clua et al. (2009)
[53]Clua et al. (2009)

Annex 5: Fisheries resources surveys identified in the Pacific Ocean.

1. Overlap of shorefishes assemblages between mangroves, soft bottoms and coral reefs within a lagoon seascape, New Caledonia

It is well established that a number of species of "coral reef" species, including those of fisheries importance utilise a number of different habitats during their life history. The objective of this study was to examine the overlap of fish species between mangroves, soft bottoms and coral reefs. Survey methods applied were as follows: mangroves (fyke nets, gill nets, rotenone), soft sediment habitat (trawls and visual census) and reefs (visual census and rotenone). While the highest numbers of fish species were recorded in coral reef habitat, the highest number of fish families was recorded in mangrove habitat.

2. Spatial distribution of reef fish communities: An investigation of the Coral Coast, Fiji Islands.

This study combined remote sensing approaches to map habitats and field work to ground truth habitat classifications and examine the link between habitat and structural components of the fish assemblage (e.g. species diversity and abundance). It provides information important to climate change with respect to linking habitat structure with the fish assemblage.

3. Pacific Reef Fish Collaboration(PaReFiCo)

The Pacific Reef Fish Collaboration (PAREFICO) is an initiative among reef biologists to assess human impacts on reef fish communities across the Pacific. It is a meta-analysis that aims to discover:

What changes humans have caused in reef fish communities through fishing, pollution, eutrophication, sedimentation and alteration of natural disturbance regimes, such as hurricanes, crown-of-thorn starfish outbreaks and coral bleaching events;

Whether and how the taxonomic richness and functional diversity of reef fish communities modify the type and severity of human impacts;

Which taxa, if any, are likely to have undergone range contractions or declines in abundance suggestive of ecological extinction as a result of human impacts; and

How the taxonomic composition, functional diversity, size structure and productivity of coral reefs are likely to respond to future changes in human population size and socio-economic conditions.

As at January 2009, the PAREFCO database contains UVC information for Hawaii, the northern Line Islands, Fiji, American Samoa, Solomon Islands, and Wallis and Futuna. Information included is from 330 stations, 1,808 sites and 5,581 replicates. The samples record information on 837,028 individual fish in 821 species and 243 genera. The total underwater search area covered by fish samples is 2,018,284 square metres.

A large number of collaborators and collaborating organisations are involved and the program is coordinated through Dalhousie University (Nova Scotia). Within the Pacific region there are collaborators from IRD and the University of New Caledonia.

4. Marshall Islands Natural Resources Assessment Surveys (NRAS)

The Marshall Islands NRAS are intended to serve as baseline data for managers and scientists to aid in the establishment of Marine Protected Areas. Reef habitats at Likiep (2001), Bikini (2002), Rongelap (2002-2003), Mili (2003), Namu (2004), Majuro (2004) and Ailuk (2006) have been surveyed. Fish species are identified using UVC (belt transects).

5. Moorea Coral Reef Long-term Ecological Research Project

The aims and structure of this integrated program were explained in a previous section. The habitat monitoring component of this project is a spatially stratified, hierarchical sampling design. Depending on the taxon or process, the scale and scope of the measurements encompass a variable number of sites, habitat types, depths, or frequencies of sampling.

6. Effects of Marine Reserves on Abundances and Sizes of Valuable Tropical Invertebrates.

This study was a detailed "beyond-BACI" study in the Solomon Islands (Arnavon Islands) specifically focussed on detecting the effects of a marine reserve on the size and abundance of giant clam, topshell and several species of holothurians (beche de mer). It is in one of the more detailed studies of its kind in the western Pacific (excluding Australia).

7. Long-term Monitoring of New Caledonian Coral Reefs

The ROCR-NC (Réseau d'observation des Récifs Coralliens) program involves annual surveys of long-term reef sites in New Caledonia. It is supported by the French Initiative for Coral Reefs in New Caledonia (IFRECOR-NC) and is led by the University of New Caledonia.

The survey worked commenced in 2003 but some of the work commenced in 1997. The program involves surveying three sites in each province with three stations at each site that cover the broad habitat types present (e.g. inner reef, lagoon). The survey locations include Marine Managed Areas as well as sites putatively impacted by mining, agriculture or urban activities. As such, it provides information that may be able to help in understanding and partitioning impacts from diverse sources. Surveying involves assessment of fish communities; habitat with a focus on live coral cover, and large epibenthic invertebrates (e.g. clams, trochus). Surveying is undertaken by scientists and volunteers particularly from scuba diving clubs. There is always a scientist present when field work is being undertaken. Community monitoring was trialled in the program but did not prove cost-effective as additional costs were incurred in trying to organise the community to undertake the monitoring.

The survey of fish communities is undertaken using UVC and targets groups of species, although a couple of selected species of fisheries importance (e.g. coral trout) are specifically monitored. Monitoring of large epibenthic invertebrates involves enumerating the number present and this includes animals of direct fisheries significance (e.g. trochus).

Habitat is also monitored in this program through point intercept methods and focuses on broad habitat categories (e.g. live coral, dead coral, bare sand etc.).

8. Biennial Surveys in United States Pacific Remote Island Areas (PRIA)

Referenced in Habitat monitoring section. See Table 9 at ATTACHMENT A.

9. American Samoa

Extensive underwater visual surveys were conducted throughout the Territory in 1996, 2002, and 2004 (Green, 2002; Schroeder, unpublished data)[54]. See Table 11 at ATTACHMENT B.

10. Marshall Islands:

Secretariat of the Pacific Community Atoll Assessments (2007)
Four atolls, Ailuk, Likiep, Majuro and Arno, were assessed by scientists from the Secretariat of the Pacific Community to determine the abundance and distribution of commercial fish and invertebrate species. At the same time, an assessment of reef health and substrate composition was completed. No results were available for inclusion in this report[55].

Natural Resource Assessment Surveys (NRAS) expeditions comprising a team of 9-10 international and local Marshallese scientists surveyed reef habitats at Likiep (2001), Bikini (2002), Rongelap (2002-2003), Mili (2003), Namu (2004), Majuro (2004) and Ailuk (2006). The NRAS surveys include baseline data on fish, sharks, corals, invertebrates and marine algae. Summary information is available at: http://www.nras-conservation.org. NRAS rapid ecological assessments (REAs) are intended to serve as baseline data for managers and scientists to aid in the establishment of Marine Protected Areas.

During these systematic surveys, four transects parallel to the shoreline were laid at four different depths (5, 10, 15, and 20 m) and divers on each transect recorded data on percentage cover of substrate type, coral life-forms and target species of corals, seaweed groups, abundance and size of target fish species, and abundance of commercial invertebrates. In addition, the 15 m transect was replicated three times to give an indication of the variability at this depth. Sites were selected on both the ocean and lagoon side of atolls, including pinnacles and patch reefs. Biodiversity of fish and corals were recorded during 60-minute vertical swims from 30 m to the surface. In 2001 in Likiep, and in 2004

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[54] Information/data/maps provided by ReefBase (http://www.reefbase.org)
[55] Beger et al. (2008)

in Arno, manta tows were also used to assess broad changes in the benthic communities of coral reefs[56].

11. The Solomon Islands – WWF GCRMN Surveys (Western Province)

Fish data is collected using Underwater Visual Census (UVC). Every fish seen within 2.5m on either side of the 50m transect and 5m above is recorded. Fish size and abundance are recorded at species level for important reef fish families such as Haemullidae, Labridae, Lethrinidae, Lutjanidae, Mullidae, Scaridae, Serranidae and Carangidae. Fish abundance is recorded at family level for the reef indicators such as Pomacentridae, Pomacanthidae, Caesonidae, Acanthuridae, Balistidae, Ostracidae and Diotonidae[57].

12. Vanuatu

Reef Check Vanuatu surveys target species of coral reef fish at 57 sites across 11 regions in Vanuatu. This monitoring program in managed by the Vanuatu Fisheries Department[58].

In 2007, the LMMA Network established its first official member site in Vanuatu, the Nguna-Pele Marine Protected Area (NP-MPA) on the north end of Efate Island. Vanuatu is still in the early stages of developing a country-wide LMMA Network however, a national environmental steering committee has been established and has been working specifically on interdepartmental cooperation and a national strategy to implement a network of LMMA's within Vanuatu. Significant financial support for the development of this program has been provided by the United States Fish and Wildlife Foundation[59].

13. Tuvalu

The Fisheries Department in Tuvalu monitors some fisheries and coastal erosion indicators, but capacity for more detailed monitoring of reef resources is lacking. Tuvalu is unable to report adequately on the status of resources and damage from shipwrecks, spills, cyclones or COTS infestations[60].

There has been regular training in GCRMN and Reef Check level monitoring over the last 6 years, but rarely is the training followed by in-country monitoring activities and many of the trained people have moved to other government positions[61].

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[56] Pinca et al. (2005)
[57] [57] Kere (2008)
[58] Raubani (2007)
[59] LMMA Network (2007) LMMA Annual Report: Toward a New Vision.
[60] Sulu et al (2002)
[61] Ibid, Sulu et al. (2002)

Annex 6: Monitoring programs and studies of coastal fisheries identified in the Pacific Ocean.

1. Trends in Reef Fish Population and Associated Fishery after Three Millennia of Resource Utilization and a Century of Socio-Economic Changes in American Samoa

This paper identifies and summarises a number of datasets including:

Shore-based data from roving catch and effort data collected by various studies in Tutuila between 1977-79, 1990-94, 1996-98 and 2002.

Boat-based data from intercept interview at the main docks between 1984 and the present which is held in Western Pacific Fishery Information Network database.

Shore-based data from roving catch and effort data collected by various studies in Tutuila and Manoa which is held in Western Pacific Fishery Information Network database.

2. CITES Trade Information

The Convention for the International Trade in Endangered Species (CITES) collects information on the export of listed species from member countries. Member countries in the Pacific are Fiji, PNG, Palau, Solomon Islands, Samoa, and all French and American territories.

CITES contains Information on the export of giant clams, the humpheaded Maori wrasse, all pipefish (Family Sygnathidae) and scleractinian corals. The information is for a country as a whole.

MICRONESIA

3. Fisheries Monitoring in Palau

Market Survey Data

In the 1970s, the Palau Federation of Fishing Association (PFFA) was the main distributor of fish both locally and internationally. PFFA was government-operated, which helped make data collection more efficient and complete. Over the years, fish distribution has become less centralized and smaller markets experience shifts in sales based upon the fisher's preference and the buyer's incentives. These markets are not required by law to provide information to Palau's Bureau of Marine Resources (BMR). Consequently, sales are reported based upon price categories and not individual species of fish. Over the last three decades, the quality of data has varied and the percentage of market information captured has varied from 30 to 85%. Often data is outdated or non-existent for many species and more studies are needed to implement appropriate management strategies for specific species[62].

Data Collection

In the past decade, the BMR has set up a data collection program to track fish exports at the species level; this program provides the most reliable source of information for exported fish. The BMR requires that all exporters submit a report with detailed information on the name, number and weight of all fish and invertebrate species and other organisms being exported by air. In addition the BMR collects data from local fisheries markets however, nearly 33% of species are lumped into the "assorted fish" category that is based on price. Market data is also being collected to track sales to hotels, restaurants and individuals in the communities[63].

4. FSM

The Conservation Society of Pohnpei (CSP) has undertaken some market-based analysis (in 2006) in conjunction with ongoing ecosystem assessment efforts in order to determine the condition of Pohnpei's reef fisheries[64].

[62]Ibid, Marino et al. (2008)
[63] Ibid, Marino et al. (2008)
[64] Ibid, George et al. (2008)

5. Republic of the Marshall Islands

Collection of live aquarium fish takes place primarily in Majuro, but also on Arno and Mili, and continues to be unregulated and unmonitored[65].

6. Nauru

Nauru Fisheries and Marine Resources Authority (NFMRA) have undertaken creel surveys of coastal fishers at the landing points in Nauru since 1995. An example of the data collection form completed during these surveys is provided at ATTACHMENT F. It is understood SPC-Coastal Fisheries will be hosting a workshop in June 2010 to investigate the rationalising the current artisanal data-collection system used by Pacific Island Countries. SPC have also commenced entering from artisinal logsheets into TUFMAN, the regional fisheries database currently supporting oceanic fisheries in many Pacific Island countries.

7. Guam

Guam Division of Aquatic and Wildlife Resources (DAWR) carry out regular creel surveys to monitor artisanal fisher catches, catch composition, catch per unit effort and other fishery indicators. Offshore catch experiments have also been conducted by DAWR at three offshore banks that experience different levels of fishing pressure to assess specific levels of impact attributable to fishing pressure[66].

MELANESIA

8. Fijian Local Marine Managed Area Network (FLMMA)

The Fiji Locally Managed Marine Area (FLMMA) network consists of marine resource practitioners from government, non-governmental organizations and communities. FLMMA was established in 2001 and formally registered in 2004 and is now working in approximately 270 villages across all provinces in Fiji[67]. The Fijian program is largely monitored and coordinated by the Institute of Applied Sciences at the University of the South Pacific[68]. A significant key to the success of the monitoring program is that the program in meaningful to the communities and responsive to community needs. Logbooks are filled in by community members without external incentives.

9. PNG Socio-economic:

Vieux (2008)[69] undertook socio-economic assessments in the Sunalailai community of PNG as part of a workshop to: 1. Provide a preliminary socioeconomic baseline on local fisheries; 2. Identify perceived threats to main local resources; and 3. Explore existing management approaches. This included gaining a better understanding of local marine resource use patterns of the Sunalailai community.

POLYNESIA

10. Fisheries Monitoring in Samoa

The Samoan Fisheries Division has a well developed internally funded program of fisheries catch monitoring. The program involves market surveys at the main markets three days a week, a survey of roadside sellers once per week and periodic household surveys (last one undertaken in 2006). The household surveys can obtain information on the subsistence fishery. The surveys are effective at identifying catch composition, size and volume. The market and roadside surveys are undertaken by trained fisheries officers who have also previously collected biological information (e.g size at maturity).

11. American Samoa

The American Samoa DMWR undertake creel surveys to document the actual species and quantities of fish extracted from the reefs at fish landing points. The DMWR has monitored artisanal bottomfish catches since 1982, but annual harvests by artisanal night-divers and subsistence fisheries have been monitored only intermittently.

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[65] Berger et al. (2008)
[66] Burdick et al. (2008)
[67] Morris and Mackay (2008)
[68] Contact: Bale Tamata, email - tamata_b@usp.ac.fj
[69] Vieux (2008)

Lobster Survey:

In 2003, a survey of the artisanal lobster fishery in American Samoa was conducted (Coutures, 2003). Results indicate that landings are small but overfishing does not seem to be occurring. Additionally, the report outlines several management recommendations.

Socio-Economic Valuations:

A comprehensive economic valuation study of American Samoa's coral reefs was completed by Spurgeon etal. in 2004[70].

In October 2006, the American Samoa Coral Reef Advisory Group (CRAG) released an economic valuation of American Samoa's coral reef resources, prepared by Jacobs, Inc. in association with MRAG Americas, the National Institution of Water and Atmospheric Research, and Professor N. Polunin.

[70] Spurgeon et al. (2008)

ATTACHMENT A: The United States Pacific Remote Island Areas (PRIA).

Table 8: Oceanographic monitoring systems in the United States Pacific Remote Island Areas (PRIA).

SYSTEM	VARIABLES MONITORED	DATES	AGENCY
Deep-water CTDs* at select locations near the islands	Conductivity (salinity), temperature, depth, dissolved oxygen, chlorophyll to a depth of 500 m	February 1999-Present	PIFSC-CRED
Shallow-water CTDs - multiple sites each island/atoll	Temperature, salinity, turbidity	February 2001-Present	PIFSC-CRED
Water Samples	Chlorophyll and nutrients (nitrate, nitrite, silicate, phosphate) concurrent with deep and shallow-water CTDs at select depths	July 2003-Present	PIFSC-CRED
Coral Reef Early Warning Buoys - 1 enhanced (Palmyra)	Enhanced: Temperature (1 m), conductivity (salinity), wind, atmospheric pressure, ultraviolet radiation, photosynthetically available radiation	February 2002-Present	PIFSC-CRED
Sea Surface Temperature (SST) Buoys - 6 (Johnston, Kingman, Wake, Jarvis, Baker, Palmyra)	Temperature at 0.5 m	February 2002-Present	PIFSC-CRED
Subsurface Temperature Recorders - 44 (all islands)	Temperature at depths between 0.5 and 30 m	February 2002-Present	PIFSC-CRED
Ocean Data Platforms (ODP) - 2 (Baker, Jarvis)	Temperature, conductivity (salinity), spectral waves, current profiles	October 2002-Present	PIFSC-CRED
Wave and Tide Recorders (WTR) - 1 (Johnston)	Wave and tidal heights	July 2003-Present	PIFSC-CRED
CTD*= Conductivity, temperature and depth.			

(Source: PIFSC-CRED[71])

[71] In: Miller et al. (2008)

Table 9: Research Programs in the Pacific Remote Island Areas of the United States.

PROGRAM	OBJECTIVES	FIRST YEAR	FUNDING	AGENCIES
Bird Monitoring	Nesting seabirds and migratory shorebirds	1985	DOI	USFWS
Oceanographic Monitoring	Water chemistry and carbonate production	2000	NOAA	PIFSC-CRED
	Circulation patterns and water movement	2006	NOAA	PIFSC-CRED
	Tide and temperature monitoring	2006	SEA	SEA
	Educational oceanography	2006	TNC/FWS	PARC
Coral Monitoring	Permanent coral/clam monitoring sites	2000	DOI	FWS
	Microbial and coral diversity	2006	NOAA	PIFSC-CRED
	Benthic dynamics and coral recovery	2006	TNC/FWS	PARC
Habitat Mapping	Produce moderate-depth habitat map	2001	NOAA	PIFSC-CRED
	Algae monitoring	2003	NOAA	PIFSC-CRED
Marine Mammal and Reptile Monitoring	Monitor and assess populations	2006	NOAA	PIFSC
	Sea turtle assessments	2006	TNC/FWS	FWS/PARC
Fisheries Monitoring	Fisheries stock assessment and monitoring	1950	NOAA	PIFSC
	Reef fish monitoring	2000	NOAA	PIFSC-CRED
	Blacktip shark monitoring	2006	TNC/FWS	PARC
	Dynamics of larval fish	2006	TNC/FWS	PARC
	Compare fish populations	2006	TNC/FWS	PARC
	Apex predators and reef ecosystem effects	2006	TNC/FWS	PARC
	Production and energy flow of fishes	2007	TNC/FWS	PARC
	Mullet and gobi diversity	2006	TNC/FWS	PARC
	Bonefish diversity and post-release stress	2006	TNC/FWS	PARC
Other Biological Studies	Opisthobranch mollusk recovery	2006	TNC/FWS	PARC
	Octopus and stomatopod diversity	2006	TNC/FWS	PARC
	Bottom dwelling diversity	2006	TNC/FWS	PARC
	Barnacle diversity	2006	TNC/FWS	PARC
	Polychaete diversity	2006	TNC/FWS	PARC
	Echinoderm diversity	2006	TNC/FWS	PARC
Geological Studies	Palmyra lagoon changes due to WWII	2006	TNC/FWS	PARC

PARC = The Palmyra Atoll Research Consortium
SEA = Sea Education Association

(Source: J. Miller and J. Maragos[72])

[72] In: Miller et al. (2008)

ATTACHMENT B: American Samoa

Table 10: Oceanographic data currently being collected within the EEZ of American Samoa[73].

System	Variables Monitored	Dates	Agency
Deepwater CTDs* at select locations near the islands	Conductivity (salinity), temperature, depth, dissolved oxygen, chlorophyll to a depth of 500 m	February 2002 - present	PIFSC-CRED
Shallow-water CTDs* - multiple sites each island/atoll	Temperature, salinity, turbidity	February 2002 - present	PIFSC-CRED
Water Samples	chlorophyll and nutrients (nitrate, nitrite, silicate, phosphate) concurrent with deep and shallow-water CTDs at select depths	January 2006 - present	PIFSC-CRED
Coral Reef Early Warning Buoys -1 Standard (Rose Atoll)	Enhanced: temperature (1 m), conductivity (salinity), wind, atmospheric pressure	February 2002 - present	PIFSC-CRED
Sea Surface Temperature (SST) Buoys - 3 (Tau, Tutuila)	Temperature at 0.5 m	February 2002 - present	PIFSC-CRED
Subsurface Temperature Recorders - 33 (all islands)	Temperature at depths between 0.5 m and 30 m	February 2004 - present	PIFSC-CRED
Ocean Data Platforms (ODP) - 1 (Swains)	Temperature, conductivity (salinity), spectral waves, current profiles	February 2002 - present	PIFSC-CRED
Wave and Tide Recorders (WTR) - 2 (Rose Atoll, Tutuila)	Wave and tidal heights	February 2004 - present	PIFSC-CRED
Ecological Acoustic Recorder (EAR) - 4 (Tutuila)	Ambient sounds up to 12.5 kHz and vessel generated sounds	February 2006 - present	PIFSC-CRED
* CTD: Conductivity, temperature and depth.			

Table 11: Overview of current monitoring activities in American Samoa[74]

PROJECT	LOCATION	YEAR	AFFILIATION/ FUNDING	PRINCIPLE INVESTIGATOR	FREQUENCY	STATUS
Aua Transect	Aua Village, Tutuila	1917	CRAG, CRI	Birkeland	Periodic	Ongoing
TMP	Tutuila and Manua	2005	DMWR, CRAG, NOAA	Fenner and Carroll	Annual	Ongoing
Resource Assessment and Monitoring Program	All Islands	2002	NOAA PIFSC-CRED	Brainard et al.	Biannual	Ongoing
Key Reef Species (fish)	Tutuila and Manua	2005	DMWR, FedAid Sportfish Recovery	Sabater	Annual	Ongoing
Coral Disease	Tutuila and Manua	2005	DMWR, FedAid Sportfish Recovery	Fenner	Annual	Ongoing
Rose Atoll	Rose Atoll	2002	USFWS	Maragos	Periodic	Ongoing
MPA Reef Flats	MPA Villages, Tutuila	2004	DMWR, FedAid Sportfish Recovery	Vaitautolu	Approx. Annual	Ongoing
Fagatele Bay Monitoring	Fagatele Bay, Tutuila	1985	Fagatele Bay NMS	Birlkeland and Green	3 years (Approx.)	Ongoing
Long-Term Monitoring	Tutuila and Manua	1982	DMWR	Green and Birkeland	5 years (Approx.)	Ongoing
Nonpoint Source Pollution	Tutuila	2003	AS EPA	Houk and Peshut	Annual	Ongoing
Inshore Creel Survey	South Shore, Tutuila	1978	DMWR, FedAid Sportfish Recovery	Iramatra	Daily	Ongoing
Reef Monitoring	National Park, North Shore, Tutuila	2007	National Park of American Samoa	Brown and Craig	Annual	Ongoing
Stream/ Beach Monitoring	Tutuila	2002	AS EPA	Zennaro and Paselio	Weekly	Ongoing
Shallow-water Benthic Habitat Maps	All Islands	2005	NOAA CCMA-BB	Battista and Monaco	One Time	One Time

[73] Ibid, Aeby et al. (2008)
[74] Ibid, Aeby et al. (2008)

ATTACHMENT C: The Federated States of Micronesia

Table 12: Summary of monitoring and data gathering activities in the Federated States of Micronesia.

PROGRAM	OBJECTIVES	START DATE	FUNDING	PARTNERS
Kosrae Fish Monitoring Program	Assess stocks of commercially important food fish in Kosrae.	2000	NOAA, KSG	KDMS
Kosrae Marine Monitoring (Reef Check)	Monitor the status of the reefs of Kosrae to assess changes in coral, fish and invertebrates over time (monitoring sites increased from six to ten in 2000).	1994	KSG, Sea Grant, Kosrae Village Resort and Volunteer Divers, NOAA	KDMS, KVR, KCSO
Pohnpei MPA Monitoring Program	Monitor important fishery species for five MPA sites within Pohnpei lagoon. Apply CSP's established fishery monitoring protocol to newly established MPA's within the network. Continue a coral and benthic habitat monitoring program established in 2004/2005. Continue monitoring of a multi-species, Serranid spawning aggregation inside the Kepahara MPA..	2003	NOAA, DOI-OIA, Packard Foundation	CSP, PMRD
Yap State Coral Reef Monitoring Program	Establish a monitoring program with simple, realistic methods. Establish a working network among agencies in Yap and in the region for collecting, processing, and sharing monitoring information. Collect and use baseline monitoring data to promote and technically support conservation efforts at the community level.	2006	NOAA, Yap State	YapCAP, YEPA, YMRMD,
Chuuk Coral Reef Monitoring Program	Under development.	Planned to start in 2008	NOAA, Chuuk State, MCT	CCS, CEPA, CMRD

CCS = Chuuk Conseration Society
CEPA = Chuuk Environmental Protection Agency
CMRD = Chuuk Marine Resources Division
CSP = Conservation Society of Pohnpei
KCSO = Kosrae Conservation and Safety Organization
KDMS = Kosrae Division of Marine Surveillance
KIRMA = Kosrae Island Resource Management Authority
KSG = Kosrae State Government
KVR = Kosrae Village Resort Ecolodge
MCT = Micronesian Conservation Trust
PMRD = Pohnpei Marine Resources Division
YapCAP = Yap Community Action Program
YEPA = Yap Environmental Protection Agency
YMRMD = Yap Marine Resources Management Division

Source: George et al. (2008)

ATTACHMENT D: Guam

Table 13: Summary information of Guam's monitoring, research and assessment activities.

ACTIVITY CATEGORY	AGENCY	YEARS	ACTIVITY DESCRIPTION	COLLECTION
Marine Preserve Monitoring	DAWR	7	Assessment of the effectiveness of Guam's marine preserves on Food Fish populations. Visual transects and interval counts are used to assess fish species.	Every 1-2 years
	UOGML	1	Investigation of the connectivity between marine preserves and exploited reefs using larval tracking methods	One time
		1	Assessment of spillover of adult target fish species from Marine preserves into adjacent areas	One time
		1	Assessment of abundance of target fish groups in marine preserves and adjacent control sites; part of larger investigation of relationship between herbivorous fish, algae and nutrient interactions within marine preserves	One time
		1	Investigation of role of soft coral as fish habitat within a marine preserve	One time
Sedimentation	NPS	4	Assess the level of sedimentation and its affect on reefs in the WAPA. Data collected include total sediment, percent organic, percent carbonate, sediment size, water temperature, light penetration, benthic cover and coral recruitment.	Monthly
Erosion	NPS	4	Land based monitoring of erosion rates in burned versus non-burned areas. In addition, erosion flumes are being used to assess possible badland mitigation techniques.	Weekly
Oceanography and Water Quality	Guam EPA	>20	GEPA 305b, Water Quality Report to Congress	Biennially
			Recreational Water Quality (microbial)	Weekly
			Monitoring wells, golf courses and restoration sites	Quarterly
		3	Environmental Monitoring and Assessment Program	Biennially
	NOAA PIFSC-CRED	5	Monitoring of: 1) conductivity, temperature, depth, dissolved oxygen, and chlorophyll to a depth of 500 m using deepwater conductivity, temperature and depth (CTD) sensors; 2) temperature, salinity, and temperature at multiple sites using shallow-water CTDs; 3) chlorophyll and nutrients (nitrate, nitrite, silicate, phosphate) concurrent with the deep and shallow-water CTDs; 4) temperature at 0.5 m using two SST buoys; and 5) temperature at depths between 0.5 and 30 m using three subsurface temperature recorders	Biennially
	UOGML	3	Evaluation of the effectiveness of using soft corals as bioindicators of water quality	One time
		1	Acquisition of monthly measurements of NOx, RP, Si, and salinity at 11 reef flat sites; part of larger investigation of relationship between herbivorous fish, algae and nutrient interactions within marine preserves	One time
	UOG WERI	1	Investigation of relationship between nutrients and *Enteromorpha clathrata* blooms in Tumon Bay (Denton et al., 2005)	One time
		1	Determination of impacts of leachate from Ordot dump on marine communities in Pago Bay (Denton et al., 2006)	One time
	NPS/U.S. Geological Service	1	Development of detailed hydrodynamic model for the Asan Beach Unit of the WAPA. Data collected for five locations within Asan Bay include 1) current speed and direction throughout the water column 2) wave height, wave period, wave direction and tide level 3) near-bed water temperature, salinity, turbidity and PAR; and 4) near-surface water temperature, salinity and turbidity. The water level in Asan River as well as wind speed, wind direction, air temperature, rainfall and incident PAR will also be monitored.	One time

Source: D. Burdick and V. Brown In: Burdick et al. (2008)

Table 13 (continued): Summary information of Guam's monitoring, research and assessment activities.

ACTIVITY CATEGORY	AGENCY	YEARS	ACTIVITY DESCRIPTION	COLLECTION
Benthic Habitat	NOAA PIFSC-CRED	5	Documentation of baseline conditions of the health of coral, algae and invertebrates, refine species inventory lists, monitor resources over time to quantify possible natural or anthropogenic impacts, document natural temporal and spatial variability in resource community, improve our understanding of the ecosystem linkages between and among species, trophic levels and surrounding environmental conditions.	Biennially
	UOGML	1	Baseline assessment and long-term monitoring of benthic community at five permanent reef sites	Tri-monthly for 1st year; then biannually or annually
Coral Disease	UOGML	1	Baseline assessment of coral disease prevalence at 10 sites; benthic composition, coral species richness, bleaching, predation and other signs of compromised health were also assessed.	One-time
		1	Monitoring of coral disease prevalence, coral community, signs of stress and disease and water temperature at four of the 10 baseline assessment sites.	Quarterly
Fisheries Monitoring	DAWR	>20	Creel, participation, and boat-based surveys to obtain information including boating activity, fishermen participation, CPUE and species composition in order to monitor the health of the fisheries resources	Semi-weekly (on average)
	NPS	1	Assessment of impacts of fishing within the WAPA	One time
	UOGML	1	Characterization of previously identified reef fish spawning aggregations and sites in Piti Bomb Holes Marine Preserve and Asan Bay	One time
Associated Biological Communities	UOGML	1	Baseline assessment and long-term monitoring of fish and macroinvertebrate communities at five permanent reef sites	Tri-monthly for 1st year; then biannually or annually
	NOAA PIFSC-CRED	6	Monitoring of reef fish communities using Rapid Ecological Assessments (belt transects, stationary point counts and roving diver surveys) and towed-diver surveys.	Biennially
	UOGML / DAWR	6	Monitoring of specific Reef Check sites using community volunteers	Annually, when possible
	UOGML	1	Assessment of COTS outbreaks using manta-tow surveys	One time
Recreational Impacts	GCMP	1	Assessment of impacts of motorized personal watercraft on water and sediment quality, benthic habitat and fish communities in East Agana Bay	One time
Socioeconomic Information	UOGML	1	Assessment of economic value of Guam's coral reefs and associated resources; the underlying motives and mechanisms behind the total economic value were also investigated by focusing on people's relationship with the marine ecosystems, local "willingness to pay" for coral reef conservation and the spatial variation of reef-associated economic values and threats.	One time
		1	Determination of the non-extractive value of coral reef icon species	One time
	UOG	1	Assessment of perceptions, values and level of awareness among Micronesian populations on Guam regarding coastal resources, particularly with regard to the marine preserves and differences in management systems (e.g., traditional marine tenure versus open access)	One time
	GCMP	<1	Evaluation of the effectiveness of GCMP's various public outreach activities and to identify the environmental issues of most concern to the public	Every 3-5 years

Source: D. Burdick and V. Brown In: Burdick et al. (2008)

ATTACHMENT E: The Republic of the Marshall Islands (RMI)

Table 14: Data-gathering activities conducted in RMI since 2000. BDS – biodiversity swims, REA – Rapid Ecological Assessment based on transects, TS – Terrestrial and turtle surveys, CS – community surveys, CB – capacity building, S – single assessment in multiple sites, Moni – temporal monitoring program.

ATOLL	OBJECTIVES	START DATE	FUNDING	PARTNERS
ASSESSMENTS				
Likiep	Assess reef-fish	2001	MIMRA	CMI
Ailinginae	BDS, REA, CB, TS (all S)	June 2002	NFWF	CMI, UH, UQ
Bikini, Ailin-ginae and Rongelap	BDS, REA, CB, (all S)	July-Aug. 2002	USDOI, Small Rufford Grant	NRAS
Mili, Rongelap	BDS, REA, CB, (all S)	July-Aug. 2003	USDOI, NFWF, MIMRA, Point Defiance Zoo and Aquarium, CMI and RalGOV	NRAS
Namu, Majuro	REA, CB, (all S)	Nov.-Dec. 2004	US-DOI, UH Sea Grant, MIMRA, PADI Project AWARE Point Defi-ance Zoo and Aquarium, CMI	NRAS
Ailuk	REA, CB (all S), CS (ongoing)	May 2006; Sept. 2006-Dec. 2007	US-DOI, Winifred Scott, Point De-fiance Zoo and Aquarium, MIMRA, Regional Natural Heritage Pro-gram, CMI	NRAS, University of Tasmania, Marine and Environmental Re-search Institute of Pohnpei, WAM
LONG-TERM DATA-GATHERING EFFORTS				
Rongelap	BDS, REA, CB, PH-tra (all long-term Monitoring)	Dec. 2006	BP-conservation programme, NOAA	CMI, MIMRA, University of Queensland, James Cook Univer-sity, Victoria University
Ailuk, Likiep, Majuro, Arno	REA, CB,	Aug.-Sep. 2007	SPC CO-Fish	SPC, MIMRA

Table 15: Methods used in NRAS surveys in the Marshall Islands

ACTIVITY	TYPE OF DATA	METHOD	FINAL INFORMATION
Coral and Fish Diversity Surveys	Species list per site, semi-quantitative abundance	Timed swim	Coral and fish species lists and abundance
Line Intercept	Percent cover of coral and benthos; two or three repli-cates at each site, at different depths between 5 and 15 m	50 x 5 m line transect, substrate type, life forms of corals, main genera and species	Percent cover composition of benthos and main scleractinia secies or genera
Belt Transect	Fish id, counts, size estimate; inverte-brate id and counts; two or three repli-cates at each site, at different depths between 5 and 15 m	50 m x 5 m x 5 m transect, fish families and commercial target species counts and class sizes; commercial inverte-brate counts	Fish abundance by families and main species; invertebrate abundance
Algae Quadrats	Percent cover of al-gae and semi-quan-titative abundance of major groups: four replicate per transect	Four 25 cm x 25 cm quadrats	Algae families and species id and diversity
Macrofauna	Timed swims	Identify and count sharks, rays, napo-leon wrasse, turtles	Abundance of macrofauna

(*Source: http://www.nras-conservation.org*)

Table 16: Rongelap Atoll Long-term monitoring project objectives and details[75].

PROJECT OBJECTIVE	DETAILS
Develop monitoring initiative at Rongelap Island to document possible ecosystem changes with resettlement	Monitoring program with nested sites and five replicates: High-settlement island outer reef, lagoon and pass, and controls of remote island outer reef, lagoon and pass
Collect baseline data for long-term monitoring program	Add spatial explicit monitoring data of fine resolution to existing data set of Rongelap Reef status (Pinca et al., 2004b); Target sites adjacent to likely sources of impacts, such as main settlements, airport, port, proposed aquaculture venture, proposed piggery
Collect data by scientists and trained locals	Scientist monitoring for detailed analysis of population trends; Trained locals (non-scien-tists/ students) monitoring to allow low-cost continuity of the program on a sustainable and locally funded basis
Involve local surveyors trained in CMI's Marine Science Program	People with previous survey experience refresh their skills; Recently trained people can obtain practical skills; Locals from RalGov, MIMRA, EPA and CMI
Create database for monitoring to be housed jointly by CMI and MIMRA	Database is accessible and easy to query for future reference; Database is able to also store future data

[75] Ibid, Beger et al. (2008)

ATTACHMENT F: The Republic of Palau

Table 17: Outline of responsible agencies and monitoring and assessment activities in Palau.

AGENCY	PLANNING/ MANGEMENT	RESEARCH	MONITORING	EDUCATION /OUTREACH	TRAINING	ENFORCE-MENT	YEAR EST.
Bureau of Natural Resources and Development	X	X	Ngermeduu Bay, Clam export and fish market		X	X	1990
Coral Reef Research Foundation		X	Temperature, marine lake				1998
Environmental Quality Protection Board			Water quality	X		X	1992
Helen Reef Resource Management Board	X		MPA	X	X	X	2000
Koror State Department of Con-servation and Law Enforcement	X	X	Marine lakes, Rock Island, MPA				1994
Palau Conservation Society	X		MPA's	X	X		1996
Palau International Coral Reef Center		X	Fish, coral MPA's, watersheds				2001
The Nature Conservancy	X	X	MPA Network	X	X		2003

ATTACHMENT G: Sample artisanal/subsistence fisher catch and effort form used for creel surveys in Nauru

<table>
<tr><td colspan="4">CANOE/FAD MONITORING LOGSHEET</td></tr>
<tr><td colspan="2">DISTRICT:</td><td colspan="2">NAME OF CANOE:</td></tr>
<tr><td colspan="2">NAME OF FISHERMAN:</td><td colspan="2">SIGNATURE:</td></tr>
<tr><td colspan="2">DATE:</td><td colspan="2" rowspan="3">NAME OF FAD (S) FISHED:</td></tr>
<tr><td colspan="2">TIME:</td></tr>
<tr><td colspan="2">TIME:</td></tr>
<tr><td colspan="4">FISHING METHODS:</td></tr>
<tr><td colspan="3">CATCH</td><td>COMMENTS</td></tr>
<tr><td>SPECIES</td><td>PIECES</td><td>WEIGHT</td><td rowspan="10"></td></tr>
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<tr><td>FISH RETAINED</td><td>PIECES:</td><td>WEIGHT:</td></tr>
<tr><td>FISHGIVEN AWAY</td><td>PIECES:</td><td>WEIGHT:</td></tr>
<tr><td>FISH SOLD</td><td>PIECES:</td><td>WEIGHT:</td></tr>
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