Chapter 36D. South Pacific Ocean

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1. Introduction

The Pacific Ocean is the Earth's largest ocean, covering one-third of the world's surface. This huge expanse of ocean supports the most extensive and diverse coral reefs in the world (Burke et al., 2011), the largest comercial fishery (FAO, 2014), the most and deepest oceanic trenches (General Bathymetric Chart of the Oceans, available at www.gebco.net), the largest upwelling system (Spalding et al., 2012), the healthiest and, in some cases, largest remaining populations of many globally rare and threatened species, including marine mammals, 2010), seabird2(e)-1(m2C)-4(mari)10(n)-4(e)-1(

The South Pacific Ocean surrounds and is bordered by 23 countrie (for the purpose of this chapter, countries west of Papua Ne considered to be part of the Sobe part o.1( )9o3nn-1()6(14(lTw

The boundaries and names shown and the designations used on this map do not imply official endorsement or acceptance by the United Nations.

Figure 1. The South Pacific Ocean. Sources: Bathymetry extracted from the GEBCO Digital Atlas (GDA): IOC, IHO and BODC, 2003. Centenary Edition of the GEBCO Digital Atlas, published on CD-ROM on behalf of the Intergovernmental Oceanographic Commission and the International Hydrographic Organization as part of the General Bathymetric Chart of the Oceans, British Oceanographic Data Centre, Liverpool, U.K. More information at

http://www.gebco.net/data_and_products/gebco_digital_atlas/

Ocean and Sea names extracted from ESRI, DeLorme, HERE, GEBCO, NOAA, National Geographic, Geonames.org, and other contributors More information at

http://www.arcgis.com/home/item.html?id=0fd0c5b7a647404d8934516aa997e6d9

With the kind assistance of the FAO.

Physical processes of the basin play an important role in driving shelf and coastal marine processes and climate across the region. Northern parts of the South Pacific Ocean are dominated by a basin-scale subtropical gyre, whose northern branch forms the South Equatorial Current (SEC; Figure 2; Reid, 1997). The SEC is predominantly driven by prevailing easterly trade winds and as water moves from the east to the west, a thick layer of warm water (>29°C), the Western Warm Pool form the poleward-flowing western boundary current, the East Australian Current (EAC).

As the EAC flows south along the Australia's North-West shelf, eddies separate from
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beneath the PCC across the slope and outer shelf. The other arm flows to the southeast of the Galápagos Islands and forms the poleward-flowing Peru-Chile Counter-Current which divides the PCC into two branches: a coastal and an oceanic branch (Strub et al., 1998).

The physical dynamics of the region vary markedly with ENSO: during La Niña, stronger trade winds increase the intensity of the SEC, pushing the WWP west, and upwelling and productivity in the Pacific Equatorial Divergence (PEQD) increase. During El Niño, trade winds weaken, the SEC weakens, allowing the WWP to extend east and upwelling and productivity in the PEQD decrease (Ganachaud et al., 2011). Shifts in the intensity of the SEC have flow-on effects for both basin-scale circulation and shelf systems at the basin edges where shifts result in weakening/strengthening of the boundary currents.

Interaction of the easterly trade winds and ocean currents with island topography modifies the flow of water downwind of the islands, creating counter-currents, eddies and upwelling. This results in enhanced mixing of deeper nutrient-rich waters with surface waters, increasing biological production and enriching coastal waters (Ganachaud et al., 2(e)-sbot92(e)-cTc 14(nd)(lo)-28(()e.10(h (,)Tj ( )Tj)10(ic)4 etlo.143 Tw 0.6

high-level indicators, including some oceanographic parameters (e.g. sea-surface temperatures, sea level) and industrial commercial fisheries (e.g. tuna, anchoveta). Indicators of pressures and impacts are similarly limited to high-level indicators of population and socio-economic measures. Long-term monitoring initiatives (e.g. those spanning multiple decades) are

of longer-term trends, given the high variability in multi-year patterns (Brodie et al., 2007).

In general, phytoplankton assemblages in the EAC are diatom-dominated in inshore regions, flagellates dominate

elsewhere in the subtropical western Pacific Ocean (Kluge, 1992; Champalbert, 1993; Le Borgne et al., 1997; Carassou et al., 2010).

Within coral reef systems, abundances of zooplankton can vary in relation the 1960s, than more recent ‘‘warm’’ decades and have been associated with regime shifts in fish communities in the region (see Section 2.4; Figure 4; Ayón et al., 2004). Similar shifts in the size distribution of zooplankton have also been observed in the eastern Pacific Ocean with smaller zooplankton dominating during warmer, lower upwelling conditions (Ayón et al., 2011).

Figure 4. Spatial and temporal variability in zooplankton biomass in the tropical and subtropical coastal waters of the eastern South Pacific Ocean. Reproduced from Ayón et al., 2004.

Zooplankton communities in temperate waters of the South Pacific Ocean, similarly to those in the tropics and subtropics, are dominated by copepod species (Tranter, 1962; Bradford, 1972; Escribano et al., 2007). Swarming gelatinous species, such as
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high variability in faunal assemblages associated with each habitat (e.g. Waycott et al., 2005).

Coral reef communities are one of the better documented benthic communities throughout the South Pacific Ocean. Although 75 per cent of the world's coral reefs are found in the Indo-Pacific region, few long-

2.4 Fish and macro-invertebrates

Fish and macro-invertebrates occurring in coastal and shelf regions of the South Pacific Ocean range from highly resident species (e.g., cardinal fishes, Apogonidae; wrasses, Labridae), species that move relatively small distances but utilize multiple habitats during their lifespan (e.g., penaeid prawns, yellowfin bream, Acanthopagrus australis), pelagic species that roam shelf waters extensively (e.g., Australian salmon or kahawai Arripis spp., white sharks, Carcharodon carcharias), to highly migratory pelagic species that utilize shelf regions periodically or seasonally (bigeye tuna, Thunnus obesus; southern bluefin tuna, T. maccoyii). A few species are anadromous ei()iryis Tc /TT0 3-(f(-)12(426(o18 TCTd [-4((e.g., shorthead and pouch lampreys, Mordaciidae) and some are catadromous (e.g. barramundi, Lates calcarifer; short-finned eel, Anguilla australis).

Time series of indicators of populations are largely limited to species that are the focus of recreational/sport, subsistence and commercial fisheries and are subject to varying degrees of management (Bates et al. 2014). Subsis 2(e)-1steh4(n)1g( )]T(t)-4(e)-05(d6(th

A large-scale assessment of coral reef fish and invertebrate communities in 17 Pacific Island countries and territories found that across 63 sites, less than one-third of the sites had resources that were in good condition; most were in average/low or poor condition (Pinca et al., 2009). Herbivores and smaller fish were more abundant in reefs of below average condition, whereas reefs in good condition had higher biomasses of carnivores and greater numbers of larger fish (Pinca et al., 2009). More recently an assessment of the status of reef fish assemblages on fished reefs estimated that reef fish assemblages around Papua New Guinea were at a point indicating fisheries collapse (Mac Neil et al., 2015). Declines have also been observed

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eastern Australia, associated with fishing, introduced alien species and ongoing changes to the marine environment as a result of climate change and coastal development (Last et al., 2011; State of the Environment Committee, 2011; Bates et al., 2014).

Coastal waters of the tropical eastern Pacific are some of the least explored in the region (Cruz et al., 2003; Zapata and Robertson, 2007); approximately 70 per cent of fish are endemic to the region. The unique oceanographic conditions and heterogeneity of the coastal regions of Chile have resulted in high levels of endemism in many invertebrate groups (Griffiths et al., 2009; Miloslavich et al., 2011). Endemism is also high in the waters of small oceanic islands in the eastern South Pacific Ocean, approximately 77 per cent of the fish at Easter Island, 73 per cent at Salas y Gómez, 72 per cent at Desventuradas and 99 per cent at the Juan Fernández Archipelago are endemic (National Geographic/Oceana/Armada de Chile, 2011, Friedlander et al., 2013; National Geographic/Oceana, 2013). Most of the oceanic islands of the eastern South Pacific are thought to have relatively healthy biomasses of fish and macro-invertebrates, with the exception of Easter Island, where fisheries have been operating for over 800 years (Hunt and Lipo, 2011). Within the last three decades, a dramatic decrease in the marine resources of Easter Island has been observed; this is largely associated with overexploitation, increasing tourist numbers with associated increases in demand for resources, illegal industrial fishing and lack of surveillance and enforcement procedures (Gaymer et al., 2013).

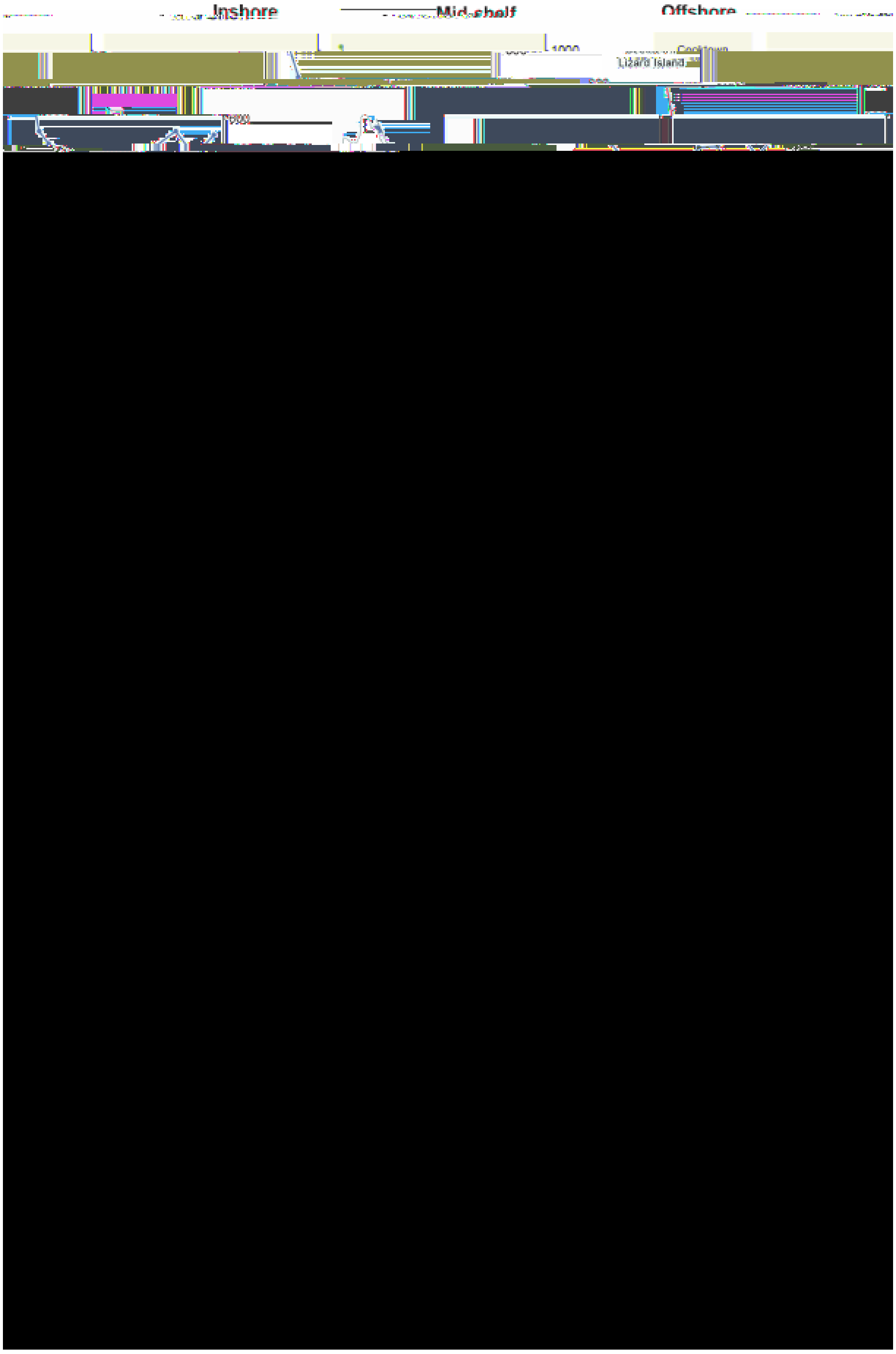

Figure 7. Time series of the abundance of some coral reef fish species in the Great Barrier Reef Marine Park 1991–2003. Taken from Great Barrier Reef Marine Park Authority (2014) and adapted from Australian Institute of Marine Science Long-term Monitoring Program (2008 and 2014)

Shallow reef habitats of the Galápagos archipelago are reported to have undergone major transformation as a result of the severe 1982/1983 El Niño warming event, resulting in local and regional decline in biodiversity, including a number of identified extinctions (Edgar et al., 2010). Artisanal fishing for lobster and fish species is thought to have magnified the impacts of the El Niño event, the grouper Mycteroperca olfax is characterized as functionally extinct in the central Galápagos region (Ruttenberg, 2001; Okey et al., 2004). Commercial fishing within the Galápagos Islands reserve has been largely banned from the area, except for artisanal fishing, which has been allowed in the reserve since 1994. The region has been subject to extensive illegal fishing for sharks, sea cucumber and a range of fish in the region and a lack of controls on or enforcement of management measures for artisanal fishing and a lack of credible assessment of stocks have resulted in over-exploitation species, including school shark, have been listed as conservation-dependent under the Environment Protection and Biodiversity Conservation Act 1999.

Recreational fisheries are subject to variable levels of assessment and monitoring and

Dugong		•		
Offshore bottlenose dolphin		•	•	
Humpback whale		•	•	
Minke whale			•	

International protection and management of saltwater crocodile populations in Australia and Papua New Guinea after periods of commercial harvesting have resulted in increases in populations to pre-exploitation levels (Thorbjarnarson, 1999; Tisdell and Swarna Nantha, 2005). Few data on the population abundances of sea snake species are available, despite substantial numbers being caught in fishing operations (e.g., Milton 2001; Wassenberg et al., 2001). What data have been collected indicate population declines (Goiran and Shine, 2013).

Most large cetaceans occurring in coastal and shelf regions throughout the South Pacific Ocean are seasonal visitors, spending large periods of time in offshore regions (e.g., Birtles et al., 2002; Hucke-Gaete et al., 2004; Olavarría et al., 2007). Of those species that historically have been subject to widespread commercial harvesting, some populations have been documented to be increasing, while the status of others in the South Pacific Ocean region is still uncertain (e.g., Baker and Clapham, 2004; Branch et al., 2007; Magera et al., 2013). Smaller coastal cetacean species, although largely lacking in population data, are considered to demonstrate varying trends: some are relatively stable and others are decreasing (e.g., Gerrodette and Forcada, 2005; Parra et al., 2006; Currey et al., 2009). Dugong (Dugong dugon) populations across the western South Pacific are considered to be declining, although estimates of abundance are lacking for most countries (Marsh et al., 1995; Marsh et al., 1999; Marsh et al., 2002 (u)19 ;Gmigu6(am)4)10.1(ar)4d(3(9)-Tosn(i)10.1pTJ 0(c climate models used to explore future changes to the global climate under emission scenarios (see Taylor et al., 2012) has identified numerous biases in ocean parameters, both within and across models. These biases are particularly evident in the tropical Pacific Ocean and are associated with difficulties in simulating sea surface temperatures, precipitation and salinity (Sen Gupta et al., 2009; Ganachaud et al., 2011). Use of a multi-model mean derived from models used in inter-comparisons considerably reduces these biases, although certain regions still retain sizeable biases, indicating systematic biases across models (Sen Gupta et al., 2009). In particular, the eastern tropical Pacific cold tongue is placed too far west and the South Pacific Convergence Zone is too elongated towards the east, resulting in biases in precipitation and ocean surface salinity, which has implications for projections of climate relating to a number of Pacific Islands. Along the Chilean shelf edge, problems with the representation of local atmospheric processes and upwelling lead to biases in cloud formation and radiative heat transfer, with flow-on impacts on ocean salinity (Randall et al., 2007; Sen Gupta et al., 2009; Brown et al., 2013; Ganachaud et al., 2013). The resolution at which most climate models are run does not take into account processes occurring in the near-coastal ocean, so pressures and associated projections derived from climate models are extrapolated from observations made offshore (Rhein et al., 2013). This is particularly problematic for projections relating to islands in the South Pacific Ocean and also for mesoscale and submesoscale processes that are important for delivering nutrients to the photic zone (Ganachaud et al., 2011). Bearing in mind the biases and the resolutions of current models, a summary of observed and projected changes to the South Pacific Ocean are presented here.

regions, because hypoxia is largely driven by eutrophication and is therefore controlled by the flow of nutrients from terrestrial origins, any increase in nutrient run-off associated with increasing agriculture or industrialization of coastal regions will also result in increasing coastal water deoxygenation (Rabalais et al., 2010; Ciais et al., 2013; see also section 3.2).

Observations of carbon concentration in the ocean demonstrate considerable

will, however, result in changes to community structure beyond the immediate effect of selective mortality caused by severe bleaching (Hughes et al., 2003).

Altered temperatures may decouple population processes of taxonomic groups that are reliant on the population processes of (an) other group(s). For example, the breeding processes of many marine species are timed to coincide with peaks in forage-species populations, whose timing is often driven by temperature. If the timing of the two is altered so that they no longer match, this will likely affect population recruitment (e.g., Philippart et al., 2003).

Figure 8.

Altered precipitation and increased storm intensity will affect the dynamics of coastal marine ecosystems through fluctuations in wave height and intensity, salinity, turbidity and nutrients. In regions where precipitation is expected to decrease, such as many Pacific Islands, these ecosystems will experience higher salinity environments, whereas those in regions where precipitation is expected to increase, such as eastern Australia, will experience fresher environments. Mangrove, seagrass and coral reef communities will be particularly prone to such changes (see Fabricus, 2005; Harley et al., 2006; Polaczanska et al., 2007).

3.2 Social and economic drivers

The South Pacific Ocean is a highly diverse region, featuring considerable variation in the social, economic, cultural and infrastructural composition of the countries and territories located within its bounds. Although climate change is considered to be one of the largest threats to marine environments over the long term, management of social and economic stressors on marine environments can be considered to be the most significant challenge over the short term (Bell et al., 2009; Center for OceanAltr b.1(d(1(s)(

Figure 9

Heritage in Danger in 2007 largely as a result of unregulated tourism development and overexploitation of marine resources (see section 5.1).

Poor management of watersheds often leads to degradation of estuaries and coastal environments (Table 2)

Ecuador have resulted in the destruction of large tracts of mangrove forest and coastal wetlands (Bailey, 1988; Martinez-Porchas and Martinez-Cordova, 2012). Operations in Chile have caused significant loss of benthic biodiversity and local changes in the physical and chemical properties of sediments have occurred in areas with salmonid farms (Buschmann et al., 2006). Pulses in dinoflagellate densities have increased and it is suggested that escaped farmed fish may have an impact on native species, although their survival in the wild appears low. In addition, the abundance of omnivorous diving and carrion-feeding marine birds in areas of aquaculture operations has increased two-fivefold (Buschmann et al., 2006).

Table 2. Social and economic drivers of change in coastal and shelf ecosystems of the South Pacific Ocean. Modified from UNEP (2006b).

DIRECT DRIVERS	**INDIRECT DRIVERS**
Habitat loss or conversion	
Coastal development (ports urbanization, tourism-related development, industria development, civil engineerin works)	Population growth; transport and enerç demands; poor urban planning and industr development policy; tourism demand; environmental refugees and interna migration
Destructive fishing practices (dynamite, cyanide, bottom trawling)	Shift to market economies; ongoing demand for live food fish, aquarium specie increasing competition associated wi diminishing resources
Coastal deforestation	Lack of alternative materials; increasi competition associated with diminishin resources; global commons perceptions
Mining (coral, sand, minerals dredging)	Lack of alternative materials; glob commons perceptions
Aquaculture-related habitat conversion	International demand for luxury item (including new markets); regional demand for food; demand for fishmeal in aquacultu and agriculture; decline in wild stocks decreased access to fisheries (or inability to compete with larger-scale fisheries)
Habitat degradation	
Eutrophication from land-based sources (agricultural waste, sewag fertilizers)	Population growth; urbanization; lack of infrastructure (stormwater, sewage systems); lack of sewage treatment; unregulated agricultural development and managemer loss of natural catchments (wetlands, etc.)
Pollution: toxins and pathogens from land-based sources	Increasing pesticide and fertiliser use; lack of regulations associated with use; lack awareness of impacts; unregulated industries

Alterations include increases in coral-eating starfish densities, leading to a decline in reef-building corals and an increase in non-reef-building species;

5. Areas of special conservation significance and associated issues of the South Pacific

5.1 World Heritage Sites

Two of the largest World Heritage sites are in the South Pacific Ocean – the Phoenix Islands Protected Area and the Great Barrier Reef. Whereas the Phoenix Islands Protected Area is comprised of largely oceanic, deep water ecosystems, the Great Barrier Reef is entirely shelf-based. Other World Heritage sites located in the South Pacific Ocean with protected marine components include the Lord Howe Island Group in Australia, East Rennell in the Solomon Islands, the lagoons of New Caledonia and the Galápagos Islands in Ecuador.

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The Great Barrier Reef is the world's largest coral reef system (34 million hectares), extending 2,000 kilometres along the eastern Australian coast. It comprises over 2,500 individual reefs and 900 islands. Declared in 1981, it was one of the first World Heritage sites. It is home to over 400 types of coral and is one of the richest areas in the world

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2010. Key threats affecting the site include changes in the identity, social cohesion and nature of the local population and community, illegal activities, tourism, visitors and recreation and the related infrastructure and management activities, systems and plans (UNESCO, 2014c).

5.2 Large Marine Ecosystems and Ecologically and Biologically Significant Areas

The South Pacific Ocean contains five Large Marine Ecosystems (LMEs), three along the eastern coastline of Australia (the north-east Australian shelf/Great Barrier Reef, the east-central Australian shelf and the south-east Australian shelf), one on the New Zealand shelf and one incorporating the Humboldt Current. The definition of these areas is based on four ecological criteria: (i) bathymetry; (ii) hydrography; (iii) productivity; and (iv) trophic relationships and definitions. These criteria provide a framework to focus on marine science, policy, law, economics and governance on a common strategy for assessing managing, recovering and sustaining marine resources and their environments (Sherman and Alexander, 1986). The approach uses five modules to measure and provide indicators of changing states within the ecosystem of each LME, including productivity, fish and fisheries, pollution and ecosystem health, socio-economics and governance. Because all of these factors have been discussed in previous sections of this chapter, details of each LME will not be provided again here.

The Strategic Plan for Biodiversity 2011-2020 developed under the Convention on Biological Diversity[2] provides a framework for reducing biodiversity loss and maintaining ecosystem services.

al., 2007). Traditional management of fisheries, which is still conducted by most national and international management agencies throughout the South Pacific Ocean, concentrates on individual fish populations strictly in demographic terms,

6.3 Integration of climate change adaptation and mitigation into marine policy, planning and management

Over the long-term, one the largest threats to coastal and marine systems within the South Pacific Ocean is climate change. Responding to the environmental and socio-economic consequences of climate change in order to maintain ecosystem services requires coordinated

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