Outlook Report on the State of the Marine Biodiversity in the Pacific Islands Region

Jeff Kinch, Paul Anderson, Esther Richards, Anthony Talouli, Caroline Vieux, Clark Peteru and Tepa Suaesi

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Outlook Report on the State of the Marine Biodiversity in the Pacific Islands Region

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Acronyms

AusAID	Australian Agency for International Development
EEZ	Exclusive Economic Zone
CNMI	Commonwealth of the Northern Mariana Islands
CITES	Convention on the Trade in Endangered Species
EAFM	Ecosystem Approach to Fisheries Management
ENSO	El Nino Southern Oscillation
FfPO	Framework for Pacific Oceanscape
FSM	Federated States of Micronesia
GPA	Global Program of Action
IUCN	International Union for Nature Conservation
MMA	Marine Managed Area
MTI	Marine Trophic Index
MTL	Mean trophic level
NAPA	National Adaptation Programmes of Action
PACC	Pacific Adaptation to Climate Change
PICTs	Pacific Island Countries and Territories (**PICs** – Pacific Island Countries, **PITs** – Pacific Island Territories)
PIFACC	Pacific Islands Framework for Action on Climate Change
PIROP	Pacific Islands Regional Oceans Policy
PNG	Papua New Guinea
SPREP	Secretariat of the Pacific Regional Environment Program
SST	Sea Surface Temperature
SPC	Secretariat of the Pacific Community
TEU	Twenty-foot Equivalent Units

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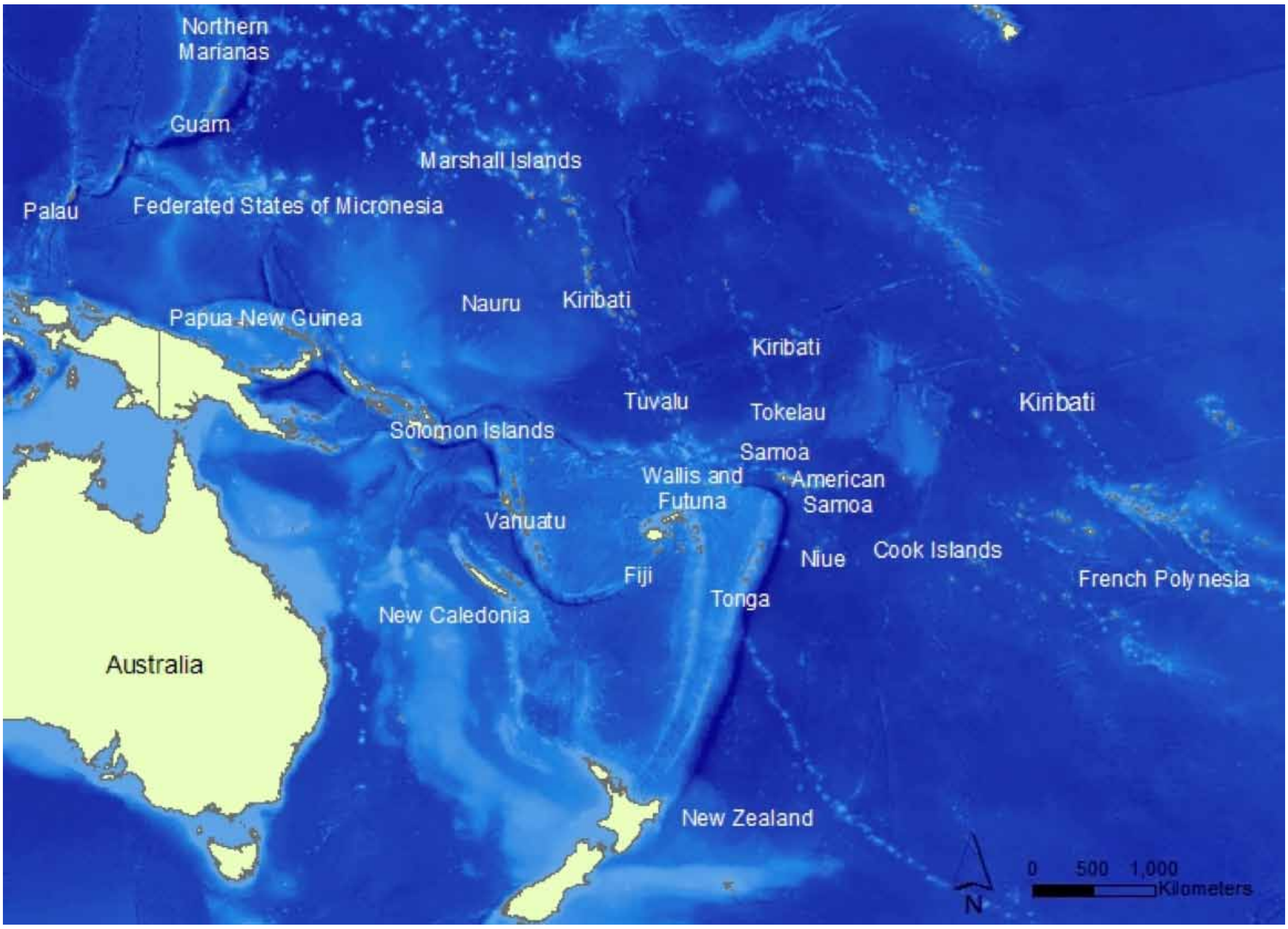

Northern Marianas
Guam
Marshall Islands
Palau
Federated States of Micronesia
Nauru
Kiribati
Papua New Guinea
Kiribati
Tuvalu
Tokelau
Kiribati
Solomon Islands
Samoa
Wallis and Futuna
American Samoa
Vanuatu
Fiji
Niue
Cook Islands
Tonga
French Polynesia
New Caledonia
Australia
New Zealand
N
0 500 1,000 Kilometers

1 Introduction

The Pacific Islands region is located in the western and central Pacific Ocean. The 14 independent countries and eight territories that make up this region are delineated into three major culture areas; these are Melanesia, Micronesia and Polynesia (Table 1), and have a combined Exclusive Economic Zone (EEZ) of approximately 29 million km^2.

Table 1: Countries and Territories in the Pacific Islands region by culture area

	Countries and Territories
Micronesia	Palau, Guam*, the Commonwealth of the Northern Mariana Islands* (CNMI), the Federated States of Micronesia (FSM), the Marshall Islands, Nauru and Kiribati
Polynesia	Tuvalu, Wallis and Futuna*, Tokelau*, Samoa, American Samoa*, Tonga, Pitcairn Islands*, Niue, the Cook Islands, and French Polynesia*
Melanesia	Papua New Guinea (PNG), the Solomon Islands, Vanuatu, New Caledonia* and Fiji

** Territories*

Total land area in the Pacific Islands region is just over 550,000 km^2, of which PNG accounts for 83 % of the total land area, and also makes up approximately 64 % of the total population for the (Table 2). On the opposite end of the spectrum, seven of the smallest Pacific Islands Countries and Territories (PICTs); the Cook Islands, Palau, Wallis and Futuna, Nauru, Tuvalu, Niue and Tokelau, when combine account together for less than 1 % of the total population for the Pacific Islands region (Table 2).

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Table 2: Area coverage and estimated population for PICTs in the Pacific Islands region

	~ Land Area (km²)	~ EEZ Area (km²)	~ Territorial Waters (km²)	~ Population (mid-2007)
American Samoa	197	390,000	9,910	65,030
CNMI	475	1,823,000	27,220	64,050
Cook Islands	180	1,830,000	31,310	15,470
Fiji	18,376	1,290,000	114,460	834,300
French Polynesia	3,521	5,030,000	243,890	260,070
FSM	702	2,978,000	49,990	110,000
Guam	549	218,000	4,580	174,000
Kiribati	726	3,550,000	75,300	93,710
Marshall Islands	720	2,131,000	107,00	52,700
New Caledonia	19,103	1,740,000	68,870	242,560
Nauru	21	320,000	1,900	9,930
Niue	258	390,000	2,980	1,580
Palau	500	629,000	14,010	20,160
Pitcairn Islands	5	800,000	8,100	50
PNG	461,690	3,120,000	355,700	6,332,750
Samoa	2,934	120,000	10,000	179,480
Solomon Islands	29,785	1,340,000	140,040	503,920
Tokelau	12	290,000	7,000	1,170
Tonga	696	700,000	37,530	102,260
Tuvalu	26	900,000	18,980	9,700
Vanuatu	12,189	680,000	69,170	227,150
Wallis and Futuna	124	300,000	5,690	15,370
Total	552,789	28,928,300	1,296,630	9,315,410

Values for EEZs (200 nm) and Territorial Waters (12 nm) should be regarded as estimates only as some PICTs have not formalized their EEZs (and some wish to extend their Continental Shelf margins) or accurately determined their Territorial Waters. *Source: Gillett, 2010; the Secretariat of the Pacific Community, and the Secretariat of the Pacific Regional Environment Program*

Major marine environmental issues have been identified in the Pacific Islands region, and these include potential (and perceived) impacts from environmental change (including climate variability and climate change), habitat loss and the effects of coastal modification, the introduction of invasive species, fishing pressure (including destructive practices), increased sedimentation and nutrient loading from land-use practices (including coastal mining), solid waste and liquid effluents, and other sources of land and marine pollution (Table 3).

Table 3: Identified threats for the Pacific Islands region for individual PICTs (from the literature)

	Nutrient loading	Land-based influence	Subsistence fishing	Commercial fishing	Acidification	Sea Surface Temperature	Invasives
American Samoa	✓	✓	✓	✓	✓	✓	✓
CNMI				✓		✓	✓
Cook Islands	✓	✓	✓			✓	
Fiji	✓	✓	✓	✓		✓	
French Polynesia	✓	✓	✓	✓		✓	
FSM	✓	✓	✓	✓			
Guam		✓		✓			✓
Kiribati	✓		✓	✓		✓	
Marshall Islands			✓	✓		✓	
Nauru						✓	
New Caledonia	✓	✓	✓	✓		✓	
Niue							
Palau	✓	✓	✓	✓		✓	✓
Pitcairn Islands							
PNG	✓	✓	✓	✓		✓	
Samoa			✓			✓	
Solomon Islands		✓	✓	✓			
Tokelau							
Tonga			✓	✓			
Tuvalu			✓				
Vanuatu		✓	✓	✓		✓	✓

Source: Center for Ocean Solutions. 2009 (see also Huber, 2009).

This report provides a summary of current information regarding pressure, state and responses to these threats for the Pacific Islands region, as well the responses by PICTs in addressing, alleviating and/or mitigating these threats.

2 Pressures

2.1 Fish stocks

The Pacific Islands region supports the largest industrial tuna fisheries in the world. The primary target species are skipjack, yellowfin, big-eye and albacore, which are caught by either trolling, longline, purse seine and/or pole-and-line. These tuna fisheries are the cornerstone upon which many PICTs depend upon for revenue and income generation.

Coastal fisheries are also extremely important for subsistence, artisanal and semi-commercial catches, though it is widely acknowledged that most coastal fisheries in the Pacific Islands region are over-exploited (South *et al*, 2004; SPC, 2009). A recent review of the literature by Newton *et al* (2007) suggests that possibly 55 % of all PICTs have overexploit their coral reef fisheries, although this statistic is uncertain due to limited data (see Kinch *et al,* 2008 for status on sea cucumber fisheries in the Pacific Islands region).

Gillett (2009) notes that estimating the production from coastal fisheries in about half of the PICTs in the Pacific Islands region is largely guesswork, though monitoring of tuna production is relatively efficient, both nationally and regionally (Gillett, 2009; Allen, 2010). Harley *et al* (2009) provide an excellent overview of the tuna fisheries and state of the stocks in the western and central Pacific Ocean, based on their work at the Oceanic Fisheries Program with the Secretariat of the Pacific Community (SPC).

For the Pacific Islands region as a whole, tuna fisheries have expanded substantially, whilst there has been no real production increase from coastal fisheries over the last decade (Gillett, 2009). Table 4 details fisheries production by sector for the year, 2007.

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Table 4: Marine fisheries production (tonnes) for PICTs: 2007

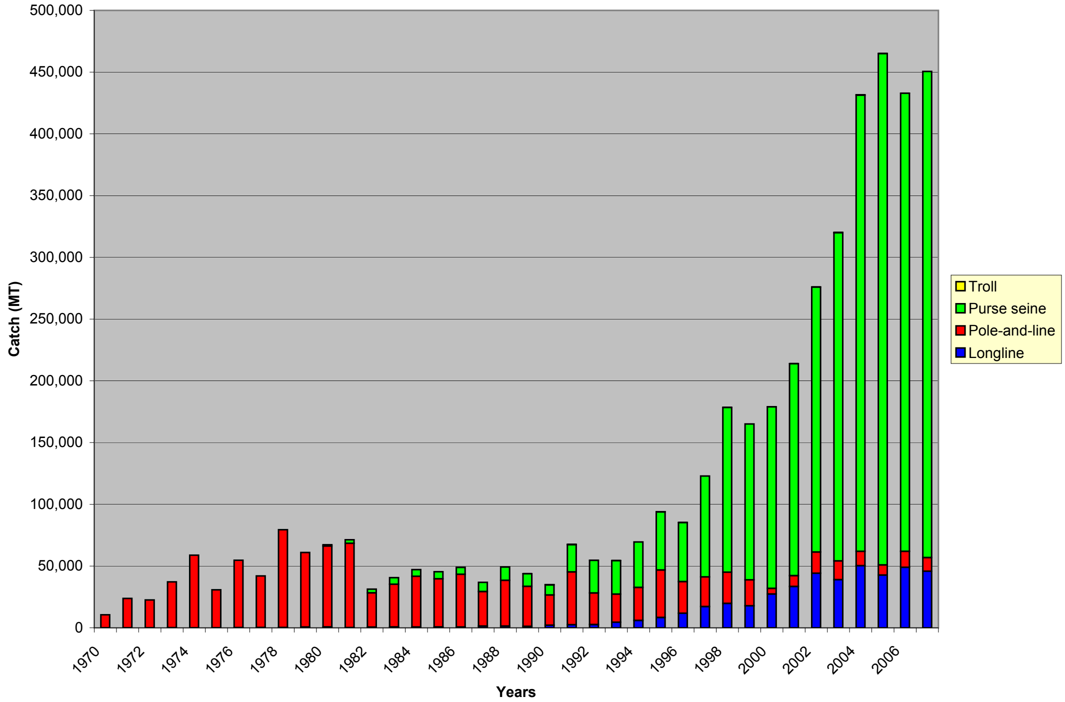
	Coastal commercial fishing	Coastal subsistence fishing	Offshore locally-based fishing	Offshore foreign-based fishing	Total (tonnes)
American Samoa	35	120	6,632		6,787
CNMI	231	220			451
Cook Islands	133	267	3,939		4,339
Fiji	9,500	17,400	13,744	492	41,136
French Polynesia	4,002	2,880	6,308		13.190
FSM	2,800	9,800	16,222	143,315	172,137
Guam	44	70			114
Kiribati	7,000	13,700		163,215	183,915
Marshall Islands	950	2,800	63,569	12,727	80,046
Nauru	200	450		69,236	69,886
New Caledonia	1,350	3,500	2,122		6,972
Niue	10	140	640	790	1,580
Palau	865	1,250	3,030	1,464	6,609
Pitcairn Islands	5	7			12
PNG	5,700	30,000	256,397	327,471	619,568
Samoa	4,129	4,495	3,755	25	12,404
Solomon Islands	3,250	15,000	23,619	98,023	139,892
Tokelau		375		318	693
Tonga	3,700	2,800	1,119		7,619
Tuvalu	226	989		35,541	36,756
Vanuatu	538	2,830		12,858	16,226
Wallis and Futuna	121	840			961

Source: Gillett, 2009, 2010.

Skipjack and small yellowfin and bigeye tuna school (frequently together) on the ocean surface and are commonly found in the tropical and sub-tropical waters. Larger yellowfin and bigeye are generally found in deeper water, where they are more widespread, although some larger yellowfin are also caught in free swimming schools. In contrast to skipjack and yellowfin tuna, albacore concentrate in temperate areas (Barclay and Cartwright, 2007).

The overall catch composition of the longline fishery, is roughly one-third for each of albacore, bigeye and yellowfin tunas. Purse-seine fisheries are by far the largest of the tuna fisheries and catch mostly skipjack tuna, but also important quantities of yellowfin and bigeye tunas. There is also an important pole-and-line fishery, which catches mostly skipjack. Trolling is a small part of fihing effort, targeting mostly albacore. Figures 1 and 2 detail effort and catch for the period 1997–2007; whilst Figure 3 details catch by PICT for the year, 2007.

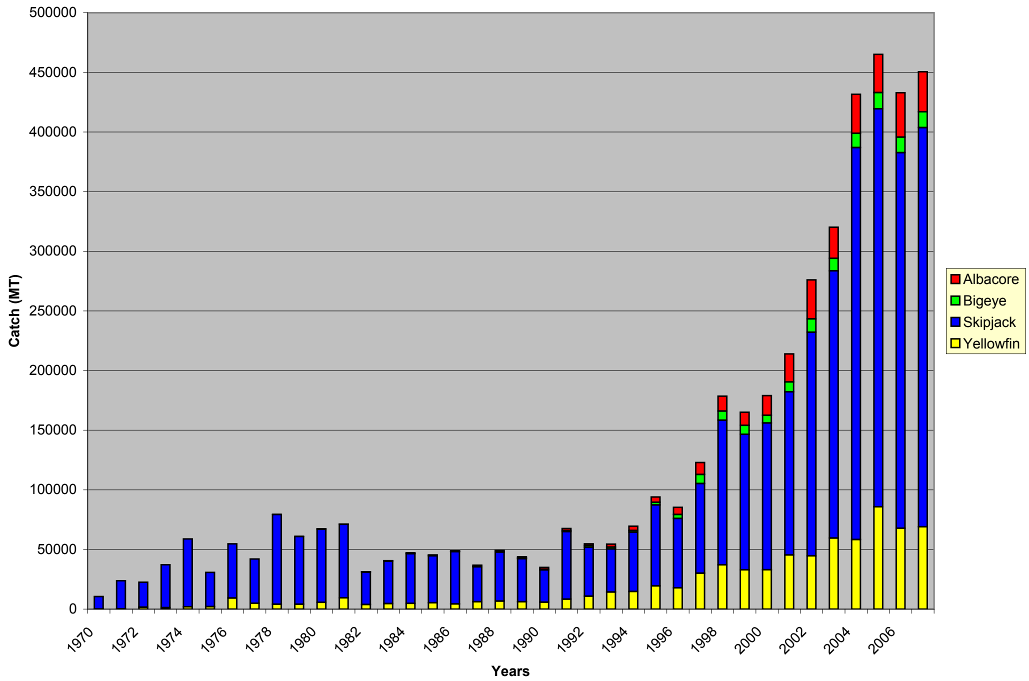
Figure 1: Catch (tonnes) by gear for the Pacific Islands region: 1970–2007



Source: Harley et al, 2009.

Recent stock assessments (see Harley *et al,* 2009) suggest that while stocks of bigeye tuna resources are not yet in an over-fished state with respect to total biomass (Figure 4), the situation is less optimistic with respect to the adult biomass, and projections indicate that the stock will certainly become over-fished in the next few years with regards to both total biomass and spawning biomass. With regards to the yellowfin tuna stocks, there is a small probability (~ 6 %) that the yellowfin stock is in an over-fished state (Figure 4) due in part to the fishing effort by purse-seiners that generally catch smaller and younger fish. Skipjack tuna stocks are highly productive, and over-fishing is not occurring within these stocks (Figure 4). Large recent catches are considered to be sustainable unless recruitment falls persistently below the long-term average. Finally, with regards to the stocks of South Pacific albacore tuna, there is some uncertainty regarding the sustainability of fishing effort targeting these stocks (Figure 4).

Figure 2: Catch (tonnes) by species for the Pacific Islands region: 1970–2007



Source: Harley et al, 2009.

Figure 3: Catch (tonnes) by species for the Pacific Islands region: 2007

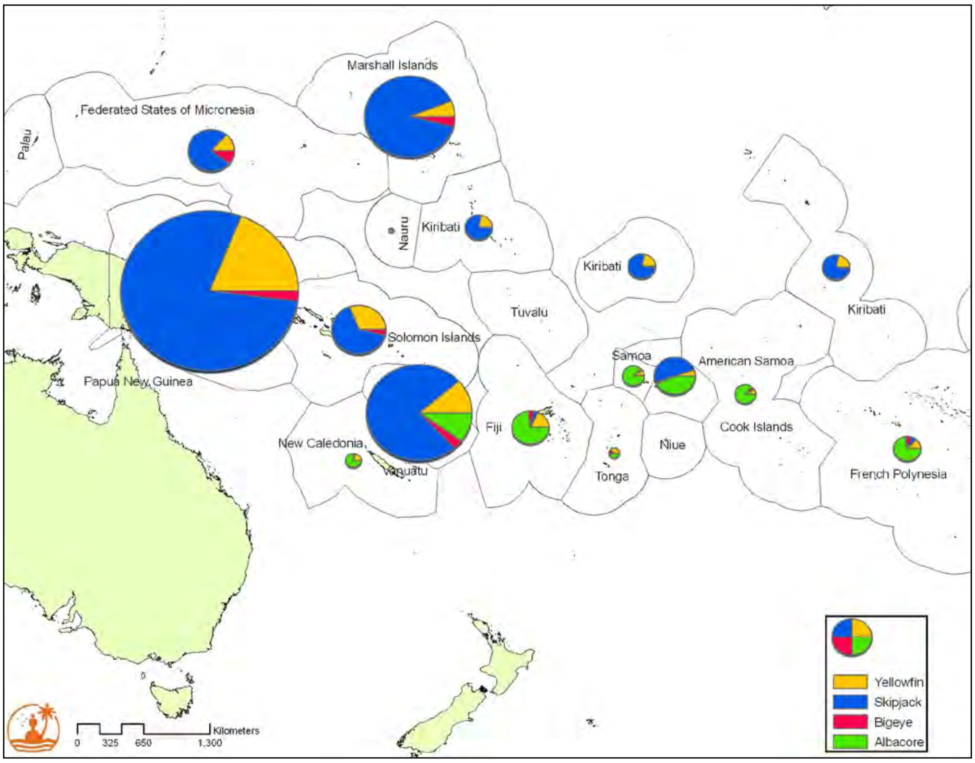
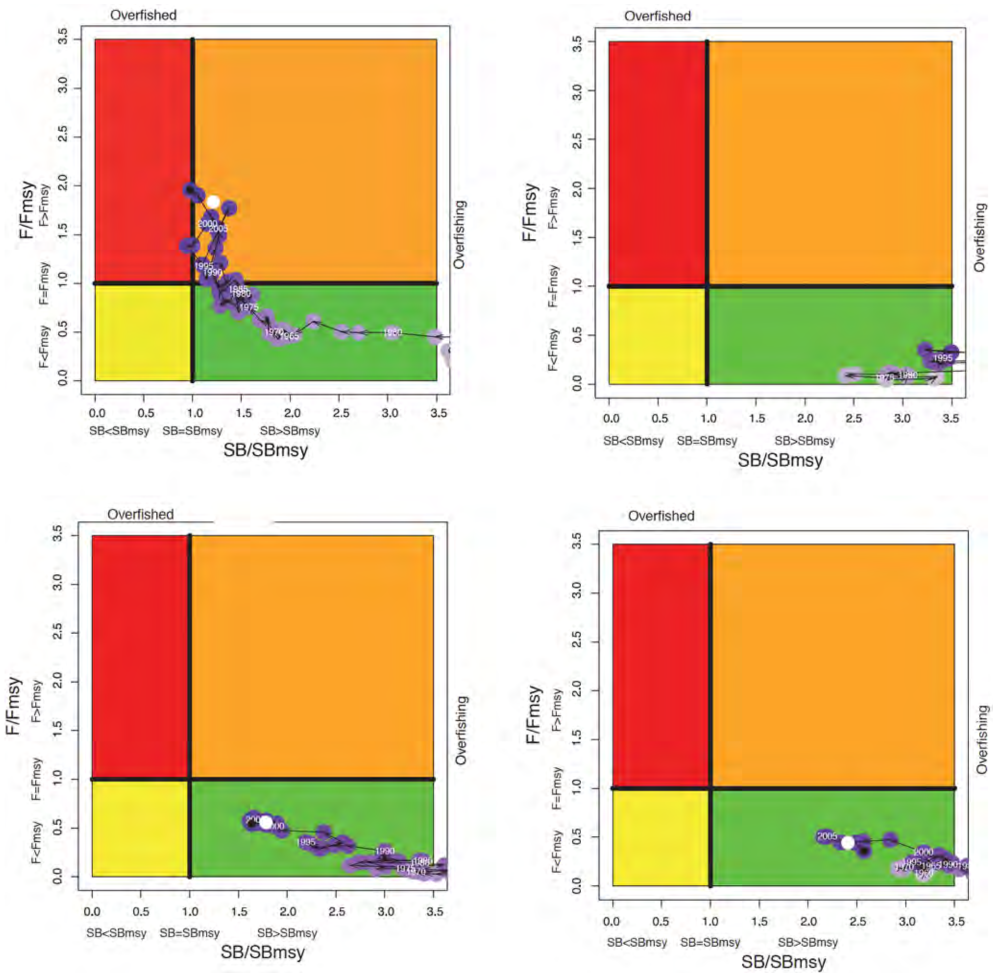


Figure 4: Results of recent stock assessments for tuna species in the western and central Pacific Ocean



Source: Harley et al, 2009.

2.2 Nutrient loading

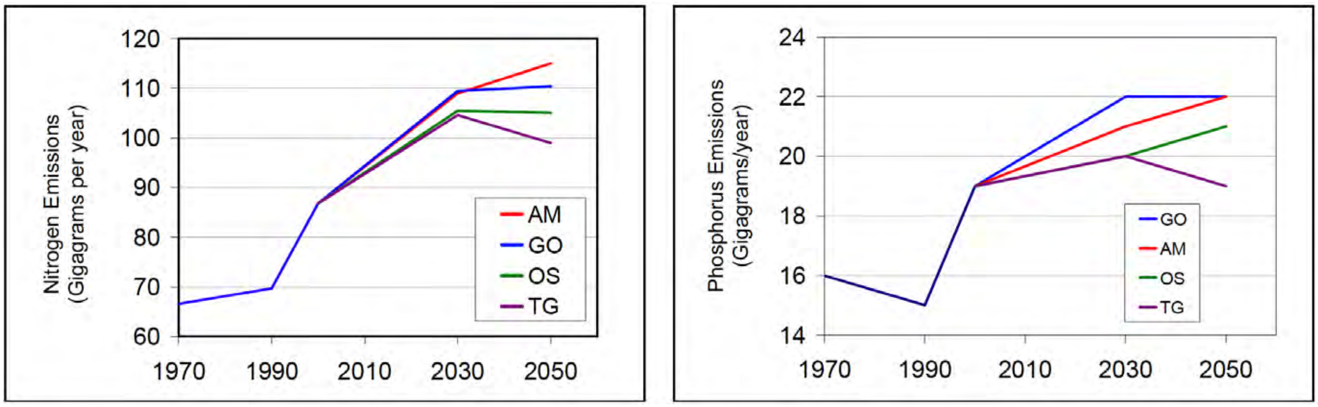
The main nutrients associated with biological productivity in marine systems are nitrates, phosphates and silicates. Variations in the supply of nutrients have been observed in the world's oceans (see Martinez *et al,* 2009). In the tropical Pacific Ocean for example, small net decreases in nutrient supply to the upper photic zone have been observed over the last 50 years (Watanabe *et al,* 2005). This is thought to be caused by increased stratification in the water column, though as Ganachaud *et al* (in press) point out, poor spatial and temporal data coverage before the satellite era means that any assessment across the Pacific Islands region is difficult.

As human populations increase, human-induced nutrient loading also increases, and these originate from point and non-point sources. Point sources include human generated waste-water effluents, while non-point sources are usually associated with diffuse entry through land-use practices, such as agriculture, and coastal mining.

Seitzinger and Harrison (2008) report that in much of Oceania (which includes all the PICTs, as well as Australia and New Zealand), a combination of high water run-off and anthropogenic activity has lead to high yields of all forms of nitrogen. Using models based on the four Millennium Ecosystem Assessment Development Scenarios; Global Orchestration, Order from Strength, Techno-garden and Adapting Mosaic; Seitzinger *et al* (2010) predicts that under the GO scenario, dissolved inorganic phosphate (DIP) export in Oceania will continue to increase between 2000 and 2030, accounting for 15 % of global DIP export, while the Adapting Mosaic 2030 scenario suggests smaller increases for Oceania.

Using the same models, van Drecht *et al* (2009) estimated that in 2000–2030 for Oceania, the discharge of nitrogen (N) to surface waters will increase by 24 to 30 % tfrom 110 to 112 Gg/yr. Between 2030 and 2050 they also predict a 5 % decrease in N discharge using the Techno-garden models and stabilization in the other scenarios. For annual phosphorus (P) discharge, the Techno-garden models predict a 7 % decrease from 18 to 16 Gg/year over 2000–2050, while other scenarios show a slight increase for 2000–2030 and stabilization for 2030–2050 (Figure 5).

Figure 5: Trends in human N (left) and P emission (right) 1970–2050 for Oceania



Source: van Drecht et al, 2009.

Overall, there is a lack of sufficient data on nutrient loading from various point and non-point sources into marine systems in the Pacific Islands region. While more research needs to be done, it is clear that as human populations and urban centers throughout the Pacific Islands region continue to grow, sewage and waste-water discharges, as well as land-based impacts will continue to contribute ever greater nutrient loads into the coastal and marine waters.

2.3 Port Activity

Data on shipping and port activity in the Pacific Islands region is limited, and has many gaps. For example, of the 10 PICT's that have provided data to SPC's Economic Development Division (reported as Twenty-foot Equivalent Units [TEU]), only the Solomon Islands has a full data set for the last decade (Table 5).

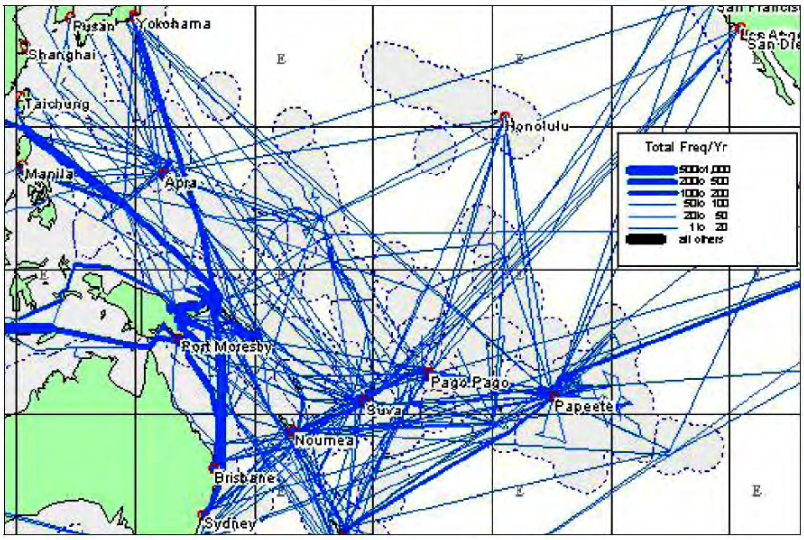
Table 5: TEU throughput for some PICTs: 1999–2008

	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Cook Islands					2,055	2,300	2,077	2,158	2,326	
Fiji								64,519	76,055	78,032
Kiribati						6,670	6,707	6,697	7,183	5,299
Marshall Islands								2,099	1,806	
Nauru						914	742	1,082	1,217	1,524
Niue									532	
PNG			100,626	107,140	103,226	103,855	136,907		131,366	
Solomon Islands	324,802	242,889	179,102	199,800	210,606	352,652	260,382	392,041	2,834	9,036
Tonga	2,834	9,036	9,254	9,845	9,168			11,994	11,616	
Tuvalu									1,192	

Source: Secretariat of the Pacific Community.

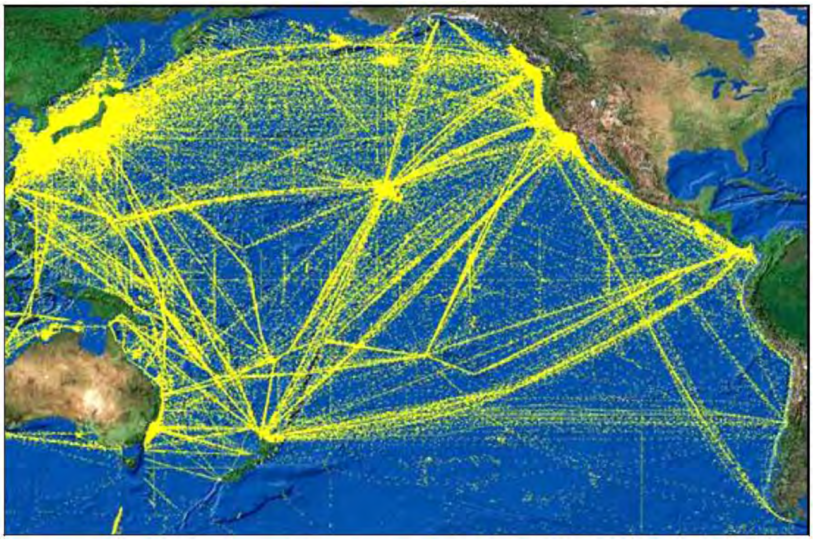
Overall, the Pacific Islands region has a high density of shipping, fishing and transit vessel activity and given the future development projected in the area, this activity is forecasted to increase, due in part to a stronger reliance by many PICTs on the importation of food, and other goods, and this trend will continue to increase (Figures 6 and 7), with subsequent risk of oil and ship-based pollution.

Figure 6: Total vessel traffic by frequency in the Pacific Islands region



Source: Anderson et al, 2003.

Figure 7: Overall shipping routes in the Pacific Ocean



Source: Trevor and Nawadra, 2002.

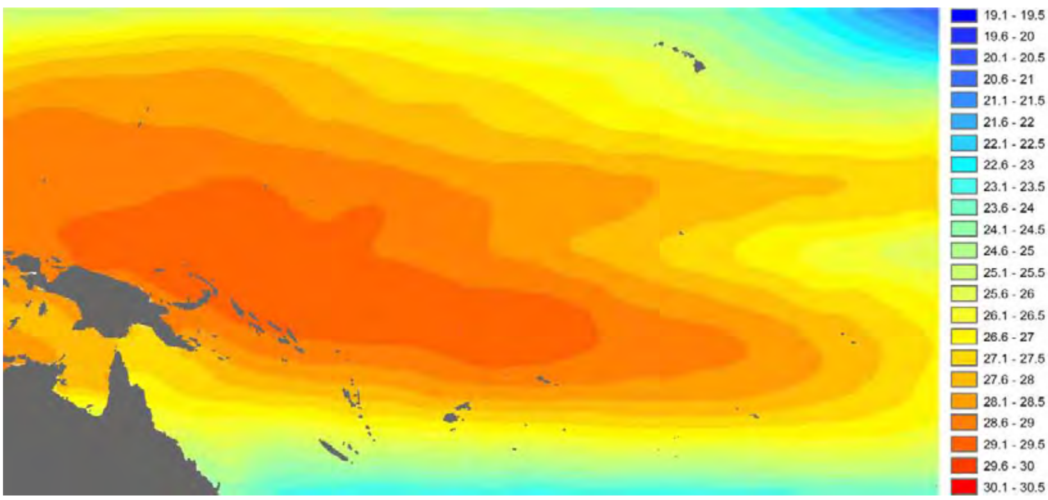
2.4 Sea Surface Temperature

Water temperature is a key oceanic feature, which strongly affects the abundance and distribution of the fish and invertebrates that support fisheries and aquaculture activities in the Pacific Islands region; and increases in Sea Surface Temperature (SST) above normal maxima are expected to have negative effects on the overall viability of some of these fisheries and aquaculture activities.

The SST of the tropical Pacific Ocean varies spatially and temporally because more solar heat is absorbed by the ocean near the equator than at higher latitudes, however there is some regional deviations to this large-scale pattern, due to the El Nino Southern Oscillation (ENSO).

The Western Pacific warm pool province is at the heart of the ENSO mechanism (Longhurst, 2006). Under 'normal' conditions, the trade winds generate surface currents that push and accumulate warm water to the west, creating a large heat reservoir that maintains the easterly trade winds via the Walker Circulation. This heat reservoir is also an important source of energy for tropical cyclones. It is also as a major influence on tuna fisheries in the tropical Pacific which are associated with this warm pool, and significant changes to future SSTs under climate change scenarios are expected to affect the distribution of tuna (which expected to move eastward) which will make the EEZs of some PICTs more, or less, favorable for increase fishing of skipjack tuna resources (Figure 8) (Lehody *et al,* in press).

Figure 8: Shift in tonnes of skipjack tuna per km^2 in the Pacific Island region: 2000–2050



Source: Lehody et al, in press.

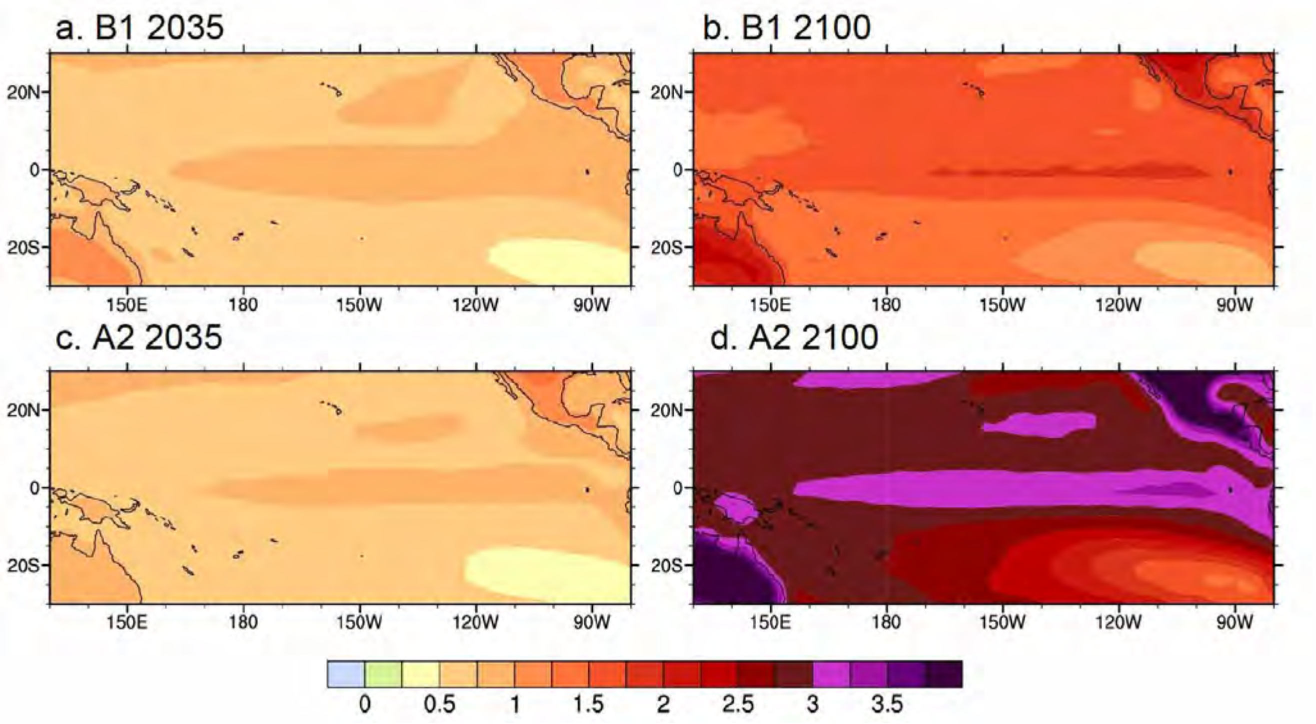
In many parts of the tropical Pacific, the most important factor affecting water density, and therefore stratification, is temperature. Because water density decreases with increasing temperature (and increases, generally to a lesser extent, with decreasing salinity), stratification occurs in the water column. As noted above, this has important implications for fisheries production, because SST and stratification influences the transfer of nutrients to the photic zone, where most primary production occurs. The strongest stratification occurs below the main atmospheric convergence zones.

Globally, SST is estimated to have warmed approximately by 0.67 °C from the beginning of the last century to present (Bindoff *et al,* 2007). In the Pacific basin, warming of SST of 1 to 1.5° C has been observed over the past 50 years (Figures 9 and 10) (Hanson *et al,* 2006; Chen *et al,* 2008; Cravatte *et al,* 2009; Ganachaud *et al*, in press; Lough *et al,* in press). In general, average SSTs are warmer in the western Pacific compared to the eastern Pacific (Lough *et al,* in press).

Separating long-term warming in SST from the natural variability of the tropical Pacific Ocean is not straightforward (Chen *et al,* 2008), but the warming trend is conspicuous, and is predicted to increase further under various climate change models (Figure 11). For the near-term (2035), both the low (B1) and high (A2) emissions scenarios show similar amounts of warming across the tropical Pacific with values ranging from about + 0.5° C to + 0.8° C, with the larger warming occurring in the equatorial regions compared to the subtropics (Liu *et al*, 2005; Lough *et al,* in press).

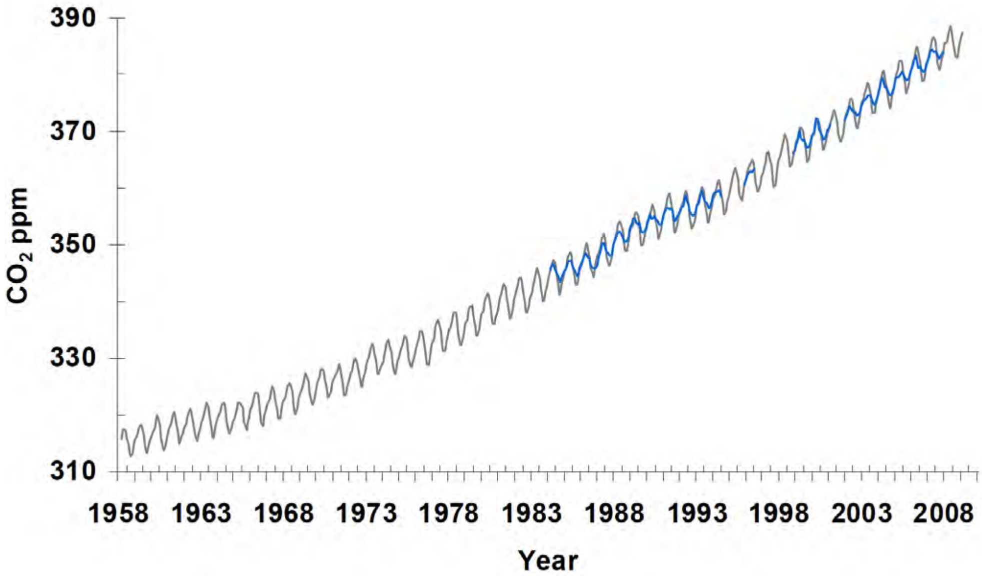
Even below the surface, increasing temperatures have been detected in all oceans and at increasing depths since the 1950s (Barnett *et al,* 2005; Levitus *et al,* 2005; Ganachaud *et al*, in press), with estimates of warming by up to 2° C in the water column between the surface and about 200 m in the tropical and sub-tropical Pacific Ocean (Han *et al,* 2006).

Figure 9: Annual tropical Pacific sea temperatures: 1950–2007



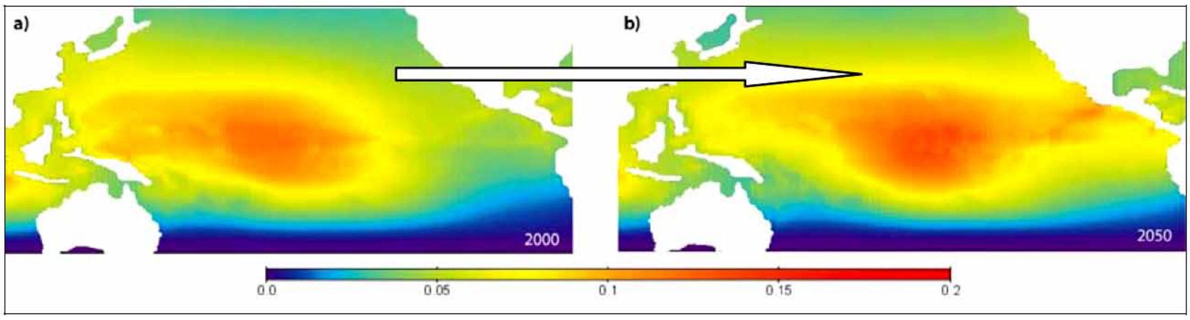
Source: Lough et al, in press.

Figure 10: Average sea surface temperature in the Pacific: 1950–2007



Source: Lough et al, in press.

Figure 11: Multi-model annual mean SST differences (C°) for the B1 (low emissions) and A2 (high emissions) scenarios: 2035 and 2100 (minus 1980–1999)



Source: Lough et al, in press.

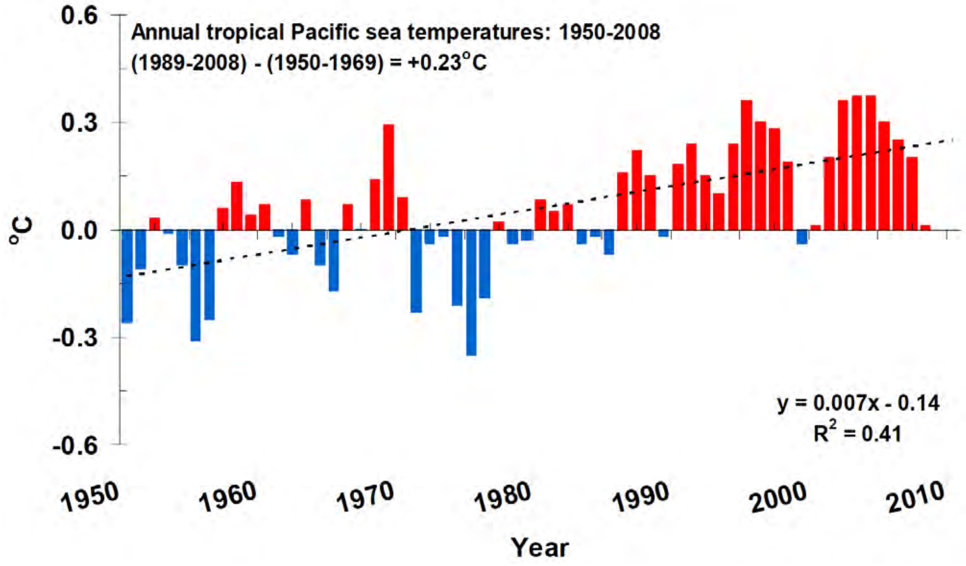
Increased SSTs across the Pacific Islands region will also have major impacts on coral reef structures and devastating coral bleaching events have increased with size, frequency and magnitude since the late 1970s. Bleaching events are triggered by small increases (+ 1–3 ° C) in water temperature, which are more often then not, linked to ENSO events (Hoegh-Guldberg *et al*, 2007).

The loss of reef-building corals through bleaching therefore has significant ramifications for the diversity of organisms inhabiting coral reefs (Bellwood *et al,* 2006; Graham *et al,* 2006; Wilson *et al*, 2006; Pratchett *et al,* 2008, Wilson *et al,* 2008; Cole *et al,* 2009), and thus communities dependent on these fisheries. Unfortunately, the current knowledge of the demographic mechanisms by which coral degradation impact fish communities over different time-scales remains limited (Feary *et al,* 2009).

2.5 CO_2 flux

Over the last 200 years, the world's oceans have taken up an excess of inorganic carbon from the atmosphere equivalent to approximately 25 to 30 % of the total emissions of human produced carbon dioxide (CO_2) (Sabine *et al*, 2004; Levitus *et al,* 2005; Canadell *et al*, 2007; Jacobson *et al*, 2007 a,b), with at least the upper 400m of the ocean, contaminated with anthropogenic CO_2 (Goyet *et al,* 2009). Takahashi *et al* (2009) have determined that carbon levels have increased in the world's oceans at about the same rate as that in the atmosphere (see Figure 12), though exceptions are observed.

Figure 12: Monthly atmospheric CO_2 concentrations for Hawaii; and Kiribati



Source: http://gaw.kishou.go.jp/cgi-bin/wdcgg

Chen-Tung and Borges (2009) present a complementary global synthesis of air-sea CO_2 fluxes for continental shelves and estuaries. Based on their analysis, Chen-Tung and Borges (2009) estimate that continental shelves act as a net global sink of 0.33 to 0.36 Pg C/yr corresponds to an additional sink of 27 % to ~ 30 % of the CO_2 uptake by the open oceans based on the most recent CO_2 climatology (Takahashi *et al,* 2009).

While the world's oceans are known to be globally a sink for anthropogenic CO_2, the equatorial belt is an upwelling area where some anthropogenic carbon can be re-injected into the atmosphere. Sea-air CO_2 flux is strengthened or weakened by the degree of upwelling on various time scales, such as ENSO, Pacific Decadal Oscillation, tropical instability waves, Kelvin waves and global warming (Christian *et al*, 2008; Fujii *et al,* 2009; Takahashi *et al*, 2009).

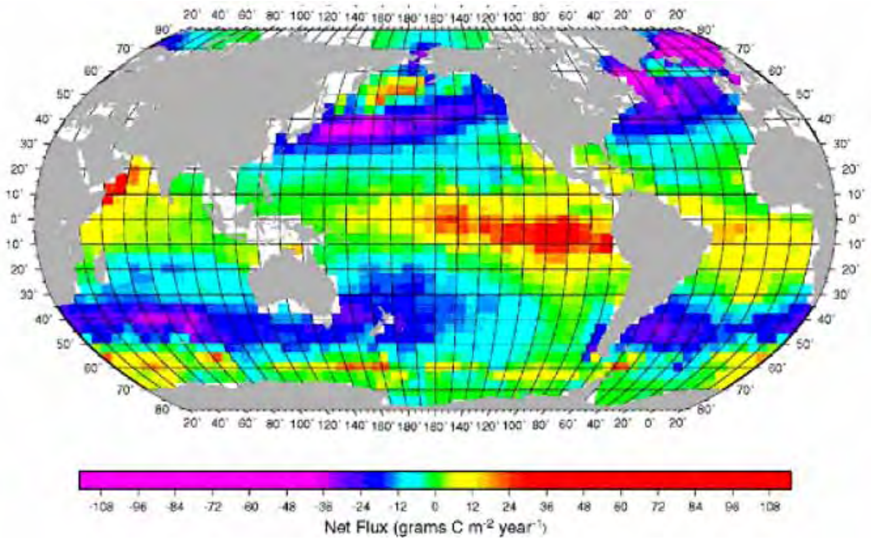
Analyzing data from the western equatorial Pacific for the period 1985–2004, Ishii *et al* (2009) estimate a surface-water carbon trend of + 1.570.2 µatm/yr, which is comparable to the atmospheric CO_2 trend over the same period and consistent with surface-water salinity-normalized dissolved inorganic carbon trends (see also Takahashi *et al,* 2009). They also show that the CO_2 trend is not constant and there is substantial inter-annual variability in surface-water carbon properties that are coherent with variations in geo-strophic transport from the subtropics into the Equatorial Pacific (Christian *et al*, 2008; Doney *et al*, 2009).

The equatorial belt (from 10° N to 10° S) plays a significant role in the global carbon cycle. It annually supplies approximately 0.8–1.0 Pg C/yr of CO_2 to the atmosphere during non-El Nino periods, but is near neutral (0.2–0.4 Pg C/yr) during strong El Nino periods (Fujii *et al,* 2009; Ishii *et al,* 2009; Takahashi *et al,* 2009). As much as 72 % of the CO_2 outgassing from the world's oceans can be attributed to the equatorial Pacific alone (Feely *et al*, 2006; Goyet *et al,* 2009; Takahashi *et al,* 2009).

Air-sea CO_2 fluxes have been estimated to range from between 0.3 to 0.9 t-C/month/km^2 with small seasonal variability in the tropical Pacific, with a mean flux of 0.8t-C/month/km^2. The high Pacific flux is due primarily to an intense upwelling of CO_2 rich deep waters in the eastern half of the zone during non-El Nino periods (Figure 13) (Takahashi *et al,* 2009).

The oceanic carbon uptake has slowed the growth rate in atmospheric CO_2 and has thus reduced the magnitude of human-driven climate change to date (Fung *et al*, 2005; Friedlingstein *et al*, 2006). However, at the same time as the anthropogenic CO_2 penetrates into the ocean, it also lowers surface-water acidity (pH), resulting in the acidification of water especially of the upper ocean which in turn will impact on marine living organisms.

Figure 13: Mean annual sea-air CO_2 flux for the year, 2000 (non-El Nino conditions)



Source: http://www.ldeo.columbia.edu/res/pi/CO2/carbondioxide/pages/pco2_flux_rate_maps.html

Assessing the future oceanic carbon cycle in the tropical-subtropical Pacific is strongly affected by various physical processes with different temporal and spatial scales, which can also potentially drive both positive and negative feedbacks on ocean-carbon storage, yet the mechanisms that regulate air-sea CO_2 flux are not fully understood due to the paucity of both measurement and modeling (Doney *et al,* 2009; Fujii *et al,* 2009; Takahashi *et al,* 2009).

Especially across most of the Pacific, data for quantification of inter-annual variability and long-term trends are relatively sparse (McKinley *et al,* 2006), and there is a need to develop further a sustained surface-ocean-carbon-observing system with improved spatial coverage and internationally coordinated data synthesis activities.

3 State

3.1 Mean Trophic Index

The Marine Trophic Index (MTI) is used to determine the mean trophic level (MTL) of fisheries landings, which in turn is used as a measure for overall health and stability of a marine ecosystem or area, but is also used as a proxy measure for over-fishing.

To calculate the MTI, each fish or invertebrate species is assigned a number based on its location in the food chain. Carnivores are assigned high numbers, and herbivores lower ones. Humans tend to fish at the top of the food chain, choosing large predatory fish at first (Stevenson *et al,* 2007; Jackson, 2008). As these stocks are depleted, smaller species are chosen and the food chain becomes unbalanced.

The MTI is calculated from datasets of commercial fish landings by averaging trophic levels for the overall catch. A negative change in the MTI generally indicates that larger predator fish are becoming depleted, and an increasing number of smaller forage fish are being caught. A zero or positive change in the Marine Trophic Index indicates the fishery is stable or improving (Pauly and Watson, 2005). Overall, low MTIs put fisheries at much greater risk of collapse (Pauly 2006).

Pandolfi *et al* (2003) suggests that the cut-off point of 3.25 for MTL is too high, as it eliminates the very herbivores whose occurrence in fisheries catches (and thus decline in the ecosystem) induces massive ecological changes, all detrimental to coral reef biodiversity. As noted above, it has been estimated that 55 % of coastal fisheries in the Pacific Islands region are or have been over-exploited (Newton *et al,* 2007); yet the MTL for PICTs shows that the MTL is relatively stable, and in some instances increasing (Table 6; Figures 14), and this is probably due to the masking of fishing and catch because much of the MTL for the Pacific, especially after the 1970s would be based on tuna landings.

Sibert *et al* (2006) analyzed all available data from Pacific tuna fisheries for the period, 1950–2004. Results of Sibert *et al* (2006) study show that current biomass ranges among species from 36 to 91 % of the biomass predicted in the absence of fishing, a level consistent with or higher than standard fisheries management targets. The trophic level of the catch has decreased slightly, but there is no detectable decrease in the trophic level of the population. Sibert *et al* (2006) results indicate substantial, though not catastrophic impacts of fisheries on these top-level predators and minor impacts on the ecosystem in the Pacific Ocean (Figure 15); though recommended management options, including catch and effort limits, restrictions on the use of artificial floating objects by the purse-seine fishery, and time and area closures, should continue to be implemented by the fisheries management organization in the Pacific to maintain sustainable fisheries for these species.

Another area that needs greater input into the MTL datasets, particularly for the Pacific Islands region is the issue of illegal, unreported and unregulated catches. Issues and other concerns about the wider ecological impact of long term reductions in the abundance, biomass and size of target species also call for the application of an ecosystem approach to fisheries management (see Preston, 2009).

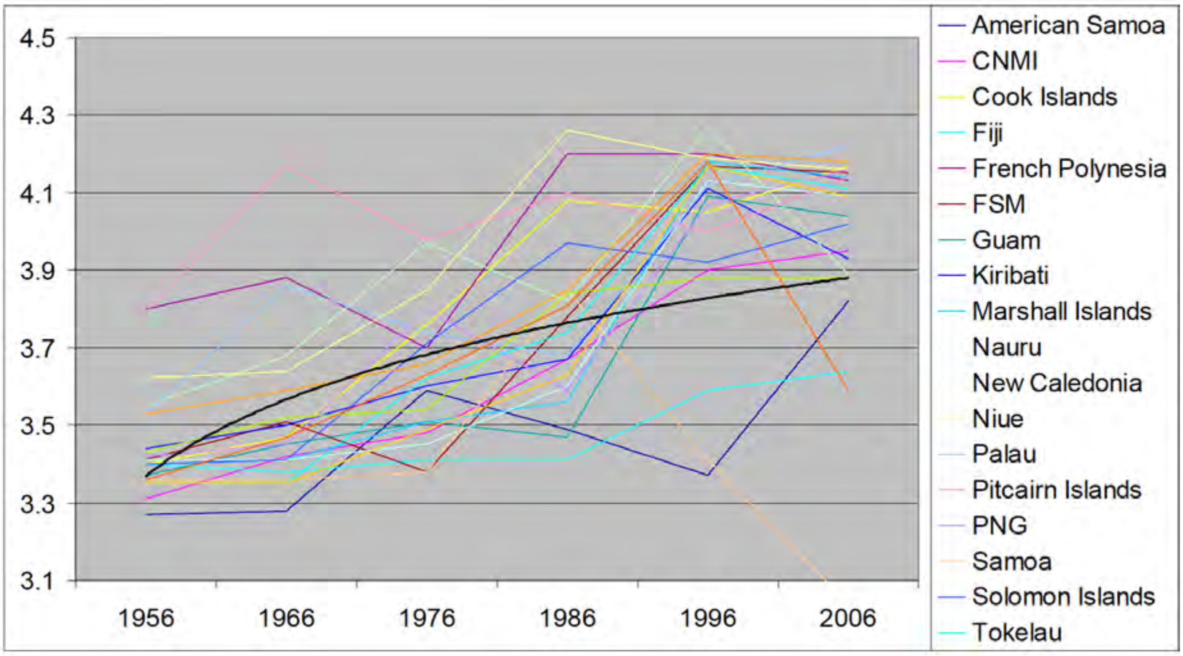
Table 6: Mean Tropic Levels for PICTs: 1956–2006

	1956	1966	1976	1986	1996	2006
American Samoa*	3.27	3.28	3.59	3.49	3.37	3.82
CNMI*	3.31	3.42	3.48	3.67	3.90	3.95
Cook Islands	3.40	3.47	3.76	4.08	4.05	4.17
Fiji	3.40	3.38	3.41	3.41	3.59	3.64
French Polynesia*	3.80	3.88	3.70	4.20	4.20	4.13
FSM	3.41	3.51	3.38	3.78	4.17	4.15
Guam*	3.37	3.45	3.51	3.47	4.09	4.04
Kiribati	3.44	3.50	3.60	3.67	4.11	3.93
Marshall Islands	3.40	3.41	3.51	3.56	4.18	4.14
Nauru	3.41	3.41	3.45	3.60	4.13	4.09
New Caledonia*	3.55	3.68	3.97	3.82	4.27	3.89
Niue	3.62	3.64	3.85	4.26	4.19	4.16
Palau	3.53	3.86	3.74	3.68	4.12	4.22
Pitcairn Islands	3.79	4.17	3.98	4.10	4.00	4.14
PNG	3.42	3.45	3.80	3.59	4.07	4.16
Samoa	3.36	3.36	3.38	3.85	3.41	3.04
Solomon Islands	3.40	3.41	3.71	3.97	3.92	4.02
Tokelau	3.35	3.35	3.62	3.74	4.17	4.11
Tonga	3.43	3.52	3.54	3.84	3.88	3.88
Tuvalu	3.35	3.35	3.49	3.63	4.17	4.09
Vanuatu	3.53	3.59	3.66	3.85	4.20	4.18
Wallis and Fatuna*	3.36	3.47	3.63	3.81	4.18	3.59

* figures based on reconstructed catches

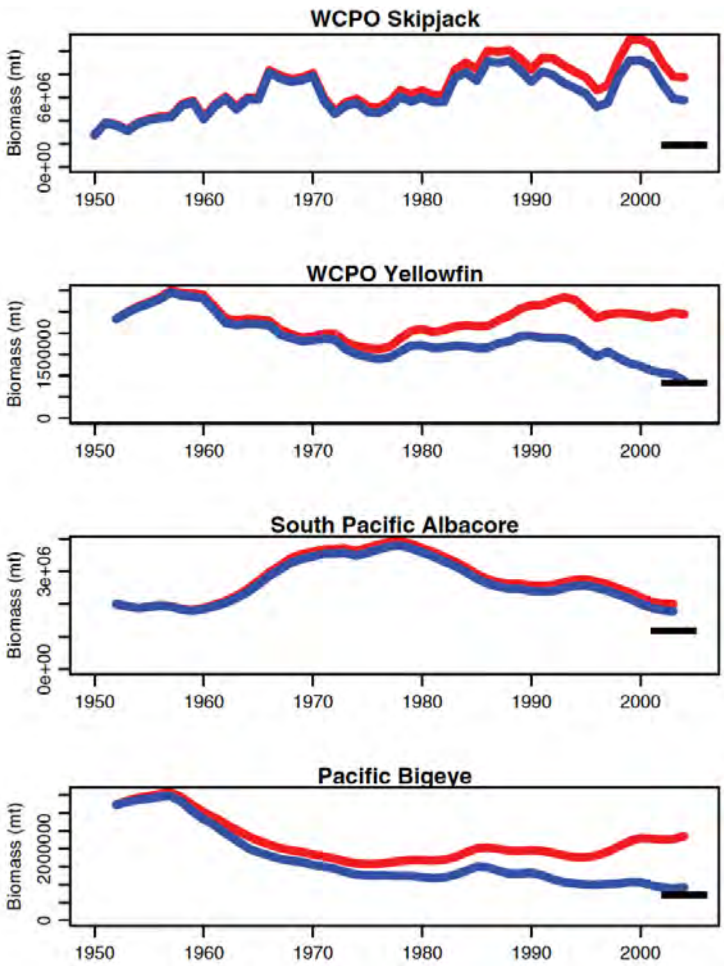
Source: http://www.seaaroundus.org/sponsor/cbd.aspx

Figure 14: Mean Tropic Level for PICTs: 1956–2006



Source: http://www.seaaroundus.org/sponsor/cbd.aspx

Figure 15: Trends in total biomass for tuna species in the western and central Pacific Ocean



Estimated from integrated stock assessment models. The blue lines indicate the biomass estimated from the observed fishing history (the exploited population), and red lines indicate the biomass estimated in the absence of all fishing (the unexploited population). The single black dash indicates the equilibrium biomass corresponding to MSY conditions, assuming current levels of recruitment and distribution of fishing mortality.

Source: Sibert et al, 2006.

3.2 Marine Fauna - Red List

The Pacific islands region is characterised by a high degree of ecosystem and species diversity, and endemism. Often, these rare and endemic species have adapted to specialised habitats and are limited to small areas of a few islands. The highest level of species richness is in Melanesia (particularly PNG and the Solomon Islands), which as would be expected, also as a high level of endemism.

The International Union for Nature Conservation's (IUCN) Red List of Threatened Species is widely recognised as the most comprehensive, apolitical approach for assessing and monitoring the status of biodiversity; and provides taxonomic, conservation and distribution data on taxa in the Pacific Islands region that have been evaluated using the Red List Categories and Criteria (Table 7, and Figure 16).

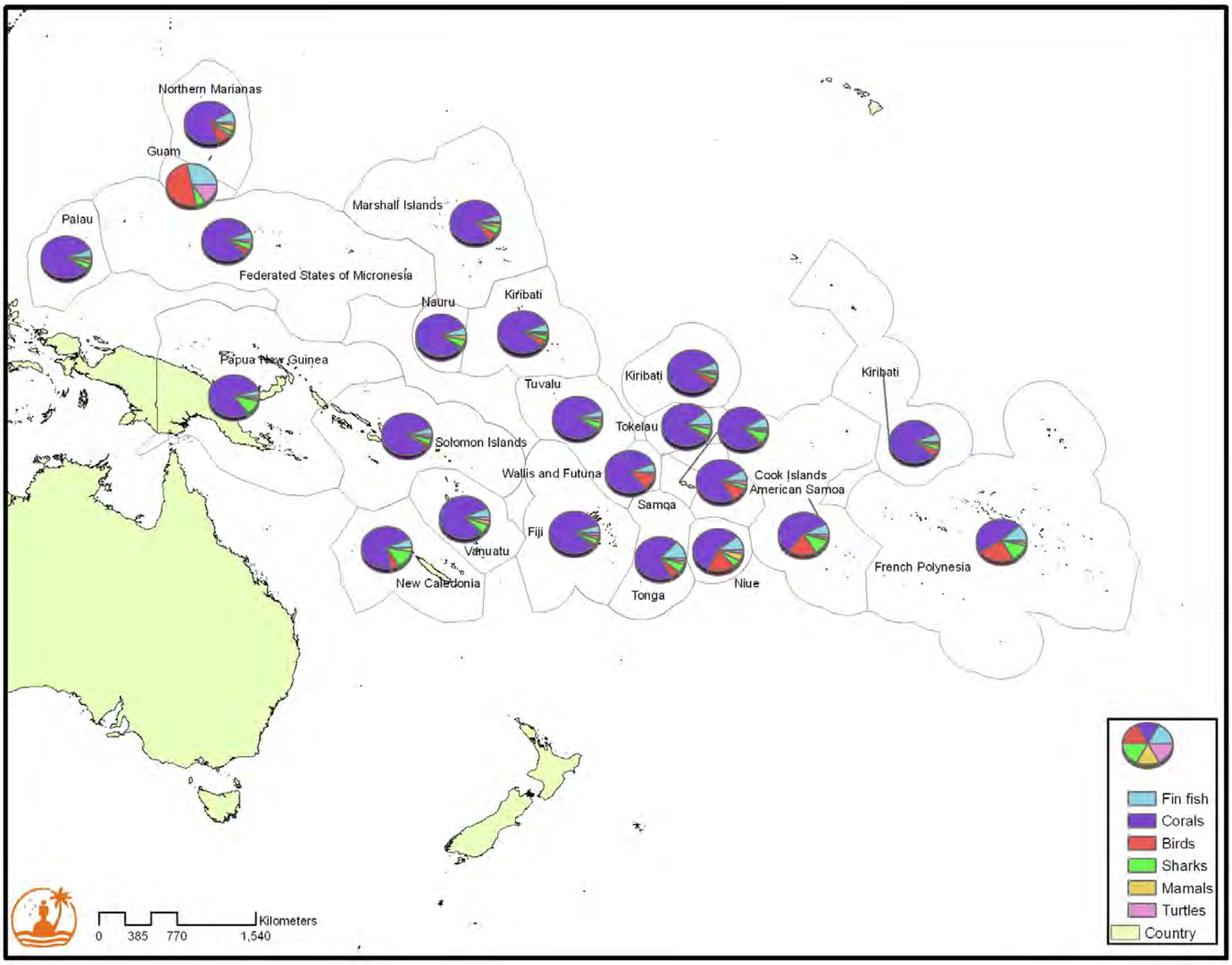
Table 7: Number of Redlisted species groups per PICT

	Fin Fish	Corals	Birds	Sharks	Mammals	Turtles	Total
American Samoa	5	52	7	2		2	68
CNMI	5	47	6	2	3	1	64
Cook Islands	3	25	9	5	1	1	44
Fiji	5	87	2	4	2	3	103
French Polynesia	6	26	14	7	1	1	55
FSM	7	104	5	6	1	3	126
Guam	4	0	7	1		2	14
Kiribati	5	72	4	3	1	1	86
Marshall Islands	4	66	5	4	2	1	82
Nauru	4	62	1	4	2		72
New Caledonia	7	83	7	15	3	1	116
Niue	4	23	8	2	2	1	40
Palau	6	97	2	5	3	2	115
Pitcairn Islands	3	10	5	4	2		24
PNG	7	157	3	20	3	4	196
Samoa	5	51	1	5	1	1	65
Solomon Islands	7	134	4	6	2	3	156
Tokelau	4	31	1	2		1	39
Tonga	6	33	3	3	1	1	47
Tuvalu	4	70	1	4	2	1	82
Vanuatu	6	78	1	6	3	2	96
Wallis and Fatuna	4	57	8	1			70

Source: www.iucnredlist.org

The number of described species for the Pacific Islands region is ambiguous for most groups, and it is often difficult to provide an accurate estimate of the number of known species for a given PICT. There is also often uncertainty surrounding taxonomy and synonyms, which makes the description of all species more difficult. Table 8 gives an estimated number of fish and hard coral species described and assessed for the Pacific Islands region.

Figure 16: Redlisted species groups for the Pacific Islands region



Source: www.iucnredlist.org

Hard corals were added to the Red List for the first time in 2008, with around a quarter of the 591 assessed species now listed as threatened (Pippard, 2009). Only approximately 5 % of the 233 described fish species in the Pacific Islands region have been assessed (and in only six PICs), and of these, 22% are listed as threatened (Pippard, 2009). The main families to have been assessed so far are groupers, seahorses and pipefish, as well as sharks and rays. Marine invertebrates such as echinoderms and sponges are not only unassessed, but largely undescribed for the Pacific Islands region.

The Melanesian countries have high numbers of threatened species overall, as may be expected by the number of species assessed and described in these countries. However, as only a few groups have been comprehensively assessed, it is difficult to analyse all species groups geographically with so little data available for many groups.

Table 8: Number of described and assessed fish and hard coral species for the Pacific Islands region

	Fish		Hard Corals	
	Species Described	Species Assessed	Species Described	Species Assessed
American Samoa	727	56	279	279
CNMI	792	50	260	260
Cook Islands	563	46	178	178
Fiji	883	77	410	410
French Polynesia	682	57	187	187
FSM	1,136	38	421	421
Guam	1,003	23	260	260
Kiribati	490	53	361	361
Marshall Islands	933	63	340	340
Nauru	76	43	330	330
New Caledonia	1,679	97	387	387
Niue	221	34	190	190
Palau	1,401	69	425	425
Pitcairn Islands	267	23	60	60
PNG	2,719	170	560	560
Samoa	949	60	278	278
Solomon Islands	746	75	503	503
Tokelau	188	36	208	208
Tonga	1,139	53	218	218
Tuvalu	188	55	353	353
Vanuatu	685	68	378	378
Wallis and Fatuna	90	40	306	306
Total	4,102	223	591	591

For total values, note that the same species can be present and assessed in more the one PICT

Source: Pippard, 2009; www.fishbase.org; and www.iucnredlist.org

Even though the Red List provides the most up-to-date collated information for the Pacific Islands region, information on the biodiversity of the Pacific Islands region is generally either limited in accuracy and scope, out of date, or poorly documented. Gaps exist for groups such as seaweeds, mangroves, seagrasses, marine invertebrates such as echinoderms (starfish, sea cucumbers and sea urchins), sponges, worms, seahorses, pipefish, and shore fishes such as damselfish and parrotfish. There are also potentially gaps in representation of marine mammals, as these species cross boundaries and may be found in more PICTs than is currently known.

To assist in the regulation and trade of many much of the biodiversity in the Pacific Islands region, several PICTs are members of the Convention on the Trade in Endangered Species (CITES) (Table 9).

Table 9: PICTs which are signatory to CITES

	Signatory Year
Australia	1976
France (including its Pacific dependents)	1978
New Zealand (including its Pacific dependents)	1989
United States of America (including its Pacific dependents)	1975
Fiji	1997
Palau	2004
Papua New Guinea	1976
Samoa	2004
Solomon Islands	2007
Vanuatu	1989

CITES has three Appendices that list species of wildlife. Each Appendix has different requirements and levels of protection. Marine species listed under Appendix II are listed in Table 10.

Table 10: Marine species listed on the CITES appendices

Fish		
Labridae	Maori Wrasse	Cheilinus undulatus
Syngnathidae	Pipefishes, seahorses	*Hippocampus* spp.
Corals*		
Scleractinia	Stony corals	*Scleractinia* spp.
Antipatharia	Black corals	*Antipatharia* spp.
Helioporidae	Blue corals	Heliopora coerulea
Tubiporidae	Organ-pipe corals	*Tubiporidae* spp.
Milleporidae	Fire corals	*Milleporidae* spp.
Stylasteridae	Lace corals	*Stylasteridae* spp.
Invertebrates		
Tridacnidae	Giant clams	Tridacnidae spp.

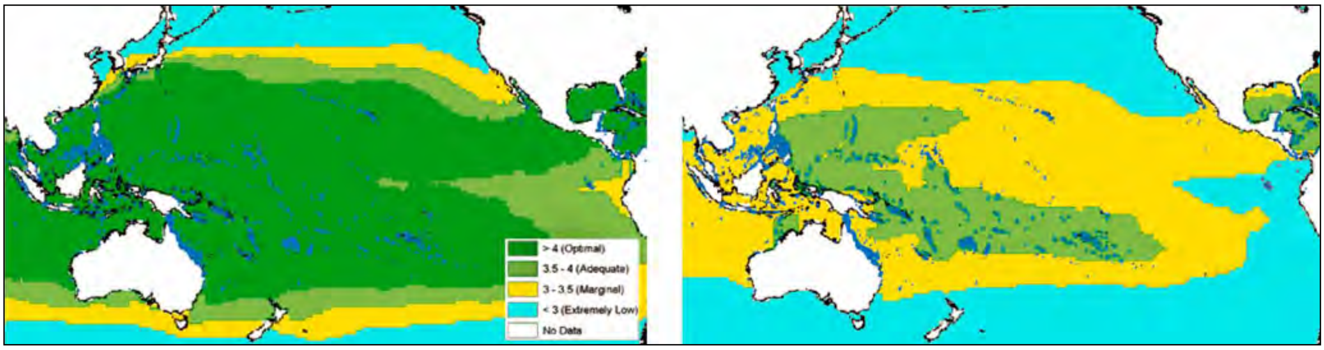
* 880 species in 120 taxa

Source: Kinch and Teitlebaum, 2009, 2010.

3.3 Acidification

Until relatively recently, it was assumed that normal oceanic processes would be sufficient to buffer the effects of increased anthropogenic CO_2 in the world's oceans, particularly as the acidity of the ocean has been relatively stable for millions of years. Due to this stability, carbonate ions (CO_3) are so naturally abundant, that the common pure minerals of calcium carbonate ($CaCO_3$) in the ocean (aragonite and calcite) are formed in surface waters and do not dissolve. This availability of CO_3 is important to the corals and other calcifying organisms that build the reefs that support coastal fisheries (Figure 17). It is also important to a range of organisms in the food webs for tuna, and for many of the invertebrates that are collected for food and income by villagers throughout the tropical Pacific (see Kinch *et al,* 2008).

Figure 17: Availability of aragonite in the Pacific Islands region: 1987–2050



Source: Guinotte et al, 2003.

Increased CO_2 concentrations lower ocean pH, which in turn lower saturation states of the carbonate minerals calcite, aragonite, and high-magnesium calcite, the materials used to form supporting skeletal structures in many major groups of benthic calcifiers such as corals calcifying macroalgae, benthic foraminifera, molluscs, and echinoderms resulting in smaller size and body weight (Shirayama and Thornton, 2005; Andersson *et al,* 2006). 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). Indeed, a decrease of 0.3 units in oceanic pH is expected to inhibit formation or limit the growth of many marine organisms (Hoegh-Guldberg *et al,* 2007, Guinotte and Fabry, 2008, Fabry *et al,* 2008). If CO_3 declines sufficiently, aragonite (the most commonly form of calcium carbonate used by marine species) actually begins to dissolve (Fabry *et al,* 2008).

The air-to-sea flux of anthropogenic CO_2 is larger in regions where there is enhanced exchange between surface and deep waters, as this facilitates the storage of anthropogenic CO_2 in the deeper ocean and keeps surface CO_2 concentrations relatively low, allowing a continued flux of anthropogenic CO_2 from the atmosphere to the ocean. Away from the equator, surface and sub-surface currents generally move it towards the subtropics, where the inventory is generally greatest. In the subtropical Pacific, the anthropogenic CO_2 penetrates to greater depths as a result of down-welling associated with convergence zones.

4 Response

4.1 Fish Stock Agreements

Regional cooperation, coordination and harmonisation for fisheries amongst PICTs is well supported by the Forum Fisheries Agency, and the SPC, and to a lesser extent, the Secretariat of the Pacific Regional Environment Program (SPREP).

In a number of instances, regional fisheries cooperation has been formalised through regionally-adopted instruments, which have the purpose of strengthening the conservation and management of shared fisheries in the region and to put in place arrangements that will facilitate long-term sustainable and responsible practices (Tables 11 and 12) (Gillett, 2010; Lugton, 2010).

For example, in the last few years, implementation in the region at national level has increased as indicated by:

- systematic revisions of national laws incorporating the principles of responsible and sustainable fisheries,
- broader application of community-based or co-management approaches to fisheries management,
- establishment of Marine Managed Areas (MMAs),
- increasing participation by non-governmental stakeholders,
- application of the Ecosystem Approach to Fisheries Management (EAFM),
- institutional reforms strengthening monitoring, assessment and management and conservation aspects of fisheries,
- addressing specific non-fishery issues (such as waste disposal) that affect marine resources,
- increased attention to mitigating impacts on non-target species, and
- several initiatives to prepare International Plans of Action (e.g. Pacific Islands Regional Plan of Action for Sharks).

All major regional organizations involved in fisheries, as well as several international agencies and a number of non-governmental organizations are encouraging the adoption of EAFM principals for both commercial and community-level fisheries.

Other

In 2004, the Pacific Islands leaders endorsed the Pacific Islands Regional Oceans Policy (PIROP). The PIROP and its Integrated Strategic Action Plan cover a broad range of issues related to integrated ocean management. A recent stock take however of progress of the PIROP implementation highlighted that there was no concerted or coordinated implementation of the PIROP. The lack of a strong integrated governance and dedicated partnership mechanism to facilitate a coordinated and holistic approach to the implementation of PIROP has been acknowledged as a significant contributing factor to this *ad hoc* implementation of the PIROP. Recently, the development of Framework for Pacific Oceanscape (FfPO) has been developed to revitalise the PIROP, and if endorsed by the Pacific Islands leaders will provide an opportunity to focus on integrated ocean management and its resources.

Table 11: Fisheries management instruments and their purpose

	Instrument
1979	*South Pacific Forum Fisheries Agency Convention* ▪ Established the Forum Fisheries Agency and tasked them to delineate EEZs, and associated legal and technical frameworks for negotiating with other fishing states
1982	*Nauru Agreement Concerning Cooperation in the Management of Fisheries of Common Interest* ▪ Established the Nauru Group for greater cooperation on matters related to arrangements with DWFNs, and to facilitate a greater and fairer financial return from their access agreements. ▪ Four implementing arrangements have been concluded under the Nauru Agreement. They are: ▪ the First and Second Implementing Arrangements Setting-forth Minimum Terms And Conditions of Access to the Fisheries Zones of the Parties; ▪ the Palau Arrangement; and ▪ the FSM Arrangement
1991	*Convention for the Prohibition of Fishing with Long Driftnets in the South Pacific* (also known as the Wellington Convention) ▪ To prohibit nationals and vessels of parties to the Convention from engaging in driftnet fishing activities in the Convention Area (i.e. the South Pacific region)
1992	*Niue Treaty on Cooperation in Fisheries Surveillance and Law Enforcement in the South Pacific Region* ▪ To cooperate in the enforcement of their fisheries laws and regulations and to develop regionally agreed procedures for the conduct of fisheries surveillance and law enforcement.
1992	*Palau Arrangement for the Management of Purse Seine Fisheries in the Western Pacific* ▪ To facilitate formal cooperation related to the number of licences to be issued to purse seine vessels of individual fleets to fish in the EEZs of Nauru Group members, and to implement the Vessel Day Scheme
1994	*Federated States of Micronesia Arrangement for Regional Fisheries Access* ▪ Provides a mechanism where the parties' domestic vessels can register on the Register of Eligible Vessels, so that they may apply for an FSM Arrangement licence, which entitles them to fish in any of the waters of the parties to the Arrangement
1993 (2003)	(FAO) *Agreement to Promote Compliance with International Conservation and Management Measures by Fishing Vessels on the High Seas* ▪ To deter reflagging of fishing vessels to avoid compliance with internationally agreed conservation and management measures
1995	(FAO) *Code of Conduct for Responsible Fisheries* ▪ To promote international understanding about the responsible conduct of fishing operations ▪ Four International Programmes of Action have been concluded within the Code of Conduct. These IPOAs address ▪ reducing the incidental catch of seabirds in longline fisheries; ▪ the conservation and management of sharks; ▪ the management of fishing capacity; and ▪ the prevention, deterrence and elimination of IUU fishing
1995	(UN) *Fish Stocks Agreement* ▪ To cooperate to ensure that high seas fisheries are managed in accordance with the provisions of the United Nations Convention on the Law of the Sea, particularly highly migratory and straddling stocks
2000	*Convention for the Conservation and Management of Highly Migratory Fish Stocks in the Western and Central Pacific Ocean* ▪ To provide for the comprehensive conservation and management of highly migratory fish stocks in the Convention Area in accordance with the 1995 UN Fish Stocks Agreement
	South Pacific Regional Ocean Fisheries Management Agreement ▪ To provide for the comprehensive conservation and management of highly migratory fish stocks that are not covered by the WCPF Convention
2005	*Pacific Plan* To develop and implement national and regional conservation and management measures for the sustainable utilisation of fisheries resources
2005	*Pacific Islands Regional Oceans Policy* To ensure the future sustainable use of our ocean and its resources by Pacific Islands communities and external partners

Table 12: Fisheries related instruments for the Pacific Islands Region

	International Instruments (Legally and Non-legally Binding)							Regional Instruments (Legally Binding)							Regional Instruments (Non-legally Binding)							
	UNCLOS	UN Fish Stocks Agreement[1]	FAO Compliance Agreement	FAO Code of Conduct for Responsible Fisheries	Convention on Migratory Species	Wellington Convention	International Whaling Convention	Forum Fisheries Agency Convention	Nauru Agreement (including FSM and Palau Arrangements)	Niue Treaty	US Multilateral Treaty	WCPFC Convention[2]	SPRFMO Convention[3]	Noumea Convention[4]	Pacific Plan	Pacific Islands Regional Oceans Policy	Oceanscape Framework (Proposed)	Apia Policy	SPC Fisheries, Aquaculture and Marine Ecosystems Strategic Plan	FFA Regional Monitoring, Control and Surveillance Strategy	FFARegional Tuna Management and Development Strategy	Te Vaka Moana Cooperation Arrangement
American Samoa																		✓	✓			
CNMI																		✓	✓			
Cook Islands	✓	✓	✓	✓	✓	✓		✓		✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓
Fiji	✓	✓	✓	✓		✓		✓		✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	
French Polynesia															✓	✓	✓	✓	✓			
FSM	✓	✓	✓	✓		✓		✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	
Guam																		✓	✓			
Kiribati	✓	✓	✓	✓		✓		✓	✓	✓	✓	✓			✓	✓	✓	✓	✓	✓	✓	
Marshall Islands	✓	✓	✓	✓			✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	
Nauru	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	
New Caledonia															✓	✓	✓	✓	✓			
Niue	✓	✓	✓	✓				✓		✓	✓	✓			✓	✓	✓	✓	✓	✓	✓	✓
Palau	✓	✓	✓	✓			✓	✓	✓	✓	✓	✓			✓	✓	✓	✓	✓	✓	✓	
Pitcairn Islands																		✓	✓			
PNG	✓	✓						✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	
Samoa	✓	✓	✓	✓	✓			✓		✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	
Solomon Islands	✓	✓	✓	✓			✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓
Tokelau		✓				✓		✓		✓								✓	✓			✓
Tonga	✓	✓	✓	✓				✓		✓	✓	✓			✓	✓	✓	✓	✓	✓	✓	
Tuvalu	✓	✓	✓	✓			✓	✓	✓	✓	✓	✓			✓	✓	✓	✓	✓	✓	✓	
Vanuatu[5]	✓		✓	✓				✓		✓	✓	✓			✓	✓	✓	✓	✓	✓	✓	
Wallis and Futuna																		✓	✓			
Total	15	14	13	13	2	6	5	15	8	15	14	14	0	8	16	16	16	22	22	14	14	4

1 Vanuatu has signed the UN Fish Stock Agreement, but has not yet ratified it.
2 American Samoa, CNMI, French Polynesia, Guam, New Caledonia, Tokelau, and Wallis and Fatuna are 'Participating Territories' in the WCPFMC.
3 Cook Islands has signed the SPRFMO Convention, but has not yet ratified it, no other members as yet.
4 Palau, Tuvalu and Pitcairn (as a dependent territory of the United Kingdom) have signed the Noumea Convention, but have not yet ratified it.
5 Vanuatu is also a 'Member' of the Indian Ocean Tuna Convention, the International Convention for the Conservation of Atlantic Tunas (which Pitcairn is also a 'Member' of because it is dependent territory of the United Kingdom); and the Inter-American Tropical Tuna Convention (which Cook Islands is a also a 'Cooperative Non-Party').

Sources: www.ffa.int; www.spc.int; www.wcpfmc.org; www.fao.org; Chasek, 2009; Lugton, 2010.

4.2 Global Program of Action implementation

Many countries have not formalized a National Programme of Action for the Global Program of Action (GPA) for the prevention of the marine environment from land-based activities. However they have developed and are implementing a number of policies, including strategies for water and waste management in many PICs.

Regional instruments which focus on protecting the region's marine and coastal environment from land-based pollution sources include the:

- Convention for the Protection of Natural Resources and Environment of the South Pacific Region (Noumea Convention) adopted in 1986 and entered into force in 1990, which obliges Parties to endeavour to take all appropriate measures to prevent, reduce and control pollution from any source and to ensure sound environmental management and development of natural resources, using the best practicable means at their disposal, and in accordance with their capabilities; and
- Protocol to the Noumea Convention for the Prevention of Pollution of the South Pacific Region by Dumping adopted in 1986 and entered into force in 1990;

Progress on GPA implementation in countries using three criteria are reported in Table 13.

Table 13: Status of GPA Implementation for PICs

	National Programme of Action or equivalent implemented or in place[1]	Flagship Projects[2]		LBS protocol or similar signed[3]
		POPs in PICs	IWP	
Cook Islands		✓	✓	✓
Fiji	✓	✓	✓	✓
Kiribati		✓	✓	
Marshall Islands		✓	✓	✓
FSM	✓	✓	✓	✓
Nauru		✓	✓	✓
Niue	✓	✓	✓	
Palau		✓	✓	
PNG			✓	✓
Samoa	✓	✓	✓	✓
Solomon Islands	✓	✓	✓	✓
Tonga	✓	✓	✓	
Tuvalu	✓	✓	✓	
Vanuatu	✓	✓	✓	
Total	8	13	14	8

1 Source: 3rd and 4th National Reports, https://www.cbd.int/reports/

2 Source: www.sprep.org

- POPs in PICs was the Persistent Organic Pollutants (POPS) in Pacific Island Countries (PICs) project which was an Australian Agency for International Development-funded project that ran from 1997–2006 and resulted in the removal and destruction of 140 tonnes of POPs in PICs.
- IWP was the International Waters Project, a seven year project that ran from 2000–2006 designed to help PICs address coastal watershed management concerns through community-based solutions.

3 Source: www.sprep.org.

4.3 National Adaptation Programmes of Action for Climate Change

The main instrument for climate change adaptation is the Pacific Islands Framework for Climate Change (Table 14). Under the United Nations Framework for Climate Change, eligible PICs (those have Least Developed State status) have developed National Adaptation Plans of Action (NAPA) (Table 14). Other initiatives for the Pacific Islands region, include the Pacific Adaptation to Climate Change (PACC) project. The PACC project aims to enhance the capacity of participating PICs to adapt to climate change, including variability, in selected key development sectors. During national consultations, several PICs confirmed that coastal management was a priority sector due to their vulnerability to climate change. Under the NAPAs and selected PACC projects in PICs, the demonstration measures are proactive initiatives to reduce the adverse consequences of climate change (Table 15).

Table 14: Climate change related instruments and projects for the Pacific Islands Region

	International Instruments		Regional Instrument	Regional Projects	
	UNFCC	Kyoto Protocol	PIFACC	NAPA	PACC
American Samoa			✓		
CNMI			✓		
Cook Islands	✓	✓	✓		✓
Fiji	✓	✓	✓		✓
French Polynesia			✓		
FSM	✓	✓	✓		✓
Guam			✓		
Kiribati	✓	✓	✓	✓	
Marshall Islands	✓	✓	✓		✓
Nauru	✓	✓	✓		✓
New Caledonia			✓		
Niue	✓	✓	✓		✓
Palau	✓	✓	✓		✓
Pitcairn Islands					
PNG	✓	✓	✓		✓
Samoa	✓	✓	✓	✓	✓
Solomon Islands	✓	✓	✓	✓	✓
Tokelau			✓		
Tonga	✓	✓	✓		✓
Tuvalu	✓	✓	✓	✓	✓
Vanuatu	✓	✓	✓	✓	✓
Wallis and Futuna			✓		
Total	14	14	21	5	13

Source: www.sprep.org

Table 15: Regional projects with marine-related activities

	NAPA	PACC
Cook Islands		Coastal zone management and protection (through climate proofing Manihiki airport)
FSM		Coastal zone management and protection (through the ehancement of coastal defenses)
Kiribati	▪ Coastal zone management and protection ▪ Coral reef conservation and restoration ▪ Enhancing coastal defenses	
Samoa	▪ Coastal zone management and protection ▪ Marine conservation	Coastal zone management and protection (through the enhancement of coastal defenses)
Solomon Islands	▪ Coastal zone management and protection ▪ Coastal and marine resource management	
Tuvalu	▪ Coastal zone management and protection ▪ Coastal and marine resource management ▪ Coastal and coral reef conservation	
Vanuatu	▪ Coastal and marine resource management	Coastal zone management and protection (through the relocation of a coastal road on Epi)

Source: www.sprep.org

In recognition of the importance of fisheries to the Pacific Islands region, SPC with support from the Australian Agency for International Development (AusAID) is developing a monitoring program to assess the likely effects of climate change on fish habitats and on the productivity of oceanic, coastal and inland fisheries and aquaculture (McPhee, 2010). The broad aim of the project is to equip policy makers and managers in Pacific Island countries and territories with information on how climate change might affect their plans for the sustainable use of fish for food, employment and national revenue. SPC has also embarked on a study to be presented to the forthcoming International Panel on Climate Change, entitled 'Vulnerability of fisheries and aquaculture in the Pacific to climate change' (Bell *et al*, in press).

SPREP, also with support from AusAID is currently developing a project, entitled 'Assessing the Vulnerability of Biodiversty to Climate Change', which will also have a marine component.

4.4 MPA establishment

The Pacific Islands region has experienced a remarkable proliferation of MMAs in the last decade. These MMAs, implemented by over 500 communities, spanning 20 PICTs represent a unique global achievement (Table 16). The approaches being developed at national levels are built on a unique feature of the region, customary tenure and resource access, and make use of, in most cases, existing community strengths in traditional knowledge and governance, combined with a local awareness of the need for action, resulting in what have been most aptly termed 'Locally Managed Marine Areas'. The main driver in most cases, is a community desire to maintain or improve livelihoods, often related to perceived threats to food security or local economic revenue. In the Pacific Islands region, conservation and sustainable use are often seen as inseparable.

In PICs, the effort of communities and their supporting governmental and non-governmental partners has resulted in nearly 17,000 km^2 coming under active management, of which 10% are 'no-take' zones. This progress comes at a time when older models of larger, centrally planned reserves have failed in almost all cases resulting in the need to review the inclusion of some 14,000 km^2 of such 'paper parks' in national and global databases of the region.

Table 16: Number of MMAs and coverage for the Pacific Islands region

	Number of active MMAs	Active MMA coverage (km^2)	~ % of EEZ under management	~ % of Territorial Waters under management
American Samoa	19	174	0.04	1.8
CNMI	8	13	0.0007	0.05
Cook Islands	24	19	0.001	0.06
Fiji	217	10,880	0.8	9.5
French Polynesia	10	2,837	0.06	1.2
FSM	12	23	0.0008	0.05
Guam	11	170	0.08	3.7
Kiribati	14	3,054*	0.08	4
Marshall Islands	1	701	0.03	0.7
New Caledonia	20	16,188*	0.9	23
Niue	3	31	0.008	1
Palau	28	1,126	0.2	8
PNG	86	59	0.002	0.02
Samoa	54	209	0.2	2.1
Solomon Islands	113	941	0.07	0.7
Tokelau	3	1	0.0003	0.01
Tonga	6	93	0.01	0.2
Tuvalu	4	76	0.008	0.4
Vanuatu	20	89	0.01	0.1
Total	1,232	34,712	2.59	58.3

This estimation excludes the Phoenix Island Protected Area that comprises 408,250 km^2 making 11% of the EEZ under management once the management plan and endowment will be finalized.

Source: Govan et al, 2009.

The PITs are also progressing well, using more Western style protected area approaches. For example, New Caledonia has recently made impressive progress with the declaration of a large lagoonal World Heritage Area. American Samoa and French Polynesia are combining traditional resource management and sustainable use approaches with national protected area systems.

With regards to international or national commitments to marine protected area coverage of EEZs or marine habitat types, a preliminary analysis suggests that Fiji, New Caledonia and French Polynesia could be on track to meeting their commitments at the inshore ecosystem level. However, the situation for other PICTs is cause for concern, and all PICTs are far from meeting their commitments of 'strict protection'. The regional MMA coverage represents under 0.2 % of the combined EEZ and only Fiji and New Caledonia are within reach of the global average of 1.5 % of EEZ protected with 0.8 % and 0.9 % respectively. Management initiatives of the high seas such as the Phoenix Island Protected Areas will be needed to meet the national commitments but will have to be supported by appropriate funding mechanisms to enforce the protection in very remote and highly coveted areas.

As mentioned above, if the FfPO if endorsed by the Pacific Islands leaders, then this may provide an opportunity to support the development of marine protected areas in the high seas under the Pacific Oceans Arc component, as well as supporting other proposed intitiatives such as IUCN's Pacific Oceans 2020 Challenge, and activities of the PIROP.

4.5 Ballast Water Regulations

The international Convention for the Control and Management of Ships' Ballast Water and Sediments was adopted in 2004. The convention is due to come in to force once ratification by 30 states and when 35 % of the world's shipping is represented. Currently, only 26 states have acceded to, or ratified, the convention representing only 24 % of the world's shipping.

In the Pacific Islands region, only the Cook Islands, Kiribati, Marshall Islands, and Tuvalu have acceded to the convention (Table 17). Some further PICs are however moving towards ratification once they have completed risk assessments.

In 2006, a Regional Strategy on Shipping Related Invasive Marine Pests in the Pacific with a regional action plan on marine invasive species for the Pacific Islands region was developed. One of the activities in the regional action plan is to develop a model Ballast Water Management Act.

The PIROP also has initiatives related to shipping and fishing-related pollution, as well as invasive species.

National legislative frameworks differ significantly between PICTs, including constitutional structure, system of national laws, policies and strategies as well as by-laws. Some PICTs have already developed strategies or legislation specific to invasive aquatic species. However, in many PICTs, invasive aquatic species is still covered only under other legislation and policies, such as those related to health, environment management, transport and shipping. Table provides information on various aspects of national ballast water management and invasive aquatic species policies and legislations.

In 2011, a Regional Training Course on Legal Implementation of the Convention with an emphasis on compliance, monitoring and enforcement of the Convention and regional co-operation in the Pacific Islands region is scheduled. Outcomes of this meeting include regionally harmonised legislations, and the development of a monitoring and evaluation regime for the Pacific Islands region.

Table 17: Ballast control related instruments for the Pacific Islands Region

	Ballast Water Convention[1]	Ballast Water Management (National)[2]	Alien Species Management (National)[2]
American Samoa		Non-indigenous Aquatic Nuisance Prevention and Control Act (Applied by the USCG in all US Territories).	National Invasives Species Act.
CNMI		Non-indigenous Aquatic Nuisance Prevention and Control Act (Applied by the USCG in all US Territories).	National Invasives Species Act.
Cook Islands	✓	Marine Pollution Prevention Act.	
Fiji		Currently developing a Marine Pollution Prevention Management Regulation under the Marine Act.	Quarantine Act.
FSM		Policies and Legislation to be developed.	Under consideration.
Guam		Non-indigenous Aquatic Nuisance Prevention and Control Act (Applied by the USCG in all US Territories).	National Invasives Species Act.
Kiribati	✓	Referred to in the Environment Act.	Quarantine Act and the Environ-mental Act
Marshall Islands	✓	Environment Act, and Water Quality Regulations	Quarantine Act.
Niue		Bio-security Bill.	Bio-security Bill.
PNG		Marine Pollution (Ballast Water Control) Bill currently awaiting approval.	Quarantine (Bio-security) Act.
Samoa		Quarantine (Biosecurity) Act, and the Marine Pollution Prevention Act.	Quarantine (Bio-security) Act.
Solomon Islands		Quarantine Act.	Quarantine Act
Tokelau		Tokelau Marine Pollution Regulations.	Bio-security Rules.
Tonga		Marine Pollution Prevention Act.	Quarantine Act.
Tuvalu	✓	Marine Act, however there is no specific mention of ballast water control.	Bio-security Act currently under review.
Vanuatu		Environment Management and Conservation Act, there is also a national policy on discharge of ballast water by international vessels.	Animal Importation and Quarantine Act, and the Plant Protection Act. Bio-security Policy is currently un-der consideration.

1 Source: http://www.imo.org/Conventions/Mainframe.asp?topic_id=867

2 Source: 3rd and 4th National Reports, https://www.cbd.int/reports/

5 Conclusion

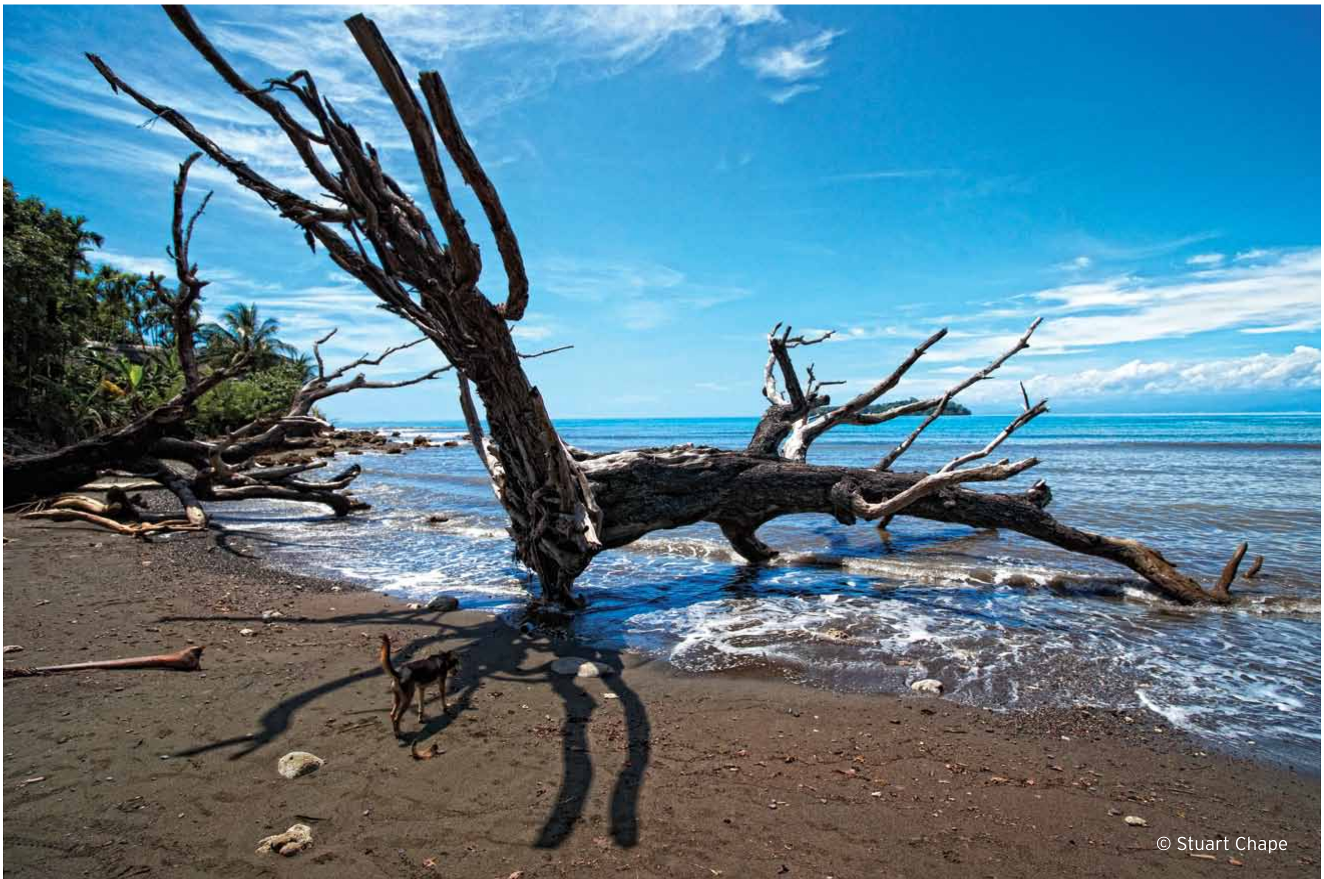
As noted throughout the report (in nearly every section in fact), there is a general paucity of data available for most of the Pacific Islands region. Reasonably reliable time series data are available for only a few high-level indicators, including some oceanographic parameters, industrial-scale fisheries (primarily tuna), population and demographics, gross economic indicators, and some indicators of human and economic development.

Overall, there is a lack of human, technical, institutional and financial capacity in PICTs, and this combined with the wide geographical distribution of PICTs over a vast, remote and generally rural area, contributes to poor monitoring. Subsequently, there is a need to build capacity and appropriate resources and funding to provide for the level of data collection, management and analysis for environmental monitoring of the marine environment in the Pacific Islands region.

SPREP, through its newly proposed Strategic Plan 2010–2015, has environmental monitoring as one of its core pillars, and appropriate funding will need to be sourced to bring this to reality.

As pressures continue to increase (and be potentially exacerbated by environmental change, climate variability, and climate change), PICTs will also require a strong institutional and governance capability to effectively implement all the necessary regulatory and governance responses.

Achieving this will require a strategic and coordinated approach at multiple levels that is capable of working across various regulatory areas due to the complicated nature of many of the challenges identified in this report. If this can be achieved, it will go some way to developing solutions, or at least mitigate the impacts of current threats and future pressures.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References

Allen, R. 2010. *International management of tuna fisheries: arrangements, challenges and a way forward.* Fisheries and Aquaculture Technical Paper, No.: 536. Rome: Food and Agriculture Organisation.

Anderson, E.; Judson, B.; Tu'itupou, S. and Thaman, B. 2003. *Marine Pollution Risk Assessment for the Pacific Islands Region (PACPOL Project Ra1).* Apia: Secretariat of the Pacific Regional Environment Program.

Andersson, A.; Mackenzie, F. and Lerman, A. 2006. Coastal ocean CO_2 – carbonic acid – carbonate sediment system of the Anthropocene. *Global Biogeochemical Cycles.* 20. doi:10.1029/2005GB002506.

Barclay, K. and Cartwright, I. 2007. Governance of tuna industries: The key to economic viability and sustainability in the Western and Central Pacific Ocean. *Marine Policy*. 31: 348–358.

Barnett, T.; Pierce, D.; Achuta Rao, K.; Glecker, P.; Santer, D.; Gregory, J. and Washington, W. 2005. Penetration of human-induced warming into the World's Ocean. *Science.* 309: 284–285.

Bell, J.; Johnson, J. and Hobday, A. in press. (eds.). *Vulnerability of fisheries and aquaculture in the Pacific to climate change*. Noumea: Secretariat of the Pacific Community.

Bellwood, D.; Hoey, A.; Ackerman, J. and Depczynski, M. 2006. Coral bleaching, reef fish community phase shifts and the resilience of coral reefs. *Global Change Biology*. 12: 1587–1594.

Bindoff, N.; Willebrand, J.; Artale, V.; Cazenave, A.; Gregory, J.; Gulev, S.; Hanawa, K.; Le Quere, C.; Levitus, S.; Nojiri, Y.; Shum, C.; Talley, L. and Unnikrishnan, A. 2007. Observations: oceanic climate change and sea level. In: Solomon, S.; Qin, D.; Manning, M.; Chen, Z.; Marquis, M.; Averyt, K.; Tignor, M. and Miller, H.; (eds.). *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change.* Pp: 385–432. Cambridge and New York: Cambridge University Press.

Canadell, J.; Quere, C.; Raupach, M.; Field, C.; Buitenhuis, E.; Ciais, P.; Conway, T.; Gillett, N.; Houghton, R.and Marland, G. 2007. Contributions to accelerating atmospheric CO_2 growth from economic activity, carbon intensity, and efficiency of natural sinks. *Proceedings of the National Academy of Sciences of the United States of America.* 104: 18870–18886.

Center for Ocean Solutions. 2009. *Pacific Ocean Synthesis: Scientific Literature Review of Coastal and Ocean Threats, Impacts, and Solutions.* Palo Alto: Stanford University.

Chasek, P. 2010. *Confronting Environmental Treaty Implementation Challenges in the Pacific Islands.* Pacific Islands Policy Paper, No.: 6. Honolulu: East-West Centre.

Chen, J.; Del Genio, A.; Carlson, B. and Bosilovich, M. 2008. The spatiotemporal structure of twentieth-century climate variations in observations and reanalyses, Part I: long term trend. *Journal of Climate.* 21: 2611–2633.

Chen-Tung, A. and Borges, A. 2009. Reconciling opposing views on carbon cycling in the coastal ocean: Continental shelves as sinks and near-shore ecosystems as sources of atmospheric CO_2. *Deep-Sea Research Part II-Topical Studies in Oceanography*. 56: 578–590

Christian, J.; Feely, R.; Ishii, M.; Murtugudde, R. and Wang, X. 2008. Testing an ocean carbon model with observed sea surface pCO_2 and dissolved inorganic carbon in the tropical Pacific Ocean. *Journal of Geophysical Research.* 113. C07047. doi:10.1029/2007JC004428.

Cole, A.; Pratchett, M. and Jones, G. 2009. Effects of coral bleaching on the feeding response of two species of coral-feeding fish. *Journal of Experimental Marine Biology and Ecology*. 373: 11–15.

Cravatte, S.; Delcroix, T. Zhang, D.; McPhaden, M. and Leloup, J. 2009. Observed freshening and warming of the western Pacific warm pool. *Climate Dynamics.* 33: 565–589.

Doney, S.; Tilbrook, B.; Roy, S.; Metzl, N.; Le Quere, C.; Hood, M.; Feely, R. and Bakker, D. 2009. Surface-ocean CO_2 variability and vulnerability. *Deep-Sea Research Part II-Topical Studies in Oceanography*. 56: 504–511.

Fabry, V.; Seibel, B.; Feely, R. and Orr, J. 2008. Impacts of ocean acidification on marine fauna and ecosystem processes. *ICES Journal of Marine Science.* 65: 414–432.

Feary, D.; McCormick, M. and Jones, G. 2009. Growth of reef fishes in response to live coral cover. *Journal of Experimental Marine Biology and Ecology*. 373: 45–49.

Friedlingstein, P.; Cox, P.; Betts, R.; Bopp, L.; von Bloh, W.; Brovkin, V.; Cadule, P.; Doney, S.; Eby, M.; Fung, I.; Bala, G.; John, J.; Jones, C.; Joos, F.; Kato, T.; Kawamiya, M.; Knorr, W.; Lindsay, K.; Matthews, H.; Raddatz, T.; Rayner, P.; Reick, C.; Roeckner, E.; Schnitzler, K.; Schnur, R.; Strassmann, K.; Weaver, A.; Yoshikawa, C. and Zeng, N. 2006. Climate-carbon cycle feed back analysis: results from the C4MIP model intercomparison. *Journal of Climate.* 19 (14): 3337–3353.

Fujii, M.;Chai, F.; Shi, L.; Inoue, H. and Ishii, M. 2009. Seasonal and interannual variability of oceanic carbon cycling in the western and central tropical-subtropical pacific: A physical-biogeochemical modeling study. *Journal of Oceanography*. 65 (5): 689–701.

Fung, I.; Doney, S.; Lindsay, K. and John, J. 2005. Evolution of carbon sinks in a changing climate. *Proceedings of the National Academy of Sciences of the United States of America.* 102: 11201–11206.

Ganachaud, A.; Sen Gupta, A.; Orr, J.; Wijffels, S.; Ridgway, K.; Hemer, M.; Maes, C.; Steinberg, C.; Tribollet, A.; Qiu, B. and Kruger, J. in press. Observed and Expected Changes to the Tropical Pacific Ocean. In: Bell, J.; Johnson, J. and Hobday, A. (eds.). *Vulnerability of fisheries and aquaculture in the Pacific to climate change*. Noumea: Secretariat of the Pacific Community.

Gillett, R. 2009. *Fisheries in the economies of the Pacific island countries and territories*. Mandaluyong City: Asian Development Bank.

Gillett, R. 2010. *Marine fishery resources of the Pacific Islands*. FAO Fisheries and Aquaculture Technical Paper, No.: 537. Rome: Food and Agriculture Organisation.

Govan, H.; Tawake, A.; Tabunakawai, K.; Jenkins, A.; Lasgorceix, A.; Schwarz, A.; Aalbersberg, B.; Manele, B.; Vieux, C.; Notere, D.; Afzal, D.; Techera, E.; Rasalato, E.; Sykes, H.; Walton, H.; Tafea, H.; Korovulavula, I.; Comley, J.; Kinch, J.; Feehely, J.; Petit, J.; Heaps, L.; Anderson, P.; Cohen, P.; Ifopo, P.; Vave, R.; Hills, R.; Tawakelevu, S.; Alefaio, S.; Meo, S.; Troniak, S.; Malimali, S.; Kukuian, S.; George, S.; Tauaefa, T. and Obed, T. 2009. *Status and Potential of Locally-managed Marine Areas (LMMA) in the South Pacific: Meeting Nature Conservation and Sustainable Livelihood Targets through Wide-spread Implementation of LMMAs*. Noumea: Coral Reef IniativeS for the Pacific.

Goyet, C.; Goncalves, I. and Touratier, F. 2009. Anthropogenic carbon distribution in the eastern South Pacific Ocean. *Biogeosciences.* 6: 149–156.

Graham, N.; Wilson, S.; Jennings, S.; Polunin, N.; Bijoux, J. and Robinson, J. 2006. Dynamic fragility of oceanic coral reef ecosystems. *Proceedings of the National Academy of Sciences. U.S.A*. 103: 8425–8429.

Guinotte, J.; Buddemeier, R. and Kleypas, J. 2003. Future coral reef habitat marginality: temporal and spatial effects of climate change in the Pacific basin. *Coral Reefs.* 22 (4): 551–58.

Guinotte, J. and Fabry, V. 2008. Ocean acidification and its potential effects on marine ecosystems. *Annual N.Y. Academy of Science.* 1134: 320–342.

Han, W.; Meehl, G. and Hu, A. 2006. Interpretation of the tropical cooling in the Indian and Pacific oceans during recent decades. *Geophysical Research Letters.* 33. L23615. doi:10.1029/2006GL027982.

Hansen, J.; Sato, M.; Ruedy, R.; Lo, K.; Lea, D. and Medina-Elizade, M. 2006. Global temperature change. *Proceedings of the National Academy of Sciences of the United States of America.* 103: 14288–14293.

Harley, S.; Williams, P.; Nicol, S. and Hampton, J. 2010. *The Western and Central Pacific tuna fishery: 2007–2008 overview and status of stocks.* Noumea: Secretariat of the Pacific Community.

Hay, J. 2009. *Assessment of Implementation of the Pacific Islands Framework for Action on Climate Change (PIFACC).* Report prepared for the Secretariat of the Pacific Regional Environment Program, Apia, Samoa.

Hay, J. 2009. *Implementation of the Pacific Adaptation to Climate Change (PACC) Project: Process, Status and Assessment.* Report prepared for the Secretariat of the Pacific Regional Environment Program, Apia, Samoa.

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

Huber, M. 2009. AoA Region: Southern Pacific Ocean. In: UNEP and IOC-UNESCO. *An Assessment of Assessments: Findings of the Group of Experts.* Pp: 182–189. Nairobi: United Nations Environment Program.

Ishii, M.; Inoue, H.; Midorikawa, T.; Saito, S.; Tokieda, T.; Sasano, D.; Nakadate, A.; Nemoto, K.; Metzl, N.; Wong, C. and Feely, R. 2009. Spatial variability and decadal trend of the oceanic CO_2 in the western equatorial Pacific warm/fresh water. *Deep-Sea Research Part II–Topical Studies in Oceanography*. 56: 591–606.

Jackson, J. 2008. Ecological extinction and evolution in the brave new ocean. *Proceedings of the National Academy of Sciences.* 105: 11458–11465.

Jacobson, A.; Mikaloff-Fletcher, S.; Gruber, N.; Sarmiento, J.and Gloor, M. 2007a. A joint atmosphere–ocean inversion for surface fluxes of carbon dioxide: 1. Methods and global-scale fluxes. *Global Biogeochemical Cycles.* 21. GB1019.

Jacobson, A.; Mikaloff-Fletcher, S.; Gruber, N.; Sarmiento, J.and Gloor, M. 2007b. A joint atmosphere-ocean inversion for surface fluxes of carbon dioxide: 2. Regional results. *Global Biogeochemical Cycles.* 21. GB1020.

Kinch, J. and Teitlebaum, A. 2009. *Proceedings of the Sub-Regional Workshop on the Marine OrnamentalTrade in the Pacific, December 2–5, 2008, Noumea. New Caledonia.* Noumea: Secretariat of the Pacific Community.

Kinch, J. and Teitlebaum, A. 2010. *Proceedings of the Regional Workshop on the Convention on the International Trade in Endangered Species (CITES) and Giant Clam Management in the Pacific, 3–7 August, 2009; Nadi, Fiji.* Noumea: Secretariat of the Pacific Community.

Kinch, J.; Purcell, S.; Uthicke, S. and Friedman, K. 2008. Population Status, Fisheries and Trade of Sea Cucumbers in the Western Pacific. In: Toral-Granda, V.; Lovatelli, A. and Vasconcellos, M. (eds.). *Sea Cucumbers: A Global Review of Fisheries and Trade*. FAO Fisheries Technical Paper, No.: 516. pp: 7–55. Rome: Food and Agriculture Organisation.

Harley, S.; Williams, P.; Nicol, S. and Hampton, J. 2009. *The Western and Central Pacific Tuna Fishery: 2007–2008 Overview and Status of Stocks.* Tuna Fisheries Assessment Report, No.: 9. Noumea: Secretariat of the Pacific Community.

Lehodey, P.; Senina, I.; Brill, R.; Portner, H.; Nicol, S.; Bopp, L.; Ilyina, T.; Calmettes, B.; Jouanno, J.; Hampton, J. and Sibert, J. in press. Ocean Fisheries. In: Bell, J.; Johnson, J. and Hobday, A. (eds.). *Vulnerability of fisheries and aquaculture in the Pacific to climate change*. Noumea: Secretariat of the Pacific Community.

Levitus, S.; Antonov, J. and Boyer, T. 2005. Warming of the world ocean, 1955–2003. *Geophysical Research Letters*. 32. L02604. doi:10.109/2004GL021592.

Longhurst, A. 2006. *Ecological Geography of the Sea*. New York: Academic Press.

Lough, J.; Meehl, G. and Salinger, M. in press. Observed and projected changes in surface Pacific climate. In: Bell, J.; Johnson, J. and Hobday, A. (eds.). *Vulnerability of fisheries and aquaculture in the Pacific to climate change*. Noumea: Secretariat of the Pacific Community.

Lugten, G. 2010. *The role of international fishery organizations and other bodies in the conservation and management of living aquatic resources. Fisheries* and aquaculture Circular, No.: 1054. Rome: Food and Agriculture Organisation.

Martinez, E.; Antoine, D.; D'Ortienzio, F. and Gentili, B. 2009. Climate-driven basin-scale decadal oscillations of oceanic phytoplankton. *Science*. 326: 1253–1256.

McKinley, G.; Takahashi, T.; Buitenhuis, E.; Chai, F.; Christian, J.; Doney, S.; Jiang, M-S.; Lindsay, K.; Moore, J.; Le Quere, C. and Lima, I. 2006. North Pacific carbon cycle response to climate variability on seasonal to decadal timescales. *Journal of Geophysical Research*. 111. C07S06. doi:1029/2005JC003173.

McPhee, D. 2010. *Monitoring the Vulnerability and Adaptation of Pacific Coastal Fisheries to Climate Change.* Report prepared for the Secretariat of the Pacific Community, Noumea, New Caledonia.

Newton, K.; Cote, I.; Pilling, G.; Jennings, S. and Dulvy, N**.** 2007. Current and future sustainability of island coral reef fisheries. *Current Biology.* 17 (7): 655–658.

Pandolfi, J.; Bradbury, R.; Sala, E.; Hughes, T.; Bjorndal, K.; Cooke, R.; McArdle, D.; McClenachan, L.; Newman, M.; Paredes, G.; Warner, R. and Jackson, J. 2003. Global trajectories of the long-term decline of coral reef ecosystems. *Science.* 301: 955–958.

Pauly, D. and Watson, R. 2005. Background and interpretation of the 'Marine Trophic Index' as a measure of biodiversity. *Philosophical Transactions of the Royal Society: Biological Sciences.* 360: 415–423.

Pippard, H. 2009. *The Pacific islands: an analysis of the status of species as listed on the 2008 IUCN Red List of Threatened Species™*. Report prepared for the IUCN Regional Office for Oceania, Suva, Fiji.

Pratchett, M.; Munday, P.; Wilson, S.; Graham, N.; Cinner, J.; Bellwood, D.; Jones, G.; Polunin, N. and McClanahan, T. 2008. Effects of climate-induced coral bleaching on coral-reef fishes: ecological and economic consequences. *Oceanography and Marine Biology*. 46: 251–296.

Preston, G. 2009. *The Ecosystem Approach to Coastal fisheries and Aquaculture in Pacific Island Countries and Territories, Part 1: A review of the current status; and Part 2: Principles and approaches for strategic implementation.* TNC Pacific Island Countries Report, No.: 1/08. Noumea: Secretariat of the Pacific Community.

Sabine, C.; Feely, R.; Gruber, N.; Key, R.; Lee, K.; Bullister, J.; Wanninkhof, R.; Wong, C.; Wallace, D.; Tilbrook, B.; Millero, F.; Peng, T.-H.; Kozyr, A.; Ono, T. and Rios, A. 2004. The oceanic sink for anthropogenic CO_2. Science 305: 367–371.

Seitzinger, S. and Harrison, J. 2008. *Sources and Delivery of Nitrogen to Coastal Systems.* In: Capone, D.; Bronk, D.; Mullholland, M. and Carpenter, E. (eds.). Nitrogen in the Marine Environment. 2nd edition. New York: Academic Press.

Seitzinger, S.; Mayorga, E.; Bouwman, A.; Kroeze, C.; Beusen, A.; Billen, G.; Drecht, G.; van Dumont, E.; Fekete, B.; Garnier, J. and Harrison, J. 2010. Global River Nutrient Export: A Scenario Analysis of Past and Future Trends, *Global Biogeochemical Cycles.* 24. GB0A08. doi:10.1029/2009GB003587.

Shirayama, Y. and Thornton, H. 2005. Effect of Increased Atmospheric CO_2 on Shallow Water Marine Benthos. *Journal of Geophysical Research.* 110. C09S08.

Sibert, S.; Hampton, J.; Kleiber, P. and Maunder, M. 2006. Biomass, Size, and Trophic Status of Top Predators in the Pacific Ocean. *Science.* 314: 1773–1776.

South, G.; Skelton, P.; Veitayaki, J.; Resture, A.; Carpenter, C.; Pratt, C. and Lawedrau, A. 2004. The Global International Waters Assessment for the Pacific Islands: Aspects of transboundary, water shortage, and coastal fisheries issues. *Ambio*. 33: 98–106.

SPC. 2009. *Status Report: Nearshore and Reef Fisheries and Aquaculture.*Noumea: Secretariat of the Pacific Community.

Stevenson, C.; Katz, L.; Micheli, F.; Block, B.; Heiman, K.; Perle, C.; Weng, K.; Dunbar, R.; and Witting, J. 2009. High apex predator biomass on remote Pacific islands. *Coral reefs.* 26 (1): 47–51.

Takahashi, T.; Sutherland, S.; Wanninkhof, R.; Sweeney, C.; Feely, R.; Chipman, D.; Hales, B.; Friederich, G.; Chavez, F.; Sabine, C.; Watson, A.; Bakker, D.; Schuster, U.; Metzl, N.; Yoshikawa-Inoue, H.; Ishii, M.; Midorikawa, T.; Nojiri, Y.; Körtzinger, A.; Steinhoff, T.; Hoppema, M.; Olafsson, J.; Arnarson, Y.; Tilbrook, B.; Johannessen, T.; Olsen, A.; Bellerby, R.; Wabnitz, C.; Andrefouet, S. and Muller-Karger, F. 2009. Measuring progress toward global marine conservation targets. *Frontiers in Ecology and the Environment*. doi:10.1890/080109.

Trevor, G. and Nawadra, S. 2002. *Risk of Marine Spills in the Pacific Islands Region and its Evolving Response Arrangements. Paper presented at* the 9th International Oil Spill Conference – Keeping the Waters Clean, 16–19 September 2002, Manly, Sydney, Australia.

van Drecht, G.; Bouwman, A.; Harrison, J. and Knoop, J. 2009. Global nitrogen and phosphate in urban wastewater for the period 1970 to 2050. *Global Biogeochemical Cycles.* 23. GB0A03. doi:10.1029/2009GB003458.

Watanabe, Y.; Ishida, H.; Nakano, T. and Nagai, N. 2005. Spatiotemporal decreases of nutrients and chlorophyll-a in the surface mixed layer of the western North Pacific from 1971 to 2000. *Journal of Oceanography.* 61: 1011–1016.

Wilson, S.; Graham, N.; Pratchett, M.; Jones, G. and Polunin, N. 2006. Multiple disturbances and the global degradation of coral reefs: are reef fishes at risk or resilient? *Global Change Biology.* 12: 2220–2234.

Wilson, S.; Burgess, S.; Cheal, A.; Emslie, M.; Fisher, R.; Miller, I.; Polunin, N. and Sweatman, H. 2008. Habitat utilisation by coral reef fish: implications for specialists vs. generalists in a changing environment. *Journal of Animal Ecology*. 77: 220–228.