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REGIONAL SEAS

J.E. Brodie et al:

State of the marine environment in the South Pacific Region

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SPREP Topic Review No. 40

Prepared in co-operation with

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PREFACE

The better understanding of the changing problems facing the marine environment is a continuing goal of UNEP's Ocean programme, as it provides the necessary scientific background for shaping UNEP's policy towards the protection of the oceans.

The main sources of factual information used in the assessment of the state of the marine environment are data published in open scientific literature, data available in various reports published as "grey literature" and data generated through numerous research and monitoring programmes sponsored by UNEP and other organizations.

Several procedures are used to evaluate critically the large amount of available data and to prepare consolidated site-specific or contaminant-specific reviews.

GESAMP, the IMO/FAO/Unesco/WMO/WHO/IAEA/UN/UNEP Joint Group of Experts on Scientific Aspects of Marine Pollution, is charged by its sponsoring bodies with preparation of global reviews. Reviews dealing with several contaminants have been already published by GESAMP and others are being prepared for publication. The first global review on the state of the marine environment was also published by GESAMP in 1982, and the second global review was published in 1990. [1/]

In parallel with the preparation of global assessments, the preparation of a series of regional assessments, following the general format of the second global review by GESAMP, was initiated by UNEP in 1986, with co-operation of the Food and Agriculture Organization of the United Nations (FAO) and the Intergovernmental Oceanographic Commission of Unesco (IOC). Fifteen task teams of scientists were set up, involving primarily experts from the relevant regions, to prepare the regional reports under the joint overall co-ordination of UNEP, FAO and IOC, and with the collaboration of a number of other organizations.

The present document is the product of the Task Team for the South Pacific Region. The final text of the report was prepared by J.E. Brodie, as Rapporteur of the Task Team for the South Pacific Region, with collaboration of C. Arnould, L. Eldredge, L. Hammond, P. Holthus, D. Mowbray and P. Tortell, whose contributions are gratefully acknowledged.

1/ Publications of GESAMP are available from the organizations sponsoring GESAMP.

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1. INTRODUCTION

1.1 Aims

This report is one of a considerable number prepared in different regions of the earth. The preparation of these reports was initiated by the United Nations Environment Programme (UNEP) and the Intergovernmental Oceanographic Commission (IOC) of UNESCO as contributions to the Group of Experts on the Scientific Aspects of Marine Pollution (GESAMP) review of the state of the marine environment. During their preparation, however, they have developed further into independent publications completely reviewing the state of the marine environment in the region concerned. The South Pacific report has aimed at reviewing knowledge of the marine environment in the subject areas specified by GESAMP Working Group 26 (responsible for the global review) with particular focus on the period from 1980 to 1989.

1.2 Geographic coverage

The region covered by this report includes the ocean and coastal areas associated with the states belonging to the South Pacific Regional Environment Programme (SPREP). SPREP is one of the UNEP regional seas and is in the area 25° N to 45° S and 130° W to 120° E. The region incorporates the small island states and territories of the central and western Pacific Ocean (Fig. 1). An Action Plan for the region is implemented through the South Pacific Regional Environment Programme (SPREP) and includes 25 states or territories. These are American Samoa (USA), Australia, Commonwealth of the Northern Marianas (USA), Cook Islands, Federated States of Micronesia, Fiji, French Polynesia (France), Guam (USA), Kiribati, Nauru, New Caledonia (France), New Zealand, Niue, Norfolk Island (Australia), Papua New Guinea, Pitcairn Island (United Kingdom), Republic of Marshall Islands, Republic of Palau, Solomon Islands, Tokelau, Tonga, Tuvalu, Vanuatu, Wallis & Futuna (France), and Western Samoa. In the case of territories the responsible state is shown in brackets.

Most of the members are of small land area and, with few exceptions, low population. However, since most of them consist of scattered islands they claim huge exclusive economic zones e.g. Kiribati with a land area of 690 km^2 and an EEZ area of 3.5 million km^2. The combined EEZ areas of the member states cover most of the western, central and south Pacific Ocean. Many of them are poor in terrestrial natural resources and look to marine resources for their prosperity. In the atoll countries (Tuvalu, Kiribati, Marshall Islands and parts of others) over 90% of protein requirements traditionally come from the sea (Johannes, 1977). Most of the island states and the northern half of Australia share a coastline type which has a mixture of mangroves, seagrass beds and coral reefs.

2. CHARACTERISTICS OF THE REGION

The region covered in this review varies from equatorial to the cold temperate conditions of the southern parts of New Zealand and Tasmania and has seas bordering the continental influence of Australia to those parts of the world's oceans furthest removed from continental effects viz. the mid-Pacific. The states of the region vary from the very large (Australia) to the very small (e.g. Nauru and Tuvalu). Very little can be said that is of general applicability with respect to ocean currents, winds and climatic conditions for such a vast region. Many of the island groups and the northern Australian coast are affected by consistent winds, particularly the South-East trades while also being regularly subjected to cyclones. The parts of the region close to the equator often have a monsoonal rainfall pattern while those south of about 25° S are influenced by the succession of eastward moving anti-cyclones. The entire region is periodically disturbed by

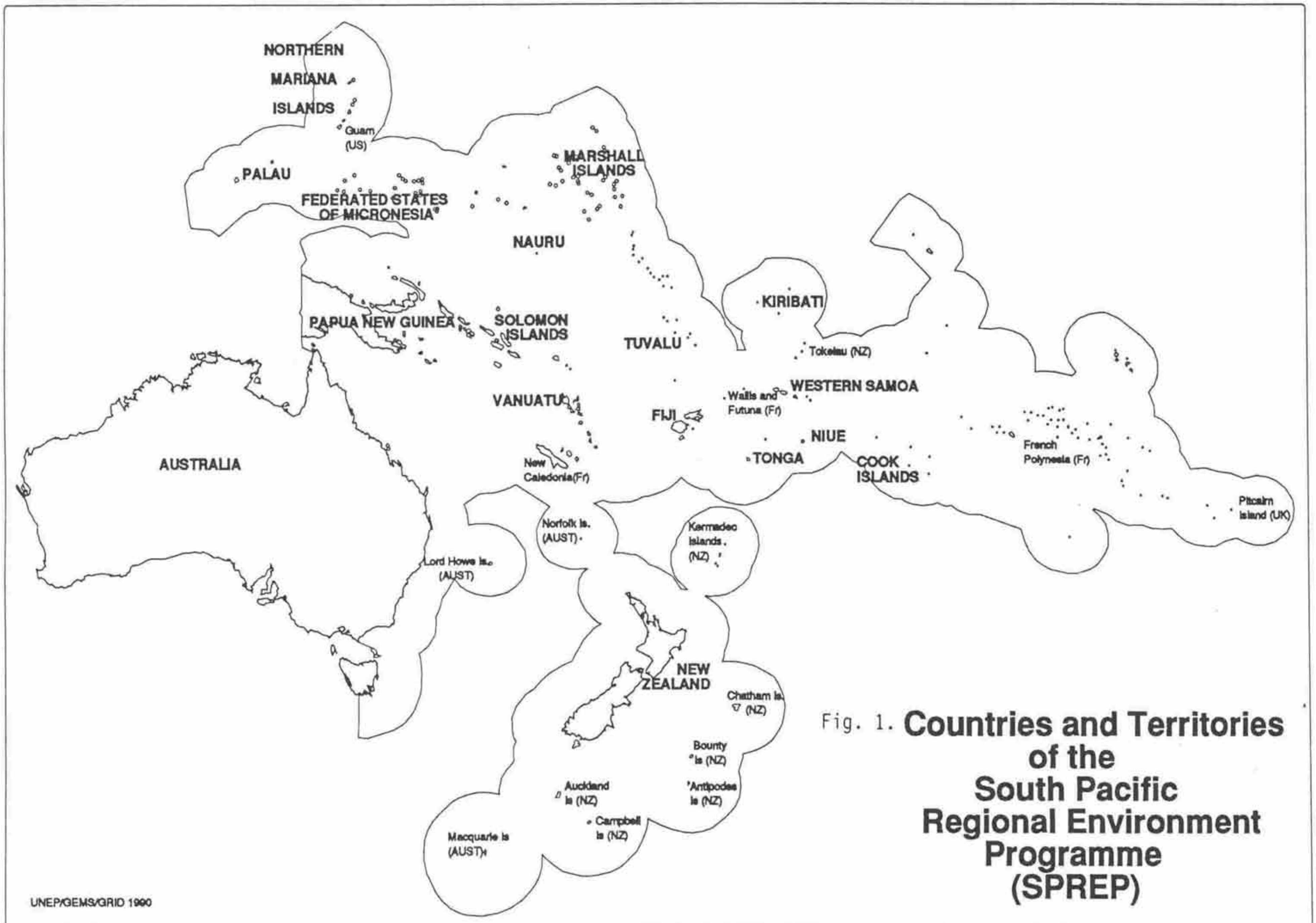

Fig. 1. **Countries and Territories of the South Pacific Regional Environment Programme (SPREP)**

the El Nino - Southern Oscillation phenomenon which can have profound effects on marine life in the Pacific (Barber & Chavez, 1983). As already mentioned most of the island states have small land areas but huge EEZ areas. These same island groups and northern Australia possess over half the world's coral reefs as well as considerable coastal areas of mangroves and seagrass beds. The coastal areas of New Zealand and southern Australia include rocky shores, sandy beaches, large coastal lagoons and the deep fiords of south western New Zealand.

At present programmes to monitor the health of the oceans in the region are of limited extent and facilities of limited capability. The member states fall into two distinct groups, those which have the facilities, personnel, expertise and funding available to mount a comprehensive long term monitoring programme (Australia, New Zealand, Guam, French Polynesia and New Caledonia) although they may not be doing so at present and the others which do not have this capacity at present. Even more obvious is the distinction in terms of development between Australia and New Zealand on one hand and the 'small island states' on the other. For convenience the discussion in this review will often treat these two groups separately. Papua New Guinea and Fiji have University research institutions which carry out limited monitoring often supported by SPREP. The Institute of Natural Resources at the University of the South Pacific in Fiji has also begun, in 1987 a programme of coastal water monitoring in selected areas of Kiribati, Tonga, Vanuatu and the Solomon Islands supported by SPREP and in association with government departments in each state but this is of limited extent at present. The French research institutions ORSTOM and LESE have well equipped laboratories and are well staffed but neither New Caledonia nor French Polynesia have regular monitoring programmes although considerable work has been done around Papeete. As a consequence of limited monitoring the hard data available for a review on the state of the marine environment is scant. Only Guam, with both its university (UOG) and well supported Environmental Protection Agency (GEPA), and some areas in Australia, New Zealand and French Polynesia have ongoing continuous marine monitoring programmes generating data which could possibly be used to detect long term changes. The University of Guam's Water and Energy Research Institute (WERI) also carries out monitoring programmes in Micronesia but these have been mainly confined to construction environmental impact assessment (Zolan et al, 1982; Clayshulte & Zolan, 1982; Clayshulte, 1983; Zolan, 1983). Projects in the rest of the region are highly localized and normally 'one off' so long term effects cannot be evaluated. Thus the data which the South Pacific region can contribute to the global review will be of a very limited nature. Much of the work and data from Australia is based on state level activity and, although uncoordinated, the amount of data available is far greater than for the other SPREP members. For this reason Australia will often be treated separately in many sections of the report.

Marine and coastal environmental research and monitoring in Australia has also been and continues to be of limited extent. Fairweather's review of coastal work (Fairweather, 1988) emphasizes gross lack of knowledge of particular Australian coastal ecosystems (saltmarshes and sandy beaches) despite continued heavy development and modification of these areas. With the establishment of the Great Barrier Reef Marine Park Authority this section of the Australian coastal seas now has long-term, comprehensive research and monitoring programmes in place, in total contrast to other coastal areas. The Australian Institute of Marine Science (AIMS) located near Townsville, has emphasized basic process research in its programmes but has not been closely involved in marine pollution work. The Victorian Institute of Marine Science (VIMS) and the Marine Science Laboratories, (MSL, Victoria) have had a continuing role in marine pollution work but restricted generally to Victorian waters while the CSIRO Division of Fisheries and Oceanography have also had a modest programme of basic marine environmental work in all Australian coastal areas. The universities, state environmental protection agencies (where these exist) and local government bodies have also been involved in marine pollution work but coordination of all this work has been almost non-existent and at present there is no system for intercalibration of results, technical meetings between agencies, interstate cooperation or planning for a coordinated marine pollution research, monitoring and prevention strategy for Australia. Australian capabilities in marine science and technology are summarized in a government report (Anon, 1989a) while laboratory capabilities in trace metal analyses are summarized by Kinsella & Willix (1985) and in organic trace analysis by Kagi (1985).

New Zealand marine pollution programmes do not suffer the lack of coordination caused by the Australian state system but a number of bodies such as the DSIR, universities, harbour boards and local government bodies are involved. Marine science in progress is summarized in Hurley (1987) and McBride et al, (1985) while the work of the DSIR Water Quality Centre is summarized in Anon (1988). A number of excellent reviews on water quality issues have been published by the National Water and Soil Conservation Authority. The preparation of a National Coastal Strategy was completed in recent years.

A number of international monitoring programmes have participants in the region. These include TOGA (the Tropical Ocean and Global Atmosphere Programme), GIPME (the IOC Global Investigation of Pollution in the Marine Environment programme) and JGOFS (the Joint Global Ocean Flux Study). With the likely accession of most states to the Convention for the Protection and Development of Natural Resources and Environment of the South Pacific Region (the SPREP convention) a more active programme to monitor and control pollution of the marine environment in this region should begin.

3. MARINE CONTAMINANTS : LEVELS AND DISTRIBUTION

3.1 Concentrations in water, sediment and biota

Most of the data available on water quality has been collected in coastal areas and has generally been associated with baseline studies and environmental impact assessments for large coastal construction projects or investigations of sewage outfalls. Thus the principal parameters measured have been bacterial and nutrient levels and general water quality indices such as salinity, turbidity and dissolved oxygen. It is only very recently that instrumentation adequate to measure trace metals, PCBs, pesticide residues and petroleum hydrocarbon residues in water or biota has become available throughout the region and the results of many initial studies are only just starting to be published. A general review of water quality in much of the region is given in Morrison & Brodie (1984, 1985).

3.1.1 Trace metals

Mercury levels in surface water in the Western Pacific fall in the range 1 to 10 ng/l (Nishimura et al, 1983) and appear to decrease from north to south. Comparison of lead levels in the North Pacific with those in the South show considerably higher elevations in the North believed to be due to anthropogenic inputs (Flegal & Patterson, 1983, Flegal, 1986). Nurnberg et al, (1983) report lead levels of 5-23 ng/l around the Galapagos Islands with copper levels in the range 30-80 ng/l and a cadmium average of 3.8 ng/l. Other essentially open ocean work includes that of Boyle et al, (1976) on cadmium levels in water and that of Duce et al, (1983, 1985, 1987), on atmospheric trace metals at Enewetak Atoll and American Samoa. Levels of heavy metals in the New Zealand atmosphere reported by Steiner & Clarkson (1985) showed no major anomalies. Studies of trace metals and the link with productivity in Australian shelf waters have been reported by Mackey (1984, 1986) and Higgins & Mackey (1987a, 1987b). The recent data on trace metals in coastal ecosystems is more comprehensive.

In Australia a number of heavy metal 'hot spots' near heavy industrial areas have been investigated. These include the Derwent River estuary near a zinc refinery (Cooper et al, 1982; Langlois et al, 1987); Port Pirie near a lead smelter (Ward & Young, 1981, 1984; Ferguson, 1983; Ward, 1987); the northern Spencer Gulf region generally (McLaren & Wiltshire, 1984); Cockburn Sound near the Kwinana industrial area (Talbot & Chegwidden, 1982); Dampier adjacent to an iron-ore loader (Semeniuk et al, 1982; Talbot, 1985); Darwin Harbour (Peerzada & Rohoza,1989; Currey,1987); Lake Macquarie near a lead-zinc smelter (Roy & Crawford, 1984; Batley, 1987); the Hunter River estuary adjacent to the steel works (Hodda & Nichols, 1986).

Port Phillip Bay with extensive surrounding industry has shown declining levels over the past 10 years or so (Fabris, 1983; Fabris et al, 1986; Hickman et al, 1984). Similarly studies at Port Kembla Harbour, near large steel works, have shown substantial reductions in heavy metal pollution from the mid 1970s to the mid 1980s (Moran, 1984). The majority of the Australian marine environment, remote from high concentrations of population or heavy industry, is considered to be relatively uncontaminated by anthropogenic materials and subject to relatively few other forms of environmental degradation (Denton & Burdon-Jones, 1986a, 1986b, 1986c, 1986d). While elevated mercury levels have been found in sharks and other large fish this is thought to be natural (Kyle, 1987, Thomson, 1985).

'Heavy Metals in the New Zealand Aquatic Environment: A Review' (Smith, 1986) comprehensively reviews the New Zealand coastal situation and also finds such contamination to be confined to 'hot spots' (Hunter & Tyler, 1987) while the general coastal environment is relatively undisturbed (Smith, 1985). More generally the publication 'Sources of Marine Pollution around New Zealand' (Ridgway & Glasby, 1984) has sections on municipal sewage, thermal effluent, oil pollution, heavy metals and other chemicals, litter and radioactivity. In abstract they claim - "The level of marine pollution around New Zealand is low relative to that encountered around other countries, particularly the industrialized nations of the Northern Hemisphere. Nevertheless, there is evidence of pollution in some semi-enclosed coastal waters (e.g. sounds, estuaries, harbours), particularly those close to urban centres where point discharges of municipal sewage and industrial effluent occur". More recently work around Auckland's Manukau Harbour (Roper et al, 1988), Coromandel Peninsula (Livingston, 1987) and Wellington Harbour (Stoffers et al, 1986) revealed considerable levels of sediment contamination by heavy metals, particularly lead, zinc, copper and cadmium.

Trace metal levels in water, biota and sediment, in the island states are summarized in Tables 1, 2 and 3. Elevated levels are confined to harbour and urban coasts and to areas affected by mining discharges and urban runoff (e.g. Guam, Zolan, 1981). Mercury levels in water and fish from Kosrae (FSM) are reported in Clayshulte & Zolan (1985).

3.1.2 Tri-butyl tin residues

While tri-butyl tin (TBT) based anti-fouling paints have been in use in the region for some time, it is only recently that residues in the marine environment have been measured. Background levels of TBT in water around Sydney have been shown to be <30 ng/l while levels near marinas averaged 300 ng/l. Shell deformations in the commercial oyster (<u>S. commercialis</u>) have been noted in the area and affected oysters shown to have TBT levels of 200-600 ng/g while unaffected oysters have levels of 4-18 ng/g (Ellis, 1988; Batley et al, 1988, 1989a, 1989b). The use of

Table 1. Trace metal levels found in coastal surface waters

Location	Hg	Cd	Pb	Cu	Zn	As	Ni
Vanuatu							
Vila Harbour[f] μg/l						<5	
New Zealand							
Taranaki Bight[g] μg/l				0.15			0.15
Otago Harbour[h] μg/l		<0.1		0.10-0.20			0.33
Taieri Estuary[i]				0.06-0.16			0.12
Papua New Guinea							
Bougainville Is.[d] East coast μg/l		<1	<1	1-11	<1-1		
West coast μg/l		<1	<1	2-14	1-3		
Misima Is.[e]		0.13-0.42	0.2-0.8	0.5-0.93	0.24-0.9		
French Polynesia							
Papeete Port[a,b,c] μg/l	0.23-1.7		1.3-3.8	1.7-3.5			

a. Fraizier et al, 1985
b. Debie et al, 1982
c. Denardi et al, 1983
d. BCL, 1986
e. NSR, 1987
f. Gangaiya & Brodie, 1986
g. Hunter, 1981
h. Dickson & Hunter, 1981
i. Hunter, 1983
j. Fraizier & Franck, 1985

Table 2. Ranges of trace metal levels found in coastal biota

Location	Tissue	Hg	Cd	Pb	Cu	Zn	As	Cr	Se
Vanuatu									
Vila Harbour									
Bivalves[d], mg/kg ww	Whole						2.4-6.5		
Fish[d], mg/kg ww	Flesh						0.37		
Fiji									
Vitogo R. estuary									
Bivalve[a], mg/kg ww	Whole	0.01-0.04	0.03-0.21	0.12-0.18	1.7-3.0	6-10	0.5-0.68	0.34-0.44	0.15-0.44
Teidamu R. estuary									
Bivalve[a], mg/kg ww	Whole	0.02-0.04	0.04-0.06	0.09-0.15	1.5-2.5	7.3-9.0	1.6	0.27-0.78	0.28-0.33
New Zealand									
Northern North Island									
Oysters[e], mg/kg ww		<0.01-0.07	0.15-46	0.20-1.0	5-42	74-352	1.1-3.6	0.07-1.0	
East coast South Island									
Fish[f], mg/kg ww		0.07-0.31							
West coast South Island									
Fish[f], mg/kg ww		1.25							
Bay of Islands									
Fish[f], mg/kg ww		0.99							
Chatham Islands									
Fish[f], mg/kg ww		0.32							
Coromandel Peninsula									
Oysters, mussels, pipis, cockles[l] mg/kg ww		0.01-0.15	0.02-8.0	0.02-0.62	0.35-38	7-520	0.2-3.2		
Finfish[l] mg/kg ww		0.02-1.1	0.01-0.03	0.03-0.18	0.12-0.75	0.8-5.1			
Papua New Guinea									
Port Moresby									
Oyster[b,g], mg/kg dw	Whole		0.04-3.3	0.1-3.3	83.731	1140-6100			
Mussel[g], mg/kg dw	Whole		0.03-0.9	0.3-0.9	15-58	15-231			
Clam[g,h] mg/kg dw	Muscle		0.7-9.9	0.2-3.1	0.3-52	5.3-2.1			
Bougainville									
East coast fish[c], mg/kg ww	Flesh	0.03-0.4	<0.01-0.10	<0.1-0.3	0.3-0.7	3-5	0.4-4		
West coast fish[m,j], mg/kg ww	Flesh	<0.02-0.3	<0.01-0.02	<0.1-0.7	0.2-0.7	3-7	0.2-3		
West coast fish[j], mg/kg ww	Liver	n.d.-0.28	n.d.-5.2	n.d.-5.2	n.d.-110	n.d.-73			
Morobe Coast									
Oyster[k], mg/kg dw	Whole			2.4-15	n.d.-375	350-3750			

a. Gangaiya et al, 1986
b. Haei & Baria, 1987
c. Powell et al, 1981
d. Gangaiya & Brodie, 1986
e. Winchester & Keating, 1980
f. Van den Broek et al, 1981
g. Balat, 1982
h. Baria et al, 1987
i. BCL, 1984
j. BCL, 1986
k. Balat, 1987
l. Livingston, 1987

Table 3. Ranges of trace metal levels found in coastal sediments

Location	Extract	Hg	Cd	Pb	Cu	Zn	As	Cr	Ni	Se
Vanuatu										
Vila Harbour[c], mg/kg	Total						<0.4-0.9			
New Zealand										
N. Island Harbours & Estuaries[f] means, mg/kg	Total			43	21	143		59	12	
S. Island fiords & Sounds, means, mg/kg	Total			35	21	84		64	28	
Wellington Harbour[e], mg/kg	Total			26-6740	15-216	55-2270		39-315	10-118	
Manukau Harbour[h], mg/kg	Total		0.02-0.26	10-60	15-95	80-300			10-15	
Papua New Guinea										
Purari estuary[d], mg/kg		0.09	<0.1	11	44	85				
Empress Augusta Bay[g], mg/kg					25-1500					
French Polynesia										
Papeete Port[a], mg/kg	Total	0.035-0.54		0.63-536	2.6-400			21-82		
Fiji										
Vitogo estuary[b], mg/kg	Total	<0.2	1.1-2.2	6.8-10	82-150	54-220	1.4-14	35-100		<0.2
	Weak acid	<0.2	<0.2	<2	7-42	7.5-13	<0.1	10-30		<0.2
Teidamu estuary[b], mg/kg	Total	<0.2	1.7-2.9	7.5-9.0	59-78	69-100	1.8-13	51-95		<0.2
	Weak acid	<0.2	<0.2	<2	13-16	9.4-13	<0.1	18-21		<0.2

a. Fraizier et al, 1985
b. Gangaiya et al, 1986
c. Gangaiya & Brodie, 1986
d. Petr, 1980
e. Stoffers et al, 1986
f. Stoffers et al, 1983
g. BCL, 1986
h. Roper et al, 1988

TBT is now restricted in New South Wales and Victoria and other states may follow in time. Its use within the Great Barrier Reef is monitored by GBRMPA particularly around marinas. Interest in TBT in Australia was highlighted by the conference held in 1988 on this topic (Holmes, 1988).

Around Auckland elevated levels of TBT have been found in water, sediment and bivalves, with levels in the oyster Crassostrea gigas of up to 2,200 ng/g and a notable correlation between TBT body burden and shell thickening (King et al, 1989). Restrictions on the use of TBT in New Zealand were introduced in 1989 restricting its use to vessels over 25m in length and only in slow-release formulations.

3.1.3 PCBs and chlorinated hydrocarbon pesticides

Most regional data on this topic comes from Australia. An overall view of PCB levels and disposal in Australia is given by Richardson (1985a, 1985b). Smillie & Waid (1985) reported the existence of a few data on organochlorine and PCB levels in the fish Arripus georgianus from Western Australia. In all cases levels were considered low (4-34 ppb). Richardson & Waid (1980, 1983) have reported on levels of PCBs in the mussel Mytilus edulis and abalone Haliotis sp. from Port Phillip Bay, Corio Bay and Bass Strait. Concentrations of up to 600 ppb were reported from Corio Bay and Hobsons Bay. Levels in Bass Strait were found to be very much lower. Subsequent studies by Murray (1987) indicated that PCB levels in biota from Hobsons Bay were similar to the earlier samples but that levels in biota from Corio Bay had decreased. Concentrations were generally between 10-50 ppb in Bass Strait except for penguins (194 ppb) which have a high lipid content and therefore the ability to accumulate PCBs. In Port Phillip Bay, levels of PCBs in fish ranged from 4-400 ppb. Various organochlorine pesticides have been detected in a range of biota from Port Phillip Bay and Bass Strait (Richardson et al, 1987). Maximum levels of DDT were 3461 ppb in blubber of the seal Arctocephalus, but Lindane, Hexachlorobiphenyls, DDT, DDE and Dieldrin in fish were relatively low (2-32 ppb).

Smillie & Waid (1985) summarized data on PCBs and organochlorines, particularly DDT and Lindane, in the Great Barrier Reef. Levels of PCBs in reef biota are similar to or less than concentrations found in biota from nonpolluted environments elsewhere in the world, except for sharks which contained concentrations ranging from 6-85 ppb. PCBs are found at higher levels in some primary producers (clams and soft corals) than they are in other biota. These data contrast with data from Olafson (1978) who did not detect PCBs. Organochlorine pesticides (e.g. DDT, DDE and Lindane) as well as other unidentified organochlorines were detectable but at very low levels. Smillie & Waid (1985) also reported that pesticide residues were not detectable in biota from the Gulf of Carpentaria in Northwest Queensland and that PCB concentrations in fish were very low (3-25 ppb). Dyall & Johns (1985) suggest the organochlorine pesticide residues (principally Lindane) they detected in GBR sediments moved into the GBR by sediment transport from rivers and that this was the principal source of these compounds in the area.

Shaw & Connell (1980a, 1980b, 1982, 1984) reported detectable levels of PCBs in biota sediments and waters of the Brisbane River estuary. Levels in biota such as seabirds and fish ranged from 2-8 ppb. Data collected in the Brisbane River estuary and associated creeks indicate a trend towards reduced concentrations of PCBs in waters and sediments between 1976 and 1983 (Water Quality Council of Queensland Annual Reports 1976-1983). Levels in sediments during the early part of that period were up to 350 ppb but by the end of the period were on average 10-100 ppb.

New South Wales data on PCBs (McMahon, 1974; Woollard & Settle, 1978; SPCC, 1979; Richardson, Smillie & Waid, 1987) suggest declining levels of PCBs in biota such as fish over the fifteen years represented by these studies. A summary of data on various pesticides in marine biota is given by Scribner (1987). Levels of DDT and Dieldrin were generally low with average values around 1 ppm or less.

In New Zealand levels of pesticides in farmed oysters have been examined (Winchester & Keating, 1980) while studies in Manukau Harbour of organochlorine contaminants in sediments (Fox et al, 1988) found significant PCB levels and pesticide levels ranging up to 2.3 ng/g total DDT, 2.0 ng/g total HCH, 0.5 ng/g Dieldrin and 5.3 ng/g total chlordane. In French Polynesia recent studies on coastal waters in Tahiti reported levels of chlorinated hydrocarbons below the detection limit (Fraizier & Debiard, 1985) in contrast to early studies which had shown elevated levels of heptachlor (30 to 170 ug/l) (De Nardi et al, 1983).

In Papua New Guinea studies by the University (UPNG) have been conducted to determine chlorinated hydrocarbon residues in marine animals. Low residues of DDT, Lindane and others have been found in animals sampled from the Purari River delta. In fish samples, residues up to 8 ug/kg wet weight have been found and levels in salt water crocodile flesh up to 24 ug/kg. Residues in marine bivalves are very low. In the mangrove oyster DDT-R residues range from 19-225 ug/kg dry weight with very low levels of HCB, lindane, heptachlor, heptachlor epoxide and Dieldrin. DDT residues in the mud clam Geloina sp. are much less, in the range n.d. -10 ug/kg wet weight (Mowbray, 1986a and 1988).

Levels of PCBs and chlorinated hydrocarbon pesticides in open ocean waters of the Pacific have been published by Harding (1986), Tanabe & Tatsukawa (1981, 1986) and Tanabe et al, (1982). There is a feeling (Goldberg, 1983) that increased DDT levels in the southern Pacific and Indo-Pacific are derived from increased usage in the Southern Hemisphere. Atlas & Giam (1981) reported on the global transport of organic pollutants and concentrations near Enewetok.

Production and use data on pesticides in the Pacific island region has been exhaustively reviewed by Mowbray (1986a, 1988).

3.1.4 Petroleum hydrocarbons

Levels of petroleum hydrocarbons and PAHs in Western Australia were reported by Alexander et al, (1982) to be of the order of 1 ppb in water samples, while levels in mussels were of the order of 50 ppm for persistent, branched and cyclic alkanes, and 5 ppm for higher molecular weight PAHs (Naphthalenes etc).

The level of petroleum hydrocarbons and PAHs in sediments and biota (principally the giant clam Tridacna maxima) were found to be extremely low at several locations on the Great Barrier Reef (Smith et al, 1984, 1985, 1987; Coates et al, 1986). Even in areas of high human activity such as harbours and tourism destinations, levels remained very low.

Burns & Smith (1982), Bagg et al, (1981) and Smith & Maher (1984) reported on levels of PAHs in water and sediment from Port Phillip Bay, Corio Bay (a coastal estuary), Western Port Bay, Mallacoota and Bass Strait. The first two locations had elevated levels of PAHs (up to 7 ppm) but Bass Strait and Mallacoota Inlet were virtually pristine environments with less than 1 ppb. Hammond & Hart (1984) reported that hydrocarbons were below detection limits in Bass Strait seawater. In a more recent study Murray (1987) has shown reduced levels of hydrocarbons in sediments from Corio and Hobsons Bays (within Port Phillip) compared to earlier studies. Levels of hydrocarbons in sediments of Manukau Harbour, New Zealand ranged from 30 mg/kg to 380 mg/kg (Roper et al, 1988).

3.1.5 Radioactivity

There is no known dumping in the region at present since the proposed Japanese plan to dump low level waste in the northern Pacific (Branch, 1984) has been shelved and proposed dumping of obsolete nuclear submarines by the USA also not yet started (Branch, 1984). No quantitative data showing contamination of marine resources by the French underground tests at Mururoa have been produced (UNEP, 1984). Concern has been expressed at longer term geological problems and possible escape of radionuclides at Mururoa (Atkinson et al, 1983) and opposition to the tests by neighbouring states continues to be expressed. None of the island states at present has laboratory facilities capable of monitoring radioactivity in water, air or biota. Many Pacific islands were used for atmospheric nuclear tests including Bikini and Eniwetok in the Marshall Islands, Christmas in Kiribati, Mururoa in French Polynesia and Johnson Island (US) (areas of Johnson are also contaminated with pesticides and dioxin and it is also used as a store for nerve gases). The continuing story of decontamination attempts on Bikini and Eniwetok are well documented (Maragos, 1986).

The New Zealand National Radiation Laboratory runs an environmental monitoring service which covers a number of Pacific island stations as well as those in New Zealand (National Radiation Laboratory, 1987). Total beta activity in air is monitored at two sites in New Zealand and one in the Cook Islands; total beta activity in rain at four New Zealand sites and one each in Western Samoa and Tonga and two in the Cook Islands; strontium-90 in rain at nine New Zealand sites and one each in Fiji and the Cook islands and strontium-90 and caesium-137 in milk at nine New Zealand sites. In 1986 the total beta activity in air averaged 0.07 m Bq m^{-3}; the average strontium-90 deposition for the year was 0.2 M Bq km^{-2}; strontium-90 in dairy milk ranged from 0.014 to 0.062 Bq gCa^{-1} and caesium-137 ranged from <0.04 to 0.86 Bq gK^{-1}. Emissions from the damaged Chernobyl nuclear reactor were not detected.

Australian uranium mines are stringently monitored for radioactive and other releases but are all well inland and not considered to affect the marine environment (Supervising Scientist, 1987).

3.2 Transport and fluxes across boundaries

Studies of airborne particulate matter transported from the continental margins into the Pacific have been underway during the period of this review and some results are now available. These include data on trace elements (Duce et al, 1983; Arimoto et al, 1987), nitrate (Huebert, 1980), sulphate and nitrate (Prospero et al, 1985; Saltzman et al, 1985, 1986) and selenium (Duce et al, 1987).

There is considerable interest in the region in coastal sediment and nutrient transport, the link with inland watershed development and effects of increased sediment and nutrient loadings on coral reefs. This has been manifested recently in concern over the long term effects on the Australian Great Barrier Reef of mining discharges from the Ok Tedi gold and copper mine on the upper Fly River in Papua New Guinea (McGhee, 1985; Hammond, 1986, 1987; Dent, 1986). Significant damage to Fijian reefs by sediment discharges due to poor watershed management have been recorded but few quantitative studies have been done (Ryland et al, 1984; Lal, 1984). Sediment distribution and links with mining discharges are being monitored by ORSTOM in the south-west lagoon of New Caledonia along with circulation and biota studies. The effects of sediment on coral growth has been quantified by Dodge et al, (1974) and Bak (1978).

There is limited data on fluxes of contaminants either on the large scale or the small scale in Australian waters. In the Great Barrier Reef region there is some evidence of flux of contaminants across the Great Barrier Reef lagoon to the reef tract particularly in the northern section (Wolanski et al, 1984; Harris, 1988; Gagan et al, 1987) but levels of contaminants in water, sediments and biota in the reef tract are extremely low (Dutton, 1985; Hopley, 1988; Wolanski et al, 1984; Coates et al, 1986). The northern shelf is narrow, terrigenous input is high and the lagoon is probably the final resting place of terrestrially derived contaminants. Possible effects of inland activities eg dams, land clearance and particularly agricultural chemical usage on the GBR have been investigated for one catchment (the Barron) by Valentine (1988). He notes the dramatically increasing fertilizer use and possible significance in downstream marine receiving waters. Johns et al, (1988) note that although the bulk of terrigenous organic matter is confined to 10 km of land near Cairns, traces of the material can be detected in reef lagoon sediments. However atmospheric flux has been considered as a pathway for PCBs to enter the Great Barrier Reef waters. The large scale movement of nutrients from the Coral Sea into the Great Barrier Reef lagoon has also been measured (e.g. Airey, 1986; Andrews & Gentian, 1982; Andrews, 1983). Data from a long-term monitoring site at Cape Grim in Bass Strait (Andreae et al, 1984) indicate little evidence of flux of anthropogenic organic compounds into pristine waters from the atmosphere. At smaller scales there is evidence of flux of contaminants into the marine environment. Ward & Young (1981) considered atmospheric deposition of Cd might explain patterns of distribution of Cd in sediments at Port Pirie. Their data was disputed by Ferguson (1983). The effect of stream discharges on local concentrations of contaminants was illustrated in Hobsons Bay, Port Phillip Bay, by data on Zn which is found at much higher concentrations after rainfall.

3.3 Data validation and management

There is increasing participation by regional laboratories in intercalibration and intercomparison exercises, especially those promoted by IOC and UNEP. A number participated in the recent IOC trace metals exercise coordinated by Topping involving WESTPAC laboratories. Some island laboratories participate in the New Zealand CHEMAQUA programme, in which the New Zealand DSIR distributes water samples for comparison analysis. Guam EPA is linked into the USEPA quality assurance programme. However a much more intensive programme is needed as results of intercomparison exercises have highlighted (Topping, 1984, 1986).

In Australia interlaboratory comparisons and calibrations for heavy metals in seawater were reported by Major & Pettis (1978) and by Bruton et al, (1984a). In general these comparisons suggested that analytical methodologies in Australia were inadequate and required upgrading. Significant differences in results of analyses of spiked seawater were found between most of 19 participating laboratories. A total of 15 Australian laboratories have been identified by Kinsella & Willix (1985) as capable of and willing to participate in quality assessment exercises in future. Interlaboratory calibration exercises for metals and petroleum hydrocarbons in marine tissues and seawater conducted by Bruton et al. (1984a, 1984b, 1984c) indicated that significant errors arose during handling and digestion of samples, that there was inconsistency in analytical methods used and that real problems exist in determining trace metals at sub-ppm levels. Kinsella & Willix (1985) indicate there are 25 Australian laboratories capable of and willing to participate in interlaboratory exercises for metals in marine tissue. There have been no detailed interlaboratory comparison exercises measuring petroleum hydrocarbons and polycyclic aromatic hydrocarbons (PAHs) in seawater or marine tissues. Surveys in 1979 (Bruton et al, 1984c) indicated that there are few laboratories with capability for accurately measuring these substances. Kagi

(1985) reported that there are no laboratories routinely measuring petroleum hydrocarbons or PAHs. Murray (1987) reported that poor precision of hydrocarbon analyses means that differences of less than 30% between samples cannot be considered. Kagi (1985) reported that there are many laboratories engaged in routine analyses of organochlorines and PCBs. However there has been no laboratory intercalibration exercise conducted for organochlorines or PCBs in Australia. There was no capability for trace analysis of polychlorinated dioxins (PCDDs) and polychlorinated furans (FCDFs).

4. HUMAN ACTIVITIES AFFECTING THE SEA

4.1 Disposal of urban and industrial waste waters

Problems associated with the disposal of sewage and uncontrolled industrial discharges are increasing in the region. Although the island industrial sector is small, the almost complete lack of effective environmental legislation and monitoring exacerbates the problems as does the reliance of a large section of the population on coastal resources such as shellfish. The few published reports on studies which have measured coliform levels in shellfish and shellfish growing waters near urban areas in the Pacific islands, have recorded high levels which would not meet international standards (Johannes et al, 1979; Borja & Wood, 1986; Kimmerer & Walsh, 1981; Gangaiya et al, 1986; Louis, 1981; Yuen, 1980; CDHC, 1985). These reports and others reporting sewage pollution (Maragos, 1986; Haddock, 1987) come from Tarawa, Fiji, New Caledonia, French Polynesia, Tonga, Vila, Guam, Truk, Majuro and Saipan. High rates of viral hepatitis and the possibly associated liver cancer are found in many of the region's states and the possibility of shellfish transmission is being investigated. However the lack of easily usable methods for monitoring viruses in water and shellfish is hindering this work.

About 60% of New Zealand's community sewage is discharged into coastal waters. There are 32 major outfalls, 13 of which discharge waste water after secondary treatment (Callaway, 1986). However, pollution from domestic, urban and industrial waste disposal around the NZ coast is generally low. The dynamic nature of New Zealand's coastal environment effectively disperses all discharges with the exception of some estuarine ones. Nearly all of the few biological studies to date indicate that effects around ocean outfalls occur within a few hundred metres of the discharge (Smith et al, 1987). The number of cases of disease related to sewage contaminated shellfish is small (Wilcox, 1985; Downey et al, 1986) and health risks associated with swimming in the vicinity of outfalls said to be low (Fox, 1985), even if faecal bacteria and enteric viruses have been detected in waters and sediments near ocean outfalls (Simmonds et al, 1983; Lewis et al, 1985; Loutit & Lewis, 1985). Apart from their social and cultural unacceptability, waste discharges may not pose any major problems to human health or marine biota. Metal concentrations, toxic substances and enrichment agents are not problems either.

Marine pollution around New Zealand is of concern not so much because of its threat to biota or human health, but because of its aesthetic impact and cultural offensiveness. These subjective concerns are not based on technical grounds but they are concerns all the same. There is a growing awareness in New Zealand of the spiritual values the indigenous Maori people place on all waters including marine. These values are being accorded prominence in legislation, planning and other aspects of waste management strategies.

In Australia sewage disposal is a major problem in most of the larger cities with lack of adequate funding over many years leading to serious coastal pollution in many cases. The prime example is Sydney where sewage from a population in excess of three million is discharged with only primary treatment (Browne, 1986) from shoreline outfalls and grossly pollutes a number of the city's famous beaches. In addition to illness among swimmers (Austin, 1989) shoreline trees have died from detergents in the seaspray and fish caught near the outfalls have been shown to contain high levels of trace metals, pesticides and microorganisms (Sweeney, 1989; McLean et al, 1989). A A$300 million dollar scheme to shift the outfalls 2-3 km offshore is now planned but the effluent will still only receive primary treatment. A number of other major Australian cities have coastal outfalls with only primary treatment (e.g. Geelong) but there are generally plans to improve treatment of most of these. Ocean outfalls of industrial wastes are also common with notorious cases in Tasmania from an electrolytic zinc refinery, a paper mill and a titanium dioxide plant. Some thermal discharges from power stations have also caused ecological changes in enclosed estuaries and lagoons (e.g. Port River estuary, Thomas et al, 1986).

Fish kills due presumably to toxic chemical releases are also common in the region but with the lack of both a governmental system able to organize investigations and adequate laboratory facilities the causative agents are not generally discovered. The coastal area around Suva, Fiji has one major fish kill per year on average but in no case has a causative agent been positively identified. In one case the mammalian poison sodium fluoroacetate (1080) which was being used as a rat bait in drains was implicated but no effective action was taken to prove or disprove this. In Australia fish kills occur around an area used for disposal of 'dunder' from a molasses to alcohol distillery near Mackay, Queensland but action has been slow to investigate and solve this long standing situation (Sadler, 1989).

4.2 Development of Coastal Areas

The loss of mangrove communities, seen as nursery areas and protective zones in cyclones is of immediate concern to island governments. A number of them are at present developing mangrove management plans (e.g. Fiji) as well as more extensive coastal zone management plans (e.g. the Commonwealth of the Northern Marianas, Chesher, 1986). The building of causeways in Tarawa (Kimmerer & Walsh, 1981), Vila, Vanuatu (Naidu et al, 1989) and Noumea (Le Roux, 1978), leading to changes in tidal flows and lagoonal water residence times, has had significant effects on nutrient and plankton levels. In the light of the delicate relationship between nutrient levels and coral reefs (Birkeland, 1987) long term impacts can be expected.

Coastal road building leading to sedimentation of adjacent fringing coral reefs has been noted in Fiji (Lal, 1984) and is the subject of an intense controversy in Australia in the Daintree area (Ayling & Ayling, 1987b). The studies of Randall & Birkeland (1978) in Guam have also showed significant loss in complexity of coral communities with increasing sediment load from adjacent rivers. The more general relationship of coral reefs and their environment has been examined by Thomassin & Masse (1985) and the possible impacts of coastal land development on the Great Barrier Reef by Bennell (1979).

Similar concerns have been expressed on the small islands of Micronesia over airport runway construction and the tendency to infill the lagoon (Maragos, 1986). The fragmented nature of the nickel deposits in New Caledonia has led to numerous harbour developments around the coast. The Noumea harbour has involved construction of extensive artificial shorelines while slag wastes from the processing plant are used to fill nearby mangrove and estuarine areas (Benezit, 1981). Harbour expansion at Touho, Tiabarama and Hiengene on the east coast is underway. In Palau plans for new marinas, hotels, artificial islands and oil drilling all involve the coastal zone and have generated concern.

New Zealand with 12 major and many minor ports has a system of evaluation of major developments by environmental agencies. Areas of attention include potential impacts on flora and fauna, habitats, recreational values, scientific values and indirect or follow-on effects including increased shipping traffic through recreational areas, wave erosion and the possibilities of pollution through fuel and oil spills. Public input is significant in many cases and can have a large influence on the final outcome. The New Zealand marine environment, because of its accessibility and relatively unmodified natural state, is a significant tourist attraction allowing the opportunity for many water based activities. With the population located predominantly coastally, there is a high ownership of boats for recreational and commercial purposes (fishing, tourism, etc). Pressure on the coastline and marine environment is gradually increasing. Conflicts exist between the various water based activities and these require adequate planning. New Zealand laws controlling the erection of structures on the foreshore and seabed and the filling in of tidal lands by reclamation are being reviewed and tightened. It will be necessary for proponents to establish (in areas outside commercial port boundaries) that the development is justified, that no alternative areas of dry land are available and that conservation values are not unacceptably compromised.

Concerns over erosion, siltation, water pollution, algal blooms and fish kills associated with large scale residential canal development have been expressed in Australia (Catlan, 1986; Nuttall & Richardson, 1987; Cosser, 1989; Morton, 1989). Coastal over-development is now of concern to many groups, in particular, professional fishermen's associations who see destruction of coastal habitats leading to loss of fish stocks. Other problems have emerged from large scale building activity on coastal dunes and subsequent erosion and massive programmes to protect the shoreline (Goldin, 1986). Building has also occurred on environmentally sensitive areas such as turtle hatcheries (Mon Repos Beach, Queensland).

The use of coastal areas for aquaculture is leading to controversy in some states. These are often built after removal of mangroves and increase the pressure for development of such areas. Introduced fish or crustaceans may be cultured in them and after escaping into nearby coastal ecosystems cause problems there. In Tasmania permits have been given to cull seals, normally a protected species, which are claimed to interfere with salmon farming. In New Zealand there is enormous potential for marine farming with excellent sites and environmental conditions. Species farmed include Pacific oyster (Crassostrea gigas), green lipped mussel (Perna canaliculus), paua or abalone (Haliotis iris), salmon (Oncorhynchus tshawytscha) and seaweed species. Marine farming is restricted to sheltered bays and inlets which brings conflict when sited adjacent to, or in, high natural value areas. A policy for salmon cage farming has recently been developed following concerns about the visual, physical and biological impacts of this activity. Marine farms and facilities constitute a threat to marine mammals which can become entangled trying to reach the farmed stock. Abandoned or lost equipment also presents a hazard. However, the main impacts from marine farming activities are not pollution but aesthetic and conflicts over space (Hickman, 1981).

4.3 Manipulation of hydrological cycles

In the Pacific islands there are no large dams and while some concern has been expressed over possible downstream effects of small dams built recently (Gibbons & Brodie, 1985), no serious problems have been noted. Although Australia has many large dams most of these are on rivers which had little discharge into the sea (eg those on the Murray-Darling system) or are so recent that long term effects on the marine environment have not yet been detected (eg the Burdekin dam).

Considerable problems have resulted from changes such as widening and deepening of the entrance channels to coastal lakes and lagoons leading to salinity changes in these water bodies and dramatic ecological change. The case of the Gippsland Lakes is notable (Anon, 1986a) where death of reeds, shoreline trees and seagrass has led to shoreline erosion.

4.4 Other land use practices

In New Caledonia the clearing of forests and burning of grasslands for grazing and agriculture have probably accelerated erosion and subsequent sedimentation at nearshore areas, but there is little data (Iltis, 1979). Many Australian estuaries and nearby areas are also suffering from increased sedimentation resulting from watershed erosion after clearing and agriculture (Hodgkin, 1988; Arakel et al, 1989; Gourlay & Hacker, 1986; Miller, 1985). Similar problems have been noted in New Zealand (Wilcock, 1986; Hume & McGlone, 1986). Beach sand mining for rutile and zircon minerals has been a controversial issue in Australia for many years with arguments concentrated on the ability of mining companies to regenerate coastal forest after mining has occurred (Unwin, 1986).

4.5 Disposal of contaminated sediments, mine tailings and industrial solid wastes

There is little direct dumping of contaminated sediments or industrial wastes at sea in the region. However the Maritime Services Board of New South Wales (Australia) is involved in a programme of dumping dredge spoil at sea. Samples of sediments to be dumped and water samples from the plume are analysed for heavy metals, hydrocarbons and organochlorines as part of the permit granting process. The results (Batley and Lilley, 1987) show insignificant release of trace metals and hydrocarbons to the water column despite elevated concentrations of lead, zinc and hydrocarbons in some sediment samples. Similar dumping of dredge spoil occurs near other ports eg Townsville but with no monitoring programmes to assess environmental impact. Dumping of jarosite waste occurs off the eastern coast of Tasmania and monitoring has taken place since 1973 but to date no measurable environmental impact has been detected. Tuna process sludge has been authorized for deep ocean disposal by the USEPA in American Samoa (Maragos, 1986).

The problems of mine tailings disposal are of great concern in Papua New Guinea and to a lesser extent New Caledonia and Fiji. The massive changes to the nearby coastal environment associated with the Bougainville copper mine have been documented but much of the quantitative data is confidential. While levels of copper in the sediment of the plume of the Jaba River (which discharges the mine tailings from the Bougainville Panguna mine) are high, ranging up to 1500 mg/kg, heavy metal residues in fish muscle from the east and west coasts of Bougainville appear to be low, not differing significantly from each other.

It is estimated that 400 million tonnes of tailings have entered Empress Augusta Bay via the Jaba River in 15 years and have formed a 7km^2 delta and have affected 100 km^2 of the sea floor. Tailings entering the bay contain 1000 mg/kg copper. The streams containing tailings before entering the bay, contain 5-10 mg/l of dissolved copper. This rises to 10-25 mg/l of copper in the plume. The levels decrease significantly away from the mouth. The Jaba River into which the tailings are disposed is 'dead', and fish populations in its tributaries are reduced. Studies by Bougainville Copper Limited on the impact of the disposal of the tailings into Empress Augusta Bay has been continuing for many years but is still incomplete. However a negative correlation exists between sediment Cu content and various biological indices (species richness, Shannon's diversity, benthic standing crop). Bougainville Copper Limited (BCL, 1986) stated that there is no evidence of an adverse effect on the fish community even around the Jaba mouth, yet also stated that it appears that the fish community in the Jaba delta is slightly different to other sites in species composition, indicating an impact (Jeffrey et al, 1985a, 1985b; Marshman et al, 1985a, 1985b; Powell et al, 1981).

The experiences of the Papua New Guinea government with the Bougainville project have made them much more wary of the potentially even more delicate Fly River system into which wastes from the new, huge Ok Tedi gold and copper mine flow. Already a spillage of 270 tonnes of sodium cyanide in containers at the mouth of the Fly, an accidental release of one million litres of cyanide solution into the upper Fly and the collapse of the tailings dam have occurred. The cyanide solution release led to the death of fish, saltwater crocodiles and turtles throughout the lower Fly and estuary area (Rongap, 1984). The Ok Tedi River flows into the Fly River and thence into the Gulf of Papua.

The chemical and biological impact of the Ok Tedi mine on the Ok Tedi and Fly River ecosystems has been the subject of many studies. Much data was collected prior to mine construction, and much is still being collected in order to monitor the impact of the mine. 30,000 tonnes of tailings per day before 1988, increasing to 80,000 tonnes per day after 1988 are disposed of into the river system. Comparison of data between 1981 and 1986 show that significant changes have occurred in the 70 km of the Ok Tedi River downstream of the mine, in suspended sediment (now 415 mg/l), particulate copper (450 mg/l), dissolved copper (35-90 mg/l), particulate zinc (140 mg/l), dissolved manganese (11 mg/l) and free cyanide (5 mg/l) (Eagle & Higgins, 1987; Gawne, 1986; Higgins, 1984; Kyle et al, 1986; Mowbray, 1986b; OTML, 1986a, 1986b). Dissolved manganese, dissolved copper, particulate copper and suspended sediment levels remain significantly above background levels below the junction of the Fly River, 190 km downstream. Significant increases in particulate zinc (150 mg/l) have been noted at a point 600 km downstream, and below the junction of the large Strickland River which itself will be carrying mine wastes in the near future from the proposed Porgera mine. The river then meanders another 385 km before it reaches the Gulf of Papua, a total distance from the Ok Tedi mine of 985 km.

The Fly River, its associated lakes, swamps, delta, and the Gulf of Papua are important breeding grounds for barramundi and other commercial fish and crustaceans in PNG. Studies of animal populations to date have shown that the tailings have produced a small impact 70 km downstream of the mine. Lead residues in fish tissues also seem to have increased. It has been predicted that suspended solids and copper could produce both short and long term effects on the river system, although is probably too early for field studies to demonstrate longterm effects of tailings on the lower Ok Tedi and Fly Rivers. Inland river dumping ultimately impinges on the coastal ecosystem. Direct spills of cyanide have plagued Ok Tedi, and cyanide will continue to be used. Unfortunately, no background monitoring at the Gulf of Papua or the Torres Strait preceded the mining operation (Mowbray, 1986b, 1986c). Guidelines for trace metal surveillance studies in the Torres Straits using the giant clam <u>Tridacna</u> <u>maxima</u> have been proposed (Denton, 1985) and a monitoring programme will begin in 1990. With the decision of the PNG government not to compel Ok Tedi to build a new tailings dam, after the collapse of the first one, local action by political representatives and their constituents has commenced in an attempt to temporarily close the mine to review environmental concerns (Townsville Bulletin, Australia, Oct. 10, 1989). Recent preliminary results of a Sydney University study have shown elevated levels of copper and cadmium in prawns from the Torres Strait region.

Tailings from the mines on the small islands of Misima (Hughes, 1989) and Lihir (Filer & Jackson, 1986) will discharge directly into the ocean over the edge of the fringing reef. It is predicted for Misima that "the tailings will accumulate on the deep sea floor and smother marine habitats there, either forcing away or killing those animals which cannot adjust to the new conditions. The Misima people do not fish at such great depths and there is little potential for commercial deep water fishing" (Hughes, 1989).

In New Caledonia mining effects on plants and the extensive erosion and sediment transport in watersheds affected by open cast nickel mines and associated road works was documented in detail by Bird et al, (1984) and others (Jaffre et al, 1976, 1977; Parrat, 1973a, 1973b; Veillon, 1973; Benezit, 1981; Guicher, 1985; Dupon, 1986). The effect on coastal systems has been the input of large amounts of often coarse grained materials, changing the extent and composition of the shoreline. Deltas and mangrove forests have been extended and low-lying muddy areas replaced by gravel beaches. A total of 36 river systems were considered to have been modified by mining wastes to some extent with 22 bays and estuaries also affected by the materials (Bird et al, 1984). The reduction in mining since the late 1970's, due to economic reasons, and the introduction of some control and rehabilitation activities have reduced the impacts to the marine environment. Slag material leftover from the nickel processing is used for mangrove and coastal landfill. No information is available on whether such material or mine tailings are toxic but some work has been done to evaluate the ecotoxicolgy of trace metals to corals (Fabre-Teste, 1985).

The possible long term use of Johnston Island as a toxic waste, and outmoded war gas, incinerator site has caused concern in neighbouring states. (Maragos, 1986). The disposal of excess pesticides, PCBs from transformers, wood treatment chemicals and other toxic concentrates has always been a problem on small islands with fragile groundwater and lagoonal systems (Mowbray, 1988; Brodie & Morrison, 1984). Excess chemicals of this type are often now shipped back to the country of origin for disposal or recovery.

Fish canneries have been associated with pollution problems in a number of Pacific states. The canneries in Pago Pago (American Samoa) have been implicated in several incidents and are presently being pressured by the American Samoa EPA to clean up their effluent (Champ et al, 1981; Soule & Oguru, 1983; ASEPA, 1987). Less severe problems have occurred in Levuka (Fiji) and Tulaghi (Solomon Islands).

4.6 Disposal of solid matter

As in many parts of the world floating debris is an aesthetic problem in the SPREP region. Litter comes from individual discards from boat or shore and urban dumps built on the coast (Brodie & Morrison, 1984). Beaches are often heavily littered by drifting material (Naidu et al, 1989) and this causes concern at least among resort operators. Plastic pellets littering New Zealand beaches have been investigated by Gregory (1977 and 1978). Attempts are now being made under the SPREP programme to quantify beach debris and make comparisons of heavily and lightly populated islands. There has been some recognition of the problems of entanglement or ingestion of marine debris by turtles (Balazs, 1982, 1985; Cawthorn, 1985), marine mammals (Coleman & Wehle, 1983; Cawthorn, 1985) and seabirds (Skira, 1986). Floating plastic waste also causes problems to fishing boats by ingestion into engine cooling water ducts or entanglement in propellers.

4.7 Marine transport of oil and other hazardous substances

As the region is not crossed by major world oil transportation routes there are few problems with oil discharge except in localized harbour areas. These discharges are normally related to problems with connections when discharging petroleum products or illegal discharge of oil-contaminated bilge water (Hayes &

Zucker, 1984). Many states have oil spill contingency plans, e.g. New Zealand (Tortell, 1981, 1982; and Anon, 1984) and the GBR, Australia (Reefplan, 1987).

There is a continuing debate - perhaps more political than environmental - as to the dangers of nuclear powered or armed ships visiting Pacific ports. The downgrading of the political relationship between New Zealand and the USA was a result of this. It is noteworthy that there are no monitoring facilities available in an emergency in any of the small island states excepting possibly French Polynesia and Guam.

The cyanide spill at the mouth of the Fly River in Papua New Guinea has been by far the largest toxic chemical spill associated with shipping (Mowbray, 1986b; Rongap, 1984) in the region.

Other spillages have included arsenic pentoxide (a tree poison) in Vila Harbour, Vanuatu (Gangaiya & Brodie, 1986).

4.8 Exploitation of non-living marine resources

The environmental effects of coral sand dredging for cement manufacture have been examined in Fiji (Penn, 1980; 1984) and generally by Bak (1978). There has been some concern expressed over coral rock removal from reefs for septic systems and other land uses (Grandperrin, pers. comm.) but this is a minor problem at present. The possible future sea floor mining of manganese nodules is often discussed but this is still well into the future (Bigham et al, 1982). There have been trials of Ocean Thermal Energy Conversion systems in Nauru. A study of nutrient rich water composition from OTEC depths in Fiji (Brodie, 1983), examining possible environmental implications, has also been completed.

In New Zealand minerals extraction in coastal areas is almost exclusively for precious metals and ironsands. Traditionally gold has been mined from beach deposits in small scale operations. With rising world prices, however, pressure is apparent for larger proposals to be approved and interest is being expressed in subtidal areas. Conversely there has been a decline in ironsand mining with falling prices. Extraction of sand and shingle continues from many beaches and some subtidal areas for commercial uses. While some of this activity is exceeding natural rates of supply and leading to erosion, new policies resulting from changes in environmental administration should soon curtail this situation. Interest continues in exploration for hydrocarbon deposits under the continental shelf around New Zealand with exploration wells still being drilled at present. A further production well is planned for the Maui gas field. As already noted Australian beach sand mining for rutile, ilmenite and zircon has been a contentious issue for many years. Mining leases offshore have now been granted in New South Wales to extract minerals from shelf deposits in 20-50m of water.

4.9 Exploitation of living marine resources

The use of explosives for fishing on coral reefs is of concern in many states (eg Truk and American Samoa) (Maragos, 1986) and procedures to detect fish caught by such illegal methods are under development. Similarly toxic plant extracts are generally banned from use but it is believed that considerable use still occurs as does the deliberate use of toxic chemicals such as chlorine bleach, paraquat and other pesticides (Eldredge, in press; Hambuechen, 1973). Deliberate destruction of corals after encirclement with nets to drive fish out is commonly practiced especially near urban areas.

Large scale export of coral pieces and molluscs does not occur in the region at present. A small trade operates from Fiji in ornamental coral pieces and also in aquarium fish. Throughout the region there is some collection of corals and shells for tourists but depletion of turtle stocks for both meat and the tourist trade is a more serious problem. In New Caledonia the harvest of coral for use in the growing trade in worked coral artifacts is monitored, with a limited harvest allowed in a restricted area. A small aquarium fish export business also exists. Sea turtles continue to be harvested during the 6 month open season (Pritchard, 1987) although traditional controls on harvest continue in outer areas. A set of data showing production of fish and shellfish from the New Caledonia lagoon over the period 1976-1986 is given in Table 4. Of note is the substantial drop in the Trochus fishery. The Trochus fishery may suffer from serious over-exploitation in the near future as there are only size limits on its harvest, without sanctuaries or seasons. The fishery for the crab Scylla serrata is also suffering from serious exploitation (Delathiere, 1988). Satellite imagery is being used to locate suitable habitat to further introduce Trochus (Bour et al, 1985). Other fisheries included in the table are not thought to be over-exploited at present. However, the growth in night spear fishing is locally over-fishing reefs accessible from Noumea. Destructive fishing practices (i.e. dynamiting) are not common.

Table 4. Convention for the Protection of the Natural Resources and Environment of the South Pacific Region and Related Protocols

The present (22 September 1989) status of signature and ratification is as follows:

Parties	Signature	Ratification/ Accession
Australia	24 November 1987	19 July 1989
Cook Islands	25 November 1986	9 September 1987
Federated States of Micronesia	9 April 1987	29 November 1988
Fiji		18 September 1989
France	25 November 1986	-
Kiribati		-
Marshall Islands	25 November 1986	4 May 1987
Nauru	15 April 1987	-
New Zealand	25 November 1986	-
Niue		-
Palau	25 November 1986	-
Papua New Guinea	3 November 1987	15 September 1989
Solomon Islands		10 August 1989
Tonga		-
Tuvalu	14 August 1987	-
United Kingdom	16 July 1987	-
United States of America	25 November 1986	-
Vanuatu		-
Western Samoa	25 November 1986	-

10 Ratifications/Accessions needed to bring convention into force.

On the Great Barrier Reef, aquarium fish collection is increasing with about forty commercial operators at present but the total number of fish collected is quite small compared with, for example, the Philippines. Effects on the reef have not been evaluated but the situation has been reviewed by Whitehead et al, (1986). Two commercial licences to collect shells in the GBR have been issued but only one is active (Barnett, 1988). 90% of shells sold in Australia come from overseas.

Another marine animal in some danger of stock depletion is the dugong (Dugong dugon). In New Caledonia a permit is required to legally hunt dugong. Generally 30-40 are taken each year. Probably 2 to 3 times the number of those exploitation (Delathiere, 1988). Satellite imagery is being used to locate suitable habitat to further introduce Trochus (Bour et al, 1985).Other fisheries included in the table are not thought to be over-exploited at present. However, legally allowed are caught accidentally in nets or taken illegally. In Palau (Brownell et al, 1979) the population is one of the few still persisting in an isolated archipelago. The estimated total population of 50 and the estimated annual poaching rate of 20 leads to the prediction that the Palau population may be exterminated by the end of this century unless effective measures are taken to reduce the level of poaching. The Australian dugong population is the focus of continuing studies and the development of a management plan (Marsh, 1988).

The giant clam Tridachna gigas is believed to have become extinct in recent times in a number of island groups due possibly to over-collection. A similar fate seems to have affected Hippopus hippopus some thousands of years ago. A large scale project to introduce or reintroduce T. gigas into a number of island states is now underway coordinated by ICLARM, James Cook University (Townsville, Australia) and the Micronesian Mariculture Demonstration Centre (Palau). There has been concern expressed that unless the stringent quarantine requirements used by ICLARM are followed, undesirable parasites may be introduced with the juvenile clams.

New Zealand's 200 nautical mile Exclusive Economic Zone encompasses an area of 3.65 million square kilometers. Resources within the zone are estimated to be capable of yielding more than 600,000 tonnes of fish annually. Average yield currently reaches approximately 400,000 tonnes. There have been conflicts between recreational fishing and commercial activity closer inshore and this is not expected to be easy to resolve. Minor conflicts also persist between waste discharges and fishing. In a few areas, fishing grounds have been restricted for health reasons while in others, nets and equipment have been fouled by discharges of meatworks origin.

In the Torres Strait region between Australia and Papua New Guinea (Poiner & Harris, 1986, 1988), in the Gulf of Carpentaria (Poiner & Harris, 1986) and in the Great Barrier Reef Marine Park (Sainsbury & Poiner, 1989) major changes have taken place in benthos and fish stock composition over the last two decades under the pressure of intensive trawling. The Southern Bluefin Tuna fishery, important to Australia, New Zealand and Japan has been the source of concern and controversy for some time as stocks decrease and catch per unit effort rises. A severe decline in catch has led to predictions of the stock being in danger of extinction (Jeffries & Kearney, 1989) and although management of catch through quotas has occurred, the fishery is still in crisis.

One of the most strongly felt environmental concerns in the Pacific island states is the use of drift nets by Japanese and Taiwanese fishing fleets. This style of fishing snares an enormous by-catch of non-target fish, mammals and reptiles as well as having the ability to completely fish out stocks in a particular region (Anon, 1989b). The South Pacific Forum, in its 1989 meeting, nominated concerns over drift-netting as one of its priority areas for international action (Anon, 1989c). While Japan has agreed to reduce the size of its drift-net fleet this has not satisfied Pacific Island states who continue to push for a complete ban on drift-netting.

5. BIOLOGICAL EFFECTS

5.1 Eutrophication and associated phenomenon

A number of studies have looked at lagoonal eutrophication (CDTC, 1982; Zann et al, 1984; Carter, 1983; Kimmerer & Walsh, 1981; Johannes et al, 1979; Naidu et al, 1989). The input of nutrients is generally due to sewage discharge rather than agricultural runoff as there are few large scale farming schemes in the island region which use large quantities of fertilizers. Erakor lagoon in Vanuatu receives much of the nutrients from Vila's urban sewage and due to long lagoonal water residence times has frequent localized phytoplankton blooms (Naidu et al, 1989; Wallis & Chidgey, 1988) and can be considered to be highly eutrophic.

The most complete description of sewage and its effects on reefs is given by Smith et al, (1981). Increasing amounts of sewage were discharged into Kaneohe Bay, Oahu, Hawaii. Major changes occurred during that time. In the late 1970's the sewage was diverted, and the study documented the response to this diversion. Biomass of plankton and benthic organisms decreased while much of the benthic composition has returned to precontamination conditions over time. More recently the effects of sewage pollution on coral reefs was reviewed by Pastorok & Bilyard (1985), Bell et al, (1987, 1989) and Hawker & Connell (1989).

Nutrient contamination appears to be potentially most deleterious in the Pacific islands. Most nutrients enter coastal waters through the various land management activities - sewage dumping, land clearing, deforestation, etc. Tropical waters are much lower in nutrients than temperate waters (Johannes & Betzer, 1975). The addition of small amounts of phosphates will greatly elevate the ambient quantity. Tropical waters have much greater clarity than temperate waters because of the low levels of suspended materials. Increased nutrients reduce water transparency with the increase of plankton biomass and particulate organic carbon. With decreased light, coral growth and carbonate production decreases (Hallock & Schlager, 1986). Additionally, the depth ranges of autotrophs and mixotrophs decreases. On the Great Barrier Reef, GBRMPA is particularly concerned with island hotel sewerage plants discharging directly onto fringing reefs and has commissioned a number of studies to examine some of the more serious cases (Green Is., Hayman Is., Hamilton Is. and Heron Is.). A number of the studies are now available (Blake & Johnson, 1988; Steven & Van Woesik, 1989; Steven et al., 1989). The long term effects on the Great Barrier Reef of enhanced nutrient levels in river runoff is also beginning to be investigated (Cosser, 1988; Rasmussen, 1988; Valentine, 1988).

In Australia one of the most significant impacts which appears to be associated with eutrophication and increasing siltation is the continuing loss of large areas of seagrass beds from coastal lagoons, bays and estuaries. Major losses have occurred in Cockburn Sound, WA (3300 ha lost - 97% of the original area), Princess Royal and Oyster Harbours, WA (1320 ha, 58%), St. Vincent's Gulf, SA (365 ha., Neverauskas, 1985), Westernport Bay, Vic. (12290 ha, 71%) and Botany Bay, NSW. (Austin, 1989). Fish catches in many of these areas have now declined and the composition of the catch has changed. Eutrophication in enclosed coastal lagoons and lakes is a widespread problem in Australia with Lake Maquarie (Roy, 1984), Lake Illawarra (Clarke & Yassini, 1986), the Gippsland lakes (Hodgkin, 1986) and the Peel-Harvey estuary (Hodgkin & Birch, 1986) among the most well documented. In the case of the Peel-Harvey estuary massive blooms of the blue-green alga Nodularia spumigena, decomposing slimes of Chaetomorpha, Enteromorpha and Ulva species, loss of fish populations and frequent offensive odours have generated intense concern among local residents and other utilizers of the waterways. The general causes in all cases are a mixture of sewage discharges, agricultural runoff and industrial waste runoff. A general review of nutrients in Australian waters (both marine and freshwater) was produced by the Australian Environment Council (1987).

In the Pacific special situations potentially exist with added nutrients. The best example of this is the proposed hypothesis that populations of the crown-of-thorns starfish (Acanthaster planci) are increased by terrestrial runoff into lagoon areas. The runoff provides nutrients which stimulate phytoplankton blooms. These blooms produce enough food to ensure successful survival of the larvae of A. planci. Increased larval survival results in outbreaks of A. planci about three years later (Birkeland, 1982). The current status of A. planci has been reviewed (Moran, 1986). Large outbreaks can lead to the destruction of extensive areas of coral reefs, and there has been a long running controversy over the effects of these starfish and whether the outbreaks are natural or anthropogenically caused.

Additional problems resulting from nutrient input fall within the areas of public health. Red tides result from blooms of certain phytoplanktonic organisms and seasonal red tides have caused massive fish kills. Paralytic shellfish poisoning results from eating shellfish which have been harvested from areas with red tides. Numerous deaths have been reported throughout the Pacific (Maclean, 1984). Red tides have been common in Australian waters in recent years resulting in closure of shellfish beds (Port Phillip Bay and Tasmania) leading to financial losses in the millions of dollars (Beckman, 1988).

Further problems result from other dinoflagellates. Investigations into ciguatera have identified the cause to be dinoflagellates living in association with certain fleshy algae. Ciguatera is the name given to poisoning resulting from ingesting tropical or subtropical finfish. These intoxications are debilitating and can cause long-term effects but the poisoning is rarely fatal. As many as 10,000-50,000 individuals may be poisoned annually (Anderson & Lobel, 1987). In the Pacific ciguatera is thought to be one of the greatest constraints to fisheries development (Gawel, 1988). There appears to be a relationship between the incidence of ciguatera and nutrients (Steidinger, 1983). Phosphates and nitrates were significantly correlated with the occurrence of dinoflagellates associated with fleshy algae. Dinoflagellates have also caused problems with salmon farming in New Zealand.

5.2 Public health effects

Many of the most publically expressed concerns about marine pollution in the region relate to public health matters. These include concerns about bacterial and viral pathogens in marine food items, ciguatera, clupeid toxins and paralytic shellfish poisoning, contamination of swimming areas and skin, eye and ear infections.

Sewage contamination of coastal areas, particularly near urban centres is common. Results of monitoring studies of water and shellfish clearly show how few areas meet international standards for recreational water or shellfish growing water and in many cases the shellfish have been shown to be contaminated (Johannes et al, 1979; Haddock, 1987; Naidu et al, 1989). It is believed in the region that viral diseases are often transmitted via shellfish but with the difficulties in quantifying viral numbers and identifying viral types using present methods this has not been adequately investigated.

There have been a number of serious infectious disease outbreaks in the region in which sewage contamination of shellfish harvesting areas has been implicated. In Kiribati a cholera outbreak in 1977/1978 led to 21 deaths and 1429 cases (Maung, 1979). A subsequent study of water and shellfish quality in the lagoon clearly showed widespread contamination (Johannes et al, 1979) and eventually led to the installation of a sewerage system for the island (CDHC, 1985) which discharges into the open ocean rather than the lagoon. However recent studies (Naidu et al, 1989) have shown that the faecal coliform levels in the water and shellfish in the lagoon are still as high as before the sewerage system was installed. Cholera has also been a continuing problem in Truk (FSM). In Majuro (Marshall Islands) between October 1981 and March 1982, ten cases of laboratory-confirmed typhoid fever occurred (Greenspan & Conrad, 1985). Microbiological testing confirmed widespread contamination of groundwater, drinking supplies and lagoon seafood harvesting areas, due to inadequate community sewage disposal. In Guam continuing cases of cholera between 1974 and 1986 were attributed to the eating of uncooked seafood (Haddock, 1987) in particular raw fish caught near Agana Bay which is known to be polluted by beach-side sewer lines. Imported shellfish, also eaten raw in Guam, have also been implicated in cholera cases (Haddock & Nocon, 1985). Outbreaks of food poisoning in Guam due to Vibrio parahaemoticus have been traced to contaminated crustaceans (shrimp and lobster) originating from the Philippines, Saipan and Palau as well as Guam (Haddock, 1979). The number of cases in Guam has been increasing steadily during the 1980s (Territorial epidemiologist, pers. comm.) and it may be a far more widespread problem in the region than is at present recognized as few regional laboratories have the capability to isolate and identify the agent.

Sydney's problems with beach and coastal pollution from a number of coastal outfalls are notorious, the effluent receiving only primary treatment and the outfalls sited right on the shoreline (Sweeney, 1989). In Sydney Harbour beaches are unsafe for swimming 62% of the time after rain and 36% in the dry.

Paralytic shellfish poisoning (PSP) is a growing problem in both South East Asia and the Pacific (Maclean, 1984). The causative agent is the dinoflagellate Pyrodinium bahamense var. compressa. Pyrodinium is responsible for chronic toxicity of shellfish in Palau and Papua New Guinea while fish kills that occur in Guam and Tuvalu, and PSP cases in Fiji and the Solomon Islands may also be Pyrodinium caused. The incidence and range of outbreaks is increasing and many believe there is a connection to marine pollution levels. In New Zealand a different dinoflagellate, Dinophysis may have caused a build up of diarrhetic shellfish poisoning detected in mussels. The problem has also become serious in Australia with red tides and associated buildup of the toxic dinoflagellate Gymnodinium catenatum in Tasmania causing closure of shellfish beds for up to six months in 1986 and a less severe outbreak in 1987 (Beckman, 1988; Hallegraeff et al, 1988a). High rainfall and enhanced runoff were implicated in the incidents (Hallegraeff et al, 1988b).

The problems of ciguatera have been noted in Section 5.1 and its role as a major constraint to fisheries development. Mean annual incidence of reported cases in the Pacific island region is about 1-4 cases per thousand (Anderson & Lobel, 1987). The actual levels of course will be much higher as most cases are never reported. There is strong evidence that ciguatera is linked to stress in a coral reef ecosystem (Bagnis, 1987).

5.3 Long-term impacts

The whole subject of possible cyclic changes in tropical marine ecosystems is of intense interest to scientists working on tropical systems. The question of whether the apparently increasingly frequent outbreaks of Acanthaster planci

(Crown-of-Thorns starfish) are natural or human-induced is of great importance to marine park management, the tourism industry and local reef users (Kenchington, 1977; Birkeland, 1982; Zann et al, 1987; Moran, 1986). Intensive research into A. planci biology is now occurring throughout the Pacific. The overall role of anthropogenic influences on Australia's Great Barrier Reef has been reviewed by Hopley (1988). The problems caused by toxic dinoflagellates have already been discussed. The rapid spread of the encrusting sponge Terpios (Bryan, 1973) in Guam and its ability to kill coral (Plucer-Rosario, 1987) is another case in point. Others are the mass mortality of the sea urchin Echinothrix in Hawaii (and similar mass mortality throughout the Caribbean (Lessios et al, 1984)); the extraordinary increase in numbers of coral-eating gastropods (Drupella spp.) in the Philippines, Japan and Okinawa (Moyer et al, 1982), in Enewetak (Boucher, 1986) and Western Australia (Ayling & Ayling, 1987a), the increased abundance of the reef burrowing urchin Echinometra mathaei in Kenya (McClanahan & Muthiga, 1988), Kuwait (Downing & El-Zohr, 1987) and Fiji (Zann, pers. comm.), incidents of circumtropical coral bleaching and death (Glynn et al, 1988; Williams & Bunkley-Williams, 1988; Oliver, 1985) and black-band disease in corals (Antonius, 1988). Long term effects of herbicide residues (Glynn et al, 1984) on corals and trace metals (Fabre-Teste, 1983) has been considered but there is little field data. Whether global incidents of coral death are linked and related to pollution levels has been examined by Brown (1987).

It has been suggested that the decline in Guam's native bird fauna is partially due to pesticide residue problems (Grue, 1985; Savidge, 1983). However numerical data is lacking.

One area of concern in small island states is the possible loss of coral reefs from long-term pollution and the consequent loss of coastal protection from cyclone damage and storm surge. Loss of coastal mangrove communities may magnify this problem as well as the predicted rise in sea-level due to atmospheric carbon dioxide buildup.

In the next few years/decades, sea-level rise attributable to earth-surface warming resulting from the "greenhouse effect" will begin to be unmistakably noticed on Pacific island coastlines and its continued rise together with the associated temperature increase represents possibly the single most serious environmental threat to Pacific island environments in the predictable future (Pernetta & Hughes, 1989; Roy & Connell, 1989). The effects of the temperature and sea-level rise on island coasts are the subject of a pilot project which reported to UNEP in 1989 in preparation for a longer-term project (Pernetta & Hughes, 1989). Preliminary work has concentrated on measuring the impact of the median scenario sea-level rise (i.e. a temperature rise of 1.5°-4.5°C and a sea-level rise of 20-140 cm) on representative islands or coasts from each nation within the region (P. Nunn, pers. comm). In Australia the Australian Marine Sciences Association have summarized the possible impacts on marine and coastal environments (AMSA, 1988).

There is also concern in Australia and New Zealand, particularly in the southernmost parts, of the 'ozone hole' over Antartica and its possible future growth. Possible effects on ocean phytoplankton have been discussed.

5.4 Damaged habitats and resources and their potential for recovery and rehabilitation

The only documented regional example of an apparently successful attempt to rehabilitate a habitat destroyed by pollution is the replanting of mangroves after an oil spill in Guam (Stillberger & Rowley, 1980; Bultitude & Strong, 1985). Over four acres of damaged area was cleaned up and successfully replanted with mangroves. Localized mangrove destruction is widespread in the region (Field & Dartnall, 1985; Allaway, 1987).

Studies on the recovery of Kanahoe Bay, Hawaii after diversion of a sewage outfall has already been referred to in Section 5.1). The paper outlining the study (Smith et al, 1981) is the best set of data available on the recovery of coral reefs from sewage damage. In general Pearson (1981) has examined the regrowth of coral reefs after destruction, in this case from the Crown-of-Thorns starfish.

Information is available on the attempts to clean up Bikini Atoll (Maragos, 1986) after the nuclear bomb testing, to a standard suitable for return of the inhabitants.

Many of the estuaries in south-western Australia appear to be in a slow state of decline with evidence suggesting the causative agents to be siltation and eutrophication resulting from catchment land-use practice (Hodgkin, 1988). Similar effects have also been documented on the east coast (Clarke & Yassini, 1986; Burgess & Woolmington, 1981).

A number of marine species in the region appear to fall into the category of endangered. These include dugongs, some species of turtles, possibly some species of seabirds and giant clams. Dugongs suffer from hunting pressures, loss of habitat and possible problems of toxic chemical buildup (Brownell et al, 1979; Denton et al, 1980; Marsh, 1985, 1988; Marsh & Saalfeld, 1989). Accidental trapping of dugongs and cetaceans in gillnets and shark nets (for protection of swimmers) is a recognized problem in Australia (Patterson, 1979; Puddicombe, 1986) and Taiwanese gill netting is to cease in the Australian fishing zone to prevent this continuing. 12,400 dolphins of 5 species were trapped in gillnets in the period 1981 -1985 (Puddicombe, 1986). Similarly turtles suffer from hunting and disturbance of their nesting sites. In New Guinea approximately 1,200 turtles are harvested each year (mostly in Western Province) in extensive subsistence and artisanal fishing. A preponderance of female turtles in the catch (male:female ratio in 1986 was 1:8) due to a local preference for female flesh may be a problem. Concern for the resource prompted research into the fishery, initiated in 1984, culminating in a management plan to secure the long-term future of the turtle population. However the management plan has not been implemented by the government although Leatherbacks are completely protected and Green, Hawksbill, Olive Ridley and Blackback turtles protected in wildlife reserves (D. Kwan, pers. comm.). In the Solomon Islands turtle shell is also traded. The turtles are killed for food and their shells are sold in pieces to exporters. It is virtually impossible to determine the size of the turtle that the shell fragments come from, and so the minimum size restriction of 30" (76 cm) is not enforceable.

Giant clams (particularly Tridacna gigas) are another group of marine organisms which may be subject to overharvesting. In New Guinea approximately 35 tonnes/year are harvested from Milne Bay both for local consumption or for export e.g. to Australia and then re-exported to Asia. T. gigas has apparently become extinct in Fiji within the last hundred years due to both local over-harvesting and poaching by overseas vessels and declining stocks have been noted throughout the Pacific (Wells et al,1983). A large scale project is now underway to reintroduce the clam Tridacna gigas into many Pacific states. In many of these this particular clam has become extinct or rare. Since it is faster growing than the other common large clams T. derasa and Hippopus hippopus and the smaller clams T. maxima and T. squamosa, its culture is desirable.

Bird problems in Guam have already been mentioned [Section 5.3]. The high loss of seabird populations on Christmas Island (in Kiribati) during the 1982-83 El Nino was presumably a normal event during ENSO episodes but this has not been confirmed. The biological consequences of El Nino were reported by Barber & Chavez (1983, 1986) and Dandonneau (1986).

Perhaps the most controversial environmental cause in the Pacific islands is the use of driftnets by Japanese, Taiwanese and Korean fishing fleets. While some data is available in Australia on the effects on non-target species (Burgin, 1986), opposition in the islands is centered more on loss of fisheries stocks (Anon, 1989b, 1989c).

5.5 Accidents and episodic events

The impact of natural volcanic ashfall has been reported by Eldredge & Kropp (1985). Most of the effects of the volcanic eruption of Pagan in May 1981 was actual smothering of coral and scouring of the intertidal zone. Hemispherical coral colonies were virtually unaffected, since the ash simply fell off. Corals with moderately spaced branches "held" more ash and were most impacted.

Unquantified effects on marine ecosystems have also accompanied the huge areas of floating pumice from an underwater Tongan volcano which erupted in early 1986. The pumice impacted on Fiji some weeks later choking harbours (Ryan, 1987) and mangrove areas and lodging in coral reefs. It disrupted shipping for several weeks. In late 1986 the pumice eventually washed up along most of the northern Australian coast.

The effects of storms (hurricane, typhoons, cyclones) have been very noticeable. Coral reefs have been affected in various ways. Guam's reefs were little impacted following Typhoon Pamela in 1976 (Randall & Eldredge, 1977). Recent cyclones and storms have greatly damaged reefs at Fiji, Vanuatu, Tokelau (Laboute, 1987) and Tuamotu (Harmelin-Vivien & Laboute, 1986). Guam is apparently surrounded by a storm-adjusted reef, whereas the others are not. Historically, Guam experiences a significant typhoon approximately every seven years (Holliday, 1975). Bagnis (1981) demonstrated that natural disturbance such as cyclones in the Marquesas may be followed by increased incidence of ciguatera.

Cyanide spills in Papua New Guinea and frequent fish kills throughout the region have already been mentioned. Small oil spills from leaking pipes, tanks damaged by landslips, ship spills and other causes have caused the destruction of mangrove forests (Stillberger and Rowley, 1980) in Guam and problems in Honiara, Suva, Vuda Point (Fiji) and other ports.

A small spillage (15 kg) of arsenic pentoxide into Vila Harbour, Vanuatu caused no long-term increase in environmental arsenic levels (Gangaiya & Brodie, 1986).

PNG lies within a zone of strong earthquake and volcanic activity. Changes in land mass due to volcanic events are quite common, the best known and most studied example in PNG being at Rabaul. In between volcanic eruptions there is a progressive rise in the land of 1-10 cm a year, these changes being much more dramatic following an eruption, e.g. new islands arise. Sudden changes will disturb tidal flow, which would be expected to change the amount of suspended sediment. However, no work has been done on this. Fish kills have been noted in the area and have been suspected to be due to released gases or thermal pollution resulting from volcanic activity. Changes in the marine environment brought about by volcanic activity are not always easy to differentiate from those caused by other factors e.g. tectonic movements, changes in the level of the Pacific.

PNG is also subject to tsunamis or seismic sea waves. There is little information on tsunamis in the area except for a review (Everingham, 1976), which details 49 recorded tsunamis since 1900. The majority of these have resulted from local earthquakes and occasional association with a submarine slide. Changes in coastal sedimentation do occur as well as changes in the distribution of fish and other marine organisms as a result of tsunamis, but as with earthquakes this information tends to be oral. Seismic activity also causes reef damage (Stoddart, 1972).

In 1980 a ship grounded off New Ireland which caused damage to the reef community. The original damage was considered minimal compared to that caused by the blasting of a channel to free the ship. The immediate short-term damage was the mass death of fishes and invertebrates including corals, crustacea, gastropods and echinoderms. The effects of the grounding of the alumina carrier, Alltrans, on Lady Musgrave reef, the Great Barrier Reef were reported by Ayling (1985).

A large scale cyanide spill occurred at the mouth of the Fly River in the Papuan Gulf (June 1984). Only 10 tonnes of the 270 tonnes of sodium cyanide lost overboard from a flat barge were recovered (Rongap, 1984). A second accident (also in June 1984) resulted in 1080 cubic metres of approximately 300 mg/l of free cyanide being released into the Ok Tedi River. 70 km downstream cyanide levels were estimated to be between 200-500 mg/l. The immediate effect was a large fish and prawn kill. In both instances, the life of the local river people was severely disrupted for many weeks (Mowbray, 1986b). Flushes of high levels of cyanide and copper not infrequently are released from the Ok Tedi mine (Jackson, 1985, 1986). The resultant concentration of these in the river water often exceeds the government set 'permissible levels'.

Kills of fresh fish by DDT and lindane used for fishing or intentionally dumped into streams, have been observed in PNG . Rotenone is used traditionally to catch both freshwater and marine fish. There have been some reports of people fishing in lagoons using chlorine bleach, paraquat and other pesticides including DDT and lindane, but 'dynamiting' and use of explosives is more common. In New Ireland one plantation reports that it dumps old and unused pesticide containers at sea (Mowbray, 1988).

Oil spills and leaks in Botany Bay, Australia have led to dieback of considerable areas of mangrove (Allaway, 1982; Anink et al, 1985) and it is thought that with the frequency of spills in Botany Bay most mangroves will be destroyed in time (Allaway, 1982; McGuinness, 1988). There are numerous other reports of small scale oil and fuel spillages in Australian harbours. In 1986 there were 142 marine oil spills, 90% in ports and in 50% of cases some clean up work was attempted (Kay, 1987).

6. PREVENTION AND CONTROL STRATEGIES

The recently formulated 'Convention for the Protection of the Natural Resources and Environment of the South Pacific Region' (SPREP convention) should be the keystone of a programme of better prevention and control strategies for the region. In mid September 1989 the convention had thirteen signatories and seven ratifications as shown in Table 4. The convention obliges signatories to monitor marine contamination and prevent marine pollution in their waters and although it is difficult to enforce it represents a valuable moral commitment. The South Pacific Regional Environment Programme (SPREP), although only a few years old, has initiated by itself and in cooperation with regional research institutions, with funding from UNEP, a number of monitoring projects. In many cases this will be the first monitoring ever done. The UNEP agency directly involved in the marine programme is the Oceans and Coastal Areas Programme Activity Centre (OCA/PAC). Scientists in the region are able to participate in worldwide marine environment activities with the support of OCA/PAC.

The region is also part of the IOC/WESTPAC area and as such participates in the Marine Pollution Research and Monitoring network. Through this network government and university laboratories participate in workshops, intercalibration and intercomparison exercises and information exchange. The closer ties between UNEP (OCA/PAC) and IOC of the last few years have had a significant impact on regional cooperation. The Joint Coordinating Committees for Offshore Prospecting/South Pacific (CCOP/SOPAC) is an intergovernmental organization which, particularly due to its access to scientific cruise ships, is often involved in offshore environmental studies.

Other conventions which have a role in marine environmental protection in the region are the Convention on International Trade in Endangered Species (CITES); the Law of the Sea (LOS); the London Dumping Convention (LDC); the Action Strategy for Protected Areas in the South Pacific; the Nuclear Free Zone Treaty; the Apia Convention and International Maritime Organization conventions e.g. MARPOL 73/78.

While national programmes for the prevention of marine ecosystem damage are still in their infancy in this region, scientists participating in marine ecosystem studies hope the activities of the SPREP and WESTPAC networks will lead to better national legislation, monitoring and control.

7. TRENDS AND FORECASTS

Concerns and problems of the coastal environment have dominated this review. This emphasis partly reflects, however, the fact that most of the research work undertaken in the region has been carried out in coastal rather than oceanic areas. The principal marine environment problems in the island states arise from nutrients and bacterial pollution from sewage in coastal areas; sediment, bacterial and nutrient inputs from rivers; major mine tailing inputs in a few localized areas, coastal development and concern for over-fishing by foreign fleets. Many of the bacterial problems have a very immediate impact on public health while the sediment/nutrient problems are of long term concern. Australia and New Zealand while sharing some of these problems also share in the marine environmental concerns of the developed, highly industrialized nations e.g. toxic chemical contamination, large scale coastal zone modification and high levels of nutrient input from agricultural activity.

The areas of particular importance can be summarized as follows:

(a) Lack of legislation,monitoring, enforcement of existing standards, background and baseline information.

(b) Public health problems associated with sewage discharge and the reliance of Pacific islanders on coastal food supplies. Particular cases are cholera outbreaks (Truk in FSM and Tarawa in Kiribati) and viral hepatitis (Fiji).

(c) Mine tailing pollution. This is currently an area specific problem, (in particular Bougainville (PNG), Ok Tedi (PNG) and New Caledonia), but one likely to become more extensive as many of the newly discovered island deposits are developed.

(d) Nutrient input from sewage and, to a lesser extent, agricultural activity, particularly into limited circulation waterbodies, the connection with eutrophication, phytoplankton blooms (particularly dinoflagellate growth), coral reef destruction and the suggested links with increased incidence of ciguatera, paralytic shellfish poisoning and Crown-of-Thorns starfish outbreaks.

(e) Coastal and inland development leading to increasing sediment loads on coastal ecosystems, particularly from logging and poor crop selection on steep slopes, road building, tourist development and badly designed urban development.

(f) Over-harvesting of marine resources, especially dugongs, turtles, some fish species, clams and some gastropods; driftnet fishing by Japanese and Taiwanese fleets.

(g) Disposal of solid wastes and toxic chemical wastes, particularly unwanted pesticides, solvent residues and oils.

(h) Sea level rise.

(i) Use of Pacific islands as sites for toxic waste dumps and incinerators.

(j) Over-development of coastal areas for tourism, loss of mangroves, seagrass beds and coastal wetlands.

There are some success stories in marine environmental management in the region. At the large scale the setting up of the Great Barrier Reef Marine Park in Australia and the work of the GBRMP Authority provides Australia with its first well managed marine area. At smaller scales are the improvement of river discharge quality in New Zealand and the prevention of dredging in Ponape after the implementation of a coastal management plan. In general however the marine environmental protection record is poor.

8. ECONOMICS

Comparative economic studies and assessments of the value of marine resources are still in their infancy in the region. While in the Caribbean the economic 'value' of a coral reef has been evaluated for compensation purposes (Gittings et al, 1988; Dennis & Bright, 1988), there are few similar cases in the western Pacific. The economic implications of sediment damage to coral reefs was investigated by Hodgson in the Phillipines (1988) by comparing the relative values of logging, fisheries and tourism and the study demonstrates the potential value of joining ecological and economic analysis in order to provide information for government planners.

In Fiji over 90% of land, coastal areas and reefs are owned by traditional landowners but held in trust by the Native Land Trust Board. When development of such lands is planned a special court holds hearings to assess loss of resources due to the development and adjudicates on a compensation payment. Since 1983 over one hundred assessments have been made by the Fisheries Department for loss of mangrove areas and judgements handed down. The planned usages included dredging, jetties, roads, industrial areas, hotels, aquaculture projects, agricultural land, restaurants, sewerage schemes, port facilities, gravel mining, residential developments, schools and small boat passages. Areas have ranged from 0.006 ha to 200 ha and compensation payments from a few dollars to F$100,000. The average has been around F$2,000 per ha. Considerations in making the judgement include the marine resources of the area (determined by a survey); the proportion which will be lost due to the development; the distance of the area from the village of the traditional owners; the number of people in the owners' village dependent on fishing and the population of the fishing rights area. Payments of less than F$200 go directly to the owners while those over $200 go to the Fiji Public Trustee and the interest on the amount goes to the owners.

The costs of beach protection in Australia and New Zealand, where coastal modifications have caused erosion has been examined by Steinle (1986). Large scale sand pumping projects to replace beaches lost to erosion are a feature of the Gold Coast region in Australia.

In the region under review, the projected additional costs of sewage treatment plants required to overcome the present deficiencies are enormous with estimates ranging from 300 million to one billion Australian dollars for Sydney to US$10 million for Vila.

9. SUMMARY AND CONCLUSIONS

Protection of the marine environment in the Pacific Islands, in the past, was founded on traditional measures such as ownership of marine areas, closure of fishing areas, taboos and catches limited to immediate needs (Johannes, 1978; Ruddle & Johannes, 1985; Siwatibau, 1984). These coped well with the population densities at that time in contrast to anthropogenic effects on the terrestrial environment which in most of the smaller islands were severe. Increasing population, concentration of population and increasing industrial and commercial development in recent times allied with the weakening of traditional measures have led to a sharp deterioration in the marine environment in localized areas. Added to this are international influences such as over-fishing by foreign fishing fleets, international mining activities, nuclear weapon testing, the greenhouse effect, and the 'ozone hole'.

In the past environmental protection has had a very low priority at government level throughout the region and although there has been some action taken against the international problems, most states have not been prepared to establish and enforce protective controls at the national level. In contrast, in recent times, increasing public pressure throughout the region has forced governments to reconsider projects from an environmental degradation viewpoint. In Australia many mining, tourism and industrial projects have been blocked by concerns, justified or not, for the marine environment. These include pulp mills (e.g. Wesley-Vale), marinas, coastal reclamation developments (e.g. Trinity Inlet, Cairns), mining (e.g. Shelbourne Bay silica deposits) and offshore oil exploration (establishment of the GBRMPA). In Papua New Guinea environmental degradation was cited by rebels on Bougainville as one cause of their struggle which has now closed the Panguna mine. Considerable protests are also escalating in the Ok Tedi region where loss of fishing in the river downstream of the mine is causing concern to local land holders. At the political level environmental concerns have become prominent, for example at the South Pacific Forum meetings with emphasis in 1989 on drift-net fishing and greenhouse warming/sea level rises, and in Australia where a 'Green' party is now in coalition in the government of the state of Tasmania. To some extent these reflect worldwide trends.

Thus while available evidence shows a continuing decline in the state of the marine environment in the region and a conspicuous lack of effective governmental action to halt the decline, recent trends in international cooperative activity and public pressure and political activity raise hopes for the future in terms of effective activity to halt the decline.

10. REFERENCES

Airey, D. (1986). The entrainment of nutrients from below the thermocline in the Coral Sea into the Great Barrier Reef Lagoon via Cook's Passage. The Science of the Total Environment, 49, 147-161.

Alexander, R., M. Cumbers, F. Flannagan, R.I. Kagi, M. Offer and R. Taylor (1982). Petroleum hydrocarbons in Cockburn Sound. A Report to BP Refinery (Kwinana) Ltd and the WA Dept. of Conservation and the Environment, Dept. of Cons. and the Envir. Bulletin No. 125, Perth.

Allaway, W.G. (1982). Mangrove die-back in Botany Bay. Wetlands (Australia), 2(1), 2-7.

Allaway, W.G. (1987). Exploitation and destruction of mangroves in Australia. In: Mangrove Ecosystems of Asia and the Pacific: Status, Exploitation and Management, editors, C.D. Field and A.J. Dartnall, AIMS, Townsville, pp 183-192.

AMSA (1988). The greenhouse effect: its impacts on marine and coastal environments. A position statement by the Australian Marine Sciences Association. Australian Marine Science Bulletin, No. 106, pp 10-11.

Anderson, D.M. and P.S. Lobel (1987). The continuing enigma of ciguatera. Biol. Bull., 172, pp 89-107.

Andreae, M.O., T.W. Andreae, R.J.Ferek and H. Raemdonck (1984). Long-range transport of soot carbon in the marine atmosphere. Sci. Total Environ., 36, 73-80.

Andrews, D.M. (1983). Water masses, nutrient levels and seasonal drift on the outer central Queensland shelf (Great Barrier Reef). Aust. J. Mar. Freshw. Res., 34, pp 821-834.

Andrews, J.C. and P. Gentian (1982). Upwelling as a source of nutrients for the Great Barrier Reef ecosystems: a solution to Darwin's question. Mar. Ecol. Prog. Ser. 8, pp 257-269.

Anink, P.J., D.E. Roberts, D.R. Hunt and N.E. Jacobs (1985). Oil spill in Botany Bay: short-term effects and long term implications. Wetlands (Australia), 5(1), pp 32-41.

Anon. (1984). New Zealand Oil Pollution Contingency Plan, Marine Division, Ministry of Transport, Wellington.

Anon. (1986a). Victoria: State of the Environment. Victorian Ministry for Planning and Environment.

Anon. (1986b). Mining activities in the South Pacific. Environment Newsletter, 7, pp 12-17.

Anon. (1988). Research Findings of the Water Quality Centre from 1985 to 1988. Water Quality Centre Pub. No. 14, Hamilton, New Zealand.

Anon. (1989a). Australia's Capabilities in Marine Science and Technology - An Overview. Commonwealth Government of Australia, Canberra.

Anon. (1989b). Trying to stop the slaughter. Pac. Islands Monthly, 59 (18), pp 8-9.

Anon. (1989c). Ironing out key issues. Pac. Islands Monthly, 59 (19), pp 12-15.

Antonius, A. (1988). Black band disease behaviour on Indo-Pacific reef corals. In: Sixth Inter. Coral Reef Symp., Townsville. Vol 3: 145-150.

Arakel, A.V., C.M. Hill, J. Piorewicz and T.B. Connor (1989). Hydro-sedimentology of the Johnstone River estuary. Hydrobiologia 176/177, pp 51-60.

Arimoto, R., R.A. Duce, B.J. Ray, A.D. Hewitt and J. Williams (1987). Trace elements in the atmosphere at American Samoa: Concentrations and depositions to the tropical South Pacific. J. Geophys. Res., 92, pp 8465-8479.

ASEPA (1987). Report of the American Samoa Environmental Protection Agency, Environmental Quality Commission. Pago Pago.

Atkinson, H.R., P.J. Davies, D.R. Davy, L. Hill, and A.C. McEwan (1983). Report of a New Zealand, Australian and Papua New Guinea Scientific Mission to Mururoa Atoll. Ministry of Foreign Affairs, Wellington, New Zealand, 166p.

Atlas, E. and S. Giam (1981). Global transport of organic pollutants: ambient concentrations in the remote marine atmosphere. Science, 211(4478), pp 163-165.

Austin, M. (1989). Our dying oceans - can we save them? The Bulletin, Jan.24, 1989, pp 36-42.

Australian Environment Council (1987). Nutrients in Australian Waters, Aust. Envir. Council, Report No. 19, Aust. Gov. Pub. Service, Canberra.

Ayling, A.M. (1985). Assessment of damage resulting from grounding of the bulk ore carrier TNT Alltrans on Lady Musgrave Island Reef. Report to GBRMPA, Townsville, Australia.

Ayling, A.M. and A.L. Ayling (1987a). Ningaloo Marine Park: preliminary fish density and habitat survey with information on coral damage due to Drupella cornus grazing. Report to the Dept. of Conservation and Land Management, Western Australia.

Ayling, A.M. and A.L. Ayling (1987b). Is silt run-off affecting coral communities on the Cape Tribulation fringing reefs? In: Fringing Reef Workshop, Science, Industry and Management. GBRMPA Workshop Series No. 9, GBRMPA, Townsville, pp 83-86.

Bagg, J., J.D. Smith and W.A. Maher (1981). Distribution of polycyclic hydrocarbons in sediments from estuaries of south-eastern Australia. Aust.J.Mar.Freshw.Res., 32, pp 65-83.

Bagnis, R. (1981). L'ichthyo-sarcotoxisme de type ciguatera: phenomene complexe de biologie marine et humaine. Oceanol. Acta., 4, pp 375-387.

Bagnis, R. (1987). Ciguatera fish poisoning! an objective witness of the coral reef stress. In: Human Impacts of Coral Reefs: Facts and Recommendations, Salvat, B. (Ed.), Antenne Museum E.P.H.E., French Polynesia, pp. 241-253.

Bak, R.P.M. (1978). Lethal and sublethal effects of dredging on reef corals. Mar. Poll. Bull., 9, pp 14-16.

Balat, N. (1982). A study of the acute toxicity of copper to two species, the shrimp, Caradina sp and the mosquitofish, Gambusia affinis from freshwaters of Port Moresby. B.Sc. (Hons) thesis, Biology Dept., University of Papua New Guinea, Port Moresby.

Balat, N. (1987). Copper, zinc and lead concentrations in the mangrove oyster Saccostrea spp from Hessen Bay and the Huon Gulf, Morobe Province, Papua New Guinea. Report in preparation.

Balazs, G.H. (1982). Driftnets catch leatherback turtles. Oryx, October, pp 429-430.

Balazs, G.H. (1985). Impact of ocean debris on marine turtles: Entanglement and ingestion. In: Proc. of the Workshop on the Fate and Impact of Marine Debris, R.S. Shomura & H.O. Yoshida, editors, Honolulu, ANOAA Tech. Memo., NOAA-TM-NMFS-SWFC-54, pp 397-429.

Barber, R.T. and F.P. Chavez (1983). Biological consequences of El Nino, Science, 222, pp 1203-1210.

Barber, R.T. and F.P. Chavez (1986). Ocean variability in relation to living resources during the 1982-83 El Nino, Nature, 319, pp 279-285.

Baria, A., E. Lacanienta and J. Pernetta (1987). Aspects of the chemistry of giant clams. Three Year Report to ACIAR, Project No. 8332, University of Papua New Guinea, Port Moresby.

Barnett, B. (1988). Shell collecting on the Great Barrier Reef. Report to GBRMPA.

Batley, G.E. (1987). Heavy metals in Lake Maquarie, Aust. J. Mar. Freshw. Res., 38, pp 591-606.

Batley, G.E. and S.G. Lilley (1987). Pollutant release in dumped dredge spoil from Wooloomooloo Bay, Sydney. CSIRO Inst. Energy and Earth Resources, Div. Energy Chemistry, Report EC/IR025.

Batley, G.E., K.J. Mann, C.I. Brockbank and A. Maltz (1988). Tributyltin in Sydney Harbour and Georges River waters. In: Proc. of the Conference on Organotin Materials in the Marine Environment, Lismore, Australia, pp 41-48.

Batley, G.E., K.J. Mann, C.I. Brockbank and A. Maltz (1989a). Tributyl tin in Sydney Harbour and Georges River waters. Aust. J. Mar. Freshw. Res., 40 (1), pp 39-48.

Batley, G.E., Chen Fuhua, C.I. Brockbank and K.I. Flegg (1989b). Accumulation of tributyl tin by the Sydney rock oyster, Saccostrea commercialis. Aust. J. Mar. Freshw. Res., 40 (1), pp 49-54.

BCL (1984). Bougainville Copper Limited Environmental Update 1972-1984, Panguna, 145 p.

BCL (1986). Bougainville Copper Limited Environmental Update 1986, Panguna, 130p.

Beckman, R. (1988). Blooms and gloom. Ecos, 57, pp 19-23.

Bell, P.R.F., P.F. Greenfield, D. Connell and D. Hawker (1987). Guidelines for management of waste discharges into the GBRMP. Report to GBRMPA, Townsville, Australia.

Bell, P.R.F., P.F. Greenfield, D. Hawker and D. Connell (1989). The impact of waste discharges on coral reef regions. Wat. Sci. Tech., 21(1), pp 121-130.

Benezit, M. (1981). Report on mining pollution in New Caledonia. SPREP Topic Review No. 1, SPC, Noumea, 20p.

Bennell, N. (1979). Coastal land development - a shadow over the Great Barrier Reef. Aust. Parks and Recreation, Nov. 1979, pp 41-45.

Bigham, G., T. Ginn, A.M. Soldate, and L. McCrone (1982). Evaluation of ocean disposal of manganese nodule processing waste and environmental considerations. U.S. Dept. of Commerce, Washington, D.C., 423p.

Birkeland, C. (1982). Terrestrial run-off as a cause of outbreaks of Acanthaster planci (Echinodermata; Asteroidea) Mar. Biol., 69, pp 78-185.

Birkeland, C. (1987). Nutrient availability as a major determinant of differences among coastal hard-substratum communities in different regions of the tropics, pp 45-97, in C. Birkeland (ed). Comparisons between Atlantic and Pacific tropical coastal ecosystems: community structure ecological processes and productivity. UNESCO Reports in Mar. Sci.

Bird, E.C.F., J.P. Dubois, and J.A. Iltis (1984). The impacts of opencast mining on the rivers and coasts of New Caledonia. United Nations University, Tokyo, 53p.

Blake, S.G. and D.P. Johnson (1988). Water quality, current patterns and sediment composition around Hamilton and Hayman Island, the Whitsundays. Report to GBRMPA, Townsville, Australia.

Borja, M.B. and H.R. Wood (1986). Environmental impact of sewage effluent at the marine outfall northern district sewage treatment plant, Guam. Guam Environment Protection Agency Report, Agana, Guam, 44p.

Boucher, L.M. (1986). Coral predation by muricid gastropods of the genus Drupella at Eniwetak, Marshall Islands. Bull. Mar. Sci., 38, pp. 9-11.

Bour, W.L., L. Loubersac and P. Rual (1985). Reef thermatic maps viewed through simulated data from the future SPOT satellite: Application to the biotope of topshell (Trochus niliticus) on Tetembia Reef (New Caledonia). Mar. Ecol. Prog. Ser., 34, pp 243-249.

Boyle, E.A., F. Sclater and J.M. Edmond (1976). On the marine geochemistry of cadmium. Nature, 263, pp 42-44.

Branch, J.B. (1984). The waste bin: nuclear waste dumping and storage in the Pacific. Ambio, 13, pp 327-330.

Brodie, J.E. (1983). Chemical characteristics of ocean water from the ocean thermal energy conversion (OTEC) site, southern Viti Levu coast, Fiji. Environmental Studies Report No. 16, INR, USP, Suva.

Brodie, J.E. and R.J. Morrison (1984). The management and disposal of hazardous wastes in the Pacific Islands. Ambio, 13, pp 331-333.

Brown, B.E. (1987). Worldwide death of corals - natural cyclical events or man-made pollution. Mar. Poll. Bull., 18, pp. 9-13.

Browne, J.H. (1986). Sewage disposal in the Sydney region. Proc. of the National Conference on Coastal Management, Coffs Harbour, Australia, pp 27-31.

Brownell, R.L., P.K. Anderson, R.P. Owen and K. Ralls (1979). The status of dugongs at Palau, an isolated island group. Proc. of Dugong Seminar, James Cook University, Townsville, Australia.

Bruton, G., B.T. Hart and E.M. Robertson (1984a). Marine quality assessment programme, heavy metals in marine tissue. Report to Australian Dept. of Home Affairs and Environment, Canberra.

Bruton, G., B.T. Hart and E.M. Robertson (1984b). Marine quality assessment programme, heavy metals in seawater. Report to Australian Dept. of Home Affairs and Environment, Canberra.

Bruton, G., B.T. Hart and E.M. Robertson (1984c). Marine quality assessment programme, petroleum hydrocarbons in marine environmental samples. Report to Australian Dept. of Home Affairs and Environment, Canberra.

Bryan, P.G. (1973). Growth rate, toxicity and distribution of the encrusting sponge Terpios sp. (Hadromerida: Suberitidae) in Guam, Mariana Islands. Micronesia, 9(2), pp 237-242.

Bultitude, D.R. and R.D. Strong (1985). Mangrove swamps, nature's nursery. Glimpses of Micronesia, 25(1), pp 53-56, 65.

Burgess, J.S. and E. Woolmington, (1981). Threat and stress in the Clarence River estuary of northern New South Wales. Human Ecol., 9, pp. 419-432.

Burgin, S. (1986). The impact of fishing on non-target species. In: Endangered Species. Social, Scientific, Economic and Legal Aspects in Australia and the South Pacific, editor, S.Burgin, Total Environment Centre, Sydney.

Burns, K.A. and J.L. Smith (1982). Hydrocarbons in Victorian coastal waters. Aust. J. Mar. Freshw. Res., 31, pp 251-256.

Callaway, R.J. (1986). Coastal marine outfalls in New Zealand: an overview, case studies and comparison with the United States. Water and Soil Miscellaneous Publication No. 96, Water Quality Centre, Hamilton, New Zealand.

Catlan, B.C. (1986). An alternative management solution for canal estate developments of NSW. In: Proc. of the Australian National Conference on Coastal Management, Coffs Harbour, Australia.

Carter, R. (1983). Baseline studies of Port Vila and Erakor Lagoons, Vanuatu. CCOP-SOPAC/SPREP Joint Report, Suva, 20p.

Cawthorn, M.W. (1985). Entanglement in, and ingestion of, plastic litter by marine mammals, sharks, and turtles in New Zealand waters. In: Proc. of the Workshop on the Fate and Impact of Marine Debris, R.S. Shomura & H.O. Yoshida, editors, Honolulu, ANOAA Tech. Memo., NOAA-TM-MNFS-SWFC-54, pp 336-343.

CDTC, Commonwealth Department of Transport and Construction, (1982). Kinoya sewage treatment plant: report on receiving water study, Fiji Public Works Department, Suva, 100p.

CDHC, Commonwealth Department of Housing and Construction (1985). Tarawa Project: Outfall reconnaissance survey. Canberra, Australia, 63p.

Champ, M.A., T.P. O'Conner and P.K. Park (1981). Ocean dumping of seafood wastes in the U.S. Mar. Poll. Bull., 12(7), pp 241-244.

Chesher, R.H. (1986). Project evaluation for the development of coastal resources in the Commonwealth of the Northern Mariana Islands. SPREP Report, SPC, Noumea, 117p.

Clarke, A. and I. Yassini (1986). Impacts of urban development on an estuary. In: Proc. of the Australian National Conference on Coastal Management, Coffs Harbour, Australia.

Clayshulte, R.N. (1983). Water quality monitoring program, airport construction site, Moen Island, Truk, TTPI. Water and Research Institute Technical Report No. 43, University of Guam, Guam.

Clayshulte, R.N. and W.J. Zolan (1982). Water quality monitoring programme, airport construction site, Moen Island, Truk, TTPI. Water and Energy Research Institute Technical Report No. 35, University of Guam, Guam.

Clayshulte, R.N. and W.J. Zolan (1985). Marine baseline water quality of the TTPI, WERI. Technical Report, WERI, Univ. of Guam, Agana.

Coates, M., D.W. Connell, J. Bodero, G.J. Miller and R. Back (1986). Aliphatic hydrocarbons in Great Barrier Reef organisms and environment. Estuarine, Coastal and Shelf Science, 23, pp 99-113.

Coleman, F.C. and D.H.S. Wehle (1983). Caught by accident - The fisherman's unwanted harvest. Oceans, July, 1983.

Cooper, R.J., D. Langlois and J. Olley (1982). Heavy metals in Tasmanian shellfish. 1. Monitoring heavy metal contamination in the Derwent Estuary: Use of oysters and mussels. J. App. Toxicol., 2(2), pp 99-110.

Cosser, P.R. (1988). Phosphorus loading to the northern Great Barrier Reef from mainland runoff. In: Proc. of Workshop on Nutrients in the GBR Region, GBRMPA Workshop Series No. 10, GBRMPA, Townsville, pp 39-43.

Cosser, P.R. (1989). Water quality, sediments and the macroinvertebrate community of residential canal estates in south-east Queensland: A multivariate analysis. Water Research, 23.

Currey, N.A. (1987). Darwin Harbour ambient water quality. In: Proc. of a Workshop on Research and Management of Darwin Harbour, editors, H.K.Larson, M.G.Michie and J.R.Hanley, Aust. Nat. Uni. N. Aust. Res. Unit, Mangrove Monograph No.4, Darwin.

Dandonneau, Y. (1986). Monitoring the sea surface chlorophyll concentration in the tropical Pacific: consequences of the 1982-83 El Nino, Fisheries Bulletin, 84(3), pp 687-695.

Debie, E., A. Raymond and J.L. De Nardi (1982). Etude sur l'origine du mercure present en milieu lagonaire dans la region de Papeete. Rapport CEA-R-5192, Commissariat a l'energie atomique, CEN-Saclay, Gif-sur-Yvette, 24p.

Delathiere, S. (1988). Etude du crabe de paletuviers (Scylla serrata) en Nouvelle Caledonie. Rapports D'activite Sciences de Mer, Oceanographie, ORSTOM, Noumea.

De Nardi, J.L., A. Raymond, M. Ricard (1983). Etude des consequences pour le lagon de Taunoa des travaux d'extension du port de Papeete Rapport CEA-R-5222, Commissariat a l'energie atomique, CEN-Saclay, Gif-sur-Yvette, 108p.

Dennis, G.D. and T.J. Bright (1988). The impact of a ship grounding on the reef fish assemblage at Molasses Reef, Key Largo National Marine Sanctuary, Florida. In: Sixth Inter. Coral Reef Symp., Townsville. Vol 2: 213-218.

Dent, J. (1986). Possible impact of Ok Tedi mining wastes on the waters of Torres Strait. In: Torres Strait Fisheries Seminar, A.K. Haines, G.C. Williams and D. Coats, editors, Port Moresby, PNG, pp 293-298.

Denton, G.R.W., H. Marsh, G.E. Heinsohn and C. Burdon-Jones (1980). The unusual metal status of the Dugong Dugong dugon. Mar. Biol., 57, pp 201-219.

Denton, G.R.W. (1985). Guidelines for trace metal surveillance studies in Torres Strait and adjacent waters. Torres St. Fisheries Seminar, Port Moresby, PNG, pp 299-307.

Denton, G.R.W. and C.Burdon-Jones (1986a). Trace metals in surface waters from the Great Barrier Reef. Mar. Poll. Bull., 17(5), pp 96-98.

Denton, G.R.W. and C. Burdon-Jones (1986b). Trace metals in corals from the Great Barrier Reef. Mar. Poll. Bull., 17(5), pp 209-213.

Denton, G.R.W. and C. Burdon-Jones (1986c). Trace metals in algae from the Great Barrier Reef. Mar. Poll. Bull., 17(5), pp 98-107.

Denton, G.R.W. and C. Burdon-Jones (1986d). Trace metals in fish from the Great Barrier Reef. Mar. Poll. Bull., 17(5), pp 201-209.

Dickson, R.J. and K.A. Hunter (1981). Copper and nickel in surface waters of Otago Harbour. N.Z. J. Mar. Freshw. Res., 15, pp 475-480.

Dodge, R.E., R.C. Aller and J. Thomson (1974). Coral growth related to resuspension of bottom sediments. Nature, Lond., 247, pp 574-577.

Downey, D., J. Clark and R.B. Ellis-Pegler (1986). Salmonella typhi infection in adults is not limited to travellers returning from the tropics. The N.Z. Medical J., 99, pp 443-446.

Downing, N. and C.R. El-Zohr (1987). Gut evacuation and filling rates in the rock-boring sea urchin, Echinometra mathaei. Bull. Mar. Sci., 41, pp 579-584.

Duce, R.A., R. Arimoto, B.J. Ray, C.K. Unni and P.J. Harder (1983). Atmospheric trace elements at Enewetak Atoll: 1, concentrations, sources and temporal variability. J. Geophys. Res., 88, pp 5321-5342.

Duce, R.A., R. Arimoto, B.J. Ray and C.K. Unni (1985). Atmospheric trace elements at Enewetak Atoll: 2, Transport to the ocean by wet and dry deposition. J. Geophys. Res., 90, pp 2391-2408.

Duce, R.A., B.W. Mosher, J.M. Prospero and D.L. Savoie (1987). Atmospheric selenium: geographic distribution and ocean to atmosphere flux in the Pacific. J. Geophys. Res., in press.

Dupon, J.F. (1986). The effects of mining on the environment of high islands: A case study of nickel mining in New Caledonia. Environmental Case Studies: South Pacific Study 1. South Pacific Environment Programme, Noumea.

Dutton I.M. (1985). Workshop on Contaminants in Waters of the Great Barrier Reef. GBRMPA Workshop Series No. 5, GBRMPA, Townsville.

Dyall, R.A. and R.B. Johns (1985). Organochlorine pesticide levels in selected sediments of the Great Barrier Reef. Report to GBRMPA, Townsville, Australia.

Eagle, M. and R.J. Higgins (1987). A study to assess the impact of mining waste discharged to a major river system - the Ok Tedi Environmental Study 1986-89. Paper presented at International Symposium for Pollution and Control, Shanghai, October 1987.

Eldredge, L.G. (in press). Poisons for fishing on coral reefs. In: Human Activities Causing Damage to Coral Reefs: Knowledge and Recommendations. Unesco Marine Science Series.

Eldredge, L.G. and R.K. Kropp (1985). Volcanic ashfall effects on intertidal and shallow-water coral reef zones at Pagan, Mariana Islands. Proc. Fifth Internat. Coral Reef Congress, Tahiti, 4, pp 195-200.

Ellis, D. (1988). Editors comment. Mar. Poll. Bull., 19(12), p 652.

Everingham, I.B. (1976). Tsunamis in PNG. Science in New Guinea, 4(1), pp 10-20.

Fabre-Teste, L. (1985). Ecotoxicologie des metaux-traces en milieu corallien: relation entre elements-traces et tissus des coraux hermatypiques, comparaison entre echantillons de Nouvelle Caledonie et de la Grande Barriere. Rapp. Final Contrat CNEXO-COB DAF 83/7241. 62p.

Fabris, J.G. (1983). Heavy metals in Corio Bay sediments. Marine Science Laboratory Technical Report No. 24, MSL, Queenscliff, Victoria.

Fabris, J.G., C.F. Gibbs and P. Brown (1986). Cadmium and other heavy metals in mussel (Mytilus edulis planulatus L) from Corio Bay, Vic. Marine Science Laboratory Technical Report No.49, MSL, Queenscliff, Victoria.

Fairweather, P.G. (1988). Ecological changes due to our use of the coast: research needs versus effort. Proc. Ecol. Soc. Aust., 16, pp 1-21.

Ferguson, J. (1983). Concentrations and speciation of Pb, Zn and Cd in seawater-like smelter effluent and adjacent marine environments, Port Pirie, S.A. Aust. J. Mar. Freshw. Res., 34, pp 375-385.

Field, C.D. and A.J. Dartnall (1985). Eds., Mangrove Ecosystems of Asia and the Pacific: Status, Exploitation and Management. AIMS, Townsville.

Filer, C.S. and R. Jackson (1986). The social and economic impact of a gold mine on Lihir. Unpub. report, UPNG.

Flegal, A.R. (1986). Lead in tropical marine ecosystems: a review. Sci. Tot. Environ., 58, pp 1-8.

Flegal, A.R. and C.C. Patterson (1983). Vertical concentration profiles of lead in the central Pacific Ocean. Earth Planet Sci. Lett., 64, pp 19-32.

Fox, E.G. (1985). Public health implications. In: Ocean Outfall Handbook, editor, B.L. Williams, Water and Soil Miscellaneous Publication No. 76, Min. of Works and Dev., Wellington.

Fox, M.E., D.S. Roper and S.F. Thrush (1988). Organochlorine contaminants in surficial sediments of Manukau Harbour, New Zealand. Mar. Poll. Bull., 19(7), pp 333-336.

Fraizier, A., J. Debiard, D. Franck, P. Benente and R. Jouen (1985). Observations sur diverses formes de pollution d'un secteur littoral de Tahiti. Repport CEA-R-5307.

Fraizier, A. and D. Franck (1985). Role de deux rivieres de zones urbaines ou industrielles de Papeete dans le transfert de divers mataux lourds en milieu lagonaire (Hg, Cd, Pb, Cr, Cu, Zn, Fe) Repport CEA-R-5303.

Fraizier, A. and J. Debiard (1985). Etude de la qualite d'un secteur cotier de l'ile de Tahiti (Polynesie Francaise). Report to SPREP, 17p.

Gagan, M.K., M.W. Sandstrom and A.R. Chivas (1987). Restricted terrestrial carbon input to the continental shelf during Cyclone Winifred: implications for terrestrial runoff to the Great Barrier Reef Province, Coral Reefs, 6 (2), pp 113-119.

Gangaiya, P., J.E. Brodie and R.J. Morrison (1986). Initial report on the quality of the Vitogo River and associated environment before the construction of an integrated sawmill/chipmill complex at Drasa, Western Viti Levu, Fiji. INR Technical Report 86/5, INR, USP, Suva, 46p.

Gangaiya, P. and J.E. Brodie (1986). Arsenic levels in water, sediments and marine organisms after a spillage of arsenic (V) oxide in Vila Harbour, Vanuatu. Environmental Studies Report No. 31, INR, USP, Suva, 13p.

Gawel, M.J. (1988). Assessment of coral reefs and resources in Micronesia. In: Sixth Inter. Coral Reef Symp., Townsville.

Gawne, K.M. (1986). Copper in the Fly/Ok Tedi River System. Speciation, Toxicity and Analysis. Report prepared for Department of Minerals and Energy, August 1986.

Gibbons, J.R.H. and J.E.Brodie (1985). The environmental and social impact of Monasavu Hydro scheme: an appraisal. Fiji Science Journal, 1(6), pp 25-31.

Gittings, S.R., T.J. Bright, A. Choi and R.R. Barnett (1988). The recovery process in a mechanically damaged coral reef community: recruitment and growth. In: Sixth Inter. Coral Reef Symp., Townsville. Vol 2: 225-230.

Glynn, P.W., J. Cortes, H.M. Guzman and R.H. Richmond (1988). El Nino (1982-1983) associated coral mortality and relationship to sea surface temperature deviations in the Tropical Eastern Pacific. Proc. of the Sixth International Coral Reef Symposium, Townsville, Australia. Vol 3: 237-244.

Glynn, P.W., L.S. Howard, E. Corcoran and A.D.Freay (1984). The occurrence and toxicity of herbicides in reef building corals. Mar.Poll.Bull., 15(10), pp 370-374.

Goldberg, E.D. (1983). Removing a mood of uncertainty. Mar. Poll. Bull. 14, pp 157-158.

Goldin, P.A. (1986). Environmental problems associated with coastal protection structures. Proc. of the National Conference on Coastal Management, Coffs Harbour, Australia. pp 391-395.

Gourlay, M.R. and J.L.F. Hacker (1986). Pioneer River Estuary: Sedimentation Studies. Dept. of Civil Engineering, University of Queensland, Brisbane, 207 p.

Greenspan, J.R. and J.L. Conrad (1985). Typhoid fever in the Republic of the Marshall Islands. Report to the Centre for Disease Control, Atlanta. 12p.

Gregory, M.R. (1977). Plastic pellets on New Zealand beaches. Mar.Pol.Bull., 8, pp 82-84.

Gregory, M.R. (1978). Accumulation and distribution of virgin plastic granules on New Zealand beaches. NZ J. Mar. Freshw. Res., 12(4), pp 399-414.

Grue, C.E. (1985). Pesticides and the decline of Guam's native birds. Nature, 316, p 301.

Guicher, A. (1985). Nature and human change of sedimentation in lagoons behind barrier reefs in the humid tropics. Proc. Fifth Intern. Coral Reef Symp., 4, pp 207-212.

Haddock, R.L. (1979). Vibrio parahaemolyticus food poisoning incidents in the Territory of Guam, USA. J. Environ. Health, 41(6), pp 329-330.

Haddock, R.L. (1987). Cholera in a Pacific Island. J. Diarrhoeal Dis. Res., 5(3), pp 181-183.

Haddock, R.L. and F.A. Nocon (1985). Nag Vibrio cholera isolated from imported shellfish in Guam. Southeast Asian J. Trop. Med. Pub. Hlth., 16(1), pp 113-116.

Hallegraeff, G.M., D.A. Steffensen and R. Wetherbee (1988a). Three estuarine Australian dinoflagellates that can produce paralytic shellfish toxins. J. Plank. Res., 10, in press.

Hallegraeff, G.M., S.O. Stanley, C.J. Bolch and S.I. Blackburn (1988b). Gymnodinium catenatum blooms and shellfish toxicity in southern Tasmania, Australia. Proc. of the Intern. Symp. on Red Tides, Takamatsu, Japan.

Hallock, P. and W. Schlager (1986). Nutrient excess and the demise of coral reefs and carbonate platforms. Palaios, 1, pp 389-398.

Hambuechen, W.H. (1973). Pesticides in the Cook Islands. Regional Symposium on Conservation of Nature: Reefs and Lagoons. South Pacific Commission, Noumea. pp 119-126.

Hammond, L. (1986). Proposal for the design of the Torres Strait pollution baseline study. Victorian Institute of Marine Science, Melbourne, 14 p.

Hammond, L. (1987). Hot-spot for Australia and Papua New Guinea. Mar. Poll. Bull., 18(4), p 147.

Hammond, L.S. and B. Hart (1984). Analyses of seawater from Bass Strait: Results of the Map-23, Map-33 and Map-35 projects. Report to the Department of Home Affairs and Environment, Victorian Institute of Marine Sciences, Melbourne, 63p.

Haei, P. and A. Baria (1987). Data on copper, lead and zinc residues in bivalves from the Port Moresby region. SPREP Coastal Water Quality Programme, University of Papua New Guinea, Port Moresby.

Harding, G.C. (1986). Organochlorine dynamics between zooplankton and their environment, a reassessment. Mar. Ecol. Prog. Ser., 33, pp 167-191.

Harmelin-Vivien, M.L. and P. Laboute (1986). Catastrophic impact of hurricanes on atoll outer reefs slopes in the Tuamotu (French Polynesia). Coral Reefs, 5, pp 55-62.

Harris, P.T. (1988). Sediments, bedforms and bedload transport pathways on the continental shelf adjacent to Torres Strait, Australia - Papua New Guinea. Continental Shelf Research, 8(8), pp 979-1003.

Hawker, D.W. and D.W. Connell (1989). An evaluation of the tolerance of corals to nutrients and related water quality characteristics. Intern. J. Environmental Studies, 34, pp. 179-188.

Hayes, T.M. and W.H. Zucker (1984). eds. Report on Pacific Regional Workshop on Marine Pollution Prevention, Control and Response, Suva. SPREP/IMO.

Hickman, R.W. (1981). Marine farming and coastal water use conflicts. Proc. of 11th New Zealand Geography Conference, pp 159-160.

Hickman, N.J., M.C. Mobley and J.G. Fabris (1984). Heavy metal contamination: Alert levels for cultured mussels (Mytilus edulis Planulatus) in Port Phillip Bay. Marine Science Laboratory Internal Report No. 84, MSL, Queenscliff, Victoria.

Higgins, R. (1984). Interim tailings disposal - Assessment of criteria and performance. Environmental Sciences Seminar, UPNG, 27 September 1984, Mimeo.

Higgins, H.W. and D.J. Mackey (1987a). Role of Ecklonia radiata (C.Ag.) J. Agardhi in determining trace metal availability in coastal waters. I. Total trace metals. Aust. J. Mar. Freshw. Res., 38, pp 307-315.

Higgins, H.W. and D.J. Mackey (1987b). Role of Ecklonia radiata (C.Ag.) J. Agarghi in determining trace metal availability in coastal waters. II. Trace metal speciation. ibid, pp 317-328.

Hodda, M. and W.L. Nichols (1986). Nematode diversity and industrial pollution in the Hunter River estuary, NSW, Australia. Mar. Poll. Bull., 17(6), p 251.

Hodgkin, E.P. (1986). Estuaries - The focus for coastal development. In: Proc. of the National Conference on Coastal Management, Coffs Harbour, pp 139-144.

Hodgkin, E.P. (1988). The dying estuaries of Australia's South West. Can they be saved? In: Proc. of Jubilee Conference of the Australian Marine Science Association. pp 131-134.

Hodgkin, E.P. and P.B. Birch (1986). No simple solutions: Proposing radical management options for a eutrophic estuary. Mar. Poll. Bull., 17(9), pp 399-404.

Hodgson, G. (1988). Sedimentation damage to coral reefs: economic implications. In: Sixth Inter. Coral Reef Symp., Townsville.

Holliday, C.R. (1975). Tropical cyclones affecting Guam. U.S. Fleet Weather Central, Guam, FLEWEACEN Tech. Note JTWC 75-3.

Holmes, N. (1988). Proceedings of the Conference on Organotin Materials in the Marine Environment. Centre for Coastal Management, Lismore, Australia.

Hopley, D. (1988). Anthropogenic influences on Australia's Great Barrier Reef. Aust. Geographer, 19, pp 26-45.

Huebert, B.J. (1980). Nitric acid and aerosol nitrate measurements in the equatorial Pacific region. Geophys. Res. Lett., 7, pp 325-328.

Hughes, P.J. (1989). The effects of mining on the environment of high islands: A case study of gold mining on Misima Island, Papua New Guinea. Environmental Case Studies: South Pacific Study 5. South Pacific Regional Environment Programme, Noumea.

Hume, T.M. and M.S. McGlone (1986). Sedimentation and catchment use change recorded in the sediments of a shallow tidal creek, Lucas Creek, Upper Waitemata Harbour, New Zealand. NZ J. Mar. Freshw. Res., 20, pp 667-687.

Hunter, K.A. (1981). Trace metal observations in Cook Strait water. HMNZS Tui cruise, 20 Jan-13 Feb, 1981. Maui Development Environmental Study Report 81-10, University of Auckland, Auckland.

Hunter, K.A. (1983). On the estuarine mixing of dissolved substances in relation to colloid stability and surface properties. Geochimica et Cosmochimica Acta, 47, pp 467-473.

Hunter, K.A. and S.R. Tyler (1987). The distribution of zinc and reactive silicate in the Otago Harbour. N.Z. Mar. Chem., 20, pp 377-387.

Hurley, D.E. (1987). New Zealand Marine Science in Progress, NZ Marine Sciences Liaison Group Report No. 3, Wellington.

Iltis, J.A. (1979). Activitie pastorale te degredation: la region de Tamala (Nouvelle Caledonie). Photo-Interpretation, 79(30), pp 23-26.

Jackson, R. (1985). All that's gold does not glitter: a third party account of the Ok Tedi gold/copper project. Industry and Environment, 8(1), pp 29-32.

Jackson, R. (1986). Ok Tedi: The Pot of Gold. University of Papua New Guinea, Port Moresby, 200p.

Jaffre, T. et al. (1976). Sebertia acuminata: a hyper accumulator of nickel from New Caledonia. Science, 193, pp 579-580.

Jaffre, T., M. Latham and M. Schmid (1977). Aspects de l'influence de l'extraction du mineral de nickel sur la vegetation et les sols en Nouvelle Caledonie. Cahiers ORSTOM, ser. Biol.,12, pp 307-321.

Jeffrey, J., N. Marshman, I. Archer and W. Salomons (1985a). Impact of mine tailings discharge on a tropical marine bay. In: Lekkas. T.D. 1985 Proc. of Inter. Conference Heavy Metals in the Environment, Vol. 2, Athens - Sept. 1985, pp 249-251.

Jeffrey, J., J. Bril, N. Marshman and W. Salomons (1985b). Modelling of copper in a tropical river system affected by acid mine drainage and mine tailings. In: Lekkas, T.D. 1985 Proc. of Inter. Conference Heavy Metals in the Environment, Vol. 2, Athens - Sept. 1985, pp 255-257.

Jeffries, B. and R. Kearney (1989). Southern Bluefin Tuna - a fishery in crisis. Australian Fisheries, 48 (8), pp 12-16.

Johannes, R.E. (1977). Traditional law of the sea in Micronesia. Micronesica, 13 (2), pp 121-127.

Johannes, R.E. (1978). Traditional conservation methods in Oceania and their demise. Ann. Rev. Ecol. Syst., 9, pp 349-364.

Johannes, R.E. and S.B. Betzer (1975). Introduction: marine communities respond differently to pollution in the tropics than at higher latitudes. pp 1-12. In: Tropical Marine Pollution. Elsevier Scientific Publ. Co.

Johannes, R E., W. Kimmerer, R. Kinzie, E. Shiroma and T. Walsh (1979). The impact of human activities on Tarawa lagoon. Report to SPC, Noumea, 83p.

Johns, R.B., B.R. Currie and S. Chong (1988). Terrigenous and anthropogenic inputs to a Cairns - Great Barrier Reef sediment transect. Report to GBRMPA, Townsville.

Kagi, R.I. (1985). Analytical quality assurance in the marine quality assessment programme. Part 2: Organic analytes. Report to the Australian Dept. of Arts, Heritage and Environment, Canberra.

Kay, D.G. (1987). Oil spill experience and risk in Australia. In: Proc. of Aust. National Oil Spill Conference, Federal Dept. of Transport.

Kenchington, R. (1977). Growth and recruitment of Acanthaster planci (L) on the Great Barrier Reef. Biol. Conserv., 11, pp 103-118.

Kimmerer, W.J. and T.W. Walsh (1981). Tarawa Atoll lagoon : circulation, nutrient fluxes and the impact of human wastes. Micronesica, 17, pp 161-179.

King, N., M. Miller and S. de Mora (1989). Tributyl tin levels for sea water, sediment and selected marine species in coastal Northland and Auckland, New Zealand. N.Z. J. Mar. Freshw. Res., 23, pp 287-294.

Kinsella, B. and R. Willix (1985). Analytical quality assurance in the marine quality assessment programme. Part 1: Trace metals. Report to the Australian Dept. of Arts, Heritage and Environment, Canberra.

Kyle, J.M. (1987). Mercury and selenium concentrations in sharks from northern Australian waters. Aust. J. Mar. Freshw. Res., 37, pp 309-321.

Kyle, J.H., J. Tinkerame and P. Haer (1986). Concentrations of zinc, copper, lead and cadmium in three species of fish from the Ok Tedi Region. Science in New Guinea 12 (3): pp 150-156.

Laboute, P. (1987). Tokelau coral damage in Cyclone Tusy, ORSTOM Report, ORSTOM, Noumea, 15p.

Lal, P.N. (1984). Environmental implications of coastal development in Fiji. Ambio, 13, pp 316-321.

Langlois, D., R.J. Cooper, N.H. Clark and D.A. Ratkowsky (1987). The effects of a mercury containment program at a zinc smelting plant on the mercury content of sand flathead in the Derwent Estuary. Mar. Poll. Bull., 18 (2), pp 67-70.

Le Roux, C. (1978). Port public de Noumea. Analyse d'une evolution. Me'moire de Maitrise, Universite' de Bretagne Occidentale, Brest, 236p.

Lessios, H.A., D.R. Robertson and J.D. Cubit (1984). Spread of Diadema mass mortality through the Caribbean, Science, 226, pp 335-337.

Lewis, G.D., M.W. Loutit and F.J. Austin (1985). Human enteroviruses in marine sediments near a sewage outfall on the Otago Coast. NZ J. Mar. Freshw. Res., 19, pp 188-192.

Livingston, M.E. (1987). Preliminary studies on the effects of past mining on the aquatic environment, Coromandel Peninsula. Water and Soil Miscellaneous Publication No. 104, Water and Soil Directorate, Min. of Works and Development, Wellington.

Louis, J.P. (1981). Les problemes de l'eau dans la presqu'ile de Noumea. Etude d'assainissement, Direction de la sante et de l'hygiene publique, Noumea, 149p.

Loutit, M.W. and G.D. Lewis (1985). Faecal bacteria from sewage effluents in sediments around an ocean outfall. NZ J. Mar. Freshw. Res., 19, pp 179-185.

Mackey, D.J. (1984). Trace metals and the productivity of shelf waters off N.W. Australia. Aust. J. Mar. Freshw. Res., 35, pp 505-516.

Mackey, D.J. (1986). Copper-complexing capacity of S. Pacific waters. Aust. J. Mar. Freshw. Res., 37, pp 437-450.

Maclean, J. (1984). Red tide - a growing problem in the Indo-Pacific region. ICLARM Newsletter, 7(4), p 20.

McBride, G.B., D.G. Smith and R.D. Pridmore (1985). Water quality monitoring in New Zealand. Water Quality Bulletin (NZ), 10, pp 91-95.

McClanahan, T.R. and N.A. Muthiga (1988). Changes in Kenyan coral reef community structure and function due to exploitation. Hydrobiologia, 166, pp 269-276.

McGhee, K. (1985). Remote PNG mine may threaten northern reef. Bull. Aust. Litt. Soc., 8(12), pp 1-3.

McGuinness, K.A. (1988). The Ecology of Botany Bay and the Effects of Man's Activities: a critical synthesis. Institute of Marine Ecology, University of Sydney, Sydney.

McLaren, N.E. and D.J. Wiltshire (1984). Northern Spencer Gulf marine biology study. Report to the SA Dept. of Environment and Planning, Adelaide.

McLean, C., A. Miskiewicz and E. Roberts (1989). Heavy metals in Cheilodactylus fuscus collected near three primary sewage outfalls, Sydney, Australia. At: First Australian Environmental Chemistry Conference, Brisbane.

McMahon, R.G.P. (1974). Environmental behaviour of PCBs. AMDEL Report No. 1089, The Australian Mineral Development Laboratories, Adelaide.

Major, J.A. and R.W. Pettis (1978). Analysis of cadmium, copper, lead and zinc in sea water: Inter-laboratory comparison among Australian laboratories. CSIRO Division of Fisheries and Oceanography, Report No. 95, Sydney, Australia.

Maragos, J.E. (1986). Coastal resource development and management in the US Pacific islands. Report to the Office of Technological Assessment, US Congress, Washington.

Marsh, H. (1985). The Dugong problem. In: Traditional Fisheries Workshop, editor, L. Zann, GBRMPA, Townsville.

Marsh, H. (1988). An ecological basis for Dugong conservation in Australia. In: Marine Mammals of Australia: Field Biology and Captive Management, editor, M.L.Augee, Royal Zoological Society of NSW, Sydney.

Marsh, H. and W.K. Saalfeld (1989). Distribution and abundance of dugongs in the Northern Great Barrier Reef marine park. Aust. Wildl. Res., 16, pp 429-440.

Marshman, N., J. Jeffrey and W. Salomons (1985a). Release of heavy metals and acid from tailings deposits in tropical environments. In: Lekkas, T.D., 1985 Proc. Inter. Conf. Heavy Metals in the Environment, Vol. 2, Athens, September 1985, pp 27-29.

Marshman, N., I. Archer and W. Salomons (1985b). Environmental impact of mine waste on terrestrial and aquatic environments working towards control strategies. In: Lekkas, T.D., 1985 Proc. Inter. Conf. Heavy Metals in the Environment, Vol. 2, Athens, September 1985, pp 258-260.

Maung, T.M. (1979). Cholera in the Gilberts, World Health, Jan. 1979, pp 6-9.

Miller, M.C. (1985). Water quality enhancement in the Burnett River. Water, 12 (1), pp 28-31.

Moran, P.J. (1984). Water quality control and the effect on the concentration of heavy metals in Port Kembla Harbour, NSW. Mar. Poll. Bull., 15 (8), pp 294-297.

Moran, P.J. (1986). The Acanthaster phenomenon. Ann. Rev. Oceanog. Mar. Biol., 24, pp 379-480.

Morrison, R.J. and J.E. Brodie (1984). Coastal and Inland Water Quality in the South Pacific. South Pacific Regional Environment Programme Topic Review No. 16, SPC, Noumea, 89p.

Morrison, R.J. and J.E. Brodie (1985). Pollution problems in the South Pacific: fertilizers, biocides, water supplies and urban wastes in UNEP: Environment and resources in the Pacific. UNEP Regional Seas Reports and Studies No. 69, UNEP, 294p.

Morton, R. (1989). Hydrology and fish fauna of canal developments in an intensively modified Australian estuary. Estuarine, Coastal and Shelf Science, 28, pp 43-58.

Mowbray, D.L. (1986a). Pesticide control in the South Pacific. Ambio, 15(1), pp 22-29.

Mowbray, D.L. (1986b). Biological impact of Ok Tedi mine tailings, cyanide and heavy metals on the Ok Tedi/Fly River ecosystems in Papua New Guinea. Biol. Dept., Uni. of PNG, 90p.

Mowbray, D. (1986c). Pollution problems in Papua New Guinea: Ok Tedi. Siren, 31, pp 11-14.

Mowbray, D. (1988). Review of Pesticide Use in the South Pacific. South Pacific Regional Environment Programme Topic Review No. 26 and UNEP RSRS No. 89, SPC Noumea, 418p.

Moyer, J.T., W.K. Emerson and M. Ross (1982). Massive destruction of scleractinian corals by the muricid gastropod, Drupella, in Japan and the Philippines. Nautilus, 96, pp 68-82.

Murray, A.P. (1987). Hydrocarbons and chlorinated hydrocarbons in the sediments of Port Phillip Bay (Australia). M.Sc. Thesis, Deakin Uni., Geelong.

Naidu, S., W.G.L. Aalbersberg, J.E. Brodie, V.A. Fuavao, M. Maata, M. Naqasima, P. Whippy and R.J. Morrison (1989). Water quality studies on selected South Pacific lagoons. Report to SPREP, 124 p.

National Radiation Laboratory (1987). Environmental Radioactivity Annual Report. Wellington, New Zealand, 12 p.

Neverauskas, V.P. (1985). Effects of the Port Adelaide treatment works sludge discharge on the adjacent marine environment. In: Proc. 1985 Aust. Conf. on Coastal and Ocean Engineering, pp 193-202.

Nishimura, M., S. Konishi, K. Matsunaga, K. Hata and T. Kosuga (1983). Mercury concentration in the ocean. J. Oceanogr. Soc., Japan, 39, pp 295-300.

NSR (1987). Natural Systems Research Pty. Ltd., Placer (PNG) Pty Ltd Misima Project Environment Plan, Appendix 3 - Water Quality Investigations, Hawthorn, Australia.

Nurnberg, H.W., L. Mart, H. Rutzel and L. Sipos (1983). Investigations on the distribution of heavy metals in the Atlantic and Pacific oceans. Chem. Geol., 40, pp 97-116.

Nuttall, P.M. and B.J. Richardson (1987). Environmental effects of canal estates in Australia. Water, 14(4), pp. 14-17.

Olafson, R.W. (1978). Effect of agricultural activity on levels of organochlorine pesticides in hard corals, fish and molluscs from the Great Barrier Reef. Marine Environ. Res., 1, pp 87-107.

Oliver, J.K. (1985). Recurrent seasonal bleaching and mortality of corals on the Great Barrier Reef. In: Proc. of Fifth Intern. Coral Reef Congress, Tahiti, Vol. 4, pp 201-206.

OTML (1986a). Review of the water quality monitoring of the Fly and Ok Tedi River system. ed. G. Johnstone, Ok Tedi Mining Limited Sixth Supplemental Agreement Environmental Study, Report No. ENV/86-08, December 1986, 137pp.

OTML (1986b). A Review of the results of biological sampling of the Ok Tedi and Fly River systems, April 1983 to June 1986. ed. K.G. Hortle, Ok Tedi Mining Limited Sixth Supplemental Agreement Environmental Study, Report No. ENV/86-09, December 1986, 206pp.

Parrat, J. (1973a). Nature protection in New Caledonia. Pages 41-48 in : Regional Symposium on Conservation of Nature - Reefs and Lagoons. SPC, Noumea.

Parrat, J. (1973b). Destruction and conservation of vegetation in New Caledonia. Pages 151-158 in : Regional Symposium on Conservation of Nature - Reefs and Lagoons. SPC, Noumea.

Pastorok, R.A. and G.R. Bilyard (1985). Effects of sewage pollution on coral reef communities. Mar. Ecol. Prog. Ser., 21, pp 175-189.

Paterson, R. (1979). Shark meshing takes a heavy toll of harmless marine animals. Aust. Fisheries, Oct.1979, pp 17-23.

Pearson, R.G. (1981). Recovery and recolonization of coral reefs. Mar. Ecol. Prog. Ser., 4 (1), pp 105-133.

Peerzada, N. and W. Rohoza (1989). Some heavy metals in sediments from Darwin Harbour, Australia. Mar. Poll. Bull., 20 (2), pp 91-92.

Penn, N. (1980). The environmental consequences and management of coral sand dredging in the Suva region. Environmental Studies Report No. 6, INR, USP, Suva.

Penn, N. (1984). Ph.D. Thesis, University College of Swansea, Wales.

Pernetta, J.C. and P.J. Hughes (1989). Studies and reviews of Greenhouse related climatic change impacts on the Pacific Islands. Report to SPREP. Presented at the SPC/UNEP/ASPEI Intergovernmental Meeting on Climatic Change and Sea Level Rise in the South Pacific. Majuro, 133 p.

Petr, T. (1980). Purari River Environment (Papua New Guinea). A summary report of research and surveys during 1977-1979. Office of Environment and Conservation, Waigani and Dept. of Minerals and Energy, Konedobu.

Plucer-Rosario, G. (1987). The effect of substratum on the growth of Terpios, an encrusting sponge which kills coral. Coral Reefs, 5, pp 197-200.

Poiner, I.R. and A.H. Harris (1986). The effect of commercial prawn trawling on the demersal fish communities of the south-eastern Gulf of Carpentaria. In: Torres Strait Fisheries Seminar, A.K. Haines, G.G. Williams and D. Coates, editors, Australian Government Publishing Service, Canberra.

Poiner, I.R. and A.N.M. Harris (1988). The effects of prawn trawling on the northern Great Barrier Reef. Proc. of the Sixth International Coral Reef Symposium, Townsville, Australia.

Powell, J.H., R.E. Powell and D.R. Fielder (1981). Trace element concentrations in tropical marine fish at Bougainville Island, Papua New Guinea. Water, Air and Soil Pollution, 16, pp 143-158.

Pritchard, P.C.H. (1987). Sea turtles in New Caledonia. Report of a literature and field investigation. Report to IUCN, Centre for Marine Conservation, Cambridge.

Prospero, J.M., D. Savoie, R.T. Nees, R.A. Duce and J. Merrill (1985). Particular sulphate and nitrate in the boundary layer over the North Pacific Ocean. J. Geophys. Res., 90, pp 10586-10596.

Puddicombe, R.A. (1986). Australian marine mammals. In: Proc. of the Australian National Conference on Coastal Management, Coffs Harbour, Australia.

Randall, R.H. and C. Birkeland (1978). Guam's reefs and beaches. Part II. Sedimentation studies at Fouha Bay and Ylig Bay. Univ. Guam Mar. Lab. Tech. Rept., 47, 77p.

Randall, R.H. and L.G. Eldredge (1977). Effects of Typhoon Pamela on the coral reefs of Guam. Proc. Third Int. Symp. Coral Reefs, Miami, 2. Biology, pp 525-531.

Rasmussen, C. (1988). Effects of nutrients carried by mainland runoff on reefs of the Cairns area: A research plan and preliminary results. In: Proc. of Workshop on Nutrients in the GBR Region, GBRMPA Workshop Series No. 10, GBRMPA, Townsville, pp 66-91.

Reefplan (1987). Oil spill contingency plan for the Great Barrier Reef. Dept. of Transport, Canberra, 75p.

Richardson, B.J. (1985a). Polychlorinated biphenyls in Australian waters. In: Pollution in the Urban Environment, eds. M. Chan, R. Hoare, P. Holmes, R. Law and S. Reed, Elsevier Applied Science, London.

Richardson, B.J. (1985b). Disposal of polychlorinated biphenyl waste in Australia. In: Pollution in the Urban Environment, eds. M. Chan, R. Hoare, P. Holmes, R. Law and S. Reed, Elsevier Applied Science, London.

Richardson, B.J. and J.S. Waid (1980). Polychlorinated biphenyls (PCBs): An Australian viewpoint on a global problem. Search, 13, pp 17-25.

Richardson, B.J. and J.S. Waid (1983). PCBs in shellfish from Australian coastal waters. Environmental Biogeochemistry Ecol. Bull.(Stockholm), 35, pp 511-517.

Richardson, B.J., R.H. Smillie and J.S. Waid (1987). Case study: The Australian Ecosystem. In: PCBs and the Environment, Vol. III, CRC Press, Boca Raton, pp 241-263.

Ridgway, N.M. and G.P. Glasby (1984). Sources of marine pollution around New Zealand. New Zealand Oceanographic Institute Oceanographic Summary No. 23, DSIR, Wellington.

Rongap, B. (1984). Cyanide spill in the Fly River delta, Papua New Guinea. Dept. of Environment and Conservation, Waigani, 5p.

Roper, D.S., S.F. Thursh and D.G. Smith (1988). The influence of runoff on intertidal mudflat benthic communities. Mar. Environ. Res., 26, pp 1-18.

Roy, P.S. (1984). New South Wales estuaries: Their origin and evolution. In: Thom, B.G., Coastal Geomorphology in Australia. Academic Press, Sydney, pp 99-121.

Roy, P. and J. Connell (1989). The Greenhouse Effect: Where have all the Islands gone. Pac. Islands Monthly, 59 (16), pp 16-21.

Roy, P.S. and E.A Crawford (1984). Heavy metals in a contaminated Australian estuary - dispersion and accumulation trend. Estuarine Coastal and Shelf Science, 19, pp 341-358.

Ruddle, K. and R.E. Johannes (1985). editors. The traditional knowledge and management of coastal systems in Asia and the Pacific. Proc. of a UNESCO-ROSTSEA Seminar, Bangkok.

Ryan, P.A. (1987). Journey, 8, (3).

Ryland, J.S., R.A. Wrigley and A. Muirhead (1984). Ecology and colonial dynamics of some Pacific reef-flat Didemnidae (Ascidiacea). Zool. J. Linn. Soc., 80, pp 261-282.

Sadler, R. (1989). Breakdown of dunder in wastes. At: First Australian Environmental Chemistry Conference, Brisbane.

Sainsbury, K. and I. Poiner (1989). A preliminary review of the effects of prawn trawling in the Great Barrier Reef Marine Park. Report to GBRMPA, Townsville, Australia.

Saltzman, E.S., D.L. Savoie, J.M. Prospero and R.G. Zika (1985). Atmospheric methane-sulphonic acid and non-sea-salt sulphate at Fanning and American Samoa. Geophys. Res. Lett., 12, pp 437-440.

Saltzman, E.S., D.L. Savoie, J.M. Prospero and R.G. Zika (1986). Methanesulphonic acid and non-sea-salt sulphate in Pacific air: regional and seasonal variations. J. Atmos. Chem., 4, pp 227-240.

Savidge, J.A. (1983). Guam: Paradise lost for wildlife. Biological Conservation, 30(4), pp 305-317.

Scribner, E. (1987). Organochlorine pesticides and PCB residues in fish and other aquatic organisms in NSW. Part 2: Marine and Estuarine Waters. Miscellaneous Bulletin 5, Fisheries Division, NSW Department of Agriculture, Sydney.

Semeniuk, V., P.N. Chalmer and I. Le Provost (1982). The marine environment of the Dampier Archipelago. J. of Royal Soc. of West. Aust., 65, pp 97-144.

Shaw, G.R. and D.W. Connell (1980a). PCBs in the Brisbane River Estuary, Australia. Mar. Poll. Bull., 11, pp 356-358.

Shaw, G.R. and D.W. Connell (1980b). Relationships between steric factors and bioconcentration of PCBs by the sea mullet (Mugil cephalus Linnaeus). Chemosphere, 9, pp 731-745.

Shaw, G.R. and D.W. Connell (1982). Factors influencing concentrations of PCBs in organisms from an estuarine ecosystem. Aust. J. Mar. Freshw. Res., 33, pp 1057-1070.

Shaw, G.R. and D.W. Connel (1984). Physiochemical properties controlling polychlorinated biphenyl concentrations in aquatic organisms, Environmental Science and Technology, 18, pp 18-23.

Simmonds, R.S., M.W. Loutit and F.J. Austin (1983). Enteric viruses in New Zealand waste waters. New Zealand Journal of Science, 26, pp 437-444.

Siwatibau, S. (1984). Traditional environmental practices in the South Pacific - A case study of Fiji. Ambio, 13 (5,6), pp. 365-366.

Skira, I.J. (1986). Food of the short-tailed shearwater in Tasmania. Aust. Wildl. Res., 13, pp 481-488.

Smillie, R. and J.S. Waid (1985). Polychlorinated biphenyls and organochlorines in Great Barrier Reef biota. In: Workshop on Contaminants in Waters of the Great Barrier Reef, GBRMPA, Townsville.

Smith, D.G. (1985). Sources of heavy metal input to the New Zealand aquatic environment. J. Royal Soc. N.Z., 15 (4), pp 371-384.

Smith, D.G. (1986). Heavy metals in the New Zealand aquatic environment: A review. Water Quality Centre, Water and Soil Miscellaneous Pub. No. 100, Hamilton.

Smith, D.G., D.S. Roper and B.L. Williams (1987). Implications for the marine environment. In: Proc. of a Seminar on Coastal Outfalls, Water Quality Centre, Water and Soil Miscellaneous Publ. No. 107, Hamilton.

Smith, J.D., J. Bagg and B.M. Bycroft (1984). Polycyclic aromatic hydrocarbons in the clam Tridacna maxima from the Great Barrier Reef, Australia. Environmental Science and Technology, 18, pp 353-358.

Smith, J.D. and W.A. Maher (1984). Aromatic hydrocarbons in waters of Port Phillip Bay and the Yarra River estuary. Aust. J. Mar. Freshw. Res., 35, pp 119-128.

Smith, J.D., J.Y. Hauser and J. Bagg (1985). Polycyclic aromatic hydrocarbons in sediments of the Great Barrier Reef region, Australia. Mar. Poll. Bull., 16, pp 110-114.

Smith, J.D., J. Bagg and Y.O. Sin (1987). Aromatic hydrocarbons in seawater, sediments and clams from Green Island, Great Barrier Reef, Australia, Aust. J. Mar. Freshw. Res., 38, pp 501-510.

Smith, S.V., W.J. Kimmerer, E.A. Laws, R.C. Brock and T.W. Walsh (1981). Kaneohe Bay sewage diversion experiment: perspectives on ecosystem responses to nutritional perturbation. Pac. Sci., 35(4), pp 279-402.

Soule, D.F. and M.A. Oguri, (1983). A report on ocean disposal of fish processing wastes off Pago Pago, American Samoa. U.S. EPA Region IX Report.

SPCC (1979). NSW State Pollution Control Commission, Toxic chemicals: environmental control study of Botany Bay, Sydney.

Steidinger, K.A. (1983). A re-evaluation of toxic dinoflagellate biology and ecology, pp 147-188 in Progress in Phycological Research, Vol.2. E.F. Round and U.J. Chapman, eds., Elsevier, New York.

Steiner, J.T. and T.S. Clarkson (1985). Heavy metals in the New Zealand Atmosphere. J. Royal Society of New Zealand, 15 (4): 389-398.

Steinle, K.R. (1986). Who pays for beach protection. In: Proc of the Australian National Conference on Coastal Management, Coffs Harbour, Australia.

Steven, A.D.L., J.E. Brodie, R. Van Woesik and D. Hopley (1989). A pilot study of baseline levels of water quality around Green Island, Cairns Section, Great Barrier Reef. Report to G.B.R.M.P.A., Townsville, Australia, 74 pp.

Steven, A.D.L. and R. Van Woesik (1988). A multidisciplinary study of the effects of sewage outfall on Hayman Island. Interim report: Water quality and waste water studies. Report to GBRMPA. Townsville.

Stillberger, G.L. and D.M. Rowley (1980). Biological effects of the GORCO oil spill on the Laguas mangrove community. GEPA Report, Agana.

Stoddart, D.R. (1972). Catastrophic damage to coral reef communities by earthquake. Nature, 239, pp. 51-52.

Stoffers, P., G.P. Glasby, W.L. Pluger and P. Walter (1983). Reconnaissance survey of the mineralogy and geochemistry of some New Zealand lakes and nearshore sediments. N.Z. J. Mar. Freshw. Res., 17, pp 461-480.

Stoffers, P., G.P. Glasby, C.J. Wilson, K.R. Davis and P. Walter (1986). Heavy metal pollution in Wellington Harbour. N.Z. J. Mar. Freshw. Res., 20, pp 495-512.

Supervising Scientist (1987). Alligator Rivers Region Research Institute, Annual Research Summary, 1986-1987, Aust. Gov. Pub. Service, Canberra.

Sweeney, C. (1989). Sydney gets its own back. Time Magazine, Feb. 20, 1989, pp 43-45.

Talbot, V. (1985). Heavy metal concentrations in the oysters Saccostrea cuccullata and Saccostrea sp. from the Dampier Archipelago, W.A., Australia. Aust. J. Mar. Freshw. Res., 36, pp 169-175.

Talbot, V. and A. Chegwidden (1982). Cadmium and other heavy metal concentrations in selected biota from Cockburn Sound, W.A. Aust. J. Mar. Freshw. Res., 33, pp 779-788.

Tanabe, S. and R. Tatsukawa (1981). Chlorinated hydrocarbons in the North Pacific and Indian Oceans. J. Oceanogr. Soc. Japan, 36, pp 217-226.

Tanabe, S. and R. Tatsukawa (1986). Distribution, behaviour and load of PCBs in the oceans. In: PCBs and the Environment, Vol. I, CRC Press, Boca Raton, USA, pp 143-161.

Tanabe, S., M. Kawano and R. Tatsukawa (1982). Chlorinated hydrocarbons in the Antarctic, Western Pacific and Eastern Indian Oceans. Trans. Tokyo Univ. Fisheries, No. 5, pp 97-109.

Thomas, I.M., R.C. Ainslie, D.A. Johnson, E.W. Offler and P.A. Zed (1986). The effects of cooling water discharge on the intertidal fauna in the Port River estuary, South Australia. Trans. R. Soc. S. Aust., 110(4), pp 159-172.

Thomassin, B.A. and J.P. Masse (1985). Les recifs coralliens actuels et leur controle sur l'environnement: aspects morphologiques, biologiques et sedimentologiques. Tethys, 11 (3-4), pp 288-301.

Thomson, J.D. (1985). Mercury concentrations of the axial muscle tissues of some marine fishes of the continental shelf adjacent to Tasmania. Aust. J. Mar. Freshw. Res., 36, pp 509-517.

Topping, G. (1984). Summary report on IOC/GEMSI intercomparison exercise for metals in biological tissue. Intergovernmental Oceanographic Commission, Paris, France, 9pp + 9 tables.

Topping, G. (1986). Quality of data: with special reference to the measurement of trace metals in marine samples. Sci. Total. Environ., 49, pp 9-25.

Tortell, P. (1981). New Zealand Atlas of Coastal Resources. NZ. Government Printer.

Tortell, P. (1982). Coastal resources and oil pollution in New Zealand. In: Proc. 4th Nat. Water Conf., Paper B-9, Auckland.

UNEP, (1984). Radioactivity in the South Pacific. UNEP Regional Seas Reports and Studies No. 40.

Unwin, G.L. (1986). Can multi land use planning incorporate mining in coastal areas. Proc. of the National Conference on Coastal Management, Coffs Harbour, Australia. pp 333-337.

Valentine, P.S. (1988). A land use study to investigate potential agricultural chemical inputs to marine environments in the northern Great Barrier Reef region. Report to GBRMPA, Townsville.

Van der Broek, W.L.F., O.M. Tracey, S.R.B. Solly and H. Avrahami (1981). Mercury levels in some New Zealand sea fishes. N.Z. J. Mar. Freshw. Res., 15, pp 137-146.

Veillon, J.M. (1973). The originality of the New Caledonia flora and its vulnerability to deterioration or pollution of the environment. pp 145-150 in: Regional Symposium on Conservation of Nature - Reefs and Lagoons. SPC Noumea.

Wallis, I. and S. Chidgey (1988). Preliminary report on a proposed sewage scheme for Vila. WHO Report for Vanuatu Government.

Ward, T.J. (1987). Temporal variation of metals in the seagrass Posidonia australis and its potential as a sentinel accumulator near a lead smelter. Mar. Biol., 95, pp 315-321.

Ward, T.J. and P.C. Young (1981). Trace metal contamination of shallow marine sediments near a lead smelter, Spencer Gulf, South Australia. Aust. J. Mar. Freshw. Res., 32, pp 45-56.

Ward, T.J. and P.C. Young (1984). Effects of metals and sediment particle size on the species composition of the epifauna on Pinna bicolor near a lead smelter, Spencer Gulf, South Australia. Estuarine, Coastal and Shelf Science, 18, pp 79-95.

Wells, S.M., R.M. Pyle and N. Collins (1983). Giant Clams. In: The IUCN Invertebrate Red Data Book, IUCN, Gland, Switzerland, pp 97-107.

Whitehead, M., J. Gilmore, E. Eager, P. McGinnity, W. Craik and P. Macleod (1986). Aquarium fish and their collection in the GBR region, GBRMPA Technical Memorandum 13, GBRMPA, Townsville, Australia.

Wilcock, R.J. (1985). Agricultural runoff: a source of water pollution in New Zealand? N.Z. Agricultural Sci., 20 (2), pp 98-103.

Wilcox, C.F. (1985). Sea water and mussel quality in Hawke Bay and their relevance to foodborne disease, 1968-1984. Napier District Health Office Report, file 34/5/5, Napier.

Williams, E.H. and L. Bunkley-Williams (1988). Circumtropical coral reef bleaching in 1987-1988. Proc. of the Sixth International Coral Reef Symposium, Townsville, Australia. Vol 3: 313-318.

Winchester, R.V. and D.L. Keating (1980). Trace metal and organochlorine pesticide residues in New Zealand farmed oysters: a preliminary survey. NZ J. Sci., 23(2), pp 161-169.

Wolanski, E.J., G.L. Pickard and D.L.B. Jupp (1984). River plumes, coral reefs and mixing in the Gulf of Papua and the northern Great Barrier Reef. Estuarine, Coastal and Shelf Science, 18, pp 291-314.

Woollard, P. and H. Settle (1978). PCB residues in mullet, Mugil cephalus, fed to captive Eastern Australian water rats, Hydromys chrysogaster. Bull. Environ. Contam. Toxicol., 20, p 606.

Yuen, T.L. (1980). Coastal survey of water quality around Port Vila, Vanuatu. South Pacific Commission Report, Noumea, New Caledonia 31p.

Zann, L.P., W.J. Kimmerer and R.E. Brock (1984). The ecology of Fanga'uta Lagoon, Tongatapu, Tonga, US Sea Grant Cooperative Report, UNIHI-SEAGRANT-CR-84-04, Honolulu.

Zann, L., J.E. Brodie, C. Berryman and M. Naqasima (1987). Recruitment, ecology, growth and behaviour of juvenile Acanthaster planci (L) (Echinodermata: Asteroidea). Bull. Mar. Sci., 41 (2), pp 561-575.

Zolan, W.J. (1981). Metal concentrations in Guam urban runoff. Water and Energy Research Institute Technical Report 25, University of Guam, Guam.

Zolan, W.J. (1983). Water quality monitoring program, Palau Airport project, Ngurusar Bay, Toegel mid channel, Babelthaup and Koror Islands, Palau District, TTPI, Part B, Construction. Water and Research Institute Technical Report No. 46, University of Guam, Guam.

Zolan, W.J., R.N. Clayshulte and S.J. Winter (1982). Air particulate and noise level monitoring program, airport construction site, Moen Island, Truk, TTPI, Part B, Construction. Water and Energy Research Institute Technical Report 32, University of Guam, Guam.

APPENDIX 1

ACRONYMS

AIMS	Australian Institute of Marine Science
AMSA	Australian Marine Science Association
ASEPA	American Samoa Environment Protection Agency
BCL	Bouganville Copper Limited
CCOP/SOPAC	Joint Coordinating Committee for Offshore Prospecting/South Pacific
CDTC	Australian Commonwealth Department of Transport and Construction
CITES	Convention on International Trade in Endangered Species
CSIRO	Commonwealth Scientific and Industrial Research Organization (Australia)
DSIR	Department of Scientific and Industrial Research (N.Z.)
EEZ	Exclusive Economic Zone
ENSO	El Nino Southern Oscillation
FSM	Federated States of Micronesia
GBR	Great Barrier Reef (Australia)
GBRMP	Great Barrier Reef Marine Park
GBRMPA	Great Barrier Reef Marine Park Authority
GEMSI	IOC Group of Experts on Methods, Standards and Intercalibration
GEPA	Guam Environment Protection Agency
GESAMP	IMO/FAO/Unesco/WMO/WHO/IAEA/UN/UNEP Group of Experts on the Scientific Aspects of Marine Pollution
GIPME	IOC Programme of Global Investigation of Pollution in the Marine Environment
ICLARM	International Center for Living Aquatic Resources Management
INR	Institute of Natural Resources (USP, Fiji)
IOC	Intergovernmental Oceanographic Commission
JGOFS	Joint Global Ocean Flux Study
LDC	London Dumping Convention

LESE	Laboratoire d'Etude et de Surveillance de l'Environnement (French Polynesia)
LOS	Law of the Sea
MSL	Marine Science Laboratory (Victoria)
OCA/PAC	Oceans and Coastal Areas Programme Activity Centre (UNEP)
ORSTOM	l'Institut Francais de Recherche Scientifique pour le Developpement en Cooperation (New Caledonia)
OTEC	Ocean Thermal Energy Conversion
OTML	Ok Tedi Mining Limited (PNG)
PAH	Polyaromatic hydrocarbons
PCBs	Polychlorinated Biphenyls
SPC	South Pacific Commission
SPREP	South Pacific Regional Environment Programme
SPREP-POL	South Pacific Regional Environment Programme - Pollution Monitoring Network
TBT	Tri-n-butyltin
TOGA	Tropical Ocean and Global Atmosphere Programme
TTPI	Trust Territories of the Pacific Islands
UNEP	United Nations Environment Programme
UNESCO	United Nations Educational, Scientific and Cultural Organization
UOG	University of Guam
UPNG	University of Papua New Guinea
USEPA	United States Environment Protection Agency
USP	University of the South Pacific
VIMS	Victorian Institute of Marine Science
WERI	Water and Energy Research Institute (UOG)
WESTPAC	Intergovernmental Oceanographic Commission Western Pacific Group
WOCE	World Ocean Circulation Experiment

APPENDIX 2

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