High Seas Pacific Marine Reserves: a case study for the high seas enclaves

A briefing to the CBD's Expert workshop on scientific and technical guidance on the use of biogeographic classification systems and identification of marine areas beyond national jurisdiction in need of protection

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A report for Greenpeace International by Eleanor Partridge

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Abbreviations and Acronyms

B_{MSY}	Biomass at maximum sustainable yield
CBD	Convention on Biological Diversity
CPMR	Central Pacific Marine Reserve
DSL	Deep scattering layer
EEZ	Exclusive economic zone
ENSO	El Niño/Southern Oscillation
EU	European Union
EUC	Equatorial Undercurrent
F_{MSY}	Fishing mortality at maximum sustainable yield
FAD	Fish aggregation device
FAO	Food and Agriculture Organisation of the United Nations
FFA	Pacific Islands Forum Fisheries Agency
FSM	Federated States of Micronesia
GEF	Global Environment Facility
GOMAR	Greater Oceania Marine Reserve
ISA	International Seabed Authority
IUCN	International Union for Conservation of Nature
IWC	International Whaling Commission
IWP	Indo-West Pacific
MOANA	Moana Marine Reserve
NECC	North Equatorial Counter-Current
NOAA	U.S. National Oceanic and Atmospheric Administration
PIR	Pacific Islands Region
PNG	Papua New Guinea
SEC	South Equatorial Current
SECC	South Equatorial Counter-Current
SMS	Seabed massive sulphide
SPC	Secretariat of the Pacific Community
SPC-OFP	Oceanic Fisheries Programme of the Secretariat of the Pacific Community
SPREP	Pacific Regional Environment Programme
SPRFMO	South Pacific Regional Fisheries Management Organisation
SPSG	South Pacific Subtropical Gyre biogeographical province
SPWS	South Pacific Whale Sanctuary
SST	Sea surface temperature
UV	Ultraviolet
WARM	Western Pacific Warm Pool biogeographical province
WCP	Western and Central Pacific
WCP-CA	Western and Central Pacific Convention Area
WCPFC	Western and Central Pacific Fisheries Commission
WOMAR	West Oceania Marine Reserve

Executive Summary

This report summarises available scientific information to demonstrate the ways in which the high seas enclaves of the Pacific Islands Region (PIR) meet the criteria for ecologically or biologically significant marine areas, developed by the Convention on Biological Diversity (CBD). The report also summarises evidence to support the inclusion of the high seas enclaves in a representative network of marine reserves, on the basis of representativity, connectivity, replicated ecological features and adequacy and viability. The PIR high seas enclaves are: the proposed West Oceania Marine Reserve (WOMAR); Greater Oceania Marine Reserve (GOMAR); Moana Marine Reserve (MOANA); and Western Pacific Marine Reserve (WPMR).

Human impacts on the open ocean ecosystem of the PIR are largely the result of industrial tuna fisheries, which have expanded dramatically in recent decades. Purse seine and longline and, to a lesser extent, pole and line and troll fishing vessels, target skipjack *Katsuwonus pelamis*, yellowfin *Thunnus albacares*, bigeye *Thunnus obesus* and albacore *Thunnus alalunga* tuna in national waters and on the high seas (Williams and Terawasi, 2008). Skipjack tuna accounted for over 72% of total landings in 2007and has, until recently, been considered to be in a healthy state (Langley and Hampton, 2008). However, it has recently been suggested that the spawning stock of skipjack in the Pacific may have declined drastically and overfishing may be occurring (OPRT, 2009). Overfishing of bigeye and yellowfin tuna is occurring and bigeye tuna are in an overfished state (Langley et al, 2007; NMFS, 2006; Langley et al, 2008). Bycatch accounts for approximately 35% of longline catch and includes threatened, vulnerable and declining species, such as oceanic whitetip *Carcharhinus longimanus* and blue *Prionace glauca* sharks; several species of sea turtle; and cetaceans, including rare and poorly understood species of beaked whale (Molony, 2007). The open ocean ecosystem of the PIR, and the nature of human impacts in the region, could change significantly in the future due to the effects of anthropogenic climate change. The impacts of climate change on the biodiversity, ecosystem functions and coastal economies of the region are not yet understood but are likely to include shifts in the distribution and abundance of prey and predator species, including commercially important tuna species (SPC, 2009).

A number of features support the designation of the PIR high seas enclaves as ecologically or biologically significant marine areas in need of protection. Key life history stages in the enclaves include: migrating leatherback turtles *Dermochelys coriacea*; the possible presence of juvenile leatherback turtles; yellowfin tuna spawning activity; migrating green turtles *Chelonia mydas*; and breeding minke whales *Balaenoptera acutorostrata*. Threatened, endangered or declining species present in the enclaves include: leatherback, green, olive ridley *Lepidochelys olivacea* and hawksbill *Eretmochelys imbricata* sea turtles; bigeye tuna; sperm whales *Physeter macrocephalus*; and potential aggregations of threatened and declining species, including pelagic sharks, in the vicinity of the Horizon Bank, a shallow seamount in WPMR. Vulnerable, fragile and sensitive species/habitats include: sea turtles; seamounts; sperm whales; the potential presence of tropical corals; and pelagic predatory species. Biologically productive areas include: areas of high tropical tuna abundance; upwelling associated with the North Equatorial Counter-Current; seamounts; the Horizon Bank; and possible hydrothermal vent locations. Biologically diverse areas include: seamounts; and the Horizon Bank.

1. Introduction

This report will demonstrate the ways in which the four high seas enclaves of the Pacific Islands Region (PIR) meet the criteria for the identification of ecologically or biologically significant open ocean and deep-sea marine areas in need of protection, developed by the Convention on Biological Diversity (CBD) (CBD, 2007).

For the purposes of this report, the high seas enclaves will be referred to by the names of proposed marine reserves chosen by winners of a public competition held in the PIR: West Oceania Marine Reserve (WOMAR); Greater Oceania Marine Reserve (GOMAR); Moana Marine Reserve (MOANA); and the Western Pacific Marine Reserve (WPMR), a name selected for this report only. See figure 1 for the locations of the high seas enclaves in the PIR.

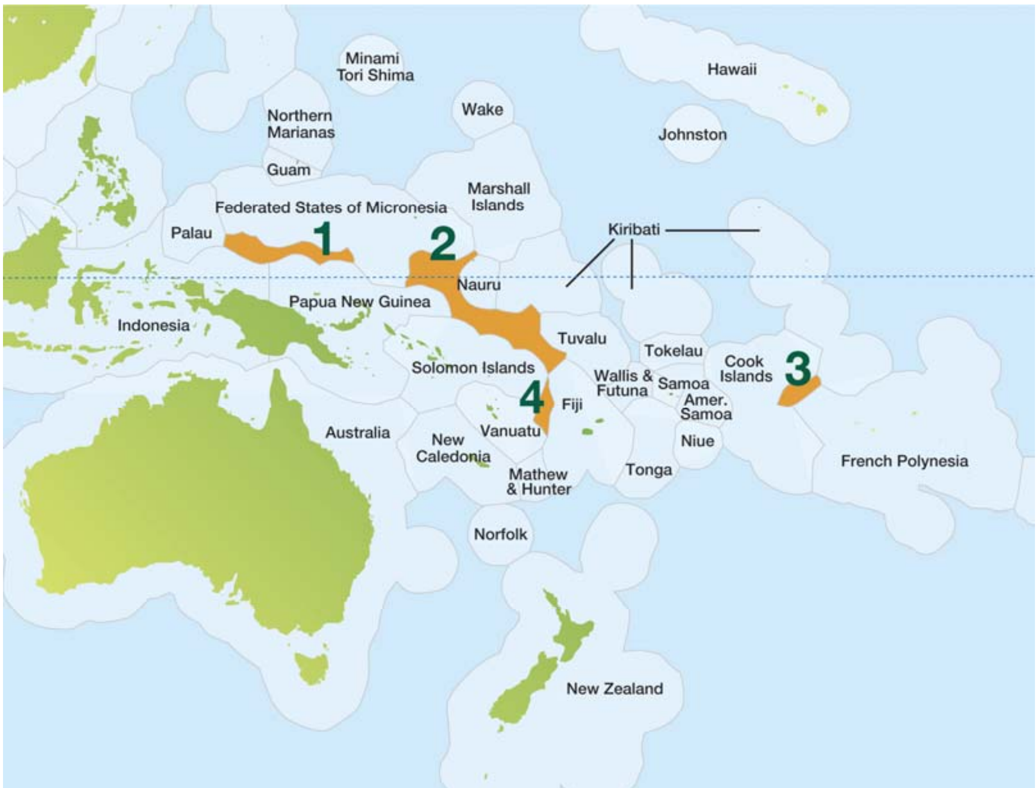


Fig. 1. Pacific Islands Region high seas enclaves 1: WOMAR; 2: GOMAR; 3: MOANA; 4: WPMR

The identification of ecologically and biologically significant marine areas is an essential first step towards the creation of high seas marine reserves, which are an essential tool in our efforts to conserve marine ecosystems and rebuild global fish populations. Overfishing is now recognised as the greatest threat facing the world's oceans – total global fisheries landings have been declining since the late 1980s (Pauly et al., 2002) and one paper has predicted the collapse of all currently-fished species by 2048, in the absence of effective action (Worm et al., 2006). Marine reserves offer a way to rebuild depleted fish stocks, conserve biodiversity and genetic variability, protect vulnerable and important habitats and enhance ecosystem resilience (Roberts et al., 2005). There is a large body of evidence for the fisheries benefits of marine reserves, which can increase catch levels in adjacent areas through 'spillover' of adult and juvenile fish and export of eggs and larvae (Gell and Roberts, 2003). Most evidence to date has been obtained from coastal ecosystems, however there is increasing support for the creation of open-ocean marine reserves to aid in the conservation of highly migratory species, including tuna, sea turtles and sharks (Norse et al, 2005). Marine reserves are also an important tool in the conservation of the deep-sea (Probert, 1999). The expansion of fisheries into the deep-sea in recent decades has resulted in the serial depletion of vulnerable fish species and the destruction of fragile seamount habitats (Koslow et al., 2000).

The designation of the enclaves as high seas marine reserves would contribute to considerable progress already being made towards the creation of large-scale marine reserves in the Western and Central Pacific (WCP). The Phoenix Islands Protected Area, currently the world's largest, encompasses 410,500km^2 around Kiribati's Phoenix Islands, including eight coral atolls and vast expanses of open-ocean and deep-sea habitat (PIPA, 2009). The Papahānaumokuākea Marine National Monument, in Hawaii, covers 357,000km^2, including thousands of square kilometres of some of the world's least disturbed coral reefs (PMNM, 2009). Australia's Great Barrier Reef Marine Park encompasses 345,000km^2, of which approximately 33% is fully protected (GBRMPA, 2003). A campaign is currently underway for the creation of a Coral Sea Heritage Park, which would protect over 1,000,000km^2 of Australian waters between the eastern boundary of the Great Barrier Reef Marine Park and the maritime borders with Papua New Guinea (PNG), the Solomon Islands and New Caledonia (Pew, 2009). France has recently committed to protect 10% of its EEZ in marine reserves by 2020, with a 700,000km^2 potential site already identified in the Marquesas Islands of French Polynesia (Le Grenelle de la Mer, 2009). The high seas enclaves are connected to the Phoenix Islands Protected Area and the proposed marine reserves in the Coral Sea and Marquesas Islands by the South Equatorial Current (SEC), which flows westwards between ~5°N and 20°S, and could potentially form a part of a functioning reserve network in the WCP. This would contribute to the implementation of the Pacific Islands Regional Oceans Policy, which calls amongst other things for the development of precautionary management regimes; a transboundary approach to marine ecosystem management; and the conservation of biodiversity at local, national and regional scales (CROP, 2005).

The southern hemisphere portions of the marine reserves would fall within the boundaries of the proposed South Pacific Whale Sanctuary (SPWS), which extends north to the equator (DEWHA, 2007). Australia and New Zealand have campaigned for the SPSW at the International Whaling Commission (IWC) since 2000 (SPREP, 2006). The proposal is endorsed by members of the Pacific Regional Environment Program (SPREP) and Pacific Forum leaders but failed to win the ¾ majority required for establishment by the IWC (SPREP, 2006). Nevertheless, there is continued support for a SPWS and high seas marine reserves could potentially form highly protected zones within the sanctuary, should it become a reality. High seas marine reserves in the PIR could also complement the protection of whale species that migrate between feeding grounds in the Southern Ocean Whale Sanctuary and breeding grounds in the tropical and subtropical Pacific (SPREP, 2006).

There is already considerable support from Pacific Island Nations for the closure of the high seas enclaves to fishing vessels. The Western and Central Pacific Fisheries Commission (WCPFC) has agreed to close WOMAR and GOMAR to purse seine vessels from January 2010 (WCPFC, 2008). Under the terms of the Parties to the Nauru Agreement Third Implementing Arrangement, any fishing activity in WOMAR and GOMAR will be forbidden to vessels fishing under license from a Nauru Agreement signatory, which should largely eliminate longlining and other fishing methods (Nauru Agreement, 2008). Closure of WPMR and MOANA to purse seine fishing will be discussed at the 6th Regular Session of the WCPFC, to be held in Tahiti, December 2009 (WCPFC, 2008).

2. Existing research on the areas and availability of information

Direct evidence for the ecological and biological characteristics of the high seas enclaves is limited. Scientific research intensity is low in the PIR, relative to other regions of the world's oceans, and those studies that were conducted related largely to nations' EEZs. For example, reports on cetaceans (Miller, 2007) and seabirds (Watling, 2003) focused on distribution within EEZs reflecting, in part, the paucity of observations from high seas areas. Due to the limited availability of direct evidence, analysis of the ecological and biological significance of the high seas enclaves was partially dependant on extrapolation from physical data, as well as biological data relating to the wider PIR. For example, the presence of seamount species assemblages was inferred from the presence of seamounts. However, in the absence of direct evidence for the presence of seamount species assemblages, the extrapolation was not extended to argue for the presence of endemic species, despite known high levels of endemism in seamount communities. This also applies to discussion of the hydrothermal vent communities that could potentially occur in WPMR. As a result, the lack of direct evidence for the characteristics of the high seas enclaves is reflected in the criteria used to justify their ecological and biological significance.

Direct and indirect evidence for the ecological and biological characteristics of the high seas enclaves was taken from a number of sources. The Oceanic Fisheries Programme of the Secretariat of the Pacific Community (SPC-OFP) collects fisheries landings data and data gathered by national fishery observer programmes in the PIR. SPC-OFP conducts stock assessments of target species and produces research relating to oceanic fisheries in the PIR. Research relevant to the high seas enclaves is also conducted by the Pelagic Fisheries Research Programme of the University of Hawaii. NOAA researchers are active in the PIR and conducted the leatherback turtle *Dermochelys coriacea* tracking studies utilised in this report. A number of oceanographic cruises have collected data in the North Fiji Basin, of which the WPMR forms a part: STARMER (France and Japan, 1987 – 1992); HYFIFLUX (France and Germany, 1995 – 1998); and the Fiji/Lau Expedition conducted by the Monterey Bay Aquarium Research Institute (2005). A number of global databases contain information relating to the high seas enclaves of the PIR, including: Seamounts Online (COML, 2009); Seamount Biogeosciences Network (EarthRef, 2009); NOAA Vents Programme (2009); and the ISA Atlas of the International Seabed Area and its Resources (ISA, 2009).

Much of the data utilised in this report indicates the potential presence of ecologically and biologically significant marine areas in the Pacific high seas enclaves. However, until further research is conducted it will not be possible to fully understand, or conclusively demonstrate, the ways in which the high seas enclaves meet the CBD criteria for significant marine areas. The findings of this report demonstrate the need to adapt or interpret the CBD criteria for application to data-scarce regions of the worlds' oceans, in order to provide an opportunity for the protection of potentially significant marine areas about which little is known.

3. Human activities and threats in the Pacific Islands Region

The WCPFC Convention Area (WCP-CA) is the site of the world's largest tuna fishery, accounting for 55% of global and 84% of Pacific tuna landings in 2007 (Williams and Terawasi, 2008). In 2007: 73% of total landings was taken by purse seine vessels, which target skipjack *Katsuwonus pelamis* and yellowfin *Thunnus albacares* tuna close to the equator; 10% was taken by longline vessels, which target yellowfin, bigeye *Thunnus obesus* and albacore *Thunnus alalunga* tuna; 9% by pole and line fishing, which occurs primarily in national waters; and 8% by trolling and artisanal fishing, which occurs primarily in the vicinity of eastern Indonesia and the Philippines (Williams and Terawasi, 2008). See figure 2 for the distribution of purse seine tuna catch by species, 2006 – 2007. See figure 3 for the distribution of longline tuna catch by species in 2006. 4869 longline fishing vessels, from 21 countries, fished in the WCP-CA in 2007, although the majority of effort was accounted for by the large-vessel, distant-water fleets of Japan, Korea and Taiwan (Lawson, 2007). The five main purse seine fleets operating in the WCP-CA are: the FSM Arrangement (combined Pacific Islands fleets); Japan; Korea; Taiwan; and U.S (Lawson, 2007). The level of IUU fishing in the Western and Central Pacific region has been estimated at 21 – 46%, much of which occurs in EEZs with illegal vessels using the enclaves to take refuge on the high seas (MRAG and FERR, 2008). The designation of the enclaves as marine reserves could facilitate a reduction in the level of IUU fishing, with benefits for the fishing industries of Pacific Island Nations, as well as marine ecosystems. It has been estimated that approximately 10% of total tuna landings from the WCP-CA are taken from the high seas enclaves (Hampton, pers. comm.).

The WCP tuna fisheries are managed collaboratively by the WCPFC, the SPC-OFP and the Pacific Islands Forum Fisheries Agency (FFA). WCPFC was founded in 2004 and is the central, decision-making body for tuna fisheries management (WCPFC, 2009). SPC-OFP conducts scientific research into offshore tuna fisheries, including stock assessments (Preston, 2005). FFA works to develop regional fishery management arrangements and strengthen the capacity of Pacific Island nations' fisheries by providing economic, policy and legislative advice (Preston, 2005). The South Pacific Regional Fisheries Management Organisation (SPRFMO) is currently under consultation prior to full establishment and will oversee the management of the region's non-highly migratory fish stocks (SPRFMO, 2009). SPREP supports environmental management and conservation in the region (Preston, 2005).

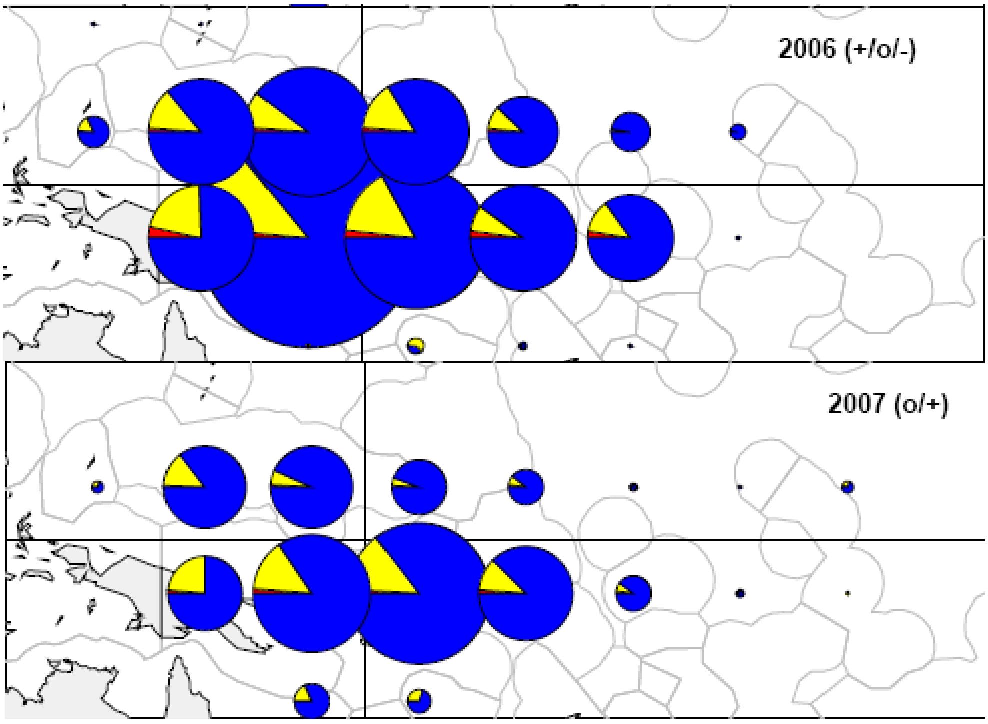


Fig. 2. Distribution of purse seine skipjack/yellowfin/bigeye tuna catch, 2006 – 2007. (Blue – skipjack; yellow – yellowfin; red – bigeye). ENSO periods are denoted by "+": La Niña; "-" : El Niño; "o": transitional period. Source: Williams and Terawasi, 2008.

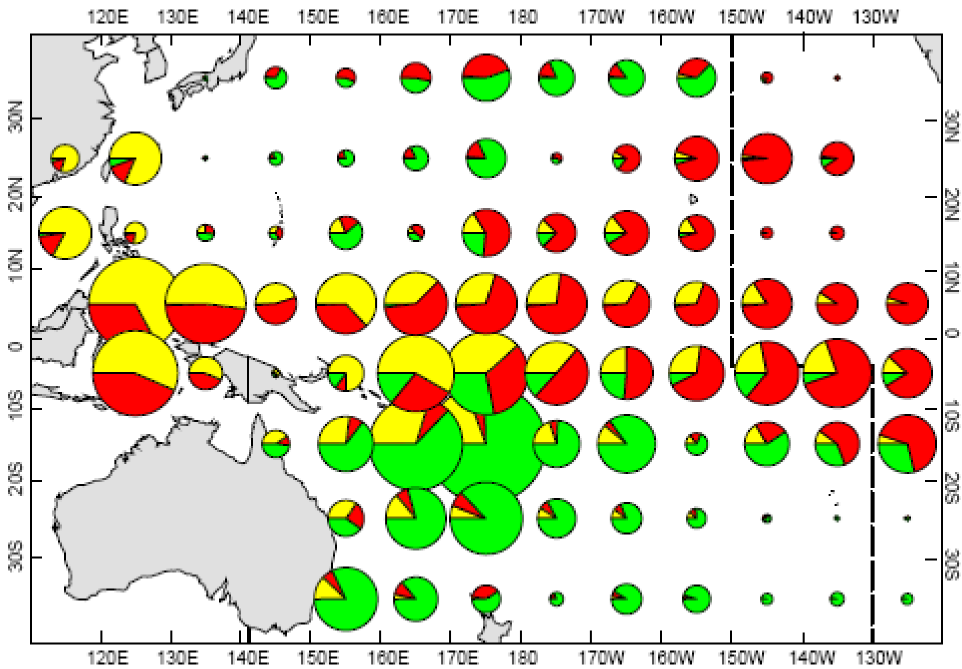


Fig. 3. Distribution of longline tuna catch by species during 2006 (*provisional*). (Yellow – yellowfin; red – bigeye; green – albacore). Source: Williams and Terawasi, 2008.

Tuna landings increased steadily throughout the 1980s, due to the expansion of the purse seine fleet, and remained stable until 1998, when they increased sharply. Landings have been increasing for the past six years. Record total landings of 2,396,815mt was recorded in 2007, 120,000mt higher than the 2006 record. This included record landings of skipjack tuna and the second highest recorded landings of bigeye tuna, which was attributed to the increased use of fish aggregating devices (FADs) by purse seine vessels (Williams and Terawasi, 2008).

Purse seine vessels target feeding schools of tuna in 'unassociated' sets or make 'associated' sets on logs and drifting or anchored FADs. Associated sets catch a higher proportion of bycatch species, including sharks and sea turtles, as well as juvenile bigeye and yellowfin tuna (Molony, 2007). The majority of yellowfin and bigeye caught in associated purse seine sets are below the size at first reproduction and it has been suggested that purse seining impacts are contributing to overfishing of these species. It is estimated that the recent impact of associated sets by purse seine vessels has reduced the total biomass of bigeye tuna by more than 20% and total biomass of yellowfin by more than 10% (Molony, 2007). The proportion of associated sets has declined in recent years, possibly as a result of the La Niña/neutral state of ENSO, which concentrates fishing effort further westwards, where feeding schools are more available (Williams and Terawasi, 2008). However, the increase in the level of total fishing effort means that landings of juvenile tuna have increased in recent years. The impact of associated sets on bigeye and yellowfin tuna could increase in the future if rising fuel prices lead to an increase in the use of FADs (FFA, 2008). An El Niño event began in early 2009 and is predicted to strengthen and last through the northern hemisphere winter of 2009/2010, which could further increase the impact of associated sets on bigeye and yellowfin tuna (NOAA, 2009).

Bigeye tuna are currently being overfished in the WCP-CA and adult biomass may have been below B_{MSY} for several years. It is estimated that total biomass of bigeye tuna had declined by ~0.5 by 1970. Stock levels are now thought to be at 20 – 26% of unexploited biomass, following a period of particularly rapid decline from the mid-1980s (Langley et al, 2008). It has been suggested that a period of elevated recruitment has maintained the bigeye stock at its current size and the stock will decline rapidly if the recruitment level returns to the long-term average and fishing effort is not reduced (Langley et al, 2008). Yellowfin tuna biomass declined steadily throughout the 1990s and overfishing is currently thought to be occurring (Langley et al, 2007; NMFS, 2006). Skipjack tuna has until recently been considered to be in a healthy state (Langley and Hampton, 2008). However, it has recently been suggested that the spawning stock of skipjack in the Pacific may have declined drastically and overfishing may be occurring (OPRT, 2009) There is considerable uncertainty regarding the current stock size and level of fishing mortality on albacore tuna (Hoyle et al, 2008). There is a swordfish longline fishery active in the WCP-CA. However, effort is concentrated in the waters around Australia and New Zealand and in the east of the convention area and landings are not significant in the high seas enclaves (Kolody et al, 2006). There are currently no deep-sea fisheries operating in the vicinity of the high seas enclaves. Interim measures adopted by parties to the SPRFMO state that bottom fishing will not expand into new areas where it is not currently occurring, including the high seas enclaves, whilst those measures are in force (SPRFMO, 2007).

A number of studies have attempted to quantify the broader impacts of fisheries on open ocean ecosystems, although knowledge in this area remains limited. Ward and Myers (2005) compared records from longline surveys in the tropical Pacific before and after intense fishery exploitation. Their results showed a decline in the mean body mass of most large, predatory species and a decline in the abundance and total biomass of all large, predatory species. Total biomass of several small species increased, due to a combination of increases in abundance and mean body mass. Several smaller species increased in relative total biomass over the study period, including skipjack tuna, which moved from tenth to third ranked position. They suggest that these changes are the result of fishing pressure, which has reduced the size and abundance of large predators, resulting in predator release of smaller species, such as skipjack tuna and pelagic rays *Dasyatis violacea* (Ward and Myers, 2005). Sibert et al. (2006) analysed Pacific fisheries data and found that biomass of the species studied ranged from 36% to 91% of unexploited levels, with no detectable decline in community trophic level. They suggested that the impact of fisheries on the ecosystem of the Pacific is less catastrophic than is often assumed although their results did find that tuna of fork length greater than 175cm had declined to less than 17% of unexploited biomass. However, their calculations were based on fisheries data, which was restricted to tuna species and one stock of blue shark *Prionace glauca* and therefore did not account for declines in other large, predatory species (Sibert et al, 2006).

Bycatch of non-target species accounted for 35% of longline catches and 1.8% of purse seine catches between 1995 and 2004 (Molony, 2007). Since 1990, observers have recorded catches of 279 species and 79 higher taxonomic groups (Molony, 2007). Observed encounter rates were low for all species groups except for pelagic sharks and related species. Low observer coverage of vessels fishing in the WCP-CA, combined with unreliable logbook data, means that estimates of bycatch mortality have wide margins for error and data is not sufficient to estimate the population status of non-target species (Molony, 2007). Observer coverage rates averaged 0.65% for longline vessels and 3.59% for purse seine vessels between 1993/4 and 2004, although coverage was distributed unevenly between fleets (Molony, 2007). Data is collected by national observer programmes. SPC-OFP and FFA support the development of active observer programmes in Pacific Island nations, using funding from the Global Environment Facility (GEF) and the EU (SPC, 2009a).

Sharks and related species are the most commonly encountered bycatch group and blue sharks the most commonly encountered species (Molony, 2007). Annual shark catch in the WCP-CA is over 667,000 by longline vessels since 1990, and 2000 – 80,000 by purse seine vessels between 1994 and 2004 (Molony, 2007; Molony, 2005). Shark catches are currently increasing. Mortality is estimated to be ~100% due to the high value of shark fins, which are sold primarily to markets in Singapore, Hong Kong and Malaysia (Molony, 2005). It has been suggested that 'shark fin revenue can double the normal wage of some crews,' and longline vessels deliberately target sharks in some parts of the WCP-CA (Williams, 1999; Molony, 2007). The species most commonly taken by longline vessels are blue, silky *Carcharhinus falciformis* and oceanic whitetip *Carcharhinus longimanus* sharks and pelagic rays (Molony, 2007). Observer data suggests that blue sharks are taken at a rate of 1.6 per thousand hooks, which is lower than the figure for temperate longline fisheries (Molony, 2005). The species most commonly taken by purse seine vessels are silky and oceanic whitetip sharks and unidentified species of manta rays (Molony, 2007). Overfishing is the primary threat to pelagic sharks and rays, which are significantly more threatened as a group than chondrichthyans as a whole (Camhi et al, 2009). A recent report has found that, of the 64 known species of pelagic sharks and rays, 6% are classified as endangered, 26% as vulnerable and 24% as near threatened (Camhi et al, 2009). See Table 1 for IUCN status of the main identified bycatch species in the WCP-CA.

Common name	Scientific name	IUCN status
Blue shark	*Prionace glauca*	Near threatened
Oceanic whitetip shark	*Carcharhinus longimanus*	Vulnerable
School shark (mainly coastal- and bottom-associated)	*Galeorhinus galeus*	Vulnerable
Silvertip shark	*Carcharhinus albimarginatus*	Near threatened
Silky shark	*Carcharhinus falciformis*	Near threatened
Shortfin mako shark	*Isurus oxyrinchus*	Vulnerable
Grey reef shark (coastal)	*Carcharhinus amblyrhynchos*	Near threatened
Thresher shark	*Alopias vulpinus*	Vulnerable (DD in Indo-West Pacific)
Porbeagle	*Lamna nasus*	Vulnerable (NT in Southern Hemisphere)
Crocodile shark	*Pseudocarcharhias kamoharai*	Near threatened
Pelagic stingray	*Dasyatis violacea*	Least concern
Bigeye thresher shark	*Alopias superciliosus*	Vulnerable
Hammerhead shark	*Sphyrna sp.*	Engangered/vulnerable

Table 1. The most commonly recorded elasmobranch bycatch species in WCP-CA with IUCN status. Source: Molony, 2007; Camhi et al, 2009.

33 species of cetacean are thought to be resident or typically migrant in the PIR (excluding the EEZs of Australia and New Zealand) (Miller, 2007). Sperm whales *Physeter macrocephalus* are the most widely reported species (SPREP, 2006). A number of species are taken as bycatch in the WCP-CA. Cetacean mortality in the longline fisheries is estimated to have been 265 per annum from 1990 to 2004, although catch rates are decreasing with an estimated mortality of less than 200 per annum since 2000 (Molony, 2007). Cetacean mortality in the purse seine fishery is estimated to have been less than 10 in total since 1998 (Molony, 2007). Table 2 lists the IUCN status of the main bycatch species in the WCP-CA. There has been a perceived increase in fishery depredation by cetaceans in recent years, leading to the use of harmful dispersal techniques, including shooting, harpooning and

‘tuna bombs’ (Miller, 2007). It has been suggested that there may be indirect competition between cetaceans and fisheries for primary production in the Pacific Ocean, which could lead to a reduction in food available to cetaceans if fishing effort continues to increase (Trites et al, 1997). Historical whaling, including commercial hunts in the PIR, led to the depletion of several cetacean species, including sperm, blue *Balaenoptera musculus*, fin *Balaenoptera physalus*, sei *Balaenoptera borealis*, Bryde’s *Balaenoptera brydei*, minke *Balaenoptera acutorostrata* and humpback *Megaptera novaeangliae* whales (SPREP, 2006). Japanese ‘scientific whaling’ in the Southern Ocean continues to target populations of minke whales that may overwinter in the Pacific Islands Region (Miller, 2007).

Common name	Scientific name	IUCN status
Bottlenose dolphin	*Tursiops truncatus*	Least concern
Short-beaked common dolphin	*Delphinus delphis*	Least concern
Spinner dolphin	*Stenella longirostris*	Conservation dependent
Dusky dolphin	*Lagenorhynchus obscurus*	Data deficient
Risso’s dolphin	*Grampus griseus*	Data deficient
Humpback whale	*Megaptera novaeangliae*	Least concern (EN in Oceania)
Short-finned pilot whale	*Globicephala macrorhynchus*	Conservation dependent
Sperm whale	*Physeter macrocephalus*	Vulnerable
‘Blackfish’	*Multiple species*	DD/LC/CD

Table 2. The most commonly recorded cetacean bycatch species in WCP-CA with IUCN status. Source: Molony, 2005; Miller, 2009.

Five of the seven species of sea turtle are found in the open ocean of the WCP-CA and all are taken as bycatch by longline and purse seine fisheries. See Table 3 for a list of the turtle bycatch species in WCP-CA and IUCN status. Sea turtle mortality in the longline fisheries is estimated to have been 918 per annum from 1990 to 2004, although rates declined towards the end of that period (Molony, 2007). Purse seine fisheries are estimated to have resulted in fewer than 500 sea turtle interactions per annum from 1994 to 2004, with a low estimated mortality rate (Molony, 2007). Of the observed instances of sea turtle bycatch between 1990 and 2004, 21% were olive ridley turtles *Lepidochelys olivacea*, 17% were green turtles *Chelonia mydas* and 10% were leatherback turtles (Molony, 2007). Species was not identified in the majority of interactions. Sea turtle bycatch in the WCP-CA is more common in tropical waters, where green turtles are the most regularly encountered species (SPC-OFP, 2001).

Common name	Scientific name	IUCN status
Olive ridley turtle	*Lepidochelys olivacea*	Vulnerable
Green turtle	*Chelonia mydas*	Endangered
Leatherback turtle	*Dermochelys coriacea*	Critically endangered
Loggerhead turtle	*Caretta caretta*	Endangered
Hawksbill turtle	*Eretmochelys imbricata*	Critically endangered

Table 3. Sea turtle species recorded as bycatch in the WCP-CA with IUCN status. Source: Molony, 2005; IUCN, 2009.

39 species of seabird breed on the tropical Pacific islands of the SPC (excluding Australia, New Zealand and Hawaii) and a further 17 species migrate through the region (Watling, 2002). However, recorded levels of seabird bycatch are extremely low. Seabird mortality in the longline fisheries is estimated at fewer than 100 per annum since 1998 and there has been only one recorded instance of seabird bycatch in the purse seine fishery since 1994 (Molony, 2007). Albatross and large petrels, the species considered most vulnerable to bycatch in longline fisheries, occur only as wandering vagrants in the region (Watling, 2002). Watling (2002) identifies four known bycatch species that occur in EEZs

of the PIR (excluding Australia, New Zealand and Hawaii), as well as seven species deemed potentially vulnerable to fisheries bycatch on the basis of their body mass (>400g). See Table 4 for a list of bycatch and potential bycatch species in the PIR. The high proportion of potentially vulnerable species that are classified as threatened by IUCN suggests that fisheries bycatch could be a more significant issue than is currently thought, particularly in light of the very low rate of observer coverage (Watling, 2002). Two critically endangered seabird species, the Fiji petrel *Pseudobulweria macgillivrayi* and Beck's petrel *Pseudobulweria becki*, breed in the region but are not thought to be at risk of bycatch due to their small body size (Watling, 2002).

Anthropogenic climate change is predicted to affect the open ocean ecosystem of the PIR in a number of ways. Shifting ocean temperatures and current patterns are predicted to affect primary productivity and O_2 concentration, leading to shifts in the availability and distribution of prey species (SPC, 2009). These effects could lead to changes in the pelagic food web and alter patterns of predator production and migration. Sea level rise and ocean acidification may cause the death, or slow the growth, of tropical corals, where these occur on seamount summits (Miller, 2007). Ocean acidification may also lead to reduced growth of deepwater coral species. Migratory species will be affected by climate change impacts outside the region. For example, reduced krill abundance in the Southern Ocean could negatively affect populations of great whales that overwinter in the PIR (Miller, 2007). Daufresne et al. (2009) found that temperature increase due to climate change resulted in reduced body size of ectotherms, including marine fishes, at the individual and community levels. Halpern et al's (2008) model of human impacts on marine ecosystems found high levels of human impact related to sea surface temperature increase, ocean acidification and UV radiation in open-ocean areas of the PIR (NCEAS, 2008). The multiple effects of climate change are likely to combine with the effects of other human activities in the region, with synergistic and unpredictable negative consequences for marine ecosystems.

Common name	**Scientific name**	**Bycatch occurrence**	**Occurrence in SPC region**	**IUCN status**
Pink-footed shearwater	*Puffinus creatopus*	Potentially vulnerable	Vagrant in eastern part of SPC region	Vulnerable
Wedge-tailed shearwater	*Puffinus pacificus*	Known bycatch species	Common breeder	Least concern
Flesh-footed shearwater	*Puffinus carneipes*	Known bycatch species	Rare, annual passage migrant	Least concern
Sooty shearwater	*Puffinus griseus*	Known bycatch species	Common passage migrant	Near threatened
Short-tailed shearwater	*Puffinus tenuirostris*	Known bycatch species	Common passage migrant	Least concern
Christmas shearwater	*Puffinus nativitatis*	Potentially vulnerable	Uncommon breeder	Least concern
Newell's shearwater	*Puffinus newelli*	Potentially vulnerable	Rare vagrant	Endangered
Heinroth's shearwater	*Puffinus heinrothi*	Potentially vulnerable	Breeds New Britain & Solomon Islands	Vulnerable
Dark-rumped/Hawaiian petrel	*Pterodroma phaeopygia/ sandwichensis*	Potentially vulnerable	Common in eastern part of SPC region	Critically endangered/ vulnerable
Juan Fernandez petrel	*Pterodroma externa*	Potentially vulnerable	Eastern part of SPC region	Vulnerable
Murphy's petrel	*Pterodroma ultima*	Potentially vulnerable	Breeds French Polynesia	Near threatened

Table 4. Seabird bycatch and potential bycatch species present in PIR EEZs (excluding Australia, New Zealand and Hawaii). Source: Watling, 2002; IUCN, 2009.

4. West Oceania Marine Reserve

4.1 Area description

The West Oceania Marine Reserve (WOMAR) is a high seas enclave in the tropical Western Pacific, bordered by the EEZs of PNG, Indonesia, Palau and the Federated States of Micronesia (FSM). It falls within FAO fishing area 71. See figure 4 for a map of WOMAR and its key features.

WOMAR is located within the Western Pacific Warm Pool (WARM) biogeographical province, which is characterised by oligotrophic, low salinity water with sea surface temperatures at or above 29°C throughout the year (Longhurst, 2006). Equatorial upwelling occurs during neutral and La Niña phases of ENSO but only results in enhanced primary productivity during periods of strong westward wind stress due to the extreme depth of the nitracline (Longhurst, 2006). This effect narrows progressively westwards. Shoaling of the thermocline and nitracline during El Niño events can lead to enhanced vertical flux of nutrients into surface waters and increased primary productivity (Longhurst, 2006). However, this effect was ephemeral during the 1986 – 1987 El Niño (Longhurst, 2006). Surface currents are dominated by the SEC, which flows westwards between ~5°N and 20°S and extends to ~100 – 150m below the surface. The North Equatorial Counter-Current (NECC), which flows eastwards north of 5°N, may also influence surface water flow in WOMAR.

WOMAR contains a number of distinct bathymetric features, with a large depth range likely to provide habitat suitable for a diverse range of deep-sea organisms. Features present include: the Eauripik Rise, an area of elevated topography rising to depths of less than 2000m; the Mussau Trench, with a maximum depth of ~7200m; and the Mussau Ridge chain of seamounts, with summit depths less than 2000m (ISA, 2009; EarthRef 2009).

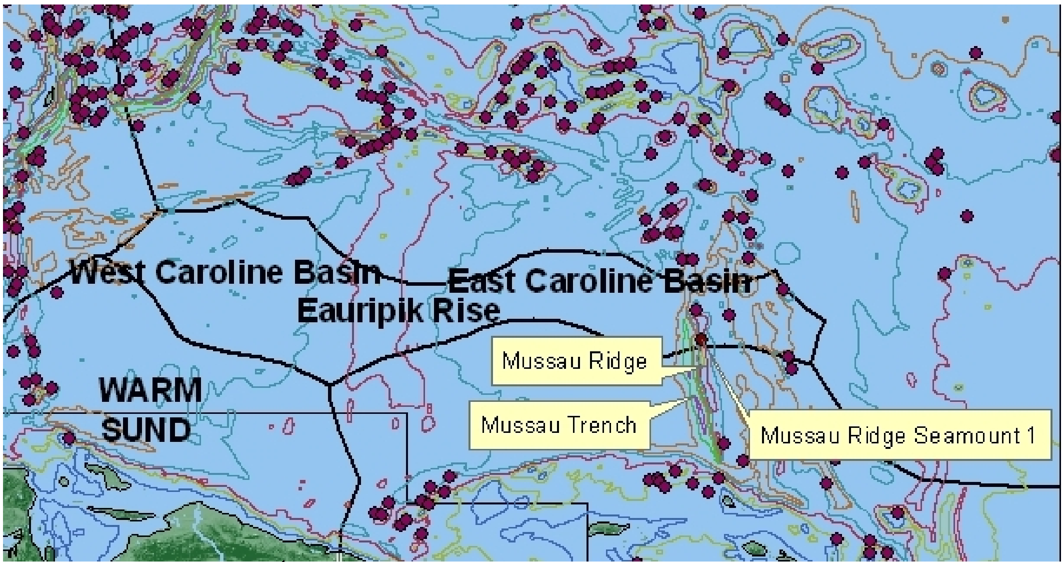
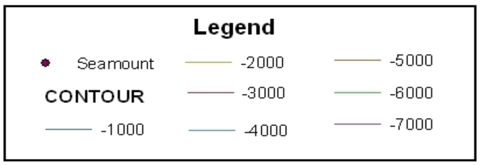


Fig. 4. WOMAR[1]



4.2 Human activities and threats

Purse seine and longline fishing vessels are active in WOMAR, targeting skipjack, yellowfin and bigeye tuna. The majority of purse seine effort consists of unassociated sets, with a significant number of sets also made on logs and a lesser proportion on drifting FADs (Williams and Terawasi,

[1] Map data sourced from GEBCO (2008), Allain et al (2008), COML (2009) and COML Maps (2009).

2008). A higher proportion of yellowfin, relative to skipjack, landings are taken from unassociated sets, which are often made on feeding schools of tuna (Williams and Terawasi, 2008). The proportion of bigeye taken in relation to yellowfin is small compared to other areas, which may reflect the relatively low proportion of sets on FADs (see figure 2). Purse seine fleets active in the vicinity of WOMAR in 2006 – 2007 were: Japan; Korea; Taiwan; and the FSM Arrangement fleet; with an extremely low level of fishing effort by the U.S. fleet (Williams and Terawasi, 2008).

The majority of longline fishing effort is by foreign-offshore fleets from Japan, China and Taiwan, with the remainder undertaken by domestic and distant-water fleets (Williams and Terawasi, 2008). Target species are yellowfin and bigeye tuna (see figure 3).

The level of commercial shipping activity in WOMAR is low on a global scale but regionally high, with potential implications for cetaceans (NCEAS, 2008). Noise pollution as a result of shipping is thought to be the primary cause of the doubling of background levels of ocean noise every decade for the past 60 years and it has been suggested that the PIR could be in line with this global average (Miller, 2007). Sub-lethal levels of noise pollution caused by shipping can affect cetaceans by disrupting feeding and mating behaviour, migratory routes and call patterns. 12 species of cetacean are reported to have suffered ship strikes in the PIR (Miller, 2007).

There is currently no mining activity in WOMAR. However, it is conceivable that noise pollution from exploratory mining of seabed massive sulphide (SMS) deposits in the Bismarck Sea, a process that began in 2005, could affect cetaceans on the high seas (Miller, 2007). Noise pollution as a result of mining can be lethal to cetaceans and the noise produced by seismic air guns is estimated to flood a region up to 300,000km^2 (Miller, 2007). There is a possibility that mining could take place in the future, as the summit depth of the Mussau Ridge falls within the 800 – 2500m optimum range for the formation of cobalt-rich ferromanganese crusts (ISA, 2008a). Both the Mussau Ridge and Eauripik Rise are the subject of an extended continental shelf claim, submitted jointly to the UN by PNG and FSM (SOPAC, 2009).

4.3 Ecological characterisation against criteria

Special importance for life history stages

WOMAR forms part of the pre- and post-nesting migratory route for leatherback turtles that nest at Papua Barat, Indonesia and the Solomon Islands (Benson et al, unpublished). Leatherbacks nesting here are thought to forage primarily in the North Pacific, including foraging grounds off the central Californian coastline (Benson et al, 2007). Of nine leatherbacks tagged by Benson et al. (2007) in 2003, 6 travelled northward or northeastward, passing through WOMAR, and one of these was tracked as far as the waters off California. Figure 5 shows the migratory pathways of leatherbacks tagged at Jamursba-Medi, Papua, Indonesia and coastal central Californian foraging grounds and tracked using satellite telemetry.

WOMAR may also be an important area for juvenile leatherback turtles, although there is no direct evidence for their presence. Juvenile leatherbacks, less than 100cm in length, have only been recorded in waters warmer than 26°C (Eckert, 2002). Of the 98 confirmed sightings worldwide, one was from an area just to the north of WOMAR (Eckert, 2002) Combined with its proximity to leatherback nesting beaches, this suggests that WOMAR could be an important area for the post-hatching migration of juvenile leatherbacks.

WOMAR may be an important spawning area for yellowfin tuna. Yellowfin spawning takes place continuously in the tropical waters of the Western Pacific (Itano, 2000). The temporal and spatial distribution of spawning activity is patchy, possibly reflecting forage availability. A positive relationship between localised areas of high forage abundance, high reproductive rates and heightened vulnerability to surface fisheries has been noted for yellowfin tuna (Itano, 2000). Yellowfin from active feeding aggregations, or 'foaming' schools, of the sort targeted by purse seine vessels in unassociated sets, have been found to be reproductively active with high spawning frequencies (Itano, 2000). The high proportion of unassociated sets by purse seine vessels suggests that spawning/feeding behaviour may be common in WOMAR. One study found that 'Japanese fishermen have been aware for several years that foaming schools are especially common in the area to the north of PNG during October to December,' (Itano, 2000).

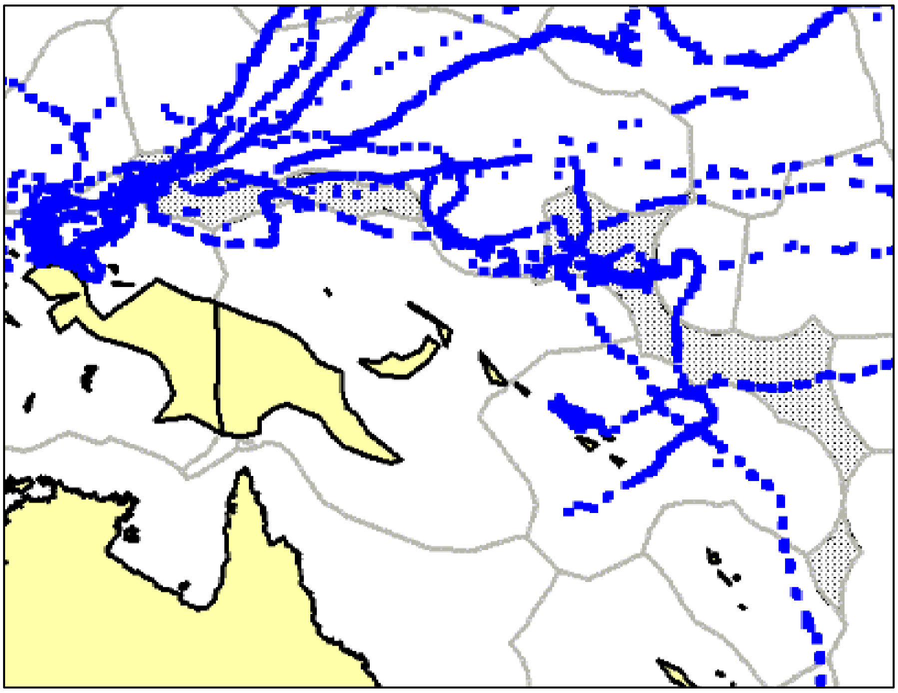


Fig. 5. Movements through Western Pacific high seas pockets by leatherback turtles approaching and departing nesting beaches in Papua Barat, Indonesia and Solomon Islands. Source: Benson et al, unpublished.

Threatened/endangered/declining species or habitats

WOMAR forms part of the pre- and post-nesting migratory route for critically endangered leatherback turtles (see figure 5). Leatherback numbers have declined precipitously in recent years and the effect has been particularly pronounced in the Pacific Ocean, where numbers have collapsed at once important rookeries in Mexico and Malaysia (Dutton et al, 2007). An analysis of published estimates suggests a reduction in the global population of adult females of 70% in less than one generation (IUCN, 2009). Many of the leatherbacks that migrate through WOMAR nest on the northwest coast of Papua, Indonesia. Although this population shows evidence of long-term decline, the effect has been less pronounced than at other nesting sites, and it is now thought to constitute the largest remaining nesting population in the Pacific (Hitipeuw et al., 2007). A number of factors have been implicated in the dramatic decline of leatherback turtles, including poaching of eggs, bycatch in longline and driftnet fisheries, targeted hunting and pollution. Whilst there is some dispute over the level of leatherback bycatch, mortality rates are probably unsustainable and a reduction in the number of leatherback interactions with fishing vessels is a conservation priority. Lewison et al. (2004) estimated that 20,000 leatherbacks were caught as bycatch by pelagic longliners in the Pacific in 2000, with mortality of 1000 – 3200. Hays et al. (2003) used data from satellite tracking studies to reach an estimated mortality rate of 0.31 for all marine turtle species in interactions with fisheries worldwide. The level of leatherback bycatch or mortality in WOMAR is not known, however the high level of longline fishing effort and the presence of migrating leatherbacks suggest that fisheries interactions are likely to occur.

Observer data demonstrates the presence of critically endangered hawksbill turtles, endangered green turtles and vulnerable olive ridley turtles in WOMAR (Molony, 2005; SPC-OFP, 2001; IUCN, 2009). A review of data from 1990 to 2000 showed a relatively high rate of sea turtle bycatch, by purse seine and longline vessels, in WOMAR (SPC-OFP, 2001). Longline bycatch was particularly concentrated in an area of equatorial waters in the vicinity of the easternmost portion of WOMAR.

Bigeye tuna are taken in WOMAR by longline and purse seine fisheries. Bigeye tuna are classified as vulnerable by the IUCN and their numbers are declining in the WCP-CA, where the stock is overfished (IUCN, 2009; Langley et al, 2008). The biomass of yellowfin tuna in the WCP-CA declined steadily throughout the 1990s and overfishing is occurring (Langley et al, 2007; NMFS, 2006). See 'Human activities and threats in the Pacific Islands Region' for details of bigeye and yellowfin tuna declines.

Vulnerability, fragility, sensitivity or slow recovery

A number of species of sea turtle are present in WOMAR. All species of sea turtle are highly vulnerable to human impacts and have a slow recovery time as a result of their life history characteristics. All species share a common life history pattern, with high fecundity, slow growth, late age at maturation, longevity and low adult mortality (Davenport, 1997). The age at first reproduction varies from 6 – 10 years for hawksbills and ridley turtles to 20 – 50 years for green turtles, which can live for over 100 years (Davenport, 1997). Leatherback turtles have a high growth rate relative to cheloniids, probably due to their warm-blooded physiology, and are thought to reach maturity more quickly (Musick, 1999). However, all species of sea turtle have an intrinsic annual rate of population increase (r) below 10%, which puts them at particular risk of depletion due to human impacts (Musick, 1999).

The Mussau Ridge could potentially include areas of fragile and sensitive habitat. Whilst there has been very little surveying of seamounts in this region, the depth range and topography of the Mussau Ridge are potentially suited to colonisation by sessile epibenthic organisms, including gorgonians, antipatharians and sponges. Whilst the majority of scleractinians and stylasterids are found at depths of 100 – 1000m, gorgonians and antipatharians are more commonly found at depths greater than 1200m, and could potentially occur on the Mussau Ridge (Rogers et al, 2007). Sampling at Mussau Ridge Seamount 1 (see figure 4) by the Soviet vessel Akademik Mstislav Keldysh, in 1984, revealed the presence of three species of hexactinellid sponge at depths of 1520 – 1780m: *Pheronema megaglobosum* Tabachnick and *Eurete lamellina* Tabachnick, which are recorded as occurring only at this location by the Seamounts Online database; and *Tretopleura styloformis* Tabachnick, which has been recorded at a number of locations in the Western Tropical Pacific (COML, 2009). Gorgonians, sponges and antipatharians create 'islands' of complexity in the deep-sea that provide habitat for a number of invertebrate and associated vertebrate species (Samadi et al, 2007). Some species can form dense stands in areas where currents sweep the summits and flanks of seamounts (Rogers et al, 2007). Deep-sea habitat builders are highly vulnerable to the impacts of deepwater fisheries and have a slow recovery time due to their life history characteristics, which include slow growth and extreme longevity. Gorgonian colonies over 500 years old have been found on seamounts in New Zealand and an individual of the hexactinellid sponge genus Monoraphis has been estimated at 440 years old (Samadi et al, 2007). Growth is extremely slow in the low-energy, deep-sea environment and one species of sponge has been estimated to grow at a rate of only 11mm per century (Samadi et al, 2007). A number of studies have documented the dramatic impacts of deepwater fisheries on seamount habitats and associated species (Clark and O'Driscoll, 2003; Probert et al, 1997; Koslow et al, 2001).There are currently no deep-water fisheries operating in WOMAR, however there is potential for the destruction of vulnerable habitats, should this activity develop in the future.

Biological productivity

WOMAR is located in the Pacific Warm Pool, an area of elevated pelagic predator abundance (Longhurst, 2006). The Warm Pool meets the nutrient-rich, upwelling waters of the Pacific Cold Tongue at the Eastern Warm Pool Convergence Zone, a dynamic area of high primary productivity located in equatorial waters (Picaut et al, 2001). It is thought that low tropic level species are advected westwards, creating a productive foraging area for tuna and other pelagic predators, including sea turtles, sharks and cetaceans, downstream of the convergence zone (Lehodey et al, 1998). This is supported by the distribution of purse seine fishing effort, which is concentrated in equatorial waters of the Warm Pool (see figure 2). The location of the convergence zone varies with ENSO. Productivity, forage and fishing effort are concentrated further westwards during neutral and La Niña phases, when relative fishing effort in WOMAR increases (Lehodey, 2001).

Phytoplankton blooms in the eastwards flowing NECC can lead to increased levels of primary productivity in WOMAR at certain times (NASA, 2009). Elevated chlorophyll levels are observed in the western portion of the NECC during the winter, spring and summer and are particularly pronounced during El Niño events (Christian et al, 2004). This effect is attributed primarily to upwelling associated with current meandering (Christian et al, 2004).

The Mussau Ridge could potentially include areas of elevated benthic productivity. Productive seamount habitats are created where sessile suspension feeders, including scleractinian corals, octocorals and sponges, colonise areas of hard substrate created by the flow of currents over seamount summits and flanks (Rogers et al, 2007). The intensification of near bottom currents in the vicinity of seamounts can substantially enhance the allochthonous food supply to deepwater planktivores, leading to elevated secondary productivity relative to surrounding areas (Genin and Dower, 2007). This effect is most pronounced on deep seamounts, such as the Mussau Ridge, where food supply is the major factor limiting productivity (Genin and Dower, 2007). Pelagic productivity is unlikely to be influenced by the Mussau Ridge, as the relatively deep summits do not penetrate the euphotic zone or the deep scattering layer (DSL) (Pew, 2007).

Biological diversity

The Mussau Ridge could potentially include areas of benthic habitat with elevated levels of species diversity. Complex structures created by scleractinian corals, octocorals and sponges on the summits and flanks of seamounts provide habitat for a number of species, including sessile and mobile invertebrates and fish (Samadi et al, 2007). Stands of gorgonians have been found to be inhabited by shrimp, galatheid lobsters and other crustaceans, crinoids, basket stars, sponges and other corals (Rogers et al, 2007). These habitats provide shelter for fish species that employ the feed-rest strategy, conserving energy by sheltering from strong currents amongst corals and sponges between periods of active feeding (Genin and Dower, 2007). Available data suggests that the overall (γ) species diversity of seamounts may be similar to that of the deep-sea as a whole and species richness on equatorial seamounts may be low relative to those at higher latitudes, although this could be an artefact of low sampling effort (Stocks and Hart, 2007; Rogers et al, 2007). However, the availability of complex habitat combined with elevated productivity results in relatively high local (α) species diversity on seamounts colonised by sessile suspension feeders (Rogers et al, 2007).

5. Greater Oceania Marine Reserve

5.1 Area description

The Greater Oceania Marine Reserve (GOMAR) is a high seas enclave in the tropical Western Pacific, bordered by the EEZs of FSM, Marshall Islands, Nauru, Kiribati, Tuvalu, Fiji, the Solomon Islands and PNG. It falls within FAO fishing area 71. See figure 6 for a map of GOMAR and its key features.

GOMAR is located within the WARM biogeographical province, which is characterised by oligotrophic, low salinity water with sea surface temperatures at or above 29°C throughout the year (see ‘West Oceania Marine Reserve’ for a description of physical conditions in WARM) (Longhurst, 2006).Surface currents in the vicinity of GOMAR are dominated by the SEC. Within the SEC, the weaker South Equatorial Counter-Current (SECC) flows eastwards between 7°S and 14°S.

GOMAR encompasses a section of the Ontong Java Rise, where depths rise to less than 2000m. The abyssal plain sinks to depths greater than 4000m in the Nauru Basin and sinks below 5000m in the Elice Basin. 14 seamounts have been identified in GOMAR, with summit depths ranging from 2412m to 4300m (Allain et al, 2008).

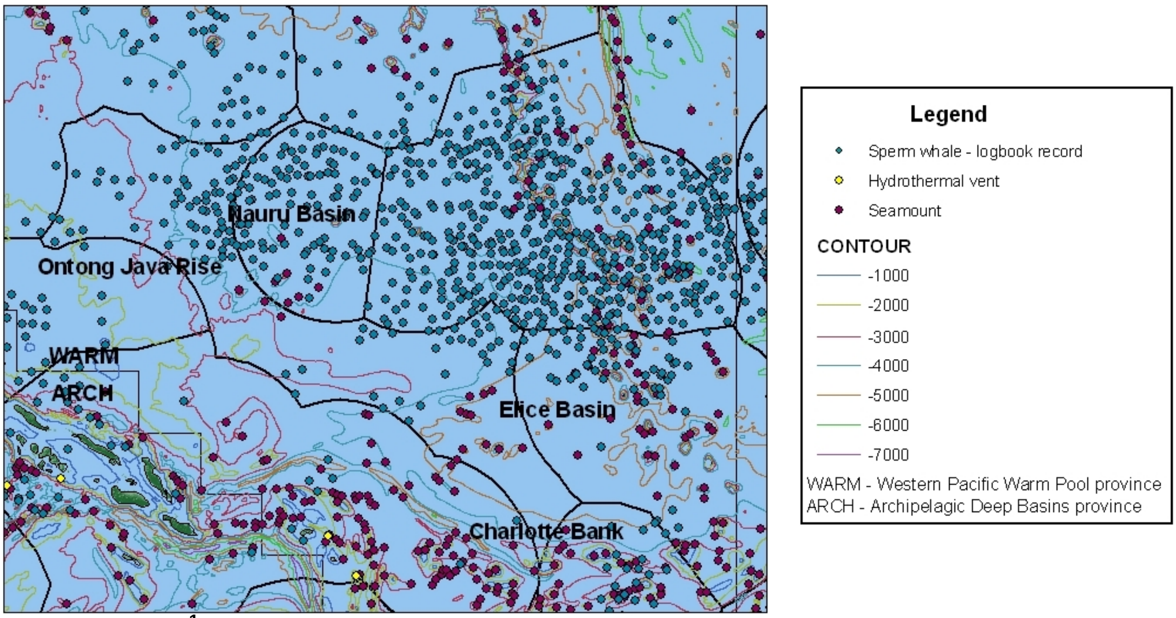


Fig. 6. GOMAR[1]

5.2 Human activities and threats

Purse seine and longline fishing vessels are active in GOMAR, targeting skipjack, yellowfin, bigeye and albacore tuna. Purse seine vessels make unassociated sets and sets on logs and drifting FADs. No one method dominates and the relative proportions vary annually (Williams and Terawasi, 2008). Skipjack tuna account for the majority of purse seine landings, with the remainder composed of yellowfin and a small proportion of bigeye tuna (see figure 2). Purse seine fleets active in the vicinity of GOMAR in 2006 – 2007 were: Japan, Korea, Taiwan, the FSM Arrangement fleet and the U.S. fleet (Williams and Terawasi, 2008).

The majority of longline fishing effort in the vicinity of GOMAR is by distant-water fleets from Japan, Korea and Taiwan, with the remainder undertaken by foreign-offshore and domestic fleets (Williams and Terawasi, 2008). Target species are yellowfin, bigeye and albacore tuna (see figure 3).

The Ontong Java Rise is the subject of an extended continental shelf claim, submitted jointly to the UN by PNG, FSM and the Solomon Islands (SOPAC, 2009). The Charlotte Bank, in the southernmost portion of GOMAR, is the subject of an extended continental shelf claim submitted jointly to the UN by Fiji and the Solomon Islands (SOPAC, 2009).

5.3 Ecological characterisation against criteria

Special importance for life history stages of species

GOMAR forms part of the pre- and post-nesting migratory route for leatherback turtles that nest at Papua Barat, Indonesia and the Solomon Islands (see 'West Oceania Marine Reserve').

There is some evidence to suggest that GOMAR may form part of a migratory route for green turtles moving between the Marshall Islands and the Solomon Islands, Australia and PNG. Data obtained from a passive tag retrieval study conducted over a period of 14 years showed green turtles moving between these locations (Klain, pers. comm.; McCoy, pers. comm.). Whilst this does not provide direct evidence for their presence, the shortest routes would pass through GOMAR, suggesting that the presence of migrating green turtles is likely.

[1] Map data sourced from GEBCO (2008), Allain et al (2008), NOAA Vents Program (2009), WCS (2007) and COML Maps (2009).

Threatened/endangered/declining species or habitats

GOMAR forms part of the pre- and post-nesting migratory route for critically endangered leatherback turtles that nest at Papua, Indonesia and the Solomon Islands (see 'West Oceania Marine Reserve'). The level of leatherback bycatch or mortality in GOMAR is not known, however the high levels of longline fishing effort and the presence of migrating leatherbacks suggest that fisheries interactions are likely to occur.

Observer data demonstrates the presence of vulnerable olive ridley turtles, as well as unidentified marine turtles, in GOMAR (Molony, 2005; SPC-OFP, 2001). Records show that green turtles are the species most commonly caught in tropical waters, suggesting that this species may also be taken as bycatch in GOMAR (SPC-OFP, 2001). A review of data from 1990 to 2000 showed that longline bycatch was particularly concentrated in an area of equatorial waters that included the northernmost portion of GOMAR (SPC-OFP, 2001).

Bigeye tuna are taken by longline and purse seine fisheries in GOMAR. Bigeye tuna are classified as vulnerable by the IUCN and their numbers are declining in the WCP-CA, where the stock is overfished (IUCN, 2009; Langley et al, 2008). The biomass of yellowfin tuna in the WCP-CA declined steadily throughout the 1990s and overfishing is occurring (Langley et al, 2007; NMFS, 2006). See 'Human activities and threats in the Pacific Islands Region' for details of bigeye and yellowfin tuna declines.

Historical records compiled from whaling logbooks show an area of high sperm whale catches in the northernmost portion of GOMAR (WCS, 2007). This corresponds to the western extreme of the 'On the Line' whaling ground and may indicate an area of historically high sperm whale abundance (Taei, pers. comm.). Sperm whales are classified as vulnerable by IUCN and have suffered significant global declines as a result of intensive exploitation during two periods of commercial whaling – 'open boat' whaling from the early 18th to early 20th centuries and 'modern' whaling during the 20th century, particularly from the 1950s to 1980s (Whitehead, 2002). The population status of sperm whales in the PIR is uncertain, however it has been estimated that the global population is at ~32% of unexploited abundance (Whitehead, 2002).

Vulnerability, fragility, sensitivity or slow recovery

Leatherback and olive ridley sea turtles are present in GOMAR and the presence of green turtles is likely. All species of sea turtle are highly vulnerable to human impacts and have a slow recovery time as a result of their life history characteristics (see 'West Oceania Marine Reserve').

Historical records compiled from whaling logbooks suggest that sperm whales may have been historically abundant in GOMAR (WCS, 2007). Sperm whales are highly vulnerable to human impacts and have a slow recovery time as a result of their life history characteristics, which include low fecundity, late age at maturation and longevity (Chivers, 2002). Sperm whales' age at first reproduction varies from 7 to 13 years for females to 20 years for males and individuals can live for over 70 years. Sperm whales give birth to single calves in a reproductive cycle that can last for over three years, including a 12 – 17 month gestation period and 2 – 3 year lactation period (Chivers, 2002).

Biological productivity

GOMAR is located in the Pacific Warm Pool, an area of elevated abundance of tuna and other pelagic predatory species (see 'West Oceania Marine Reserve'). High secondary productivity is indicated by the relatively high levels of longline and purse seine fishing effort in GOMAR (see figures 2 and 3). Productivity, forage and fishing effort are concentrated further eastwards during El Niño phases of ENSO, when relative fishing effort in GOMAR increases (Lehodey et al, 1998).

6. Moana Marine Reserve

6.1 Area description

The Moana Marine Reserve (MOANA) is a high seas enclave in the Central Pacific, bordered by the EEZs of the Cook Islands, French Polynesia and Kiribati. It falls within FAO fishing area 77. See figure 7 for a map of MOANA and its key features.

MOANA is located within the South Pacific Subtropical Gyre (SPSG) biogeographical province. SPSG is one of the most uniform and least studied regions of the open oceans and is characterised by warm, salty, oligotrophic surface water (Longhurst, 2006). Surface currents in the vicinity of MOANA are dominated by the SEC, within which flows the weaker SECC (see 'Greater Oceania Marine Reserve).

The bathymetry of MOANA is relatively uniform and is dominated by the abyssal plain at a depth of approximately 5000m. Allain et al. (2008) record one seamount in MOANA with a summit depth of 3201m.

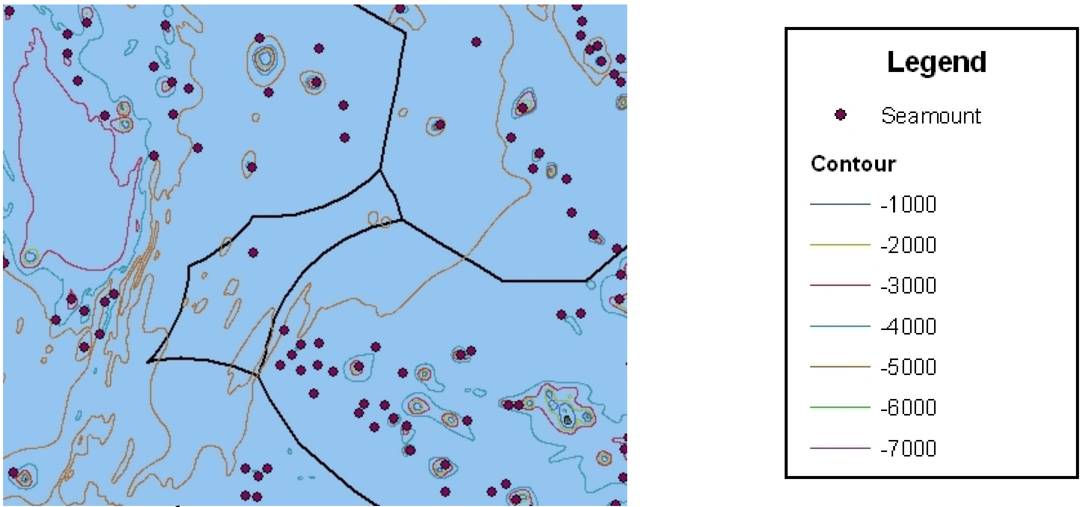


Fig. 7. Moana[1]

6.2 Human activities and threats

Longline fishing vessels are active in MOANA, although fishing intensity is low relative to other areas of the WCP-CA (see figure 3). Landings consist primarily of albacore tuna, with lesser proportions of yellowfin and bigeye tuna also taken. Fishing effort is by distant-water and domestic fleets (Williams and Terawasi, 2008). There is no purse seine or demersal fishing effort.

The ISA (2009) records the presence of polymetallic nodules in MOANA. Polymetallic nodules are rock concretions formed of concentric layers of iron and manganese hydroxides (ISA, 2008b). Found scattered on the abyssal plain of all ocean basins, polymetallic nodules have been the focus of intense mining interest. Commercially viable mining of polymetallic nodules is not economically or technologically feasible at present, however mining could potentially take place in MOANA in the future (Glasby, 2000).

[1] Map data sourced from GEBCO (2008) and Allain et al (2008).

6.3 Ecological characterisation against criteria

Special importance for life history stages of species

MOANA occurs in an area that may be important for breeding minke whales. Kasamatsu et al. (1995) recorded an above average encounter rate with southern minke whales in waters between 10°S and 20°S and 150°W and 160°W during the month of October. Southern minke whales are thought to breed in open ocean areas north of 30°S, with a peak conception period between August and October. Therefore it was suggested that the area of increased sightings incorporating MOANA could form an important breeding area for minke whales in the Western South Pacific (Kasamatsu et al, 1995).

7. Western Pacific Marine Reserve

7.1 Area description

The Western Pacific Marine Reserve (WPMR) is a high seas enclave in the Western Pacific, bordered by the EEZs of Fiji, Vanuatu and the Solomon Islands. It falls within FAO fishing area 71. See figure 8 for a map of WPMR and its key features.

WPMR straddles the boundary between the WARM and SPSG biogeographical provinces. Both provinces are characterised by oligotrophic water, with higher salinity in the SPSG province due to lower rates of precipitation. SST is higher in the WARM province, which is delimited by the 29°C isotherm (Longhurst, 2006). Surface currents in the vicinity of WPMR are dominated by the SEC, within which flows the weaker SECC (see 'Greater Oceania Marine Reserve').

The WPMR is located in the North Fiji Basin, a back-arc basin with a depth of ~3000m. The North Fiji Basin is limited by the Vitiaz Lineament subduction zone to the north; the Matthew Hunter fracture zone to the south; the Fiji Plateau to the east; and the New Hebrides Arc and subduction zone to the west (Dèsbruyeres et al, 1994). The basin is spreading actively at a rate of ~7.2cmy^{-1} and contains areas of hydrothermal activity (Nojiri et al, 1989). The northern portion of the basin's central spreading axis, oriented 160°N, is located in WPMR (Auzende et al, 1990). This portion of the axis is bathymetrically complex and consists of a double ridge, separated by a graben reaching depths of over 4000m (Auzende et al, 1990). The South Pandora/Rotuma Ridge, which trends east-northeast in the northern part of the basin also passes through WPMR (Lagabrielle, 1995) It has been suggested that the ridge may be a new active spreading centre and piston core samples taken from its vicinity show anomalously high levels of Fe, Mn, Cu and Zn, indicating proximity to hydrothermal vent activity (Exon, 1983). No hydrothermal vent sites have been identified within WPMR. However, the presence of two active spreading ridges suggests that hydrothermal vent activity could potentially occur. A number of vents have been studied at the triple-plate junction of the central spreading axis, located within the Fijian EEZ, including the White Lady, LHOS, Pére Lachaise and Mussel Valley vents and the Sonne 99 vent field (NOAA Vents Program, 2009; MBARI, 2005; Géoazur, 2005; Halbach et al, 1995). Nojiri et al. (1989) detected a megaplume, a short-term, massive release of hydrothermal fluids, at 173°30'E, 18°50'S.

The South Pandora/Rotuma Ridge rises to a summit depth of 45m at Horizon Bank, a drowned atoll located in the north of WPMR (Allain et al, 2008). Henry W. Menard, an oceanographer at Scripps Institution of Oceanography, described the discovery of Horizon Bank during the 1967 Nova Expedition in *Anatomy of an Expedition* (1969): '*The bottom kept going up and up and up as we changed scale on the depth recorder until it levelled at 70 feet, deepened slightly and then rose again to 70 feet before dropping abruptly into water two miles deep. What we had just discovered was a drowned atoll…There is always a bonus in discovering a mountain – you get to name it…Considering everything it seemed appropriate to name it after the ship, "Horizon Bank," following a common custom…banks are hard to find these days and we thought she deserved one last tribute*.' Allain et al. (2008) identify a further four seamounts in WPMR, with summit depths ranging from 2328m to 1470m.

WPMR is the subject of an extended continental shelf claim, submitted to the UN by Fiji (SOPAC, 2009).

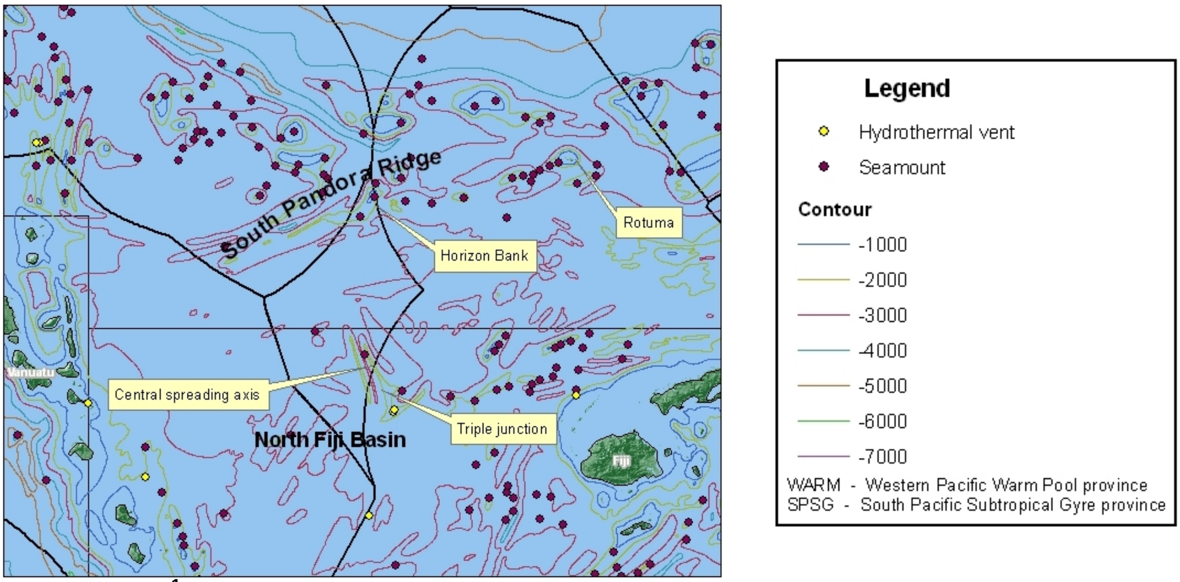


Fig. 8. WPMR[1]

7.2 Human activities and threats

Longline fishing vessels are active in WPMR, targeting albacore, yellowfin and bigeye tuna. Albacore tuna account for the majority of landings (see figure 3). Fishing effort is dominated by domestic fleets, with some activity by foreign-offshore and distant-water vessels (Williams and Terawasi, 2008). There is limited purse seine effort in WPMR. There is currently no evidence for demersal fishing activity in WPMR, however there is potential for shallow- and deepwater demersal fisheries to develop in the future.

The elevated abundance of pelagic predators in the vicinity of shallow seamounts, such as Horizon Bank, can increase the impacts of fisheries on target and non-target species. Catches taken from the vicinity of seamounts often contain relatively high proportions of juveniles as well as non-target species, including sea turtles and seabirds (Holland and Grubbs, 2007). Species' vulnerability to fishery impacts is increased by aggregating behaviour, which leads to preferential targeting of seamounts in many fisheries (Holland and Grubbs, 2007). It has been suggested that fishery removals of pelagic species could affect benthic communities due to bentho-pelagic coupling, as the supply of energy from surface waters may be reduced (Pew, 2007). There is some evidence for the depletion of commercial stocks due to preferential targeting of seamounts. Campbell and Hobday (2003) suggested that declining landings in the eastern Australian swordfish fishery were partly attributable to the serial depletion of seamount-associated stocks, which were preferentially targeted by fishing vessels.

Rotuma and its surrounding islets, located ~400km east of Horizon Bank, on the South Pandora/Rotuma Ridge, support breeding colonies of seabirds, suggesting that seabird numbers and the consequent risk of longline interactions could be high in the vicinity of Horizon Bank. J. W. Boddam-Whetham, the nineteenth century author of *Pearls of the Pacific* (1876), described an islet near Rotuma where, '*immense quantities of seabirds congregate*.' Frigatebirds *Fregata sp.* and brown boobies *Sula leucogaster* were regularly observed by Zug et al. (1988) in their study of Rotuman fauna. Boobies are amongst the bird groups vulnerable to longline bycatch in the PIR and account for 22% of seabird bycatch in the tropical Peruvian artisanal longline fishery (Watling, 2002; Jahnke et al, 2001). Frigatebird bycatch has been recorded by observers on Taiwanese longline vessels in the WCP-CA (Huang et al, 2008). It seems possible, therefore, that levels of seabird bycatch could be elevated in the vicinity of Horizon Bank.

[1] Map data sourced from GEBCO (2008), Allain et al (2008), NOAA Vents Program (2009) and COML Maps (2009).

Human activities undertaken at hydrothermal vent sites include mining, bioprospecting and scientific research. If hydrothermal vents are discovered in WPMR in the future, there is potential for these activities to develop. SMS deposits, found at the site of collapsed 'black smoker' vent chimneys, are currently the focus of exploratory ventures by mining companies, including in the EEZ of PNG (Glasby, 2000). SMS deposits are targeted for the very high concentrations of metal sulphides, including copper, gold, zinc and silver, which they contain (Glasby, 2000). Bioprospecting at hydrothermal vents is currently focused on thermophilic and hyperthermophilic bacteria and archaea, which have a range of applications in industry (Leary, 2004). At least seven companies are currently working with vent organism derivatives, of which three have products on the market. All sampling work to date has been undertaken by scientific research vessels (Leary, 2004).

7.3 Ecological characterisation against criteria

Threatened/endangered/declining species or habitats

Shallow seamounts, such as Horizon Bank, are associated with elevated densities of pelagic predatory species, including sea turtles, cetaceans and pelagic sharks (Genin and Dower, 2007). A number of the species that could potentially occur at Horizon Bank are threatened, endangered or declining. Horizon Bank is within the distribution range of leatherback, loggerhead *Caretta caretta*, green and hawksbill sea turtles, which are classified as vulnerable to critically endangered by IUCN (IUCN, 2009). Horizon Bank is also within the range of several of the threatened species of pelagic shark that have been recorded as bycatch in the WCP-CA, including bigeye thresher *Alopias superciliosus*, oceanic whitetip and short-fin mako *Isurus oxyrinchus* sharks, all of which are classified as vulnerable by IUCN (IUCN, 2009). Threatened cetaceans potentially found in the vicinity of Horizon Bank include sperm whales, which are classified as vulnerable by IUCN (IUCN, 2009). Tropical tuna, including yellowfin and bigeye tuna, are known to associate with shallow seamounts. A study of Cross Seamount found that bigeye tuna, which are classified as vulnerable by IUCN, remained resident for an average of 32 days, double the recorded residence time of yellowfin tuna (Holland et al, 1999). This may be explained by the ability of bigeye tuna to feed at depth and therefore take full advantage of enhanced foraging opportunities at shallow seamounts (Holland and Grubbs, 2007).

Vulnerability, fragility, sensitivity or slow recovery

The Horizon Bank has a summit depth of 45m and therefore penetrates the euphotic zone and may provide conditions suitable for colonisation by tropical corals and associated species (Maragos, pers. comm.). Tropical coral communities are vulnerable to a range of human impacts, including overfishing, the effects of demersal fishing gear and anthropogenic climate change. The growth rate of tropical coral species decreases with depth, suggesting that tropical coral reefs on Horizon Bank would recover very slowly, if at all, from damage due to human impacts (Kaiser et al, 2005).

Horizon Bank, and other seamounts and complex ridge areas located within WPMR, could potentially include areas of fragile and sensitive deepwater habitat. The depth range of Horizon Bank is suitable for colonisation by scleractinians, stylasterids, gorgonians, antipatharians and sponges (Rogers et al, 2007). Other seamounts identified in WPMR are within the depth range of gorgonians, antipatharians and sponges. Deepwater, habitat-building species are highly vulnerable to human impacts due to their fragility and life history characteristics, which include slow growth and extreme longevity (see 'West Oceania Marine Reserve').

Shallow seamounts, such as Horizon Bank, are associated with elevated densities of pelagic predatory species, which are thought to visit for feeding and navigational purposes (Holland and Grubbs, 2007). Shallow seamounts provide enhanced foraging opportunities and may act as navigational waypoints, detectable by their magnetic signatures (Holland and Grubbs, 2007). Many pelagic predators are vulnerable to human impacts as a result of their life history characteristics, which can include low fecundity, slow growth, late age at maturation, longevity and low adult mortality. Elasmobranchs are known to be highly vulnerable to fishery impacts due to their k-selected life history traits (Musick, 1999). Longline surveys conducted at seamounts in the Eastern Pacific and Eastern Atlantic demonstrated pelagic shark abundance up to 20x greater than in surrounding waters (Litvinov, 2007). Aggregations consisted primarily of large blue sharks and may have been for breeding purposes. Cetacean-seamount interactions have been largely unstudied but it has been suggested that spinner dolphins *Stenella longirostris* and beaked whales may visit seamounts to take advantage of enhanced foraging opportunities (Kaschner, 2007). One report found that encounters with Baird's beaked whale *Berardius bairdii* were more common in the vicinity of submerged escarpments and seamounts (Kaschner, 2007). Sea turtles may also associate with seamounts although evidence to date has been gathered primarily from the Azores (Santos et al, 2007).

Biological productivity

Shallow seamounts, such as Horizon Bank, are associated with elevated pelagic productivity, due to a combination of enhanced primary productivity and elevated abundance of predators, including tuna, billfish, cetaceans, sea turtles, seabirds and pelagic sharks. Enhanced primary productivity has been observed from some, but not all, shallow seamounts and does not appear to be a permanent feature where it has been recorded (White et al, 2007). High primary productivity occurs as a result of upwelling caused by oceanographic processes, including: isopycnal doming; the creation of Taylor columns and cones – large, stationary eddies formed over the summits of seamounts; and the effects of seamount topography on deep-sea currents and tides (White et al, 2007). Elevated predator abundance at seamounts where no increase in primary productivity has been observed is explained by the effect of seamount topography on the organisms of the DSL (Genin and Dower, 2007). It has been suggested that DSL organisms may become trapped by the summits of seamounts in the course of their diel migrations, creating areas of elevated prey species abundance that are targeted by pelagic predators. Enclosed water circulation patterns may also help to retain prey species in the vicinity of seamounts (Genin and Dower, 2007). An acoustic study conducted at Cross Seamount revealed that unidentified species of beaked whale hunt in the vicinity of the seamount almost every night and hypothesised that whales may have been taking advantage of the reduced dive times required to hunt mesopelagic species trapped by the seamount (Johnston et al, 2008). Analysis of the stomach contents of tuna taken at Cross Seamount revealed that bigeye tuna, which are able to hunt to depths of 500m, gained a significant trophic advantage from association with the seamount and fed on a wide range of species (Holland and Grubbs, 2007). Yellowfin tuna, which hunt in shallow waters, did not gain a significant trophic advantage from seamount association and had fed on fewer species. Morato et al's (2009) analysis of tuna longline logbook data suggested that at least 5 – 10% of seamounts in the Pacific are associated with a significantly elevated CPUE of at least one tuna species. The horizontal extent of the impact of shallow seamounts on pelagic productivity is not fully understood. However, a study conducted at Horizon Seamount found some effect on pelagic productivity up to 100km distant (Pew, 2007).

Horizon Bank, and other seamounts and complex ridge areas located within WPMR could potentially include areas of elevated benthic productivity. Productive seamount habitats are created where sessile suspension feeders, including scleractinian corals, octocorals and sponges, colonise areas of hard substrate created by the flow of currents over seamount summits and flanks (see 'West Oceania Marine Reserve'). Horizon Bank may provide conditions suitable for colonisation by tropical corals and other species. Tropical coral reefs are amongst the most productive ecosystems in the oceans, with primary productivity approaching levels found in upwelling systems (Kaiser et al, 2005).

WPMR may contain hydrothermal communities, which show elevated levels of productivity in relation to other deep-sea habitats (Bachraty et al, 2009). Hydrothermal vent communities consist of a small number of species that are dependent on symbiotic relationships with chemoautotrophic bacteria as well as associated heterotrophic species (Bachraty et al, 2009). Hydrothermal vents in the Southwest Pacific, including sites studied in the North Fiji Basin, are dominated by mytilid bivalves of the genus Bathymodiolus, which contain thioautotrophic and methanotrophic bacteria in their gill tissue and are also capable of ingesting organic materiel (Dubilier et al, 1998). Associated species observed at hydrothermal vent sites in the North Fiji Basin include: Alviniconcha and Ifremeria gastropods; limpets; barnacles; crabs; bresiliid shrimp; chirostylid and galatheid lobsters; annelid and polychaete worms; sponges; dumbo octopus (Grimpoteuthis sp.); vampire squid (*Vampyroteuthis infernalis);* vestimentiferans; chimaera; gorgonians; and crinoids (Dubilier et al, 1998; Desbruyères et al, 1994; MBARI, 2005; Halbach et al, 1995).

Biological diversity

Shallow seamounts, such as Horizon Bank, are amongst the most diverse areas in the high seas, due to the combined presence of pelagic and shallow- and deep-water benthic species. Dr Jim Maragos (pers. comm.), Coral Reef Biologist at the U.S. FWS Pacific Remote Islands National Wildlife Refuge Complex explained that, '*In the high seas arena it is these shallow water formations, to depths of 500m or less, that support the greatest biodiversity…These are the features warranting the most protection in the high seas because they offer habitat for a variety of attached as well as related (demersal) fishes and other deep-sea creatures hovering just above the bottom or sides of these formations*.' Tropical and deepwater corals and other sessile epibenthic organisms provide habitat suitable for a large number of associated species and represent diversity hotspots in the open ocean and the deep sea (see 'West Oceania Marine Reserve'). The concentration of pelagic predators for feeding and navigational purposes can lead to increased levels of local (α) species diversity in the vicinity of shallow seamounts.

8. A Representative Network of Marine Protected Areas

8.1 Representativity

The high seas enclaves contain a range of the pelagic and benthic biota and habitats present in the PIR and could form a portion of a representative network of marine protected areas. WOMAR and GOMAR are located in the WARM biogeographical province and MOANA is located in the SPSG biogeographical province. WPMR is located on the dynamic boundary between these two provinces. All four commercially important tuna species are present in the high seas enclaves. Skipjack and yellowfin tuna biomass is concentrated in WARM; albacore tuna are present in SPSG; and bigeye tuna are present in all four enclaves.

Benthic surveying has been extremely limited in the deep-sea of the PIR, however the range of benthic biota and habitat types present in the high seas enclaves can be inferred from their bathymetry. The enclaves incorporate a number of different bathymetric features, including: the Mussau Ridge; Mussau Trench; Eauripik Rise; Ontong Java Rise; South Pandora/Rotuma Ridge, including Horizon Bank; North Fiji Basin, including the central spreading axis; and abyssal plain at depths ranging from ~3000m to >5000m. Between them, the enclaves potentially provide habitat for tropical coral species; deepwater seamount assemblages; hydrothermal vent communities; and species of the abyssal plain. Taking depth as a proxy measurement for species present, the extremely large depth range of the enclaves, from 45m at Horizon Bank to >7000m in the Mussau Trench, as well as the large range of seamount summit depths, from 45m to 4300m, suggest that a broad range of benthic species are present.

8.2 Connectivity

The high seas enclaves are connected by the SEC, which flows westwards between ~5°N and 20°S. GOMAR, WPMR and MOANA are also connected by the SECC, which flows weakly eastwards between ~7°S and 14°S. These oceanographic features, and in particular the stronger SEC, provide a means by which plankton, larvae and pelagic species could potentially be transported between the enclaves. Lehodey et al. (2003) suggest that tuna larvae are advected by currents during the first quarter of their lives, raising the possibility that the enclaves are connected by transport of larval tuna. Skipjack, yellowfin and bigeye tuna larvae occur throughout WARM and could therefore be transported between GOMAR and WOMAR (Longhurst, 2006). Albacore tuna larvae occur between 5°S and 20°S and could therefore be transported between MOANA, WPMR and GOMAR (Murray, 1991).

Adults of some pelagic species are thought to use ocean currents in the course of their life histories. Luschi et al. (2003) highlight the role of ocean currents in the life histories of sea turtles. All species (with the possible exception of the flatback turtle *Natator depressus*) are thought to become sequestered in oceanic currents during the hatchling and early juvenile phases. Whilst migrations between breeding and feeding areas usually involve active swimming towards a fixed target, turtles may utilise ocean currents during some parts of their journey. Leatherback and olive ridley turtles are primarily pelagic species that may occasionally utilise oceanic currents during the course of their migrations and 'wanderings.' There are examples of sea turtles utilising oceanic currents in the PIR, although there is no direct evidence for use of the SEC. Benson et al. (2007) tracked two leatherback turtles which travelled in the eastwards flowing NECC during post-nesting migrations from Papua, Indonesia. Polovina et al. (2004) tracked olive ridley turtles using the North Equatorial Current (NEC) and NECC.

A number of the pelagic species found in the PIR undertake active migrations or travel extremely long distances, during the course of which they are likely to travel through more than one of the high seas enclaves. Leatherback turtles that nest at Papua Barat, Indonesia and the Solomon Islands are known to travel through WOMAR and GOMAR in the course of their post-nesting migrations (see figure 5). Tuna are known to be capable of travelling extremely long distances. Tagging studies have shown that yellowfin tuna can travel >1000nm and a skipjack tuna has been recovered ~9000km from where it was tagged, distances which could potentially take tuna between the enclaves (Sibert and Hampton, 2003; Sund et al, 1981). However, Sibert and Hampton (2003) found that, whilst some tagged tuna do travel extremely long distances, the median lifetime displacement is just 420 – 470nm for skipjack tuna and 20% less for yellowfin tuna. This finding suggests that, whilst there may be some migration of adult tuna between the high seas enclaves, the level of exchange is likely to be limited.

8.3 Replicated ecological features

Certain key habitat types and biota are replicated within the four high seas enclaves. Seamounts and areas of abyssal plain occur in all four enclaves. Bigeye and yellowfin tuna are present in all four enclaves, whilst skipjack tuna are present in WOMAR and GOMAR and albacore are present in WPMR and MOANA. Many of the pelagic predatory species found in the PIR, including sharks, cetaceans and sea turtles, have wide distributions and are likely to occur in some or all of the enclaves.

The equatorial area of high tropical tuna productivity indicated by concentrated fishing effort and catch is replicated in WOMAR and GOMAR, and shifts from the vicinity of one to the other in accordance with ENSO. During La Niña and neutral phases of ENSO, tuna biomass and fishing effort are concentrated further westwards, including in the vicinity of WOMAR. During El Niño events, tuna biomass and fishing effort are concentrated further eastwards, including in the vicinity of GOMAR (Lehodey et al, 1998).

8.4 Adequate and viable sites

The high seas enclaves are adequate and viable sites for the creation of marine reserves. Stationary features, which are likely to receive adequate protection within the enclaves, include: seamounts; abyssal plain habitat; possible hydrothermal vent communities; and the tropical corals and pelagic species that may be present at Horizon Bank. Further conservation measures will be required to ensure the adequate protection of highly mobile species, including sea turtles and tuna. Sibert and Hampton (2003) suggest that the creation of marine reserves in the enclaves could enhance regional tuna management. They calculate that the high level of fishing pressure in WOMAR and GOMAR means that the ‘half-life’, or the amount of time taken for populations to decrease by half, of tuna is ~2 months in WOMAR, although somewhat longer in GOMAR. This is considerably lower than the median figure of 6 months for all EEZs in the region. They suggest that closing WOMAR and GOMAR to fishing could bring the tuna ‘half-life’ of these enclaves into line with the regional average, with significant benefits for tropical tuna populations in the PIR. It has been calculated that closure of the four high seas enclaves could reduce overfishing of bigeye tuna by 10.7% (SPC-OFP, 2008).

By their nature, high seas enclaves are buffered from many of the human impacts that have contributed to environmental degradation in inshore and continental shelf areas, including nutrient pollution, small-scale and recreational fisheries and sedimentation as a result of coastal development.

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Appendix 2: List of contacts and contact details

Valerie Allain, SPC (valeriea@spc.int).
Transform Aqorau, FFA (transform.aqorau@ffa.int). Emphasised that arguments for the closure of the high seas enclaves have been based on the need for a reduction in total tuna mortality. Suggested that broader ecological arguments would not be sufficiently strong by themselves to support the closure of these areas.
Robin Baird, Cascadia Research Collective (rwbaird@cascadiaresearch.org).
George Balazs, NOAA NMFS Pacific Fisheries Science Center (gbalazs@honlab.nmfs.hawaii.edu).
Jim Barry, MBARI (barry@mbari.org).
Mike Batty, SPC (mikeb@spc.int). Emphasised the role of economic concerns and IUU fishing in the decision to close the high seas enclaves. The enclaves are 'subject to intense fishing activity in a productive area for surface tuna' and their closure should have conservation benefits. Could be described as important for juvenile stages, as tuna spawn throughout the Pacific. However, archpelagic waters of the Philippines, Indonesia and PNG are likely to be of greater importance in this regard.
Lui Bell, SPREP (luib@sprep.org).
Scott Benson, NOAA Southwest Fisheries Science Center (scott.benson@noaa.gov). Provided unpublished data showing the movement of leatherbacks through high seas enclaves. Emphasises the need to consider transfer of ecological footprint if the enclaves are closed.
Andrew Brooks, UCSB (brooks@lifesci.ucsb.edu).
Bill Chadwick, NOAA Vents Program (bill.chadwick@noaa.gov).
Paul Dalzell, Western Pacific Regional Fishery Management Council (p.dalzell@noaa.gov). Stated that the enclaves have no particular biological significance, and the 'island effect' means that EEZ waters are probably more important for aggregating tuna. 'Any benefits from fixed high seas area closures are going to be ephemeral at best' due to the ENSO-driven movements of tuna stocks.
Gerry Davis, NOAA NMFS Pacific Regional Office (gerry.davis@noaa.gov).
Mike Donoghue, New Zealand Department of Conservation (mdonoghue@doc.gov.nz).
Scott Eckert, Wider Caribbean Sea Turtle Conservation Network (seckert@widecast.org).
Jack Frazier (kurma@shentel.net).
Karen Frutchey, NOAA NMFS Pacific Islands Regional Office (Karen.frutchey@noaa.gov).
Alexandre Gannier, Groupe de Recherche sur les Cétacés (a_o.gannier@club-internet.fr).
Peter Gill, Blue Whale Study Inc. (petegill@bigpond.com). Discussed a potential blue whale winter breeding area in the Solomons Sea.
Kristina Gjerde, IUCN (kgjerde@eip.com.pl).
Ben Halpern, UCSB (halpern@nceas.ucsb.edu).
Mario Hernandez, UNESCO (m.hernandez@unesco.org).
Dave Johnston, Duke University (david.johnston@duke.edu). Emphasised the importance of seamounts for the distribution of pelagic predators.
Benjamin Kahn, APEX Environmental (bkahn@apex-environmental.com). Suggests that the high seas enclaves are likely to contain a diverse array of oceanic cetaceans, including migratory and residential species, but may be no more important than EEZ waters. Explained the use of outstanding habitat features to map PPH (persistent pelagic habitats) for future surveying. Suggested that the closure of the enclaves offers a way to increase the consistency of management plans implemented in EEZs.
Iain Kerr, Ocean Alliance (iaink@oceanalliance.org).
Jeffrey Kinch, SPREP (jeffreyk@sprep.org).
Sarah Klain (s.klain@gmail.com) . Former Peace Corps volunteer in Palau. Provided maps for the results of sea turtle tagging projects in Palau and the Marshall Islands.
Corinne Knutson, SeaWeb (cknutson@seaweb.org).
Willy Kostka, Micronesia Conservation Trust (mctdirector@mail.fm).
Trina Leberer, The Nature Conservancy (tleberer@tnc.org).
Andrew Lewin (Andrew.lewin@sympatico.ca).
Jim Maragos, U.S. Fish and Wildlife Service Pacific/Remote Islands National Wildlife Refuge Complex (jim_maragos@fws.gov). Provided information on biogeography of the region and warm-water coral communities on shallow seamounts. Suggests that the University of Hawaii Underwater Research Laboratory or National Geographic Society might be interested in selective exploration of 'these truly last frontiers on the globe,' to make a better case for their lasting protection.
Gerald McCormack, Cook Islands Biodiversity and Natural Heritage (Gerald@nature.gov.ck).

Mike McCoy, Gillett, Preston and Associates (mmc@aloha.net). Provided information regarding the tagging of green turtles in the Marshall Islands (see **Sarah Klain**).
Cara Miller, Whale and Dolphin Conservation Society (cara.miller@wdcs.org).
Michael Milne, Sea Turtle Restoration Project (Michael@tirn.net). Emphasised the importance of this area for Pacific leatherbacks and concern at the impacts of bycatch in the region.
Craig Osenberg, University of Florida (osenberg@ufl.edu).
Jennifer Palmer, IUCN (jpalmer@iucnus.org).
Samuel Pooley, NOAA NMFS Pacific Islands Fisheries Science Center (Samuel.pooley@noaa.gov).
Norman Quinn (Norman.quinn@gmail.com).
Scott Radway, SeaWeb (sradway@seaweb.org).
Kesaia Tabunakawai, WWF South Pacific Programme (ktabunakawai@wwfpacific.org.fj).
Sue Taei, Conservation International (s.taei@conservation.org). Provided summary literature review conducted for Phoenix Islands Protected Area and information regarding 'On-the-line' whaling grounds.
Ana Tiraa, SPREP (anat@sprep.org).
Verena Tunnicliffe, University of Victoria (verenat@uvic.ca).
Bryan Wallace, Conservation International (b.wallace@conservation.org). Emphasised leatherback conservation issues in the region.