

# APN Project #2000-11

## “Recent Sea-level Change and Coastal Management Implications for Oceania”

Project Report March 2001

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# ***APN Project # 2000-11 Recent Sea-level Change and Coastal Management Implications for Oceania***

## **1 INTRODUCTION**

### **1.1 Background**

In October 1998, START Oceania held its inaugural meeting in association with a Climate Change and Sea-Level Workshop sponsored by the Asia-Pacific Network for Global Change (APN). The aim of this meeting was to encourage in-region capacity building and address Pacific island development within the context of climate change and sea level change. At this meeting, four major projects were developed as potentially suitable to approach international funding agencies. One of these four projects was designed to investigate island development and coastal response in relation to sea-level change. The proposal covered both high islands and atoll islands in Oceania and because of its scope it required a multi-million dollar budget. Subsequently, it was decided that Associate Professor Nick Harvey (University of Adelaide, Australia – and Member of START-Oceania) should attempt to produce a smaller more focused project in collaboration with other sea-level researchers in the region; Professor Roger McLean (ADFA, University of NSW, Australia), Professor Patrick Nunn (University of South Pacific, Fiji), Dr Paul Kench (IGCI, University Of Waikato, New Zealand), and Dr Chalapan Kaluwin (Pacific Climate Change and Sea Level Monitoring Project, Samoa).

The project was focused in terms of its research plan and also its geographical scope. The area for study was focused on a longitudinal axis spanning the equator and including the storm belts of both hemispheres. The countries selected for study were Fiji, Tuvalu, Kiribati and The Republic of Marshall Islands.

The project proposal 'Recent Sea-Level Change and Coastal Management Implications for Oceania' was submitted to APN September 1999 for consideration as part of its 2000 round of research grant proposals. This application (project 2000-11) was successful in becoming one of APN's funded projects for 2000. Project funds became available in late July 2000 when the project commenced.

## **1.2 Aims and Objectives of the Project**

The project had two main AIMS:

- a) First, the project will provide a focused global change research framework for investigating recent sea-level change and coastal response in selected areas of Oceania. Importantly, the project will build on earlier research and recent initiatives in the area, including those of APN. This research will be conducted in collaboration with researchers in the region at the same time as providing training for new researchers from Oceania.
- b) Second, the project will use the scientific findings to better inform coastal management policy in the region. This will be done with key regional policy advisers and adapted for different countries, particularly the Pacific small island states. This will be conducted with existing agencies in Oceania to provide capacity building support.

The project had the following objectives:

- a) To determine the coast impacts, particularly for small island states, of recent sea-level variations related to climate change variations in the last few thousand years.
- b) To examine the implications of the identified coastal impacts for management systems and adaptation techniques, in particular to assess the relative importance of short-term sea-level variations and their impact for management purposes within the context of long-term sea-level change predictions.
- c) To provide relevant capacity building through: a) awareness raising and developing research capacity for a better understanding of the coastal morphodynamics and coastal geomorphological systems, and b) practical application of sea-level related coastal process studies as a basis for modifying/adapting contemporary local and strategic planning for management.

## **1.3 Scientific significance of project**

Regional sea-level changes over the last few thousand years have been principally determined by small eustatic contributions from fluctuations in global ice volume, steric contributions due to fluctuations in ocean circulation, and continuing post-glacial geodynamic adjustments to the ocean basins. Interpretation of these sea-level changes at coastal sites is often complicated by vertical movements of the land through tectonic and sedimentary processes. In some areas there is a need to better define the neotectonic component of recent sea-level changes from mid-Holocene to present. Elsewhere, similar research has provided insights for global sea-level rise predictions. However, this geochronological research should not overshadow the important effect of century to millennial scale climatic fluctuations on late Holocene sea level, ocean circulation and regional patterns in ocean salinity and density.

Several international programmes including the IOC Group of Experts on the Global Sea-Level Observing System (GLOSS) and Global Ocean Observing System (GOOS), the Permanent Service for Mean Sea-Level (PSMSL), the WCRP Climate Variability and Predictability Programme (CLIVAR) deal with the rates and causes of modern sea level changes, including climatic forcing of steric height changes and ocean circulation patterns, together with geoidal variations. Great effort has gone into numerically modelling predictions of future sea-level rise (IPCC, 2001) but little has been focused on hindcasting the last millennial sea-level history. Recent research has demonstrated that regional sea-level in parts of the south western Pacific Ocean have experienced fluctuations on the order of a few decimeters over a few hundred years which are synchronous with observed temperature and proxy temperature oscillations. These sea-level fluctuations are on the order of the observed globally averaged 0.15 to 0.25 cm rise in sea-level for this century.

Evidence for climatic fluctuations during the last few thousand years is increasing for each of the PAGES PEP (Polar-Equatorial-Polar) transects, and includes: proxy sea surface temperatures (SST) from deep sea sediments and coral time series; proxy temperature and rainfall records from mangrove, coastal swamp and lake sediments, fluvial sedimentation patterns, coral reef growth, ice core stratigraphy and tree ring chronologies; and proxy SST from fluctuations in sea ice cover, biogenic and terrestrial sedimentation in polar shelf sediments.

The small islands and atolls of the Oceania region are some of the most vulnerable to modern and predicted sea-level rise. Modern sea-level monitoring programmes on low atolls and islands in the south Pacific and in the Maldives, in the Indian Ocean would also benefit from a greater coverage of detailed relative Holocene sea-level curves for the period following the peak of the postglacial sea-level transgression, in particular the last 1,000-3,000 years.

#### **1.4 Work Plan and Progress Report**

The work plan for the project comprised four main elements:

- a) Compilation of a scientific literature review on sea-level change in the Oceania region.
- b) Scientific investigations into coastal response to recent sea-level changes.
- c) An atoll-based workshop focused on atoll response to recent sea-level changes.
- d) A capacity building and training element both within the workshop and also the provision of special training programs related to sea-level change and coastal management (funding for this element came primarily from the START component of the APN grant).

First, the scientific literature review has been completed and is contained in a separate report acknowledging the support of APN. The material in this report will be used for the

background material in publications arising from this project. The data in this report have provided the capacity for better scoping and planning for the larger project, by producing some preliminary results and by providing a background report on existing studies. It was also useful in defining field sites for the scientific research components of this project.

Second, the scientific research has been conducted in two key locations. Work has been conducted on the South coast of Viti Levu to determine a local sea-level curve for the region. Sediment samples from this research are currently being dated at the Waikato Radiocarbon laboratory in New Zealand. Results from this and other sea-level change research conducted in Fiji will be published in the international refereed scientific literature with appropriate acknowledgement to the support of APN. Similar scientific research has been conducted in Kiribati on Bonriki and Buota islands of Tarawa. Again, samples have been submitted for dating and results are awaited. Finally, the last phase of the scientific research program is being conducted in Tuvalu. Originally it was planned to conduct research in The Marshall Islands but time and money have prevented this. Results from all the scientific research will be published in the scientific literature.

Third, the workshop component of the project was completed in February 2001 and Section Three of this report comprises the workshop report. This report has also been produced as a stand alone report for wider distribution.

Fourth, the capacity building component is funded through the START funding elements of the project for which there are separate reporting requirements. The initial plan was to provide for two students from the region to study at the University of the South Pacific (USP) in Suva, Fiji. However, political unrest in Fiji during 2000 created logistical problems with this plan. An alternative training program was set up as an intensive short course at Adelaide University with provision for 4-5 coastal researchers from Oceania to further their skills and knowledge of Integrated Coastal Management and sea-level change.

## 2 SCIENTIFIC WORK

### 2.1 Review of existing sea-level change studies

This review of recent literature on sea level change focuses on the Republics of the Marshall Islands, Kiribati, Tuvalu and Fiji. The literature search is largely confined to material published since 1980, although it is acknowledged that there is a considerable amount of earlier scientific work, particularly associated with scientific expeditions to the area, that is of direct relevance to this project.

In one of the earliest attempts to model the geographic pattern of Holocene sea level change in the Pacific, Clarke *et al.* (1978) suggested that the maximum relative sea-level height in the Holocene declined from approximately +2m at 52° S to 0 m at 11° N and that there was a parallel progression towards younger ages for the first achievement of modern sea level at 6000 BP in the southern Pacific to modern times at 11° N. Over the past two decades since Clarke *et al.* (1978) a large body of literature has been published concerning evidence for Holocene sea level changes in Pacific islands including several regional reviews (e.g. Hopley 1987, Nunn 1991a, 1994, McLean 1993). It is now generally accepted that in the wider Pacific sea levels first reached their present position about 6000-4000 BP, rising above that level to around +1-2 m between 4000-2000 BP after which time they have fallen steadily to present levels (Schofield 1977b, Pirazzoli and Montaggioni 1988, Woodroffe *et al.* 1990, McLean 1993). However, questions still remain as to the relationship between local and geographic patterns of Holocene sea level adjustment within the Pacific and, in particular, to variation in sea level change along latitudinal gradients.

Accordingly, the purpose of the attached bibliography is to bring together the recent literature on sea levels in four island nations which lie along a latitudinal gradient - the Marshall Islands, Kiribati, Tuvalu and Fiji. The objectives of this review (with accompanying tables and diagrams) are to identify the most recent evidence for Holocene shoreline change in these four island nations and, where possible, to identify the contributing causes of sea level changes. Isolating the different components of relative sea level and coastal changes is important for understanding and predicting the potential impacts of future sea level rise. Another major objective of the bibliography and review is to identify gaps in current knowledge of Holocene sea level changes in these four nations.

In the following section the individual components of ocean and land level variation that combine to produce relative sea levels are discussed. Subsequent sections contain a review of Holocene sea level changes in the Pacific and selected tables and diagrams with evidence for Holocene sea levels in the Marshall Islands, Kiribati, Tuvalu and Fiji. The



tables and diagrams are presented as in their original form without evaluation of the data contained therein.

### *Causes of Sea Level Change*

Relative sea level, the position of the sea relative to that of the land, results from a combination of climatic, lithospheric, tectonic and geoidal influences (McLean 1993). These include changes in :

- ocean water volumes (from glacial, groundwater and other terrigenous sink fluctuations, thermal expansion of the oceans etc.),
- ocean basins (from lithospheric flexure and tectonic activity) and
- the gravity and rotation of the earth (McLean 1993).

In addition, variations in sea level may be produced by changes in the topography of the sea surface induced by climatic and meteorological influences such as trade wind set-up and barometric pressure changes (McLean 1993). The following is a brief discussion of literature concerning the individual components of recent sea level change in the Pacific (see McLean 1993 for more detail). Other factors influencing the sea level record are also discussed. Secular changes in Pacific island sea levels are discussed below.

Recent changes in Pacific Island relative sea levels over the last century have been derived mainly from tide gauge data. However, contamination by vertical land movement and geographical bias in the distribution of usable tide-gauge data pose major problems for using land-based tide gauge benchmarks to determine eustatic sea level signals in the Pacific (see Aung 1998 for the distribution of gauge sites in the Pacific). Even after attempts to minimise these effects by subtracting long-term sea level trends and by regional weighting schemes, there are still large uncertainties regarding estimates of the eustatic component of change (Aubery and Emery 1993, Gornitz 1993, Warrick 1993a).

Despite the problems inherent in using tide gauge data, Gornitz and Lebedeff (1987) have constructed Pacific and global sea level curves with data from six sites in the mid-western Pacific and over 200 gauges elsewhere. Their globally averaged results indicate a rise in sea level of up to  $1.2 \text{ mm.yr}^{-1}$  since 1880. In contrast the trend in the Pacific appears to have been an average rise of  $0.1 \text{ mm.yr}^{-1}$  since 1910 but with a falling trend since 1932 (Gornitz and Lebedeff 1987).

A marked feature of Gornitz and Lebedeff's (1987) Pacific islands record is the large interannual variations in sea level. Interannual and seasonal influences on Pacific sea levels are large (0.5 m) and include changes in the sea surface induced by the breakdown of the trade wind system in the central and western Pacific during El Niño cycles. In an extreme example, during the 1982-83 El Niño sea level at Kiritimati rose to a maximum level of +28 cm (November 1982), subsequently falling to a minimum level of -21 cm

(October 1983) (McLean 1993, see Lucas *et al.* 1984 and Wrytki 1984 for details of Pacific-wide variations due to the 1982/3 El Niño).

Large short- to medium-term variations in Pacific sea levels such as those discussed in this section pose problems for the detection of past sea levels due to the nature of the coral evidence used to infer those levels. Additional factors that may operate to obscure the Holocene relative sea level record include moating of corals in lagoons above contemporary sea levels and the movement of coral debris, beachrock and conglomerate during storms (Spencer *et al.* 1987, Woodroffe and McLean 1992b). Due to these influences, which operate in addition to secular sea levels to produce the sea level record, evidence of former 'sea levels' from individual radiocarbon dated samples should be interpreted with caution and within an envelope of potential non-eustatic change. Particular caution should be applied to dated material for which the in-situ origin cannot be explicitly established. For a critical discussion of much of the evidence used to infer Pacific sea levels see Hopley (1987). The following section reviews evidence for the secular sea level record in the Pacific.

#### ***Holocene Sea Levels in the Pacific***

In all four regions under examination, secular changes in ocean water volume and in the ocean basin have been the major determinant of regional sea levels throughout the Mid to Late Holocene (see Goodwin 1996, Spencer *et al.* 1987). At the local scale, however, Holocene sea levels in the three low-island environments of the Marshall Islands, Kiribati and Tuvalu have been influenced by reef growth and island sedimentation. For example, atolls in the Marshall Islands, Kiribati and Tuvalu may have Pleistocene foundations as deep as 20 m below modern sea level. During the Holocene, Pacific island reefs are believed to have operated in 'catch-up' mode and, as a consequence, reef flat growth and island development may have been as much as 2000 years behind the first attainment of modern sea levels (Hopley 1987). In addition to reef growth and sedimentation influences, local sea levels on the islands of Fiji also have been influenced by tectonic activity (Nunn 1991b, 1998c).

Few secular sea-level curves have been determined for Pacific Ocean islands which are both relatively free of tectonic and sedimentation influences, and which span the entire Mid to Late Holocene in detail (Goodwin 1996). The best example of such a sea level curve is that of Pirazzoli and Montaggioni (1988), constructed with evidence from radiocarbon-dating of insitu corals from the Tuamotu Island and Gambier Island archipelagos in French Polynesia. These archipelagos span 2000 km across the Pacific from approximately 133-151° W and 14-25° S. Pirazzoli and Montaggioni's (1988) curve describes sea level changes in French Polynesia from 6000 BP to present as follows: A 1.2 m rise in mean sea level occurred from 6000 BP to the highstand at 3800 BP. Subsequently sea level fell by 0.3 m to 3000 BP. A stable sea level stand occurred

between 3000-1500 BP, which was followed by a sharp fall in sea level of 0.7 m to the present (Pirazzoli and Montaggioni 1988).

Goodwin (1996) compared the regional sea level curve of Pirazzoli and Montaggioni (1988) to modeled variations in the Holocene Antarctic ice mass in order to determine the importance of Antarctic contributions for determining eustatic sea levels. The two curves were found to follow a similar pattern between 6000-2000 BP but to diverge from 2000 BP to present, indicating that variations in Antarctic accumulation were a primary determinant of eustatic sea levels between 6000-2000 BP but not from 2000 BP to present. The fall in sea level indicated in Pirazzoli and Montaggioni's (1988) curve for the latter part of the Holocene has also been noted at Enewetak Atoll in the Marshall Islands (Buddemeier *et al.* 1975), in the Northern Cook Islands (Scoffin *et al.* 1985) and in New Caledonia (Coudray and Delibrias 1972). Goodwin (1996) suggested that it occurred, despite increasing Antarctic ice-melt, due to isostatic rebound of the oceanic lithosphere.

### ***Review References***

- Aubrey, D.G. and Emery, K.O. 1993: In: Warrick, R.A. Barrow, E.M. and Wigley, T.M.L. (eds.), *Climate and Sea Level Change: Observations, Projections and Implications*. Cambridge, Cambridge University Press: 45-56.
- Aung, T.H. 1998: In: Terry, J.P. *Climate and Environmental Change in the Pacific*. School of Social and Economic Development, University of the South Pacific, Suva, Fiji. pp 27-48.
- Buddemeier, R.W., Smith, S.T. and Kinzie, R.A. 1975: *Geological Society of America Bulletin* 86: 1881-1884.
- Clark, J.A., Farrell, W.E. and Peltier, W.R. 1978: *Quaternary Research* 9: 265-287.
- Coudray, J. and Delibrias, G. 1972: *Caiers Recherches de l'Academie de Sciences, Paris*, D 275: 2623-2626.
- Goodwin, I.D. 1996: In: Aung, T.H. (ed.) *Proceedings of the Ocean and Atmosphere Pacific International Conference (23-27 October 1995, Adelaide Australia)*. National Tidal Facility, The Flinders University of South Australia. pp 66-71.
- Gornitz, V. 1993: In: Warrick, R.A., Barrow, E.M. and Wigley, T.M.L. (eds.) *Climate and Sea Level Change: Observations, Projections and Implications*. Cambridge, Cambridge University Press: 25-44.
- Gornitz, V. and Lebedeff, S. 1987: In: *Sea-level Fluctuation and Coastal Erosion, SEPM Special Publication* 41: 3-16.
- Hopley, D. 1987: Holocene sea-level changes in Australasia and the Southern Pacific. In: Devoy, R.J.N. *Sea Surface Studies: A Global Perspective*. Croom Helm, New York. pp 375-408.
- Lucas, R., Hayes, S.P. and Wyrcki, K. 1984: *Journal of Geophysical Research* 89(C6): 10425-10430.

- McLean, R.F. 1989: Kiribati and sea level rise. Report on a field visit in May 1989 to consider the implications of a projected sea level rise in Kiribati. Expert Group on Climatic Change and Sea Level, Commonwealth Secretariat, Canberra, Australia. 87p.
- McLean, R.F. 1993: In: Hay, J.E. and Kaluwin, C. (eds.) *Climate Change and Sea Level Rise in the South Pacific Region*. Proceedings of the Second SPREP Meeting, Noumea, New Caledonia, 6-10 April 1992, Apia, Western Samoa, South Pacific Regional Environment Programme: 101-114.
- McLean, R.F. and Hosking, P.L. 1991a: Geomorphology of reef islands and atoll motu in Tuvalu. *South Pacific Journal of Natural Science* 11: 167-189.
- Nunn, P.D. 1991a: In: Workshop on Coastal Processes in the South Pacific Island Nations, *SOPAC Technical Bulletin* 7: 79-90.
- Nunn, P.D. 1991b: In: Workshop on Coastal Processes in the South Pacific Island Nations, *SOPAC Technical Bulletin* 7: 67-76.
- Nunn, P.D. 1994: *Oceanic Islands*. Blackwell Publishers, Oxford. 413p.
- Nunn, P.D. 1998c: *Pacific Island Landscapes*. Institute of Pacific Studies. The University of the South Pacific.
- Pirazzoli, P.A. and Montaggioni, L.F. 1988: *Palaeogeography, Palaeoclimatology, Palaeoecology* 68:153-175.
- Schofield, J.C. 1977b: *New Zealand Journal Geology and Geophysics* 20: 503-529.
- Scoffin, T.P., Stoddart, D.R., Tudhope, A.W. and Woodroffe, C.D. 1985: *Proceedings of the 5th International Coral Reef Congress, Tahiti* 3: 137-140.
- Spencer, T., Stoddart, D.R. and Woodroffe, C.D. 1987: *Zeitschrift für Geomorphologie* Suppl. Bd. 63: 87-102.
- Tracey, J.I. and Ladd, H.S. 1974: Quaternary history of Eniwetak and Bikini Atolls, Marshall Islands. In: *Proceedings of the Second International Coral Reef Symposium, Brisbane* 2: 537-550.
- Warrick, R.A. 1993a: In: Warrick, R.A., Barrow, E.M. and Wigley, T.M.L. (eds.) *Climate and Sea Level Change: Observations, Projections and Implications*. Cambridge, Cambridge University Press: 3-21.
- Woodroffe, C.D. and McLean, R.F. 1992a: Kiribati: vulnerability to accelerated sea level rise: a preliminary study. Based upon research funded by the Department of Arts, Sports, Environment and Territories, Government of Australia. Department of Geography, University of Wollongong, Wollongong. 82p.
- Woodroffe, C.D. and McLean, R.F. 1992b: Report on a research project funded by the Australian International Development Assistance Bureau.
- Woodroffe, C.D., Stoddart, D.R., Spencer, T., Scoffin, T.P. and Tudhope, A.W. 1990: *Coral Reefs* 9: 31-39.
- Wyrтки, K. 1984: *Journal of Geophysical Research* 89: 10419-10424.

## 2.2 Field studies

In accordance with the aims of this project, several radiocarbon analyses were conducted for sea-level indicator sediments collected from Fiji by two of the Principal Investigators (Harvey and McLean). A key purpose for this analysis was to provide initial scoping for the age of raised sea-level indicators in an area where there are conflicting interpretations of former sea-level heights and ages. These results provide an important indication for future fieldwork sites and the magnitude of sea-level trends over the last few millennia.

Samples from three microatolls (palaeosea-level indicators) at higher than present sea-level on the south coast of Viti Levu were prepared and submitted for dating at the University of Waikato Radiocarbon Dating Laboratory. Results indicated the existence of a higher than present relative sea level occurring between 3,000 to 5,000 yrs BP (Table 1). It should be noted that variations in relative sea level could be attributed to a number of factors influencing both land and sea movements. Three dates (samples FJ1, FJ2 and FJ3) collectively provide a rough guide to the age of a raised sea-level event on the south coast of Viti Levu, one of the High Islands in the study area. However, the dates in themselves do not give an indication of the spatial extent of such raised deposits, nor do they provide an accurate level of the former sea level. In order to establish this further research has been conducted by Harvey and McLean (December 2000) and sediment samples have been submitted for analysis. Results of this work will be published in the scientific literature as soon as results and analysis have been completed

A fourth sample (FJ4) from the west coast of Viti Levu, collected by McLean, indicates the presence of a higher than present sea level event which predates (see Table 1) the south coast sea-level event by over one thousand years. This may be the same event or there could be a regional difference in the elevation of palaeo sea-level indicators for any number of reasons, including local tectonics. It is not possible to draw any conclusions without further data. Additional fieldwork conducted in Fiji by Harvey and McLean was aimed at obtaining additional information plus producing accurate survey for all sites relative to modern sea level. This work was completed in December 2000 but results of the radiocarbon dating are not yet available. The total data set for this site will be analysed and written up as a scientific paper.

This type of evidence is consistent with data from elsewhere in the region particularly from a number of the High Islands. However, the atoll sediments needed to be treated separately from the High Islands and are a major focus of the APN project. For this reason, preliminary field investigations were conducted in Kiribati in December 2000 by Harvey and McLean. This was followed up by detailed investigations by Harvey, Kench and Hart in February, 2001.

**Table 1 Radiocarbon Dating Results (this study)**

<i>sample code</i>	<i>sample material</i>	<i>sample location</i>	<i>sample level (relative to modern sea level)</i>	<i>radiocarbon age BP (no correction applied)</i>
FJ 1 Wk-6887	<i>Porites</i> coral microatoll	south coast Levu (surveyed 12/00, results analysed)	higher than present (surveyed 12/00, results analysed)	4,530±60
FJ 2 Wk-6889	<i>Porites</i> coral microatoll	south coast Levu (surveyed 12/00, results analysed)	higher than present (surveyed 12/00, results analysed)	4,750±50
FJ 3 Wk-6890	<i>Porites</i> coral microatoll	south coast Levu (surveyed 12/00, results analysed)	higher than present (surveyed 12/00, results analysed)	3,540±50
FJ 4 Wk-6888	<i>Porites</i> coral microatoll	west coast Levu (surveyed 12/00, results analysed)	higher than present (surveyed 12/00, results analysed)	5,910±50

The Kiribati sea-level research comprised two elements. First, drill samples were obtained in conjunction with a separate hydrogeological drilling program being conducted on the islands of Bonriki and Buota, on Tarawa. The drilling by Afrac Drilling Pty Ltd obtained core material from the upper few metres (*ie* island sediments and immediate substrate) from four drill-holes on Bonriki and one on Buota. All cores have been logged and sediment samples have been extracted for radiocarbon dating. The results of this drilling and radiocarbon dating program will be used to better understand aspects of atoll island evolution.

The second research program was a detailed surveying of the modern reef flat on Buota (at the same site as previously conducted by McLean (1989) in order to determine the relative elevation of modern living coral with a field of raised *Porites* microatolls and an elevated bed of *Heliopora* coral adjacent to the modern beachrock. Sediment samples taken from the raised microatolls and *Heliopora sp* have been submitted for radiocarbon dating. This reef flat transect has been surveyed into the Buota drill-hole site and it should be possible using sedimentary evidence and radiocarbon dating to make some preliminary interpretations on late Holocene sea-level and island response.

The remaining scientific investigations are scheduled to be undertaken in late March in Tuvalu (Harvey, McLean and Kench). This research program, as with the Kiribati study, is focused on accurate survey and reconstruction of a Holocene sea-level curve. Once this has been completed it will be possible to examine aspects of island evolution and coastal response to sea-level change over time. The proposed research for The Marshall Islands has been cut from the project because of time and money. Research results from Tuvalu will be made available through the scientific literature once the work has been completed.

## **3 WORKSHOP REPORT**

### **3.1 WORKSHOP BACKGROUND**

#### **3.1.1 Workshop Objectives**

The workshop had three objectives:

- 1) To provide participants with a concise summary of relevant coastal science research in the region relating to sea level change impacts.
- 2) To provide an opportunity for participants from the three atoll states of Kiribati, Tuvalu and The Republic of Marshall Islands (RMI), to present material and raise issues on current coastal impacts and those resulting from sea-level change in the region. These impacts would then be related to relevant policy and coastal management for the respective countries.
- 3) To produce an action list for implementing the findings of this project and workshop based on agreements reached at the workshop.

#### **3.1.2 Workshop Description**

The workshop is part of the capacity building element of the APN project that brings global change researchers together with representatives from the region in an attempt to relate coastal sea-level change science to climate change and coastal management policy for the region.

The workshop was held in Tarawa, Republic of Kiribati. Participants attended from countries made up wholly of atolls or low islands - Tuvalu, Republic of the Marshall Islands, and the Republic of Kiribati. Other participants included the APN project leader (Associate Professor Nick Harvey), one of the key project collaborators (Dr Paul Kench), a SPREP Pacific Islands Climate Change Assistance Project (PICCAP) Technical Advisor (Mr James Aston) and an atoll researcher (Ms Deirdre Hart).

In addition to the present workshop report, there will be other publications arising from the project, which will be published in internationally refereed scientific literature. There will not be a separate publication of proceedings from this workshop as the current report contains a summary of the key issues and strategies.

Two other meetings were held in parallel with the workshop. The first was an extraordinary meeting of the Kiribati PICCAP country team held on the morning of Friday 16 February to hear a presentation on 'technology transfer' by Mr James Aston (SPREP PICCAP Advisor) as well as other PICCAP issues. A second meeting was a training course in coastal profiling sponsored by the World Bank. Dr Paul Kench of IGCI led this course



from Tuesday 20 to Sunday 25 February on the island of Maiana with a follow up workshop at the Otintaii Hotel on Monday 26 February.

## **3.2 WORKSHOP PROGRAM**

### **3.2.1 Setting**

The venue for the workshop was the Otintaii Hotel in Bikenibeu, South Tarawa, Kiribati. Workshop sessions were held on Thursday 15 February, Friday 16 February and Monday 19 February. A field excursion was held on Saturday 17 February. The workshop was also held in conjunction with other research and training activities. A program summary is given in Appendix 2.

### **3.2.2 Welcome Address**

The project leader, Associate Professor Nick Harvey (Adelaide University, Australia) acknowledged the Kiribati hospitality in making the workshop delegates welcome to their country. Dr Harvey commented on the research importance of sea-level change to atoll states and noted that Kiribati has been at the forefront of sea-level politics and research in the region. Kiribati also held the Pacific Forum in 2000 and has been active in raising awareness in the international forum on the plight of atoll countries to sea level change. Dr Harvey noted that this APN workshop was originally going to be held in Suva but since the main focus of the research was on atoll states, it had been decided to hold the workshop in Kiribati.

Dr Harvey then formally welcomed delegates from Kiribati, The Marshall Islands, Tuvalu, Australia and New Zealand and tendered apologies from Dr Kaluwin (Samoa) who had to withdraw at short notice, and from Professor McLean (Australia) who had IPCC commitments in Geneva. Dr Harvey acknowledged funding for the project from the Asia-Pacific Network for Global Change, without whose support the workshop would not have been possible.

Dr Harvey then went on to provide some background to this project which arose from an APN/SSTART-Oceania workshop in October 1998 and subsequently was developed into a successful funding proposal. Dr Harvey also provided a commentary on related research initiatives in the region and previous workshops funded by various agencies. He stressed that there would be an attempt to build on previous initiatives and avoid any duplication in this workshop.

Dr Harvey concluded by placing the workshop in the broader context of the APN project which had a strong scientific research component along with a capacity building element. He noted that some research had already been conducted in Fiji and Kiribati, although the analysis of these results would take some time. He assured the delegates that all research

results would be made available and attempts would be made to publish these results in internationally refereed scientific literature so that they would be available for future IPCC reports. Dr Harvey concluded by noting that there was a capacity building element of the project enabling coastal researchers from the region to obtain a professional qualification related to the issue of coastal management and sea-level change. He stressed that it was important to develop expertise in the region rather than relying on foreign aid and consultant expertise to address the issue of sea-level change and related coastal response.

### **3.3 WORKSHOP SESSIONS AND DISCUSSION SUMMARIES**

#### **3.3.1 Current coastal issues for Atoll States**

*Chair: James Aston*

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*James Aston*

##### *Recent Regional Initiatives Addressing Sea Level Rise*

Climate change and sea level rise concerns were first given prominence during the 1990 Rio Earth Summit and later during the Forum meetings of Pacific Island governments. SPREP was given the mandate to help the Forum island governments deal with these issues. The Climate Change Programme within SPREP coordinates and implements activities related to the science and impacts of climate change and the development of viable response options for Pacific island countries. It also provides advice to countries concerning their obligations under and the ongoing development of the United Nations Framework on Climate Change Convention (UNFCCC).

Recent regional initiatives that deal with climate change, climate variability and sea level rise issues in the Pacific region include: a series of Coastal Protection Meetings in 1993; the South Pacific Sea Level and Climate Monitoring Project; a series of coastal vulnerability resilience studies; the Australia /SPREP Vulnerability Initiative for Atoll States and; more recently, the Pacific International Coral Reef Initiative. These initiatives have helped to build the capability of Pacific Island Countries in the assessment of, and response to, coastal impacts of climate change and sea level rise. However, a number of the recommendations that have come out of this work have not been actioned or have not affected the level of change that was expected of them.

Some of the constraints to sustainable development that Pacific Island Countries face with accelerated sea level rise and climate change relate to cultural and institutional development, central and island government priorities, education and awareness, a lack of quality data, information and appropriate analytical methods. Although many countries share similar problems, there is a high degree of variability among islands. Actions to

ensure the sustainable development of the islands may therefore need to be tailored to suit the settings and circumstances of individual islands, not the region as a whole. This will require resources to facilitate the development of unique approaches and methodologies, which will inevitably have a different emphasis than those imported from international or metropolitan countries.

### *Seluka Seluka*

#### *Coastal Change and Protection Strategies in Tuvalu*

Many of Tuvalu's atoll islands are less than 4 m above mean sea level, making them vulnerable to the effect of possible future climate and sea level change. Previous studies by SOPAC and SPREP have identified the existence of coastal erosion problems. However, there has not been any consistent research to monitor the effects of coastal erosion and establish scenarios that can be used for future planning. Anecdotal observations suggest that the natural causes of erosion are strong winds, waves, flooding and currents. Dust from long periods of droughts also contributes to the pollution of water in the enclosed water cisterns and water tanks. Human induced causes of erosion such as mining for materials along the foreshore and removal of vegetation are expected to worsen with population growth, particularly around Funafuti.

Management of the erosion problem around the main settlement areas of Funafuti is exacerbated by the complexity of land tenure issues, increased sedimentation, pollution of the seawater from land based activities and the use of unfriendly fishing methods, which can eventually lead to the death of corals. The lagoons of Nanumea, Nui, Nukufetau, Funafuti and Nukulaelae seem to be becoming shallow especially the areas near to the land.

Most government policies in Tuvalu do not specifically address coastal erosion problems. However, the National Environmental Management Strategies provide a multi pronged approach involving: integrating government policy and strategy; improving environmental awareness; population policy; waste management; development; environmental monitoring and reporting. The more successful environmental awareness mechanisms include radio, posters, essay competitions, song competitions and TV advertisements. Conservation areas have also been established to encourage people to look after their own islands. Other management strategies include extending waste management to more islands, focusing on education and strengthening the links between local initiatives, environmental monitoring and NGOs.

Management of individual sites to combat erosion will require approaches other than the use of gabion baskets and concrete blocks. More integrated systems should be explored which include use of tree planting in conjunction with hard structures. The sustainability of such initiatives will require financial resources and technical expertise as well as strengthened links between the various sectors of government.

### ***Discussion***

Most of the discussion centred on the need to source and regulate gravel and sand extraction on the atolls. There is a clear need to better manage this process as the excessive cost of importing aggregate from other countries is not generally a viable solution (although two container loads of soil was imported into Kiribati under quarantine regulations). Regulations for gravel extraction were only introduced about a year ago but there are conflicts with landowners over what they may do on their own land.

Recognising the lack of knowledge on gravel extraction rates, more information is required about the broader sediment budget and areas where gravel may be extracted with the least impact. Previous attempts to determine budgets have involved interpreting profile volume data along with information on longshore transport rates. No field study has been done on the carbonate production by Pacific reefs, or subsequent sediment production. However, SOPAC has conducted some one off studies on gravel availability in Tuvalu and a New Zealand funded study on sediments of taro pits showed that lagoon sand has been dredged to fill these pits, which were originally dug out to construct the airstrip.

Given the lack of financial and technical resources on the islands, it was suggested that local experts from neighbouring islands could collectively travel to individual atolls to work out solutions to these problems. There is also an immediate need for studies in order to establish baseline information for mining. Studies on the productivity of organisms such as *foraminifora* would also be useful to determine the biological contributions to the sediment budget.

### ***Abraham Hicking***

#### ***Coastal Erosion Issues in the Marshall Islands***

Erosion is now recognized as a major concern on the islands of Ebeye and Majuro. Causal factors are common to other atolls and include population growth, dredging, sand mining, building of causeways etc. Reefs have been blasted to produce boulders as a source of aggregate, altering the wave regime. Permits are required for aggregate dredging but there are very few people trained to monitor such activity. Similarly, there is a lack of technical expertise to monitor beach profiles, although two people were trained by SOPAC five years ago.

Dredging is a major cause of soil erosion on Majuro and the local people are fully aware of this. There has been a proposal to clear channels to increase lagoonal sediment transport such as occurs naturally on Tarawa. Dredging along one side of the island has been identified as unsustainable in a SOPAC report. The northeast side of the island has been identified as a potentially viable area to dredge although a cost benefit analysis will be required as well as the support and approval of local landowners.

The Environmental Protection Authority (EPA) of the RMI has been approached to deal with coastal erosion issues. However, EIA recommendations have not always been followed up. For example, a causeway built in Majuro to connect two islands did not have sufficient culverts to encourage water exchange between the lagoon and ocean. Safety and environmental issues associated with the coastal environment of the RMI need to also be taken into account.

### ***Discussion***

Whilst the general causes of erosion are known for atoll environments, there is a need to know more about what is happening at the site level. The sources and transport mechanisms of sediment budgets and the effect of structures that protrude out from the foreshore (eg rainwater reservoirs and the airport runway in Majuro) on the local hydrodynamics need to be better understood. For example, in Majuro, the Japanese government constructed a causeway using material excavated from the reef flat but it appears that the effects on sedimentation and erosion were not monitored despite the fact that a complex EIA was carried out as part of the development.

There are a number of existing studies and reports on coastal erosion in the RMI but have yet to be analysed or used to develop policy and plans. In addition, the quality and integrity of these studies is unknown and should be evaluated.

In the RMI, policies relating to the regulation of coastal impacts have been developed but, in practice, there is little compliance monitoring of activities. A handful of people, mainly from government, have received training in beach profile monitoring but such programs or studies have yet to be established because people may have moved to other jobs or have lost interest in continuing the monitoring. It was suggested that atolls could share their expertise with neighbouring atolls at minimal cost. Incentives in the form of airfares and per diems could be used to coax the inter-island exchange of experts.

### **3.3.2 Current coastal management in Atoll States and relevance for sea-level change** ***Chair: Seluka Seluka***

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#### ***Komeri Onorio***

*The use of EIA in atoll states for coastal management with particular reference to sea-level rise*

EIA started with the American National Environmental Policy Act (NEPA) of 1970, which called for impact statements, public input and informed decision making in projects. The

three core values of EIA are sustainability, integrity and utility. The eight guiding principles include participation, certainty, transparency, cost effectiveness and practicality.

EIA is now used worldwide, including in atoll nations. An EIA should allow the modification and improvement of design; ensure efficient resource use; enhance the social aspects of projects; identify measures for monitoring and managing impacts; allow informed decision-making and provide justification for the proposal. An EIA should consider a variety of impacts in an integrated manner such as the socio-economic situation, health, sea level rise, biophysical effects, risk and uncertainty.

Scoping is used to set out the terms of reference for an EIA. There is a need to seek both expert and community comment early in the scoping process and throughout an EIA. Delays in an EIA are caused when the process is initiated too late in a project or when the Terms of Reference are poorly defined.

There are two levels to the EIA process in Kiribati. During the first stage, an initial environmental assessment is carried out so that a decision can be made as to whether the second stage should commence through a full EIA report. To date, only two EIAs have been conducted in Kiribati (both by Komeri).

Under Kiribati legislation, any construction related development requires a permit from the Ministry of Environment and Social Development. However, during the construction of a meeting house, retaining sea wall, pier and 200m dredged channel on one of the outer islands (built and funded by the Australian Government especially for the recent South Pacific Forum meeting), an EIA was not prepared nor was a development permit issued by the Kiribati government. The channel construction and coastal works, fortified with sand bags imported from Betio, were built at a cost AUD65, 000 but were washed away in January 2000, during a period of high spring tides. This loss could have been prevented had local village people's knowledge about currents and tides been sought through the EIA process.

### ***Discussion***

At present, the EIA mechanism only takes account of the current state of the environment. That is, EIA is based on an assessment of existing impacts and does not make allowances for the problems arising from future climate change and sea level rise, such as those developed under the UNFCCC scenarios. In Kiribati, for example, construction of Parliament did not take into account climate, climate variability and sea level change hazards and impacts. In addition, historical and geological information are not generally defined during the EIA process, which will make it difficult to find a baseline that can be used to assess the vulnerability of systems.

Without a holistic approach to management of island environments (eg through integrated management plans and policies), the impacts of a multitude of development projects, on any scale, are often wide ranging and can lead to diffuse and cumulative impacts. Such problems are often exacerbated when permits alone are used to regulate development. This is because permits are often issued that allow a wide range of activities, but few of those activities are unlikely to be conducted or implemented at the time that the permit is issued. However, as business expands or where people increase the range of their activities, the extra activity puts pressure on the resources, eventually leading to a magnification of use conflicts and other environmental problems.

In the RMI, although EIA is required, it is not generally instigated. In some cases, projects are often started before the need for an EIA is realized. The cost of an EIA is seen as a major constraint to development and is generally not included in original project budgets. This differs from Kiribati, where EIA costs are included in project formulations because there is a national policy requiring EIA to be conducted at the time when the feasibility studies are prepared. Some developers see EIA as a costly and unnecessary process. However, if it is done properly, it can save money. The EIA can reveal not only the effects of the development on the environment but also the effects of the environment on the development.

### ***Karness Kusto***

#### *Developing an integrated coastal management approach for atoll states*

The Majuro Coastal Management plan is a UNDP USD300, 000 project initiated in 1996. It was developed over 2 years through a five-phase process but has never been implemented. Among the reasons for the collapse of the planning process and development of the plan itself are: change of government (mayor); loss of interest in the plan; emphasis on a top down rather than a bottom up approach and; lack of demarcation and identification of responsibilities within government. However, the level of awareness of potential climate change and sea level rise problems and support for solutions is very high amongst local landowners, who are generally unhappy about the delays in the adoption and implementation of the plan.

The process for developing the plan was modelled on the Tarawa Lagoon Management Plan (which also was never implemented). Stage 1 involved the identification of planning needs, using in-country expertise. Stage 2 involved identifying coastal issues and problems, the resource base, the legal and financial capacity and scope of the program. Stage three defined the goals, objectives and outputs of the plan. Stage four determined the boundaries of the management plan and stage five was to coordinate the concerns of all involved.

### ***Discussion***

Previously, coastal management plans in the Pacific were often developed from the top down (i.e. imposed by government rather than originating from communities) but this is slowly changing. One of the problems is that funding which is channelled to countries on a multilateral basis often comes through the CROP regional agencies whose members are governments of the countries, not the private sector, communities or other NGOs which are based in those countries.

Because conventional planning approaches do not tend to work in the Pacific islands, many coastal management plans are, by necessity, pilot projects designed to test the feasibility of innovative approaches tailored to the particular island. Pilot projects cost less to implement and encourage government to absorb the strategies contained within management plans into governmental processes and activities. The RMI Coastal Management Plan is an example of a pilot project that was given to local government to implement. The idea was to develop a plan for one island and modify as necessary for other islands within the RMI archipelago.

It is understood that the Tarawa Lagoon Management Plan referred to in the above talk has never been implemented. Also, apart from some coastal erosion monitoring sites in Tarawa and the outer islands, there are no other management plans for those islands.

### **3.3.3 Relating coastal impacts resulting from sea level change to policy and management**

***Chair: Deirdre Hart***

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#### ***Karness Kusto***

*The role of education and technology in awareness raising of sea-level change and coastal management issues*

Awareness raising initiatives of the importance of sea level rise have been carried out in the RMI in attempt to inform the community and change attitudes to non sustainable practises. Awareness raising activities have often proved more effective than policy initiatives.

The choice of appropriate terms, level of language and understanding of the target audience is very important when communicating with people about the issues of sea level rise. Many of the terms of sea level rise are new and unfamiliar to people. For example, 'sea level rise' is a term, which can invoke fear in people while the term 'sea level change' is less likely to be as emotive. In the RMI, it was found that the concept of sea level change and adaptation is difficult for many people to grasp. For example, there are reports of



people who have opted for overly simplistic adaptation measures such as extending the foundations of their houses so as to cope with the effects of accelerated sea level rise.

At a workshop in Apia recently, an attempt was made to incorporate sea level rise issues and concerns into primary school curricula. However, the College of Education deemed it more appropriate for Upper High School and College students. Unfortunately, because of the lack of trained teachers with sufficient knowledge of sea level issues, the booklet is not being used.

Workshops are another medium that has proved effective in raising people's awareness of the negative impacts of sea walls. The most effective workshops are those that are informal (e.g. after work discussion in a bar over a few drinks or in the workplace with villagers) and where messages are conveyed by taking people to sites in their own environment and asking them to start the conversation from their local knowledge base. The problem with this approach is that there are usually very few competent people available to travel to the outer islands and do this work.

Apart from personal contact, other effective mediums of communication include newsletters, video, acted drama, radio and publications. Signs in public places, such as those saying "Do Not Take Sand", can be very effective in spreading messages. Material (eg the Coasts of the Pacific publication produced by SOPAC) that has been translated into local languages has proved particularly effective. However, the costs can be prohibitively expensive (typically around USD30,000 to 45,000 translation costs for 20 pages).

### *Discussion*

In Tuvalu, radio and leaflets are used to raise awareness of coastal erosion and inundation. A television program is also being made. Kiribati currently does not have any structured programs for education and awareness raising, although this could change with the completion of the National Implementation Strategies (NIS), being developed under the UNFCCC.

The impact of environmental education in the RMI is evidenced by the outcry against dredging in the outer islands. In the RMI, the focus is usually more about awareness raising and introducing new terms to people, such as sea level change. Nevertheless, there is also a danger that such messages raise expectations and that responsible agencies will not be able to respond to those expectations, at least in the short term.

A number of people need to be aware of the effects of sea level rise on the coastal environments of atolls. These include landowners, mayors, high officials, regional organizations (eg SOPAC and SPREP), non-governmental agencies (eg the newly

### ***Discussion***

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A number of people need to be aware of the effects of sea level rise on the coastal environments of atolls. These include landowners, mayors, high officials, regional organizations (eg SOPAC and SPREP), non-governmental agencies (eg the newly

established office of IMA – International Marinelife Alliance) as well as people outside of the island nations.

*James Aston*

*Technologies for coastal management*

A range of technologies has been identified on a global scale to adapt to the hazards brought about by climate change, climate variability and sea level rise. Technologies are available to develop information and awareness for adaptation in coastal zones, to plan and design adaptation strategies, to implement them, and to monitor and evaluate their performance. The question for atoll environments is to identify which of those technologies has the potential to work in the coastal environments of Pacific atoll nations under the UNFCCC climate change, climate variability and sea level rise scenarios.

Currently, the range of ‘hard’ technology options on atolls are: gabion baskets filled with coral rock, (used in Kiribati, Tarawa and Tuvalu); integrated systems of gabion baskets and tree planting (Tuvalu); sand bags filled with concrete or sand (Kiribati); pre-cast concrete blocks (RMI and Tuvalu); vertical face hand placed coral rock wall (most atolls); cemented vertical face coral rock wall (Kiribati); sloping face coral rock wall (Kiribati); revetments made of debris or rubbish such as disused bulldozers (Kiribati and RMI); armour rock walls produced by blasting reef rock on the reef edge (RMI); concrete seawalls (RMI); offshore breakwaters (Kiribati); and traditional or indigenous methods such as fish traps (Kiribati). Apart from the armour rock seawalls which may be used on the ocean side of atolls, nearly all of these technologies will only be suitable in sheltered wave environments, such as along the lagoon foreshore.

Technologies currently under development that cant support implementation of retreat (managed), accommodation or protection coastal adaptation options include: bubble curtains; self-priming buried sand pumps, movable structures; fields of underwater screens/horizontal slabs; underwater pneumatic breakwaters; wave energy generating floating breakwaters and floating/inflatable breakwaters. However, most of these technologies are largely untried, generally expensive and would only be expected to protect particularly valuable properties or very small areas of atolls.

Some of the ‘soft’ technologies that are currently not widely used in Pacific atolls but which have potential are: full implementation of plans and policies such as the Pacific Region Strategy for the International Coral Reef Initiative (ICRI) and the National Implementation Strategies (NIS); insurance; decentralization policies (i.e. settlement in areas not prone to erosion); overseas remittances from family following high energy events and; international aid released once the Kyoto Protocol is ratified. Such technologies have the potential to be applied at the scale of the whole atoll.

In determining the impact of development on the natural environments of atolls, the range of direct and indirect effects must be understood and evaluated. For example, the direct effects of hard shoreline stabilisation using groynes, jetties, breakwaters and seawalls can change the location of erosion/deposition and its severity and/or reduce or prohibit on/off island sediment exchange. The indirect effect of these structures can lead to further development, putting more property at risk or encouraging the need for more structures. Similarly, the construction of buildings can alter wind patterns and truncate beach areas.

Apart from environmental considerations, it will be important to conduct a comprehensive needs assessment, identify the conditions required to make the technology work properly and any capacity that needs to be strengthened. Given the limited resources of atoll nations, it will be important to transfer technologies to other islands. This will require investigation and testing of new technologies and specific evaluation and performance monitoring criteria.

In summary, there may not be very many new technologies that can be used to respond to the problems of sea level rise. Standard practices are expected to continue (legal regulation, construction requirements and protective engineering) but more emphasis should be given to understanding coastal processes and the use of that information to develop and implement appropriate site specific and non structural mitigation techniques and policies. Throughout the process, it will be important to fully involve all stakeholders and other (e.g. off island) interested parties.

### *Discussion*

There is a perception that hard structures are the best form of protection from sea level rise, particularly amongst senior members of atoll governments. However, hard structures do not necessarily solve erosion problems but rather temporarily fix the shoreline. To date, technologies that have worked best on atolls are not sophisticated or 'high tech' options but those that can be built and maintained inexpensively using local resources and expertise. Some technologies (such as the gabion baskets) are not seen as effective in Kiribati or Tuvalu unless used in conjunction with other methods or where their limitations (eg life spans) are realised.

The availability of raw materials for construction of technologies is a problem for most atoll nations. Material that is mined from the reef flat generally leads to erosion of the adjacent or adjoining foreshore. Accretion can also occur as it has in some areas of Tuvalu, for example. However, accreting materials are often targeted to be mined or removed, again leading to further erosion.

Some atoll countries have budgets specifically to address coastal erosion. For example, the Environment Protection Agency (EPA) in Majuro have set aside US\$20, 000 to protect their existing buildings and plants.

Insurance or trust funds were suggested as a possible response to risk of land loss due to sea level rise or resettlement to other countries (as a worst case scenerio). Trust funds or insurance are not available currently but could become available once the Kyoto Protocol is ratified.

In Tuvalu, the government has encouraged the decentralization of Funafuti. This strategy has mixed results but could be used to lessen the risk in other areas. Alternatively, people, assets and protection works can be concentrated and protected if they are located (contained) in a small area.

Coastal protection works are generally paid for with aid funds or by overseas sources in some atolls (eg Tuvalu). In Kiribati and the RMI, however, structures tend to be funded privately. In some cases, the government funds works that protect infrastructure.

As in all atoll nations, land is scarce. The beaches are often used as dumping grounds. Land tenure issues can make it difficult to put in place protective or conservation works. For example, in Kiribati, if land is reclaimed in front of a property, the adjoining owners also have claim to it. Land below the mean high water mark is government owned, as is newly accreted land.

Private developers are not held responsible or liable for any erosion problems that they cause. In the RMI however, the authorities tried unsuccessfully to fine a private developer through the courts for building an "irresponsible" structure. If a landowner in Kiribati has an erosion problem there is no authority that they can go to for information on appropriate technologies and solutions.

### **3.3.4 Monitoring and measuring coastal changes in atoll environments**

*Chair: Komeri Onorio*

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#### ***Tupulaga Poulasi***

##### ***Monitoring fisheries and coastal areas in Tuvalu***

Under the Fisheries Act of Tuvalu, the Department of Fisheries has responsibility for management of coastal and marine resources including the collection of scientific data for industry development. Local councils and the Council of Chiefs are also involved in

controlling use of fisheries resources, mainly through revolving closures and use of by-laws such as bans on spear fishing and nets.

In Tuvalu, the term "Conservation Areas" covers marine areas while "Protected Areas" refer to areas of the foreshore. The crown restricts where people can fish and mine sediment on Funafuti. Public ownership of the land ceases at the high tide level. Outside of this area, the Crown owns the land. In 1970, a hurricane caused the deposition of a large rubble and shingle bank on Funafuti (adjoining the airport runway). Under the land tenure system, the Crown had legal ownership of this new deposit. However it was eroded due to uncontrolled removal of the rubble. Now, there are only a few areas left which are also very good fishing grounds for the local people.

A beach-profiling program was recently set up to collect baseline coastal data. The program aims to recognize change and compare protected and non-protected areas in order to quantify rates of erosion. Four sites with three replicates spaced at 5 m intervals at each site are monitored; two in protected areas and two outside the protected areas. However, the program was recently stopped as a result of funding constraints and because staff departed overseas or moved into other ministries.

A fish spawning monitoring program found that two years after a specific area was designated as a conservation area there was a significant increase in diversity of fish species and total biomass. There are plans to link the fisheries monitoring and foreshore monitoring datasets.

### ***Tekena Teitiba***

#### *30 years of recent record of temperature and rainfall data in Kiribati: techniques and recording*

Rainfall and wind are the driving forces of coastal change. Rainfall contributes to surface erosion and runoff where as sea storms (which are driven by wind) are thought to exacerbate coastal erosion.

Southeasterly winds are dominant eighty percent of the time in Kiribati. Easterly winds are especially dominant under La Nina conditions. El Nino conditions commonly bring westerly winds with strengths of around 30 knots. When winds exceed 40 knots, large oceans swells are generated, triggering erosion. 2001 is the fourth consecutive year in which La Nina conditions have been experienced in Kiribati.

The low-pressure average is 1010 MB. However, during the last full moon, a low of 1000 MB was experienced but this did not coincide with strong winds. Fortunately, Kiribati now has the facilities to predict devastating winds.

The Kiribati rainfall record extends back to 1947. The record is of sufficient length to discern patterns. It is analysed in 5 year intervals because that is the expected frequency of El Nino events. Rainfall has been very variable (with a high standard deviation) and has generally decreased since 1947. The range of rainfall experienced in Kiribati is from 0-180 mm per day.

Temperature has been measured since 1983 although there are financial problems with the station's maintenance program. The recorded daily temperature range in Kiribati is from 28-31 degrees Celsius on land. The trend is one of increasing minimum daily temperatures, although the correlation is weak (stronger if only data from the last 30 years are used). No measures of water temperature are taken.

The Meteorology office has a public warning system to broadcast forthcoming high tides so that people might prepare for them. However, people often do not know how to prepare for such events. Suggestions to date have included moving pigs, securing loose materials and strengthening house foundations.

### *Discussion*

Data on extreme events and wind and rainfall is freely available from the Meteorology Bureau of Kiribati. The Bureau does not measure sea surface temperatures and currents.

The main users of meteorological data include some scientists from Japan and the Kiribati Ministry of Natural Resources, who have used the records to develop climate change scenarios. Their analyses indicate that temperature variations will decrease with climate change and that minimum temperatures will increase faster than maximum temperatures. There are currently no links between the Meteorology and Minerals Departments and no one has used the data to hind cast wave data.

The Met office has some new equipment and a Disaster Preparedness plan. The plan consists of a warning system which is triggered from Hawaii.

### *Nick Harvey*

#### *Summary talk*

Variation in the Hawaii sea level gauge record is of the order of +/- 0.5 m. In the National Tidal Facility (NTF) data there is an El Nino spike common to records from Tuvalu, Kiribati and the RMI. During such events sea level ranges from +30 cm to -40 cm. Therefore, variability in sea level is a regional phenomenon.

Sea level information, coupled with wind data, could allow us to examine how islands are responding to wind shifts. In order for this to happen, process data needs to be linked to shoreline behaviour as determined from beach monitoring. The anecdotal evidence



suggests that shoreline erosion correlates to variability in water level and climate. Roger McLean has recorded events such as the 1982/1983 El Nino spike in the NTF data in the micro atolls of Christmas Island. Lessons can be learnt from this variability and applied to the prediction of long-term sea level change. It is important to monitor both sea level variability and sea level change. Kiribati records from the NTF tidal gauges are too short for determining sea level trends, although the data record from the Hawaii tide gauges is longer.

### **3.3.5 Climate change and sea-level issues**

*Chair: Paul Kench*

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#### *Nakibae Teutabo*

*Policy Issues Relating to Sea Level Change For Atoll States with particular reference to Kiribati*

In 1985 UNEP/WMO/ICSU convened a workshop of scientists at which about 50 of them world wide were attending. Their brief was “to assess the role of increased CO<sub>2</sub> and other radiatively active constituents of the atmosphere...on climate change associated impacts”.

They concluded that:-

- (a) a doubling of CO<sub>2</sub> by 2030s
- (b) a temperature increase in range of 1.5 and 4.5 Celsius
- (c) a sea-level rise of between 20 and 140 cm.

We know now that the upper bound of the sea-level rise is unrealistic.

Scientific research on sea-level rise continues. Some work assessed global sea-level rise over the last hundred years had been between 1 and 1.5 mm per year. Others gave the range of 1.5-3.3mm. One work observed that about 28% of an histogram of stations and the observed trends equate with a trend of about 2 mm. All these mean that the global sea level has been rising.

Responses from some small island states came in 1988 with the president of the Maldives making statements at the UNGA on two occasions saying that sea-level rise would “drown these paradise of ours”, and again “we are an endangered nation”.

The president of Kiribati at one FORUM meeting said that scientists were predicting that the sea level around Kiribati could rise by more than 1 metre over the next 50 to 60 years. He did not wish to believe them but he would like to be kept abreast of the developments.

In 1989, the president of the Marshall islands, at the regional meeting on climate change at Majuro, stated that it was “truly frightening” to think that the ocean would turn against us.

The reaction from the general public was not different. The Tuvalu representative at the Majuro said he would need more information. On the other hand, the representative of Tokelau requested that something must be done.

One issue of the PIM had on its front cover these words "Say good bye to Kiribati, Marshall Islands, and Tuvalu".

The political response is one of genuine concern, but of different degrees depending on the information available to leaders and their understanding. But there was also "confusion and bewilderment" as reported for Kiribati by McLean. This stage was dispelled when IPCC, established by WMO and UNEP, published their First Assessment Report.

An incident that showed the solidarity of small island states occurred during the Second World Conference in late 1990. A technical meeting preceded the Ministerial segment, and an Alliance of Small Island States was then informally formed. Kiribati official advised his minister to propose an amendment to a ministerial statement being considered. The amendment was to change "could" to "would" in a text that refers to the climate change and sea-level rise threatening the survival of small islands. Plucking his courage, the Kiribati minister made that intervention, but immediately the most powerful nations, USA and RUSSIA put up their flags and objected to the proposed amendment.

Kiribati realized there was no sympathy that it presumed to be possessed by big developed countries for small developing island nations, and it quickly surrendered to remain with a little voice as of a small island country. The block put up by the USA and RUSSIA provoked interventions from many islands supporting the amendment. Kiribati had not insisted, but the solidarity of small island states to articulate their common concern was demonstrated. AOSIS became an effective group during the negotiation for the UNFCCC and the Kyoto Protocol.

Kiribati is a party to the UNFCCC and has signed the KP. It tries to implement the Convention, considers IPCC as the most authoritative source of information on climate change and sea-level rise. However, sea-level rise becomes just one of the issues that influence national policies and actions. Climate change and sea-level rise involve complex issues which must be addressed.

Sea-level rise, however, remains a marker issue to establish the need to get more action done to address climate change problems, and to get the Kyoto Protocol enter into force. Regrettably, we cannot establish yet the sea level in Kiribati, and I am sure this is the too of Tuvalu, and Marshall islands.

### ***Abraham Hicking***

#### *Climate Change Policy for the Republic of Marshall Islands and Sea Level Issues*

The preparation of the national statement of areas of focus of climate change policy review is wide ranging. RMI does not at this stage, have the resources and capacity to complete this review internally. It already has a Coastal Zone Conservation Act 1993 which is of some relevance. However, RMI is not going to develop a national implementation strategy until the Kyoto Protocol has been ratified. It is considered that the national policy should be separate from regional and international policies.

Although the Coastal Conservation Act came into effect in 1993 and has provision for control of sediment removal, there is insufficient information on sediment budgets to make informed decisions. In addition, the Act makes very little reference to sea level change. Only described problems of sea level rise. Other legislation includes NEMS, Water Quality Act, Earth Moving regulations.

Although they have some data on GHG emission, there is a need to translate the international science into national policies.

### ***Seluka Seluka***

#### *Climate Change Policy and Sea Level Issues for Tuvalu*

Under the National Development Strategy 1995-1998 and beyond called "Te Kakeega, o Tuvalu", the primary aim of government is "to provide an environment, based on existing cultures, within which the people of Tuvalu can strive to attain the highest possible standard of living".

In the Constitution of Tuvalu 1998 there is no specific mention of government's policy on coastal erosion. However, the main goal of the plan is to provide an environment that enable the people of Tuvalu to pursue a full, free, and happy life (Constitution of Tuvalu 1998). In the National Environment Management Strategy (NEMS), the main objectives for attaining sustainable development are:

- Integrating environmental considerations into economic development
- Improving environmental awareness and education
- Population policy, balanced development and planned urbanization
- Improving waste management and pollution control
- Development and protection of natural resources
- Environmental monitoring and reporting.

The current strategy government is taking to address the above policies include the following:

- Establishment and implementation of the Falekaupule Act.

- Establishment of the Conservation Area on Funafuti with a view to expand the programme to other islands
- Implementation of the waste management programme (Funafuti) with a view to the rest of the islands
- Strengthen the awareness programme through radio programmes, TV, leaflets, posters, essay competitions, song competitions and field trips
- Identification of the priority issues in climate change and sea level rise
- Development and implementation of the national implementation strategy on climate change
- Strengthen the links between the key environment sectors and participation of the different groups and island communities in environment/climate change activities
- Strengthening of the education system to train more technical people in the area of environment, climate and sea level rise
- Review of the Environment Structure to enable government to absorb the required number of trained staff

The major constraint facing the implementation of the above government policies are funding, the lack of technical expertise and possibly the monitoring/sustainability of the systems/activities.

Tuvalu has no existing climate change policy although the NIS is currently being drafted. There is a need to look at international and regional frameworks. The Tuvalu Country team visited the outer islands to draw out peoples main concerns on climate change and sea level rise to obtain baseline information. They looked at the most vulnerable areas and will focus on 5 priorities 1) water, 2) coastal fisheries 3) coastal erosion, 4) renewable energy 5) beach monitoring.

Looking within these policies are strategies such as renewable energy, use of diesel generators, solar cells, and integration of sewage systems. Water is in short supply. Looking at catchment management and water use. Need to locate new underground sources by digging wells and salination plants. Groundwater resources need to be protected and new systems built. There are two types of waste. It is feared that imported fertilizers may contaminate groundwater and fisheries. Pollution from livestock (pigs, poultry) and human waste. AusAID currently has a project looking at these problems. Another issue is that changes of climate may impact on health such as mosquito and dengue (vector borne diseases), cataracts.

The NIS once in place can be used to attract aid and channel funds to issues such as coastal erosion. At present the NIS is wide ranging and covers water, food and fisheries as these are all linked. One issue is who is in charge of coastal issues plus there is a lack of expertise in this area. In Tuvalu they try to use skills from each department where

appropriate, such as Survey and Lands, Fisheries and Agriculture. The NIS will be reviewed every 4 years.

### **3.3.6 Understanding and modeling coastal responses to sea-level change**

*Chair: Komeri Onorio*

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*Nick Harvey*

*Local effects on sea-level change*

It is important to note that sea-level change is different for different locations. An example was given from South Australia where two long-term tide gauge records at Port Adelaide and Port Pirie were considered reliable for analysis of mean sea-level trends and had been used in contributing to determinations of global mean sea-level averages. These two sites are only a few hundred metres apart and yet have quite different sea-level histories. At Port Adelaide the mean sea-level trend shows a significant sea-level rise whereas the Port Pirie tide-gauge data suggest that sea level is falling. It has been demonstrated using geological studies that there is significant human impact at Port Adelaide where groundwater withdrawal and sediment subsidence accounts for over half of the sea-level rise signal. In contrast the effect of continental margin deformation from post-glacial water loading on the continental shelf has caused hydroisostatic warping of the land at Port Pirie (*ie* it is has moved relatively higher) giving the impression that the sea-level is falling.

These two examples, in close proximity to each other, demonstrate the importance of using geological studies to determine an accurate sea-level curve for each location. In Oceania there are numerous examples of slightly elevated sea-level in the Holocene. These sea-level records can be determined using palaeosea-level indicators such as microatolls. Research conducted in this project has demonstrated elevated sea-levels between 3,500 and 6,000 years ago on the south and west coast of Viti Levu in Fiji.

However, it is important to note that high islands, such as Viti Levu, can be subject to differential tectonic movement which complicates the sea-level record. In the atoll states of Kiribati, The Marshalls and Tuvalu, sea level has been relatively stable although there is evidence of slightly higher sea levels in the last few thousand years. It is important to understand this sea-level history in order to begin to understand the evolution of the atoll islands and to analyse coastal response to subtle sea level changes. One of the most challenging aspects for this research is to determine coastal response to regional sea-level fluctuations caused by El Nino type events. The relative short term fluctuations (years)

and the magnitude ( $\pm 0.5\text{m}$ ) of these events is significant for coastal response and has to be placed in context with the nature of IPCC projections.

*Deirdre Hart*

*Atoll island sediment sources, pathways and sinks*

Geological, climatic and oceanographic factors combine to produce the relative level of the sea on an atoll coast. Sediment budgets are an important contributor to that relative sea level. Further, sediment budgets are predicted to underpin the response of low islands under future accelerated sea level rise scenarios. The following is a brief summary of the origins of atoll sediments and techniques for determining the sediment budget of low islands.

Mid-ocean low islands, such as those that make up Kiribati, Tuvalu and the Marshall Islands, are almost entirely constructed of biogenic sediments. Island building material is known to have originated from surrounding reef and lagoon ecosystems, although little detailed knowledge exists regarding the relationship between carbonate production and the ultimate islands sediments.

Current rates of carbonate production and sediment supply to atoll islands in the Pacific are unknown. Information on the sediment budget of these islands is needed in order to inform shoreline development, sand and aggregate abstraction projects and to predict possible shoreline adjustments to accelerated sea level rise. Techniques that may be used to investigate the state of atoll island sediment budgets include the following:

- Set up a network of cross-island profiles and measure the depth of unconsolidated sediment at several points along each survey in order to calculate the volume of sediment in current island deposits.
- Examine the reef flat for deposits of surface sediments, documenting changes in their thickness and composition.
- Construct maps of currents and sediment transport pathways across the reef by tracing dye and dyed sand and by trapping sediment.
- Document areas of shoreline change (erosion and accretion) using beach profile and planform map surveys, repeated at annual or six-month intervals.
- Determine the nature (chronic or episodic) and cause of erosion at selected sites by examining field evidence, talking to local residents and analysing aerial photographs.
- Examine the affects of human interactions with the coast and sediment production, transport and deposition systems. For example, investigate changes in local sediment budgets caused by construction of causeways, sea walls and other solid coastal structures.

In conclusion, shorelines and sediment budgets are not fixed. On the contrary, they respond to natural environmental variations (e.g. El Nino), direct and indirect human interventions (e.g. coastal development or accelerated sea level rise). In order to interact with coastal systems to protect island hinterlands, it is important to understand that beaches are dynamic buffer zones.

### ***Paul Kench***

#### *Modelling the effect of changes in sea level and sediment budgets on atoll islands*

This presentation discussed possible modelling options that allow evaluation of the morphological adjustments of atoll islands to changing sea level and sediment budgets. The standard Bruun Rule is an inappropriate tool to assess morphological change in atoll environments. In contrast, the Generalised Bruun Rule (involving the barrier rollover response) is considered to better represent the physical mechanisms that promote morphological change in atoll islands and, therefore, is a better tool to evaluate physical response of islands to sea level rise.

The presentation outlined the underlying principles of the modified Shoreface Translation Model (which incorporates the Generalised Bruun Rule) and the special modifications made to the model for application to reef islands (horizontal and non-erodable reef surface and truncated beach profiles).

A case study was presented using the model to assess the effects of climate change on Buariki Island, North Tarawa. Simulations showed that the island would retreat through washover processes between 10 and 30 m under a 1.0m sea-level rise scenario and depending on the morphology of the coast. Results demonstrated the great variation in response that will be expected between islands.

Changes in sediment supply and its effect on island shorelines were also simulated. Results indicate that contemporary reefs supply small amounts of sediment to island shorelines, which if removed from the system increases the rate of shoreline retreat. However, more significant changes in the sediment budget (through shifts in alongshore sediment transport or human extraction) can promote shoreline changes of an order of magnitude larger than sea level alone. Results indicate that in addition to knowing the effects of changing sea level on islands, process changes (waves and alongshore currents) and changes in sediment supply may have equally significant effects on atoll island shorelines as sea level.

### ***Naomi Atauea***

#### *Coastal Survey Data and Monitoring Program for Kiribati*

In 1982 a profile survey program was set up to determine the impact of the Nippon causeway on sediment accretion. Profiles were set up around Betio and Bariki in South

Tarawa. A detailed description was given of the profile data taken to date but a number of problems were outlined such as difficulties in fixing profile data to the temporary benchmarks and the difference in the length of the profiles (eg 30-50 m).

While training had been given through SOPAC there was a need for follow up assistance once the surveying was underway. A major concern was that while considerable effort was put into data collection twice a year, there was a need for training in further analysis of the data, particularly the calculations of sediment fluxes relative to changes in the profiles. At present there is only one officer to do the profiling, which has to be done in school holidays with the help of school children. There was a suggestion for a cooperative approach to sharing of data and expertise between the three atoll countries.



### **3.4 Fieldwork and Training (Undertaken on Day 3 of the Workshop, Saturday 17 February 2001)**

***Leader: Dr Paul Kench***

***Participants:***

*James Aston,*

*Ioketan Binataake*

*Nick Harvey*

*Karness Kusto*

*Tupalanga Poulasi*

*Tekena Teitiba*

*Naomi Atauea*

*Deirdre Hart*

*Abraham Hicking*

*Komeri Onorio*

*Sekuka Seluka*

*Nakibae Teuatabo*

The purpose of the field training day was to introduce participants to field survey techniques and to visit a number of sites to examine at first hand various coast protection technologies and areas of differential erosion and accretion. The following provides a summary of the sequence of activities for the day.

1. training in surveying and monitoring for coastal change – conducted on Bikebinbau to demonstrate use of levelling equipment (automatic level and staff)
2. visit to site of drilling on Buota – had talk from Alan Ryan, Chief Driller of Afrac Drilling Pty Ltd – discussed drilling operations, nature of groundwater lens in the area, construction of monitoring well, collection of solid core from island sediments – also discussed nature of island sediment accumulation and procedures for sediment analysis and radiometric dating
3. visit to northern part of Buota Island (separate island) to examine nature of reef sediments, reef conglomerate, phases of cementation and phases of island building with storm events and ridge development
4. visit Bonriki Island to examine and discuss coast protection technologies of seawall, gabion baskets and need to understand natural erosion and accretion – examined sites of both sediment loss and accretion with new beach berm in front of previous erosion scarp and evidence of old gabion baskets
5. visit area of lagoonal sediment accretion on lagoon side of Bikenibu
6. inspection of erosion and protection strategies west of President's house

### 3.5 Workshop Discussion and Action Plan

Associate Professor Harvey reiterated the intended outcomes of the workshop as follows:

- A. To provide a summary of coastal science data on sea level change
- B. To link science to coastal impacts and policy
- C. To discuss workshop findings and formulate an action plan for dealing with key issues.

Dr Harvey noted that the first outcome had in part been achieved through presentations at the workshop but would be supplemented from review material contained in a separate report and also summarised in the APN Final Report (this document). The second outcome had also been achieved through the discussion of coastal science related to policy. However, there was a need to follow by obtaining more information on specific coastal policy, legislation and regulations. The third outcome was to discuss workshop findings and suggest an action plan. This is outlined below.

#### 1. Collation and coordination of data

There is a need for collation and analysis of existing data on coastal monitoring and coastal processes. In addition there is a need to identify the location and availability of existing data.

*Action: Naomi Atuaea, Seluka Seluka, and Abraham Hicking agreed to follow this up in their respective countries (ie Kiribati, Tuvalu and The Marshalls).*

#### 2. Collection and analysis of new data and need for training of collection of data

There is a need for a basic understanding of coastal profiling and coastal processes. There is a need for governments to make time to work on the profiles and the need for a mechanism for providing advice when people encounter problems. There needs to be an opportunity for staff to go back to the trainers or resource people for more help once they have returned to their own country and are using the techniques. It needs to be repetitive and ongoing training with sufficient follow up and support.

To ensure the continuity of programs, there is a need to identify a responsible government department with clearly identified job description to ensure the profiling takes place as part of the normal work program.

Apart from the need for data collection and analysis, there is also a requirement for this to be translated into policy with government resource allocation to enable its implementation.

*Action: Nick Harvey and Paul Kench to seek funds to set up a coastal monitoring training programme for the three atoll countries of Oceania. As part of this action, it was agreed that, in order to be effective, this would require cooperation with participants from the three countries and endorsements from their governments.*

### **3. Coastal Adaptation technologies**

There is a need for more research and development on hard and soft coastal protection options that are suitable for atoll environments. This would require an evaluation of existing technologies to look at effectiveness.

*Action: James Aston to seek funds for a project to evaluate existing technologies used in the atoll countries.*

### **4. Security of water resources related to coastal processes and extreme events**

This issue was a major concern for Tuvalu. It was recommended that discussions be initiated with hydrological experts such as Tony Falkland.

*Action: Seluka Seluka in consultation with Paul Kench.*

### **5. Sediment Budget for Atoll Islands**

Although there is some work on sediment budgets on islands, more detailed work needs to be done in parallel with reef carbonate budgets. It was noted that there was a SOPAC STAR meeting in Majuro in September which may be an appropriate forum to action these issues.

*Action: Paul Kench to request a focus is given to sediment budgets in the STAR meeting.*

It was also noted that this APN workshop was part of a larger scientific project which, as part of its brief, is investigating atoll response to sea level change including atoll island evolution. There was also another scientific programme (Colin Woodruffe) which has potential to provide some answers to sediment budgets and atoll evolution. In addition, Paul Kench and Peter Cowell are continuing to refine their sediment budget models for atoll islands.

*Action: Nick Harvey and Paul Kench to pursue the science funding for sediment budget work and pass on results to atoll countries.*

### **6. Linkages between policy/legislation and sea level issues**

Although there is some coastal related legislation (eg RMI) and environment legislation, it is currently unclear to what extent the current science of sea level change is incorporated into these policy documents. The linkages between individual policies and legislation/guidelines needs to be better defined for sea level and coastal management issues.

*Action: Nick Harvey and James Aston to follow with individual countries.*

**BIBLIOGRAPHY AND REVIEW OF RECENT LITERATURE ON SEA LEVELS IN THE REPUBLICS OF THE MARSHALL ISLANDS, KIRIBATI, TUVALU AND FIJI**

- Aalbersberg, W. and Hay, J. 1991: Implications of climate change and sea level rise for Tuvalu: report of a preparatory mission. *SPREP Reports and Studies* No. 54. Apia, Western Samoa: South Pacific Regional Environment Programme. 80p.
- Aalbersberg, W. 1993: Climate change, agriculture and land use in the South Pacific. In: Hay, J.E. and Kaluwin, C. (eds.) *Climate Change and Sea Level Rise in the South Pacific Region*. Proceedings of the Second SPREP Meeting, Noumea, New Caledonia, 6-10 April 1992, Apia, Western Samoa, South Pacific Regional Environment Programme: 115-118.
- Aalbersberg, W. and Nunn, P.D. 1993: Review of impact studies in the South Pacific region. In: Hay, J.E. and Kaluwin, C. (eds.) *Climate Change and Sea Level Rise in the South Pacific Region*. Proceedings of the Second SPREP Meeting, Noumea, New Caledonia, 6-10 April 1992, Apia, Western Samoa, South Pacific Regional Environment Programme: 94-96.
- Aalbersberg, W., Nunn, P.D., Ravuvu, A. (eds.), *Climate and Agriculture in the Pacific Islands: Future Perspectives*. Institute of Pacific Studies, Suva.
- Abete, T. 1993: The Kiribati preliminary assessment to accelerated sea-level rise. In: McLean, R. and Mimura, N. (eds.) *Vulnerability Assessment to Sea Level Rise and Coastal Zone Management*. Proceedings of the IPCC/WCC '93 Eastern Hemisphere Workshop, Tsukuba, 3-6 August 1993. Canberra, Department of Environment, Sport and Territories: 91-98.
- Allen, M.S. 1998: Holocene sea-level change on Aitutaki, Cook Islands: Landscape change and human response. *Journal of Coastal Research* 14(1), 10-22.
- Ash, J. 1987: Holocene sea levels in northern Viti Levu, Fiji. *New Zealand Journal of Geology and Geophysics* 30, 431-435.
- Ash, J. and Ash, W. 1985: Holocene marine deposits on the south coast of Viti Levu, Fiji. *New Zealand Journal of Geology and Geophysics* 28, 571-573.
- Association of South Pacific Environmental Institutions 1988: Potential impacts of greenhouse gas generated climatic change and projected sea level rise on Pacific Island States of the SPREP Region, preliminary report, prepared for the Forth Consultative Meeting of Research and Training Institutions and Second Intergovernmental Meeting on the South Pacific Regional Environment Programme, Noumea.
- Association of South Pacific Environmental Institutions 1990: Overview of potential impacts of climate change in the SPREP Region. In: Pernetta, J.C. and Hughes, P.J. (eds.) *Implications of expected climate changes in the South Pacific region: an*

- overview. UNEP Regional Seas Reports and Studies No. 128. United Nations Environment Programme, Nairobi. pp1-13.
- Aubrey, D.G. and Emery, K.O. 1993: Recent global sea levels and land levels. In: Warrick, R.A. Barrow, E.M. and Wigley, T.M.L. (eds.), *Climate and Sea Level Change: Observations, Projections and Implications*. Cambridge, Cambridge University Press: 45-56.
- Aung, T.H. 1998: Early results from the South Pacific Sea Level and Climate Change Monitoring Project. In: Terry, J.P. *Climate and Environmental Change in the Pacific*. School of Social and Economic Development, University of the South Pacific, Suva, Fiji. pp 27-48.
- Aung, T.H. and Lennon, G.W. 1998: The Impacts of climate change from a viewpoint two metres above sea level. The plight of the atoll nations of the Pacific. *South Australian Geographer* 13(2), 13-17.
- Barnett, T.P. 1983: Recent changes in sea level and their possible causes. *Climatic Change* 5:15-38.
- Basher, R.E. 1993: Summary of scientific information available in the South Pacific region: climate variability and change. In: Hay, J.E. and Kaluwin, C. (eds.) *Climate Change and Sea Level Rise in the South Pacific Region*. Proceedings of the Second SPREP Meeting, Noumea, New Caledonia, 6-10 April 1992, Apia, Western Samoa, South Pacific Regional Environment Programme: 23-27.
- Basher, R.E., Collen, B., Fitzharris, B., Hay, J.E., Mullan, B. and Salinger, J. 1990: Basic studies for South Pacific climate change. Present climate and its impacts, data resources and scenario possibilities. Contract Report Commissioned by the New Zealand Ministry for the Environment. New Zealand Meteorological Service, Wellington, NZ. 75pp.
- Beniston, M. 1993: Potential impacts of abrupt climate change. In: Hay, J.E. and Kaluwin, C. (eds.) *Climate Change and Sea Level Rise in the South Pacific Region*. Proceedings of the Second SPREP Meeting, Noumea, New Caledonia, 6-10 April 1992, Apia, Western Samoa, South Pacific Regional Environment Programme: 83-93.
- Berryman, K. 1979: Seismotectonic zoning of the Fiji Islands. *New Zealand Geological Survey Report* 70.
- Bloom, A.L. 1980: Late Quaternary sea level change on south Pacific coasts: A study in tectonic diversity. In: Mörner, N-A. (ed.), *Earth Rheology, Isostasy and Eustasy*. John Wiley & Sons, Chichester, pp. 505-516.
- Brown, A. 1986: The ancient elevated shorelines of Wakaya, Nairai and Batiki, as seen through an examination of their relict morphological expressions. B.Sc. dissertation, University College London, UK. 67p.
- Bryant, E. 1988: Sea level variability and its impact within the greenhouse scenario. In: Pearman, G. *Greenhouse '87: Planning for Climatic Change*. CSIRO, Melbourne, pp135-146.

- Bualia, L. 1990: The impacts of sea level rise on a low-lying coastal landscape in Papua New Guinea: a case study from the Gulf of Papua. In: Pernetta, J.C. and P.J. Hughes (eds.) *Implications of Expected Climate Changes in the South Pacific Region: An Overview*, UNEP Regional Seas Reports and Studies, No. 128: 224-237.
- Bualia, L. and Sullivan, M. 1990: The impacts of possible global warming generated sea level rise on selected coastal environments in Papua New Guinea. In: Pernetta, J.C. and P.J. Hughes (eds.) *Implications of Expected Climate Changes in the South Pacific Region: An Overview*, UNEP Regional Seas Reports and Studies, No. 128: 193-199.
- Buddemeier, R.W., Smith, S.T. and Kinzie, R.A. 1975: Holocene windward reef-flat history, Enewetak atoll. *Geological Society of America Bulletin* 86: 1881-1884.
- Buddemeier, R.W. 1993a: Coral reef responses to climate change: issues for Pacific island nations In: Hay, J.E. and Kaluwin, C. (eds.) *Climate Change and Sea Level Rise in the South Pacific Region*. Proceedings of the Second SPREP Meeting, Noumea, New Caledonia, 6-10 April 1992, Apia, Western Samoa, South Pacific Regional Environment Programme: 97-100.
- Buddemeier, R.W. 1993b: IOC/UNEP/WMO/IUCN global monitoring system of coastal and near-shore phenomena related to climate change. In: Hay, J.E. and Kaluwin, C. (eds.) *Climate Change and Sea Level Rise in the South Pacific Region*. Proceedings of the Second SPREP Meeting, Noumea, New Caledonia, 6-10 April 1992, Apia, Western Samoa, South Pacific Regional Environment Programme: 62.
- Buddemeier, R.W. 1993c: Corals, climate and conservation. *Proceedings of the 7th International Coral Reef Symposium*, Guam 1: 1-10.
- Buddemeier, R.W. and Hopley, D. 1988: Turn-ons and turn offs: causes and mechanisms of the initiation and termination of coral reef growth. *Proceedings of the 6th International Coral Reef Symposium*, Townsville 1: 253-261.
- Buddemeier, R.W. and Oberdorfer, J.A. 1990: Climate change and island groundwater resources. In: Pernetta, J.C. and P.J. Hughes (eds.) *Implications of Expected Climate Changes in the South Pacific Region: An Overview*, UNEP Regional Seas Reports and Studies, No. 128: 56-57.
- Buddemeier, R.W. and Smith, S.V. 1988: Coral reef growth in an era of rapidly rising sea level: predictions and suggestions for long-term research. *Coral Reefs* 7: 51-56.
- Caldwell, P., Wyrski, K. and Nakahara, S. 1989: TOGA Sea Level Center: data from the Pacific. Joint Institute of Marine and Atmospheric Research, University of Hawaii, Honolulu. 34p.
- Cameron, J. 1993: The framework convention for climate change and international law. In: Hay, J.E. and Kaluwin, C. (eds.) *Climate Change and Sea Level Rise in the South Pacific Region*. Proceedings of the Second SPREP Meeting, Noumea, New Caledonia, 6-10 April 1992, Apia, Western Samoa, South Pacific Regional Environment Programme: 174.

- Campbell, J. 1993: Policy development for climate change impacts: adaptation. In: Hay, J.E. and Kaluwin, C. (eds.) *Climate Change and Sea Level Rise in the South Pacific Region*. Proceedings of the Second SPREP Meeting, Noumea, New Caledonia, 6-10 April 1992, Apia, Western Samoa, South Pacific Regional Environment Programme: 161-168.
- Campbell, J. 1996: Contextualising the effects of climate change in Pacific Island countries. In: Giambelluca, T.W. and Henderson-Sellers, A. *Climate Change: Developing Southern Hemisphere Perspectives*. John Wiley and Sons: Chichester, pp 349-374.
- Canning, D.J. 1991: *Global Climate Change, Sea Level Rise, and the Pacific Northwest*. Olympia, Washington. 20p.
- Carey, J.J. and Mieremet, B. 1992: Reducing vulnerability to sea level rise: international initiatives. *Ocean and Coastal Management* 18: 161-177.
- Chappell, J. 1983: Sea level changes and coral reef growth. In: Barnes, D.J. (ed.) *Perspectives on Coral Reefs*. Australian Institute of Marine Science, Townsville. pp. 38-55.
- Cheney, R.E. and Miller, L. 1990: Recovery of the sea level signal in the western tropical Pacific from Geosat altimetry. *Journal of Geophysical Research* 95(C3): 2977-2984.
- Clark, J.A., Farrell, W.E. and Peltier, W.R. 1978: Global changes in postglacial sea level: a numerical calculation. *Quaternary Research* 9: 265-287.
- Cole, J.E., Fairbanks, R.G. and Shen, G.T. 1993: Recent variability in the Southern Oscillation: Isotopic results from a Tarawa Atoll coral. *Science* 260: 1790-1793.
- Cole, R.V. (ed.) 1993: *Pacific 2010. Challenging the Future*. National Centre for Development Studies, Research School of Pacific Studies, Canberra.
- Connell, J. and Lea, J. 1993: Global warming: meeting the planning challenge in island states. In: Hay, J.E. and Kaluwin, C. (eds.) *Climate Change and Sea Level Rise in the South Pacific Region*. Proceedings of the Second SPREP Meeting, Noumea, New Caledonia, 6-10 April 1992, Apia, Western Samoa, South Pacific Regional Environment Programme: 149-156.
- Connell, J. and Roy, P. 1990: The greenhouse effect: the impact of sea level rise on low coral islands in the South Pacific. In: Pernetta, J.C. and P.J. Hughes (eds.) *Implications of Expected Climate Changes in the South Pacific Region: An Overview*, UNEP Regional Seas Reports and Studies, No. 128: 88-115.
- Connell, J., and Maata, M. 1992: Environmental planning, climate change and potential sea level rise: report on a mission to the Republic of the Marshall Islands. *SPREP Reports and Studies Series* No. 55. Apia, Western Samoa : South Pacific Regional Environment Programme. 94p.
- Coudray, J. and Delibrias, G. 1972: Variations du niveau marin au-dessus de l'actuel en Nouvelle Calédonie depuis 6000 ans. *Caiers Recherches de l'Academie de Sciences, Paris, D 275*: 2623-2626.

- Crawford, M. 1993b: Socio-economic impacts of projected sea level rise: a case study for Majuro Atoll, Republic of the Marshall Islands. In: Hay, J.E. and Kaluwin, C. (eds.) *Climate Change and Sea Level Rise in the South Pacific Region*. Proceedings of the Second SPREP Meeting, Noumea, New Caledonia, 6-10 April 1992, Apia, Western Samoa, South Pacific Regional Environment Programme: 196-197.
- Crawford, M., Holthus, P., Makroro, C., Nakasaki, E. and Sullivan, S. 1992: Assessment of the vulnerability of Majuro Atoll to sea level rise. In: O'Callahan, J. (ed.) *Global Climate Change and the Rising Challenge of the Sea*. Proceedings of the IPCC Workshop, Margarita Island, Venezuela, 9-13 March 1992. Silver Spring, Maryland, National Oceanic and Atmospheric Administration: 49-106.
- Delcroix, T. 1993: On sea level changes in the tropical Pacific at seasonal and interannual time scales. In: *Climate Change and Sea Level Rise in the South Pacific Region*, J.E. Hay and C. Kaluwin (eds.), Proceedings of the Second SPREP Meeting, Noumea, New Caledonia, 6-10 April 1992, Apia, Western Samoa, South Pacific Regional Environment Programme: 69-75.
- Delcroix, T., Eldin, G., Radenac, M.H., Toole, J. and Firing, E. 1992: Variation of the western equatorial Pacific Ocean, 1986-1988. *Journal of Geophysical Research* 96(C4): 6981-6992. .
- Delft Hydraulics 1993: Vulnerability assessments for population, coastal wetlands and rice production on a global scale. *Sea level rise. A global vulnerability assessment*. Second revised edition. Delft Hydraulics, Tidal Waters division, Rijkswaterstaat, Ministry of Transport, Public Works and Water Management, The Netherlands.
- Devine, N. and Psuty, N.P. 1992: Quantification of resources at risk to sea level rise in developing countries. In: O'Callahan, J. (ed.) *Global Climate Change and the Rising Challenge of the Sea*. Proceedings of the IPCC Workshop, Margarita Island, Venezuela, 9-13 March 1992. Silver Spring, Maryland, National Oceanic and Atmospheric Administration: 571-606.
- Dickinson, W.R. 1999: Holocene sea-level record on Funafuti and potential impact of global warming on central Pacific atolls. *Quaternary Research* 51, 124-132.
- Dowell, S.L. and Rickards, L.J. 1993: Recent developments in sea level networks and data centres. In: *Sea Level Changes and their Consequences for Hydrology and Water Management*, International Workshop, Noordwijkerhout, Netherlands 19-23 April 1993, Koblenz, IHP-OHP Secretariat, Bundesanstalt für Gewässerkunde, 1: 39-50.
- Ellison, J.C. 1992: Impacts of sea level rise on Pacific island mangrove swamps. In: O'Callahan, J. (ed.) *Global Climate Change and the Rising Challenge of the Sea*. Proceedings of the IPCC Workshop, Margarita Island, Venezuela, 9-13 March 1992. Silver Spring, Maryland, National Oceanic and Atmospheric Administration: 641-657.
- Ellison, J.C. 1994: Palaeo-lake and swamp stratigraphic records of Holocene vegetation and sea-level changes, Mangaia, Cook Islands. *Pacific Science* 48, 1-15.



- Erda, L. et al. (eds.) 1996: *Climate change vulnerability and adaptation in Asia and the Pacific*. Kluwer Academic Publishers, Dordrecht.
- Field, J.C. 1997: *Assessing Coastal Zone Sensitivity and Vulnerability to Regional Climate Change in the Pacific Northwest*. Unpublished Thesis (M.M.A), University of Washington. 82p.
- Fifita, N.P, Mimura, N. and Suzuki, K. 1993: Assessment of the vulnerability to sea level rise for the Kingdom of Tonga: summary of the Tongan case. In: Hay, J.E. and Kaluwin, C. (eds.) *Climate Change and Sea Level Rise in the South Pacific Region*. Proceedings of the Second SPREP Meeting, Noumea, New Caledonia, 6-10 April 1992, Apia, Western Samoa, South Pacific Regional Environment Programme: 186-195.
- Fifita, N.P., Mimura, N. and Hori, N. 1992: Assessment of the vulnerability of the kingdom of Tonga to sea level rise. In: O'Callahan, J. (ed.) *Global Climate Change and the Rising Challenge of the Sea*. Proceedings of the IPCC Workshop, Margarita Island, Venezuela, 9-13 March 1992. Silver Spring, Maryland, National Oceanic and Atmospheric Administration: 119-139.
- Fletcher, C.H. III and Jones, A.T. 1996: Sea-level highstand recorded in Holocene shoreline deposits on Oahu, Hawaii. *Journal of Sedimentary Research* 66(3), 632-641.
- Fletcher, C.H. III and Sherman, C.E. 1995: Submerged shorelines on O'ahu, Hawaii: archive of episodic transgression during the deglaciation. *Journal of Coastal Research*, Special Issue No. 17, 141-152.
- French, A. 1986: The formation and mineralogical composition of beachrock, and its validity as an indicator of sea level change, with particular reference to its distribution on Batiki, Wakaya and Nairai of Lomaiviti, Fiji. B.Sc. dissertation, University College London, UK. 67p.
- Fujimoto, K. 1997: Mangrove habitat evolution related to Holocene sea-level changes on Pacific islands. *Tropics* 6(3), 203-213.
- Gerges, M.A. and El-Sayed, M. Kh. 1992: Climate impact studies in low-lying coastal areas and small islands of UNEP's regional seas programme. In: O'Callahan, J. (ed.) *Global Climate Change and the Rising Challenge of the Sea*. Proceedings of the IPCC Workshop, Margarita Island, Venezuela, 9-13 March 1992. Silver Spring, Maryland, National Oceanic and Atmospheric Administration: 525-538.
- Goodwin, I.D. 1996: The interpretation of mid-oceanic sea level history with respect to the Antarctic meltwater contribution. In: Aung, T.H. (ed.) Proceedings of the Ocean and Atmosphere Pacific International Conference (23-27 October 1995, Adelaide Australia). National Tidal Facility, The Flinders University of South Australia. pp 66-71.
- Gornitz, V. 1993: Mean sea level changes in the recent past. In: Warrick, R.A., Barrow, E.M. and Wigley, T.M.L. (eds.) *Climate and Sea Level Change: Observations, Projections and Implications*. Cambridge, Cambridge University Press: 25-44.

- Gornitz, V. and Lebedeff, S. 1987: Global sea level changes during the past century. In: *Sea-level Fluctuation and Coastal Erosion, SEPM Special Publication 41*: 3-16.
- Green, R.G. 1979: Lapita. In: Jennings, J. (ed.) *The Prehistory of Polynesia*. Australian National University Press, Canberra.
- Grigg, R.W. and Dollar, S.J. 1990: Natural and anthropogenic disturbances on coral reefs. In: *Coral Reefs: Ecosystems of the World 25*, Z. Dubinsky (ed.), Elsevier, Amsterdam: 439-452.
- Grossman, E.E. and Fletcher, C.H. III. 1998: Sea level higher than present 3500 years ago on the northern main Hawaiian Islands. *Geology* 26(4), 363-366.
- Hamnett, M.P. 1989: Policy development and planning for global climate change and sea level rise in the Pacific Islands. Pacific Basin Development Council, Social Science Research Institute, University of Hawaii, Honolulu. 21p.
- Hamnett, M.P. 1990: Policy and planning options for global warming and sea level rise in the Pacific Islands: phase II and III, final report. Pacific Basin Development Council, Social Science Research Institute, University of Hawaii, Honolulu. 71p.
- Hay, J.E. 1993a: Climate change science: a view from the South Pacific. In: Hay, J.E. and Kaluwin, C. (eds.) *Climate Change and Sea Level Rise in the South Pacific Region*. Proceedings of the Second SPREP Meeting, Noumea, New Caledonia, 6-10 April 1992, Apia, Western Samoa, South Pacific Regional Environment Programme: 17-22.
- Hay, J.E. 1993b: Potential impacts of climate change on Pacific island nations. In: Hay, J.E. and Kaluwin, C. (eds.) *Climate Change and Sea Level Rise in the South Pacific Region*. Proceedings of the Second SPREP Meeting, Noumea, New Caledonia, 6-10 April 1992, Apia, Western Samoa, South Pacific Regional Environment Programme: 182-185.
- Hay, J.E. 1997: A Pacific response to climate change. *Tiempo* 23, 1-10.
- Hay, J.E. and Kaluwin, C. (eds.) 1993: *Climate Change and Sea Level Rise in the Pacific Region: Proceedings of the Second SPREP Meeting on Climate Change and Sea Level Rise in the South Pacific Region*, Noumea, New Caledonia, 6-10 April 1992. South Pacific Regional Environment Programme, Apia, Western Samoa. 238p.
- Henry, R. 1996: Use of TOPEX/POSEIDON Data in a Tidal Model of Fiji. In: Aung, T.H. (ed.) *Proceedings of the Ocean and Atmosphere Pacific International Conference (23-27 October 1995, Adelaide Australia)*. National Tidal Facility, The Flinders University of South Australia. pp 98-102.
- HIPAC 1988: A compiled list of radiocarbon dates for the samples in the southwest Pacific. In: Yonekura, N. (ed.) *Sea-Level Changes and Tectonics in the Middle Pacific: Report of the HIPAC Team in 1986 and 1997*. University of Tokyo, Japan. pp 23-34.
- Holthus, P.F., Crawford, M., Makroro, C. and Sullivan, S. 1992: Vulnerability assessment of accelerated sea level rise. Case study: Majuro Atoll, Republic of the Marshall

- Islands. *SPREP Reports and Studies Series No. 60*. SPREP, Apia, Western Samoa. 107p.
- Hoozemans, F.M.J., Marchand, M., Pennekamp, H., Stive, M., Misdorp, R. and Bijlsma, L. 1992: The impacts of sea level rise on coastal areas: some global results. In: O'Callahan, J. (ed.) *Global Climate Change and the Rising Challenge of the Sea*. Proceedings of the IPCC Workshop, Margarita Island, Venezuela, 9-13 March 1992. Silver Spring, Maryland, National Oceanic and Atmospheric Administration: 607-622.
- Hopley, D. 1987: Holocene sea-level changes in Australasia and the Southern Pacific. In: Devoy, R.J.N. *Sea Surface Studies: A Global Perspective*. Croom Helm, New York. pp 375-408.
- Hopley, D. 1992: Coral reef islands in a period of global sea level rise. In: Saxena, N. (ed.) *Recent Advances in Marine Science and Technology*, 92. Proceedings of the 1992 PACON Congress. pp 453-462.
- Howorth, R. and Radke, B. 1991: Investigation of historical shoreline changes: Betio, Tarawa Atoll, Kiribati; and Fongafale, Funafuti Atoll, Tuvalu. In: Workshop on Coastal Processes in the South Pacific Island Nations, *SOPAC Technical Bulletin 7*: 91-98.
- Huanting, S. 1993: Applications of the study on the mean sea level and its calculation methods. In: *Sea Level Changes and their Consequences for Hydrology and Water Management*, International Workshop, Noordwijkerhout, Netherlands 19-23 April 1993, Koblenz, IHP-OHP Secretariat, Bundesanstalt für Gewässerkunde, 1: 73-81.
- Hulm, P. 1989: *A Climate of Crisis. Global Warming and the Island South Pacific*. Association of South Pacific Environmental Institutions, Port Moresby. 22p.
- Jones, A.T. 1998: Late Holocene shoreline development in the Hawaiian Islands. *Journal of Coastal Research* 14, 3-9.
- Jones, C.B. 1990: *What the Marshall Islands can do about global climate change and the environment*. VHS videocassette (20 min.). Honolulu, HI: Pacific Basin Developmental Council, RIM Environmental Protection Authority.
- Kaluwin, C. 1996: Development of "No Regrets" Response Options in the Pacific Region. In: Aung, T.H. (ed.) Proceedings of the Ocean and Atmosphere Pacific International Conference (23-27 October 1995, Adelaide Australia). National Tidal Facility, The Flinders University of South Australia. pp 124-131.
- Kaluwin, C. and Hay, J.E. (comps) 1999: *Proceedings of the Third SPREP Meeting on Climate Change and Sea Level Rise in the South Pacific Region*. SPREP, Apia, Samoa.
- Kaluwin, C. and Homes, G.M. 1996: Climate change information and training strategy. In: Aung, T.H. (ed.) Proceedings of the Ocean and Atmosphere Pacific International Conference (23-27 October 1995, Adelaide Australia). National Tidal Facility, The Flinders University of South Australia. pp 132-142.

- Kaplin, P.A. 1981: Relief, age and types of oceanic islands. *New Zealand Geographer* 37(1): 3-12.
- Kench, P.S. 1999: Coastal Impacts (Chapter 3). In: *Climate Change and Adaptation Assessment for Kiribati*. Unpublished report to World Bank. 131p
- Kenny, G., Howden, M. and Aalbersberg, B. 1995: The impacts of climate change on agriculture in Oceania: A review and assessment of future research needs. *Asia Pacific Journal on Environment and Development* 2(2), 1-29.
- Leatherman, S.P. (ed.) 1997: Island states at risk: global climate change, development and population. *Journal of Coastal Research* Special Issue No. 24. 242p.
- Leatherman, S.P. and Beller-Simms, N. 1997: Sea-level rise and small island states: an overview. *Journal of Coastal Research* Special Issue No. 24, 1-16.
- Lennon, G.W. 1993: Australian initiatives in sea level and climate monitoring for the South Pacific and adjacent regions. In: Hay, J.E. and Kaluwin, C. (eds.) *Climate Change and Sea Level Rise in the South Pacific Region*. Proceedings of the Second SPREP Meeting, Noumea, New Caledonia, 6-10 April 1992, Apia, Western Samoa, South Pacific Regional Environment Programme: 28-33.
- Lennon, G.W. 1996: The South Pacific sea level and climate change monitoring project: a brief history. In: Aung, T.H. Proceedings of the Ocean and Atmosphere Pacific International Conference (23-27 October 1995, Adelaide Australia). National Tidal Facility, The Flinders University of South Australia. pp 165-168.
- Lennon, G.W. 1996: Sea level measurements to meet the demands of climate change. In: Aung, T. (ed.) Proceedings of the Ocean and Atmosphere Pacific International Conference (23-27 October 1995, Adelaide Australia). National Tidal Facility, The Flinders University of South Australia. pp 169-176.
- Lewis, J. 1988: Sea level rise Tonga, Tuvalu (Kiribati). Report of a Rapid Field Reconnaissance Mission, Nov. 1988. Commonwealth Secretariat, Canberra. 95p.
- Lewis, J. 1989: Sea-level rise: some implications for Tuvalu. *Ambio* 18: 458-459.
- Lewis, J. 1990: The vulnerability of small island states to sea level rise: the need for holistic strategies. *Disasters* 14: 241-248.
- Lucas, R., Hayes, S.P. and Wyrтки, K. 1984: Equatorial sea level response during the 1982-1983 El Nino. *Journal of Geophysical Research* 89(C6): 10425-10430.
- Machida, S., Mimura, N., Harasawa, H. and Yamada, K. 1993: Database system for vulnerability assessment to sea level rise: an Asia-Pacific VA. In: McLean, R. and Mimura, N. (eds.) *Vulnerability Assessment to Sea Level Rise and Coastal Zone Management*, Proceedings of the IPCC/WCC '93 Eastern Hemisphere Workshop, Tsukuba, 3-6 August 1993. Canberra, Department of Environment, Sport and Territories: 69-77.
- Maeda, Y., Miyata, T., Rodda, P., Sugimura, A., Matsumoto, E. and Matsushima, Y. 1986: Holocene sea-level changes in Viti Levu and Vanu Levu, Fiji. Survey on Holocene marine deposits in Viti Levu. In: Sugimura, A. (ed.) *Sea-level Changes and*

- Tectonics in the Middle Pacific: Report of the HIPAC Project in 1984 and 1985.*  
Department of Earth Sciences, Kobe University, pp 72-78.
- Maharaji, R.J. 1999: Report on UN framework convention on climate change (UNFCCC) experts meeting on coastal adaptation technologies. *SOPAC Miscellaneous Report* 322.
- Marshall, J.F., Jacobson, G. 1985: Holocene growth of a mid-plate atoll: Tarawa, Kiribati. *Coral Reefs* 4: 11-17.
- Matsushima, Y., Sugimura, A., Berryman, K., Ishii, T., Maeda, Y., Matsumoto, E., Yonekura, N. 1984: Holocene sea-level changes in Fiji and Western Samoa. In: Sugimura, A. (ed.) *Sea-Level Changes and Tectonics in the Middle Pacific: Report of the HIPAC Project in 1981, 1982 and 1983.* Department of Earth Sciences, Kobe University, pp 137-185.
- Maul, G.A. 1988: Pacific Ocean sea level variability. *Marine Geodesy* SI 12(4): 229-325.
- Maul, G.A. 1992: Activities and plans of the IOC related to coastal zone management and sea level rise. In: O'Callahan, J. (ed.) *Global Climate Change and the Rising Challenge of the Sea.* Proceedings of the IPCC Workshop, Margarita Island, Venezuela, 9-13 March 1992. Silver Spring, Maryland, National Oceanic and Atmospheric Administration: 483-486.
- McGregor, G. 1990: Possible consequences of climatic warming in Papua New Guinea with implications for the tropical southwest Pacific area. In: Pernetta, J.C. and P.J. Hughes (eds.) *Implications of Expected Climate Changes in the South Pacific Region: An Overview*, UNEP Regional Seas Reports and Studies No. 128: 25-40.
- McLean, R.F. 1980b: Spatial and temporal variability of external physical controls on small island ecosystems. In: Brookfield, H.C. (ed.) *Population-Environment Relations in Tropical Islands: The Case of Eastern Fiji.* MAB Technical Note UNESCO, Paris, 13: 149-175.
- McLean, R.F. 1989: Kiribati and sea level rise. Report on a field visit in May 1989 to consider the implications of a projected sea level rise in Kiribati. Expert Group on Climatic Change and Sea Level, Commonwealth Secretariat, Canberra, Australia. 87p.
- McLean, R.F. 1993: Sea-level change and sea-level variability. In: Hay, J.E. and Kaluwin, C. (eds.) *Climate Change and Sea Level Rise in the South Pacific Region.* Proceedings of the Second SPREP Meeting, Noumea, New Caledonia, 6-10 April 1992, Apia, Western Samoa, South Pacific Regional Environment Programme: 101-114.
- McLean, R.F. and Woodroffe, C.D. 1993: Vulnerability of atolls to accelerated sea-level rise: a case study of Australia's Cocos (Keeling) Islands. In: McLean, R. and Mimura, N. (eds.) *Vulnerability Assessment to Sea Level Rise and Coastal Zone Management.* Proceedings of the IPCC/WCC '93 Eastern Hemisphere Workshop, Tsukuba, 3-6 August 1993. Canberra, Department of Environment, Sport and Territories: 99-108.

- McLean, R.F. and Woodroffe, C.D. 1994: Coral atolls. In: Carter, R.W.G and Woodroffe, C.D. (eds.) *Coastal Evolution: Late Quaternary Shoreline Morphodynamics*. Cambridge University Press, Cambridge. pp 267-302.
- Meehl, G.A. 1997: Pacific Region Climate Change. *Ocean and Coastal Management* 37, 137-147.
- Mieremet, R. 1993: Vulnerability to sea level rise. In: Hay, J.E. and Kaluwin, C. (eds.) *Climate Change and Sea Level Rise in the South Pacific Region*. Proceedings of the Second SPREP Meeting, Noumea, New Caledonia, 6-10 April 1992, Apia, Western Samoa, South Pacific Regional Environment Programme: 175-181.
- Mimura, N. and Pelesikoti, N. 1997. Vulnerability of Tonga to future sea-level rise. *Journal of Coastal Research* Special Issue No. 24, 117-132.
- Miyata, T., Maeda, Y., Matsumoto, E., Matsushima, Y., Rodda, P., Sugimura, A. 1988: Emerged notches and microatolls on Vanua Levu, Fiji. In: *Sea-level Changes and Tectonics in the Middle Pacific*. Report of the HIPAC Project in 1986 and 1987. University of Tokoyo, Japan. pp 67-76.
- Miyata, T., Maeda, Y., Matsumoto, E., Matsushima, Y., Rodda, P., Sugimura, A. and Kayanne, H. 1990: Evidence for a Holocene high sea-level stand, Vanua Levu, Fiji. *Quaternary Research* 33, 352-359.
- Muller, M. 1993: The French research programmes on the ecological and socio-economic consequences and on the technical aspects of sea level rise related to climate change. In: Hay, J.E. and Kaluwin, C. (eds.) *Climate Change and Sea Level Rise in the South Pacific Region*. Proceedings of the Second SPREP Meeting, Noumea, New Caledonia, 6-10 April 1992, Apia, Western Samoa, South Pacific Regional Environment Programme: 61.
- Nakada, M. 1986: Holocene sea levels in oceanic islands: implications for the rheological structure of the earth's mantle. *Tectonophysics* 121: 263-276.
- Neumann, A.C. and Macintyre, I. 1985: Reef response to sea level rise: keep up, catch up or give up. *Proceedings of the 5th International Coral Reef Symposium*, Tahiti 3: 105-110.
- Newell, N.D. and Bloom, A.L. 1970: The reef flat and two-meter eustatic terrace of some Pacific atolls. *Geological Society American Bulletin* 81: 1881-1894.
- NTF 1994a: *Information and Training Plan*, Programme Component 4, South Pacific Sea Level and Climate Monitoring Project, National Tidal Facility, The Flinders University of South Australia, Adelaide, March 1994.
- NTF 1994b: *Round One Sub-regional Training Workshops on Sea Level and Climate Change* 11-29 April 1994, National Tidal Facility, The Flinders University of South Australia, Adelaide, June 1994.
- NTF 1994c: *Round Two Sub-regional Training Workshops on Sea Level and Climate Change*, Monitoring the Ocean and Atmosphere, 3-21 October 1994, National Tidal Facility, The Flinders University of South Australia, Adelaide, December 1994.

- NTF 1995: *Round Three Sub-regional Training Workshops on Sea Level and Climate Change, Data Interpretation and Its Application*, 6-24 March 1995, National Tidal Facility, The Flinders University of South Australia, Adelaide, June 1995.
- Nunn, P.D. 1988: Future sea-level rise in the Pacific: effects on selected parts of Cook Islands, Fiji, Kiribati, Tonga and western Samoa. *SSED working paper* No. 12. Suva, Fiji: University of the South Pacific. 46p.
- Nunn, P.D. 1989: Effects of global warming on South Pacific islands, 1900-2100. In: Streets, D.G. and Siddiqi, T.A. (eds.) *Responding to the Threat of Global Warming. Options for the Pacific and Asia*. Argonne National Laboratory, Argonne, IL, pp 5-63-5-107.
- Nunn, P.D. 1990a: Coastal processes and landforms of Fiji: their bearing on Holocene sea-level changes in the south and west Pacific. *Journal of Coastal Research* 6 (2), 279-310.
- Nunn, P.D. 1990b: Potential impacts of projected sea level rise on Pacific island states (the Cook Islands, Fiji, Kiribati, Tonga and Western Samoa): A Preliminary Report. In: Pernetta, J.C. and Hughes, P.J. (eds.) *Implications of expected climate changes in the South Pacific region: an overview*. UNEP Regional Seas Reports and Studies No. 128, UNEP, Nairobi, Kenya, 127-148.
- Nunn, P.D. 1990c: Recent coastline changes and their implications for future changes in the Cook Islands, Fiji, Kiribati, The Solomon Islands, Tonga, Tuvalu, Vanuatu and Western Samoa. In: Pernetta, J.C. and Hughes, P.J. (eds.) *Implications of expected climate changes in the South Pacific region: an overview*. UNEP Regional Seas Reports and Studies No. 128, UNEP, Nairobi, Kenya, 149-160.
- Nunn, P.D. 1990d: Recent environmental changes on Pacific islands. *The Geographical Journal* 156(2): 125-140.
- Nunn, P.D. 1990e: Warming of the south Pacific region since 1880: evidence, causes and implications. *The Journal of Pacific Studies* 15, 35-50.
- Nunn, P.D. 1991a: Sea-level changes during the past 8000 years in Fiji, Tonga and Western Samoa: implications for future coastal development. In: Workshop on Coastal Processes in the South Pacific Island Nations, *SOPAC Technical Bulletin 7*: 79-90.
- Nunn, P.D. 1992: Keimami so vakila na liga ni Kalou (Feeling the hand of God): human and non-human impacts on Pacific island environments. East-West Center, Occasional Paper (2<sup>nd</sup> revised edition)13. 69p.
- Nunn, P.D. 1993a: Beyond the naïve lands: human history and environmental change in the Pacific basin. In: Waddell, E. and Nunn, P.D. (eds.) *The Margin Fades: Geographical Itineraries in a World of Islands*. Institute of Pacific Studies, University of the South Pacific, Suva, pp 5-27.
- Nunn, P.D. 1993b: Recent sea-level changes in the Pacific with emphasis on the evidence for recent sea-level rise in Fiji. In: Aalbersberg, W., Nunn, P.D., Ravuvu, A. (eds.),

- Climate and Agriculture in the Pacific Islands: Future Perspectives*. Institute of Pacific Studies, Suva, pp. 53-57.
- Nunn, P.D. 1993c: Recent warming of the south Pacific region. In: Aalbersberg, W., Nunn, P.D., Ravuvu, A. (eds.), *Climate and Agriculture in the Pacific Islands: Future Perspectives*. Institute of Pacific Studies, Suva, pp. 7-19
- Nunn, P.D. 1994: *Oceanic Islands*. Blackwell Publishers, Oxford. 413p.
- Nunn, P.D. 1995: Holocene sea-level changes in the south and west Pacific. *Journal of Coastal Research*, Special Issue No. 17, 311-319.
- Nunn, P.D. 1996: Geomorphological evidence of climatic change in the Pacific. In: Aung, T.H. (ed.) *Proceedings of the Ocean and Atmosphere Pacific International Conference (23-27 October 1995, Adelaide Australia)*. National Tidal Facility, The Flinders University of South Australia. pp 265-275
- Nunn, P.D. 1997: Late Quaternary environmental changes on Pacific Islands: controversy, certainty and conjecture. *Journal of Quaternary Science* 12(5), 443-450.
- Nunn, P.D. 1998a: Consequences of sea-level change during the Holocene in the Pacific Basin: Introduction. *Journal of Coastal Research* 14, 1-2.
- Nunn, P.D. 1998c: *Pacific Island Landscapes*. Institute of Pacific Studies. The University of the South Pacific.
- Nunn, P.D. 1998d: Sea-Level changes over the past 1,000 years in the Pacific. *Journal of Coastal Research* 14, 23-30.
- Nunn, P.D. 2000: Coastal changes over the past 200 years around Ovalau and Moturiki Islands, Fiji: implications for coastal zone management. *Australian Geographer* 31 (1): 21-39.
- Nunn, P.D. and Finau, F.T. 1995: Holocene emergence history of Tongatapu Island, South Pacific. *Zeitschrift für Geomorphologie* 39(1): 69-95.
- Nunn, P.D. and Mimura, N. 1997: Vulnerability of south Pacific island nations to sea-level rise. *Journal of Coastal Research*, Special Issue No. 24, 133-151.
- Nunn, P.D., Aalbersberg, W., Clarke, W., Korovulavula, I., Mimura, N., Ohno, E., Yamada, K., Serizawa, M. and Nishioka, S. 1996: *Coastal vulnerability and resilience in Fiji: assessment of climate change impacts and adaptation, Phase IV*. SPREP, Apia, Western Samoa.
- Nunn, P.D., Kay, R.C., Ravuvu, A. and Yamada, K. 1993: Assessment of coastal vulnerability and resilience to sea-level rise and climate change; case study: Vitu Levu Island, Fiji. Phase I: Concepts and Approach. SPREP.
- Nunn, P.D., Ravuvu, A.D., Aalbersberg, W., Mimura, N. and Yamada, K. 1994: Assessment of coastal vulnerability and resilience to sea-level rise and climate change, case study: Yasawa Islands, Fiji. Phase II: Development of Methodology. SPREP. 118p.
- Nurse, L.A., McLean, R.F and Suarez, A.G. 1998: Small Island States. In: Watson, R.T., Zinyowera, M.C. and Moss, R.H. (eds.) *The Regional Impacts of Climate Change. An assessment of vulnerability*. A Special Report of IPCC Working Group II.



Published for the Intergovernmental Panel on Climate Change by Cambridge University Press, Cambridge, 331-354.

- Nyenzi, B. 1993: Summary of IPCC working group III: response strategies. In: Hay, J.E. and Kaluwin, C. (eds.) *Climate Change and Sea Level Rise in the South Pacific Region*. Proceedings of the Second SPREP Meeting, Noumea, New Caledonia, 6-10 April 1992, Apia, Western Samoa, South Pacific Regional Environment Programme: 169-170.
- Obasi, G.O.P. 1992: The challenge of sea level rise for the World Meteorological Organization. In: O'Callahan, J. (ed.) *Global Climate Change and the Rising Challenge of the Sea*. Proceedings of the IPCC Workshop, Margarita Island, Venezuela, 9-13 March 1992. Silver Spring, Maryland, National Oceanic and Atmospheric Administration: 565-567.
- O'Collins, M. 1990: Carteret islanders at the Atolls Resettlement Scheme: a response to land loss and population growth. In: Pernetta, J.C. and P.J. Hughes (eds.) *Implications of Expected Climate Changes in the South Pacific Region: An Overview*, UNEP Regional Seas Reports and Studies, No. 128: 247-269.
- O'Collins, M. 1990: Social and cultural impact: a changing Pacific? In: Pernetta, J.C. and P.J. Hughes (eds.) *Implications of Expected Climate Changes in the South Pacific Region: An Overview*, UNEP Regional Seas Reports and Studies, No. 128: 116-126.
- Ozasa, H. Hoh, T. and Hosokawa, Y. 1993: Engineering methods in response to sea level rise. In: McLean, R. and Mimura, N. (eds.) *Vulnerability Assessment to Sea Level Rise and Coastal Zone Management*. Proceedings of the IPCC/WCC '93 Eastern Hemisphere Workshop, Tsukuba, 3-6 August 1993. Canberra, Department of Environment, Sport and Territories: 227-236.
- Palmer, G.W.R. 1988: The greenhouse effect and its relevance to the Pacific Region. East-West Centre, Honolulu, Hi. 20p.
- Pernetta, J.C. 1990: Projected climate change and sea level rise: a relative impact rating for the countries of the Pacific Basin. In: Pernetta, J.C. and P.J. Hughes (eds.), *Implications of Expected Climate Changes in the South Pacific Region: An Overview*. UNEP Regional Seas Reports and Studies, No. 128, United Nations Environment Programme, Nairobi, Kenya. pp14-24.
- Pernetta, J.C. 1992: Impacts of climate change and sea-level rise on small island states. National and international responses. *Global Environmental Change* 2(1), 19-31.
- Pernetta, J.C. 1993: Mangrove forests, climate change and sea level rise: hydrological influences on community structure and survival. In: *Sea Level Changes and their Consequences for Hydrology and Water Management*, International Workshop, Noordwijkerhout, Netherlands 19-23 April 1993, Koblenz, IHP-OHP Secretariat, Bundesanstalt fur Gewasserkunde, 5: 3-49.

- Pernetta, J.C. and Elder, D.L. 1992: Climate, sea level rise and the coastal zone: management and planning for global change. *Ocean Coast Management* 18: 113-160.
- Pernetta, J.C. and Hughes, P.J. (eds.) 1989: Studies and reviews of greenhouse related climatic change impacts on the Pacific Islands, a report prepared for the SPC/UNEP/ASPEI Intergovernmental Meeting on Climate Change and Sea Level Rise in the South Pacific, Majuro. Association of the South Pacific Environmental Institutions, University of Papua New Guinea, Port Moresby.
- Pernetta, J.C. and Hughes, P.J. 1990: *Implications of expected climate changes in the South Pacific region: an overview*. UNEP Regional Seas Reports and Studies No. 128: 279. United Nations Environment Programme, Nairobi.
- Pirazzoli, P.A. 1986: Secular trends of relative sea level (RSL) changes indicated by tide gauge records. *Journal of Coastal Research* SI 1: 1-26.
- Pirazzoli, P.A. 1991: *World Atlas of Holocene Sea-Level Changes*. Elsevier Oceanography Series 58, Elsevier, Amsterdam. 300 p.
- Pirazzoli, P.A. and Montaggioni, L.F. 1988: Holocene sea-level changes in French Polynesia. *Palaeogeography, Palaeoclimatology, Palaeoecology* 68:153-175.
- Pirazzoli, P.A., Montaggioni, L.F., Salvat, B. and Faure, G. 1988: Late Holocene sea level indicators from twelve atolls in the central and eastern Tumotus (Pacific Ocean). *Coral Reefs* 7: 57-68.
- Primo, L.H. 1997: Sea-level rise vulnerability of Kosrae, Federated States of Micronesia and strategies for adaptation. *Journal of Coastal Research* Special Issue No. 24, 107-115.
- Pugh, D.T. 1993: Improving sea level data. In: Warrick, R.A., Barrow, E.M. and Wigley, T.M.L. (eds.) *Climate and Sea Level Change: Observations, Projections and Implications*. Cambridge, Cambridge University Press: 57-71.
- Rabie, A., Serizawa, M., Mimura, N., Sannami, T., Yamada, K. and Furuike, K. 1997: Assessment of sea-level rise impacts on the coastal area of Funafuti, Tuvalu. In: *Pacific Coasts and Ports '97*. Proceedings of the 13th Australasian Coastal and Ocean Engineering Conference and the 6th Australasian Port and Harbour Conference. Volume 2. Centre for Advanced Engineering, University of Canterbury, Christchurch, New Zealand, 687-692.
- Richmond, B.M., Mieremet, B. and Reiss, T.E. 1997: Yap Islands natural coastal systems and vulnerability to potential accelerated sea-level rise. *Journal of Coastal Research* Special Issue No. 24, 153-172.
- Roy, P. and Connell, J. 1989: 'Greenhouse': the impact of sea level rise on low coral islands in the South Pacific. *RIAP Occasional Paper* No. 6. Research Institute for Asia and the Pacific: Sydney. 55p.
- Roy, P. and Connell, J. 1990: Greenhouse effects on atoll islands in the South Pacific. *Geological Society of Australia Symposium Proceedings* 1: 57-70.

- Roy, P. and Connell, J. 1991: Climatic change and the future of atoll states. *Journal of Coastal Research* 7: 1057-1075.
- Salinger, M.J. and Collen, B. 1993: Climate trends in the South Pacific. In: Hay, J.E. and Kaluwin, C. (eds.) *Climate Change and Sea Level Rise in the South Pacific Region*. Proceedings of the Second SPREP Meeting, Noumea, New Caledonia, 6-10 April 1992, Apia, Western Samoa, South Pacific Regional Environment Programme: 34-46.
- Salinger, M.J., Basher, R.E., Fitzharris, B.B., Hay, J.E., Jones, P.D., Macveigh, J.P. and Schmidely-Leleu, I. 1995: Climate trends in the south-west Pacific. *International Journal of Climatology* 15, 285-302.
- Schofield, J.C. 1969: Notes on Late Quaternary sea levels, Fiji and Rarotonga. *New Zealand Journal of Geology and Geophysics* 13: 199-206.
- Schofield, J.C. 1977a: Effect of late Holocene sea level fall on atoll development. *New Zealand Journal of Geology and Geophysics* 20: 531-536.
- Schofield, J.C. 1977b: Late Holocene sea level, Gilbert and Ellice Islands, west central Pacific Ocean. *New Zealand Journal Geology and Geophysics* 20: 503-529.
- Schofield, J.C. 1980: Postglacial transgressive maxima and second-order transgressions of the southwest Pacific Ocean. In: Mörner, N-A. (ed.), *Earth Rheology, Isostasy and Eustasy*. John Wiley & Sons, Chichester, pp. 517-521.
- Scoffin, T.P., Stoddart, D.R., Tudhope, A.W. and Woodroffe, C.D. 1985: Exposed limestones of Suvarrow Atoll. *Proceedings of the 5th International Coral Reef Congress, Tahiti* 3: 137-140.
- Shennan, I. 1993: Geographic information systems and future sea level rise. In: Warrick, R.A., Barrow, E.M. and Wigley, T.M.L. (eds.) *Climate and Sea Level Change: Observations, Projections and Implications*. Cambridge, Cambridge University Press: 215-228.
- Smith, S.V. and Buddemeier, R.W. 1992: Global change and coral reef ecosystems. *Ann. Rev. Ecol. Syst.* 23: 89-118.
- Solomon, S. 1997: Assessment of the vulnerability of Betio, South Tarawa, Kiribati, to accelerated sea-level rise. *SOPAC Technical Report 251*.
- SPC/UNEP/ASPEI 1989: *Intergovernmental Meeting on Climatic Change and Sea Level Rise in the South Pacific: Majuro, Marshall Islands*. Noumea, New Caledonia: South Pacific Commission. 73p.
- Spencer, T., Stoddart, D.R. and Woodroffe, C.D. 1987: Island uplift and lithospheric flexure: observations and cautions from the south Pacific. *Zietschrift für Geomorphologie Suppl. Bd. 63*: 87-102.
- Spennemann, D.H.R., Belz, L.H. and Byrne, G. 1990: The potential impacts of projected climatic change and sea level rise on Tongatapu, Kingdom of Tonga. In: Pernetta, J.C. and Hughes, P.J. (eds.) *Implications of expected climate changes in the South Pacific region: an overview*. UNEP Regional Seas Reports and Studies No. 128, UNEP, Nairobi, Kenya, pp 161-192.

- SPREP 1995a: *A Long-term look at Sea Levels and Changing Climate*. Fact Sheet 13/1: The South Pacific and Climate Monitoring Project, Apia, Western Samoa. 4p.
- SPREP 1995b: Fact Sheet 13/2: The South Pacific and Climate Monitoring Project, Apia, Western Samoa.
- SPREP (monthly): *South Pacific Sea Level Bulletin*: the monthly data report from the South Pacific Sea Level and Climate Monitoring Project. Published in association with the National Tidal Facility (NTF), Australia and Australian International Development Assistance Bureau (AIDAB), Adelaide.
- SPREP (quarterly): *South Pacific Sea Level and Climate Newsletter*: South Pacific Regional Environment Programme and the National Tidal Facility (NTF), Adelaide.
- Sullivan, J. and Pernetta, J. 1990: The effect of sea level rise on atolls and motu. In: Pernetta, J.C. and P.J. Hughes (eds.) *Implications of Expected Climate Changes in the South Pacific Region: An Overview*, UNEP Regional Seas Reports and Studies, No. 128, UNEP, Nairobi, Kenya, pp 41-55.
- Sullivan, M. 1990: The effects of sea level rise on raised coral and high islands. In: Pernetta, J.C. and P.J. Hughes (eds.) *Implications of Expected Climate Changes in the South Pacific Region: An Overview*, UNEP Regional Seas Reports and Studies, No. 128: 218-223.
- Sullivan, M. and Gibson, L., 1991: Environmental planning, climate change, and potential sea level rise: report on a mission to Kiribati. *SPREP Reports and Studies Series* No. 50. Noumea, New Caledonia: South Pacific Regional Environment Programme. 55 p.
- Taft, B.A. and Kessler, W.S. 1991: Variations of zonal currents in the central tropical Pacific Ocean during 1970 to 1987. *Journal of Geophysical Research* 96(C7): 12599-12618.
- Tanaka, S., Yamamoto, K. and Iwasaki, Y. 1993: Effects of global climate change in littoral areas. In: McLean, R. and Mimura, N. (eds.) *Vulnerability Assessment to Sea Level Rise and Coastal Zone Management*. Proceedings of the IPCC/WCC '93 Eastern Hemisphere Workshop, Tsukuba, 3-6 August 1993. Canberra, Department of Environment, Sport and Territories: 125-133.
- Taylor, F.W. 1978: Quaternary tectonic and sea-level history, Tonga and Fiji, southwest Pacific. Unpublished Ph.D. thesis, Cornell University, Ithaca, New York. 355 p.
- Terry, J. 1998: *Climate and environmental change in the Pacific*. University of the South Pacific: Suva, Fiji. 144p.
- Tewungwa, S. 1993: Climate change information and awareness raising: intergovernmental panel on climate change (IPCC). In: Hay, J.E. and Kaluwin, C. (eds.) *Climate Change and Sea Level Rise in the South Pacific Region*. Proceedings of the Second SPREP Meeting, Noumea, New Caledonia, 6-10 April 1992, Apia, Western Samoa, South Pacific Regional Environment Programme: 207.

- Titus, J.G. 1993: Regional effects of sea level rise. In: Warrick, R.A., Barrow, E.M. and Wigley, T.M.L. (eds.) *Climate and Sea Level Change: Observations, Projections and Implications*. Cambridge, Cambridge University Press: 395-399.
- Titus, J.G. and Narayanan, V. 1992: Probability distribution of future sea level rise. In: O'Callahan, J. (ed.) *Global Climate Change and the Rising Challenge of the Sea*. Proceedings of the IPCC Workshop, Margarita Island, Venezuela, 9-13 March 1992. Silver Spring, Maryland, National Oceanic and Atmospheric Administration: 659-675.
- Tooley, M.J. 1993: Long term changes in eustatic sea level. In: Warrick, R.A., Barrow, E.M. and Wigley, T.M.L. (eds.) *Climate and Sea Level Change: Observations, Projections and Implications*. Cambridge, Cambridge University Press: 81-107.
- Töppe, A. 1993: Longtime cycles in mean tidal levels. In: *Sea Level Changes and their Consequences for Hydrology and Water Management*, International Workshop, Noordwijkerhout, Netherlands 19-23 April 1993, Koblenz, IHP-OHP Secretariat, Bundesanstalt für Gewässerkunde, 1: 133-143.
- Van Lierop, H.E.R. 1993: The status of negotiations on a framework convention on climate change. In: Hay, J.E. and Kaluwin, C. (eds.) *Climate Change and Sea Level Rise in the South Pacific Region*. Proceedings of the Second SPREP Meeting, Noumea, New Caledonia, 6-10 April 1992, Apia, Western Samoa, South Pacific Regional Environment Programme: 173.
- Veitayaki, J. 1993: Addressing climate change and sea level rise: the role of NGOs. In: Hay, J.E. and Kaluwin, C. (eds.) *Climate Change and Sea Level Rise in the South Pacific Region*. Proceedings of the Second SPREP Meeting, Noumea, New Caledonia, 6-10 April 1992, Apia, Western Samoa, South Pacific Regional Environment Programme: 212-216.
- Verstraete, J.M. and Musiela, G. 1996: Low-frequency sea level variability from seasonal to inter-annual time scales in the western tropical Pacific Ocean. In: Aung, T.H. (ed.) Proceedings of the Ocean and Atmosphere Pacific International Conference (23-27 October 1995, Adelaide Australia). National Tidal Facility, The Flinders University of South Australia. pp 366-379.
- Warrick, R.A. 1993a: Climate and sea level change: a synthesis. In: Warrick, R.A., Barrow, E.M. and Wigley, T.M.L. (eds.) *Climate and Sea Level Change: Observations, Projections and Implications*. Cambridge, Cambridge University Press: 3-21.
- Warrick, R.A. 1993b: Projections of future sea level rise: an update. In: McLean, R. and Mimura, N. (eds.) *Vulnerability Assessment to Sea Level Rise and Coastal Zone Management*. Proceedings of the IPCC/WCC '93 Eastern Hemisphere Workshop, Tsukuba, 3-6 August 1993. Canberra, Department of Environment, Sport and Territories: 51-67.
- Waterman, P. and Kay, R. 1993: Review of the applicability of the "common methodology for assessment of vulnerability of sea level rise" to the Australian

- coastal zone. In: McLean, R. and Mimura, N. (eds.) *Vulnerability Assessment to Sea Level Rise and Coastal Zone Management*. Proceedings of the IPCC/WCC '93 Eastern Hemisphere Workshop, Tsukuba, 3-6 August 1993. Canberra, Department of Environment, Sport and Territories: 237-248.
- Weaver, A.J. 1993: The oceans and global warming. *Nature* 364: 192-193.
- Wigley, T.M.L. and Raper, S.C.B. 1992: Implications for climate and sea level of revised IPCC emissions scenarios. *Nature* 357: 293-300.
- Wigley, T.M.L. and Raper, S.C.B. 1993: Future changes in global mean temperature and sea level. In: Warrick, R.A., Barrow, E.M. and Wigley, T.M.L. (eds.) *Climate and Sea Level Change: Observations, Projections and Implications*. Cambridge, Cambridge University Press: 111-133.
- Wigley, T.M.L. and Raper, S.C.B. 1993: Global mean temperature and sea level projections under the 1992 IPCC emissions scenarios. In: Warrick, R.A., Barrow, E.M. and Wigley, T.M.L. (eds.) *Climate and Sea Level Change: Observations, Projections and Implications*. Cambridge, Cambridge University Press: 401-404.
- Woodroffe, C.D. 1992: Preliminary assessment of the vulnerability of Kiribati to accelerated sea level rise In: O'Callahan, J. (ed.) *Global Climate Change and the Rising Challenge of the Sea*. Proceedings of the IPCC Workshop, Margarita Island, Venezuela, 9-13 March 1992. Silver Spring, Maryland, National Oceanic and Atmospheric Administration: 29-47.
- Woodroffe, C.D. and McLean, R.F. 1990: Microatolls and recent sea level change on coral atolls. *Nature* 344: 531-534.
- Woodroffe, C.D. and McLean, R.F. 1992a: Kiribati: vulnerability to accelerated sea level rise: a preliminary study. Based upon research funded by the Department of Arts, Sports, Environment and Territories, Government of Australia. Department of Geography, University of Wollongong, Wollongong. 82p.
- Woodroffe, C.D. and McLean, R.F. 1992b: Assessment of recent sea-level change on Pacific and Indian Ocean atolls: deciphering the record from microatolls. Report on a research project funded by the Australian International Development Assistance Bureau.
- Woodroffe, C.D. and McLean, R.F. 1998: Pleistocene morphology and Holocene emergence of Christmas (Kiritimati) Island, Pacific Ocean. *Coral Reefs* 17: 235-248.
- Woodroffe, C.D., Stoddart, D.R., Spencer, T., Scoffin, T.P. and Tuldhope, A.W. 1990: Holocene emergence in the Cook Islands, South Pacific. *Coral Reefs* 9: 31-39.
- Woodworth, P.L. 1993: Sea level changes. In: Warrick, R.A., Barrow, E.M. and Wigley, T.M.L. (eds.) *Climate and Sea Level Change: Observations, Projections and Implications*. Cambridge, Cambridge University Press: 379-391.
- Wyrtki, K. 1974: Sea level and the seasonal fluctuations of the equatorial currents in the western Pacific Ocean. *Journal of Physical Oceanography* 4: 91-103.

- Wyrтки, K. 1984: The slope of sea level along the equator during the 1982/83 El Nino. *Journal of Geophysical Research* 89: 10419-10424.
- Wyrтки, K. 1990: Sea level rise: the facts and the future. *Pacific Science* 44(1), 1-16.
- Wyrтки, K., Constantine, K., Kilonsky, B., Mitchum, G., Miyamoto, B., Murphey, T., Nakahara, S., and Caldwell, P. 1988a: The Pacific Island sea level network. *Joint Institute of Marine and Atmospheric Research Contribution* 88-0137, University of Hawaii.
- Wyrтки, K., Constantine, K., Kilonsky, B., Mitchum, G., Miyamoto, B., Murphey, T., Nakahara, S., and Caldwell, P. 1988b: The IGOSS sea level pilot project in the Pacific. *Joint Institute of Marine and Atmospheric Research Contribution* 88-0150, University of Hawaii.
- Yamada, K., Nunn, P.D., Mimura, N., Machida, S. and Yamamoto, M. 1995: Methodology for the assessment of south Pacific island countries to sea-level rise and climate change. *Journal of Global Environment Engineering* 1, 101-125.

### ***Coastal Erosion***

- Carter, R. 1983: Coastal erosion in Kiribati. *CCOP/SOPAC Cruise Report* 76. 25p.
- Collen, J.D. 1995: Preliminary comment on visit to Funafuti, Majuro and Tarawa Atolls, June-July 1995. *SOPAC Preliminary Report* 81. 6p.
- Fawcett and Partners 1982: *Report on Prevention of Coastal Erosion*. Government of Tuvalu. 125pp.
- Forbes, D.L. and Hosoi, Y. 1995: Coastal erosion in South Tarawa, Kiribati. *SOPAC Technical Report* 225. 91p.
- Gillie, R.D. 1992d: Reconnaissance survey of coastal erosion sites in the Gilbert Island Group, Republic of Kiribati, 10-19 August 1992. *SOPAC Preliminary Report* 52. 18p.
- Gillie, R.D. 1993a: Coastal erosion problems in the Gilbert Islands group, Republic of Kiribati. *SOPAC Technical Report* 167.
- Gillie, R.D. 1993b: Reconnaissance survey of coastal erosion sites in the Gilbert Island Group, Republic of Kiribati (Phase II). *SOPAC Preliminary Report* 55. 22p.
- Gillie, R.D. 1993c: Historical changes of shoreline accretion and erosion Betio Islet, South Tarawa, Kiribati. *SOPAC Technical Report* 179. 22p.
- Gillie, R.D. 1994: Coastal erosion problems in the Gilbert Islands group, Republic of Kiribati. *SOPAC Technical Report* 191. 151p.
- Gillie, R.D. 1997a: Causes of coastal erosion in Pacific island nations. *Journal of Coastal Research* Special Issue No. 24, 173-203.
- Gillie, R.D. 1997b: Coastal Processes and causes of erosion on Pacific Islands. Coastal and environmental geoscience studies of the Southwest Pacific Islands. *SOPAC Technical Bulletin* 9, 51-76.

- Gillie, R.D. 1997c: Historical changes of shoreline accretion and erosion, Betio Islet, South Tarawa, Kiribati. Coastal and environmental geoscience studies of the Southwest Pacific Islands. *SOPAC Technical Bulletin 9*, 89-100.
- Harper, J.R. 1989b: Reconnaissance survey of coastal erosion sites on Abaiang Atoll, Republic of Kiribati, 3-4 April 1989. *CCOP/SOPAC Technical Report 92*.
- Holden, B.J. 1992: Coastal protection Tebunginako Village, Abaiang, Kiribati. *SOPAC Technical Report 136*. 46p.
- Howorth, R. 1982: Coastal erosion in Kiribati: visit to South Tarawa 22 January – 10 February 1982. *CCOP/SOPAC Technical Report 22*.
- Howorth, R. 1983: Coastal erosion in Kiribati: visit to South Tarawa September 1983. *CCOP/SOPAC Technical Report 31*.
- Ladd, H.S. and Hoffmeister, J.E. 1927: Recent negative shift in the strand line in Fiji and Tonga. *The Journal of Geology* xxxv, 542-556.
- Mimura, N. and Nunn, P.D. 1998: Trends of beach erosion and shoreline protection in rural Fiji. *Journal of Coastal Research* 14, 37-46.
- Pierce, C. 1999: The changing coastline at Mele Beach, Vanuatu. *Geography* 363(84), 149-163.
- Pittock, A.B. and Flather, R.A. 1993: Severe tropical storms and storm surges. In: Warrick, R.A., Barrow, E.M. and Wigley, T.M.L. (eds.) *Climate and Sea Level Change: Observations, Projections and Implications*. Cambridge, Cambridge University Press: 392-394.
- Raper, S.C.B. 1993: Observational data on the relationships between climatic change and the frequency and magnitude of severe tropical storms. In: Warrick, R.A., Barrow, E.M. and Wigley, T.M.L. (eds.) *Climate and Sea Level Change: Observations, Projections and Implications*. Cambridge, Cambridge University Press: 192-211.
- Rearic, D.M. 1991: Mapping survey and baseline study of coastal erosion on the islands of Tuvalu. *SOPAC Preliminary Report 38*. 12p.
- Reynolds, C.G. 1981: *Coastal erosion in Tuvalu*. Public Works Department, Government of Tuvalu. 24p.

#### ***Geological / Geomorphic Surveys***

- Baines, G.B.K. and McLean, R.F. 1976: Sequential studies of hurricane deposit evolution at Funafute Atoll. *Marine Geology* 21(M): 1-8.
- Biribo, N. and Smith, R. 1994: Sand and gravel usage, South Tarawa, Kiribati, 1989-1993. *SOPAC Preliminary Report 75*. 13p.
- Bryne, G. 1991: Sediment movement on Tarawa: Kiribati. Workshop on Coastal Processes in the South Pacific Island Nations (Lae, Papua New Guinea, 1-8 October 1987). *SOPAC Technical Bulletin 7*: 155-159.
- Buddemeier, R.W., Smith, S.V. and Kinzie, R.A. 1975: Holocene windward reef-flat history, Enewetak Atoll. *Geographical Society of America Bulletin* 86: 1581-1584.



- Burne, R.V. 1983: Origin and transportation of beach sand, Betio-Bairiki, Tarawa, Kiribati. CCOP/SOPAC Cruise Report 81. 81p.
- Cloud, P.E. 1952: Preliminary report on geology and marine environments of Onotoa Atoll, Gilbert Islands. *Atoll Research Bulletin* 12: 1-73.
- David, T.W.E. and Sweet, G. 1904: The geology of Funafuti. In: *The Atoll of Funafuti*. The Royal Society of London. pp 61-124.
- Dickson, W.R., Burley, D.V., Nunn, P.D., Anderson, A., Hope, G., De Biran, A., Burke, C. and Matararaba, S. 1998: Geomorphic and archaeological landscapes of the Sigatoka dune site, Viti Levu, Fiji: interdisciplinary investigations. *Asian Perspectives* 37(1), 1-31.
- Forbes, D.L. 1995: Coastal sedimentation and shore processes Natadola Beach, Viti Levu, Fiji. *SOPAC Preliminary Report* 83. 40p.
- Forbes, D.L. and Biribo, N. 1996: Shore-zone sand and gravel of South Tarawa, Kiribati. *SOPAC Technical Report* 235. 47p.
- Forbes, D.L., Kruger, J., Motuiwaca, S. and Naibitakele, N. 1995: Coastal sedimentation and shore processes Natadola Beach, Viti Levu, Fiji. *SOPAC Preliminary Report* 83. 40p.
- Gibb Australia 1985: *Tuvalu Lagoon Bed Resources Survey*. Report to Australian Development Assistance Bureau, Canberra. 261p.
- Gillie, R.D. 1992a: Air photo survey, South Tarawa, Kiribati. *SOPAC Miscellaneous Report* 136. 18p.
- Guillou, H., Brousse, R., Guillot, P.Y. and Guille, G. 1993: Geological reconstruction of Fangataufa Atoll, South Pacific. *Marine Geology* 110: 377-391.
- Kitekeiaho, T., Yeo, G. and Biribo, 1998: Investigation of the channel through the Bairiki-Betio causeway, Kiribati. *SOPAC Technical Report* 65. 29p.
- Lloyd, J.W., Miles, J.C., Chessman, G.R. and Bugg, S.F. 1980: A groundwater resources study of a Pacific Ocean atoll: Tarawa, Gilbert Islands. *Water Resources Bulletin* 16: 646-653.
- Locke, C.A. 1991: Geophysical constraints on the structure of Funafuti. *South Pacific Journal of Natural Science* 11: 129-140.
- Maragos, J.E., Baines, G.B.K., Beveridge, P.J. 1973: Tropical cyclone creates a new land formation on Funafuti atoll. *Science* 181: 1161-1164.
- McLean, R.F. 1979: The coast of Lakeba: a geomorphological reconnaissance. UNESCO/UNFPA Fiji Islands Report 5: 65-81. Australian National University, Canberra.
- McLean, R.F. 1991: Reef islands and atoll motu in Tuvalu: formation, persistence and change. In: Workshop on Coastal Processes in the South Pacific Island Nations, *SOPAC Technical Bulletin* 7, 77-78.
- McLean, R.F. and Hosking, P.L. 1991a: Geomorphology of reef islands and atoll motu in Tuvalu. *South Pacific Journal of Natural Science* 11: 167-189.

- McLean, R.F. and Hosking, P.L. 1991b: Tuvalu land resources survey country report. AG: TUV/80/001. A report prepared for the Food and Agriculture Organisation of the United Nations acting as executing agency for the United Nations Development Programme. Department of Geography, University of Auckland, Auckland, New Zealand. 115p.
- Nunn, P.D. 1991b: Tectonic environments of Fiji. In: Workshop on Coastal Processes in the South Pacific Island Nations, *SOPAC Technical Bulletin 7*: 67-76.
- Radke, B. 1985: Bathymetry and beach profiling, Funafuti, Tuvalu, September and October 1984. *CCOP/SOPAC Cruise Report 106*.
- Richmond, B.M. 1990: Nearshore sediment distribution, South Tarawa, Kiribati. *CCOP/SOPAC Technical Report 91*. 27p.
- Richmond, B.M. 1992: Development of atoll islets in the central Pacific. *Proceedings of the 7<sup>th</sup> International Coral Reef Symposium*, Guam 2: 1185-1194.
- Richmond, B.M. 1993: Reconnaissance geology of the Gilbert Group, western Kiribati. *SOPAC Technical Report 77*. 65p.
- Rogers, K.A. 1991: A brief history of Tuvalu's natural history. *South Pacific Journal of Natural Science* 11: 1-14.
- Roy, P.S. 1988: Coastal and nearshore geology of Savusavu Bay, Vanu Levu, Fiji. *CCOP/SOPAC Technical Report 60*.
- Shepherd, M.J. 1988: The evolution of a moderate energy coast in Holocene time, Pacific Harbour, Viti Levu, Fiji. *New Zealand Journal of Geology and Geophysics* 33, 547-556.
- Shepherd, M.J. 1990: The higher energy coasts of southern Viti Levu, Fiji, with particular reference to the geomorphology of the Deuba coast. *The Journal of Pacific Studies* 14: 1-19.
- Sherwood, A. and Howorth, R. 1996: Coasts of Pacific islands. *SOPAC Miscellaneous Report 222*. 39p.
- Shorten, G.G., Whippy, F. and Prasad, S. 1991: Geotechnical study and hazard zonation of Suva City and harbour. In: Workshop on Coastal Processes in the South Pacific Island Nations, *SOPAC Technical Bulletin 7*: 167-188.
- Smith, R. 1995a: Assessment of lagoon and aggregate resources Funafuti Atoll, Tuvalu. *SOPAC Technical Report 212*. [concerns: marine sediments]
- Smith, R. 1995b: Sand and aggregate resources Majuro Atoll, Marshall Islands. *SOPAC Technical Report 215*. 57p.
- Smith, R., Young, S. and Biribo, N. 1994: Bathymetric, seismic and alternative sand and gravel resource surveys, Tarawa Atoll, Kiribati. *SOPAC Preliminary Report 72*. 14 p. and 3 appendices.
- Sugimura, A., Maeda, Y., Matsushima, Y., Rodda, P. and Matsumoto, E. 1988: Lobau lowland, Viti Levu, Fiji. In: Yonekura, N. (ed.) *Sea-Level Changes and Tectonics in the Middle-Pacific: Report of the HIPAC Project in 1986 and 1987*. University of Tokyo, Japan. pp 59-65.

- Szabo, B.J., Tracey, J.I. and Goter, E.R. 1985: Ages of subsurface stratigraphic intervals in the Quaternary of Eniwetak Atoll, Marshall Islands. *Quaternary Research* 23: 54-61.
- Tracey, J.I. and Ladd, H.S. 1974: Quaternary history of Eniwetak and Bikini Atolls, Marshall Islands. In: *Proceedings of the Second International Coral Reef Symposium, Brisbane* 2: 537-550.
- Valencia, M.J. 1977: Christmas Island (Pacific Ocean) reconnaissance geological observations. *Atoll Research Bulletin* 197: 1-14.
- Weber, J.N. and Woodhead, P.M.J. 1972: Carbonate lagoon and beach sediments of Tarawa Atoll, Gilbert Islands. *Smithsonian Institution, Atoll Research Bulletin* 156. 21 p, 9 figures.
- Woodhall, D. 1991: *Geology of the Lau Group*. Mineral Resources Department Bulletin, Suva, Fiji.
- Woodroffe, C.D. 1991: Vegetation of Tuvalu. *South Pacific Journal of Natural Science* 11:82-128.
- Woodward, P. 1998a: Re-survey of Dud and Laura beach profiles, Majuro Atoll, Republic of Marshall Islands, 23-24 April 1998. *SOPAC Preliminary Report* 93.
- Woodward, P. 1998b: Re-survey of Bikenibeu Beach profiles, Tarawa, Kiribati: 30 April 1998. *SOPAC Preliminary Report* 94.
- Woodward, P. 1998c: Re-survey of Fongafale beach profiles, Funafuti, Tuvalu, 5-6 May 1998. *SOPAC Preliminary Report* 95.

### ***Coastal Management***

- Barstow, S.F. and Haug, O. 1994: The wave climate of the southwest Pacific. *SOPAC Technical Report* 206. 26p.
- BioSystems Analysis, Inc. 1994: Tarawa lagoon management plan [first draft], volume 1: Project summary. Unpublished report to US Agency for International Development, Ministry of Environment and Natural Resources Development (GOK), and University of the South Pacific. 21p.
- Brook, R. 1993: Feasibility study on climate monitoring and impacts in the South West Pacific. In: Hay, J.E. and Kaluwin, C. (eds.) *Climate Change and Sea Level Rise in the South Pacific Region*. Proceedings of the Second SPREP Meeting, Noumea, New Caledonia, 6-10 April 1992, Apia, Western Samoa, South Pacific Regional Environment Programme: 47-49.
- Buddemeier, R. 1993a: Climate change and island freshwater resources In: Hay, J.E. and Kaluwin, C. (eds.) *Climate Change and Sea Level Rise in the South Pacific Region*. Proceedings of the Second SPREP Meeting, Noumea, New Caledonia, 6-10 April 1992, Apia, Western Samoa, South Pacific Regional Environment Programme: 158-160.
- Burgess, S.M. 1987: *The climate and weather of western Kiribati*. New Zealand Meteorological Service Miscellaneous Publication 188/7.

- Crawford, M. 1993a: Coastal management in island states: potential uses of satellite imagery, aerial photography and geographic information systems. In: McLean, R. and Mimura, N. (eds.) *Vulnerability Assessment to Sea Level Rise and Coastal Zone Management*. Proceedings of the IPCC/WCC '93 Eastern Hemisphere Workshop, Tsukuba, 3-6 August 1993. Canberra, Department of Environment, Sport and Territories: 269-272.
- Forbes, D.L. 1995: Circulation and sand supply on Pacific atolls: coastal management challenges at Tarawa (Kiribati) and Aitutaki (Cook Islands). Proceedings of the Canadian Coastal Conference 1995, Dartmouth, N.S. Canadian Coastal Science and Engineering Association and Natural Research Council, Ottawa.
- Forbes, D.L. and Soloman, S.M. 1997: Approaches to vulnerability assessment on Pacific Island coasts: examples from Southeast Viti Levu (Fiji) and South Tarawa (Kiribati). *SOPAC Miscellaneous Report 277*.
- Gillie, R.D. 1991: Beach profile surveys on Betio and Bairiki and along the Nippon Causeway, South Tarawa, Kiribati, Jan. 1991. *SOPAC Preliminary Report 37*. 15p.
- Gillie, R.D. 1992b: Beach profile surveys Cuvu Harbour, Viti Levu, Fiji. *SOPAC Preliminary Report 49*. 7p.
- Gillie, R.D. 1992c: Beach profile survey data 1984 to 1991 Fongafale, Funafuti, Tuvalu. *SOPAC Preliminary Report 50*.
- Harper, J.R. 1989a: Evaluation of beach profile data from Betio and Bairiki, Republic of Kiribati, 1982-1988. *CCOP/SOPAC Technical Report 94*. 136p.
- Hay, J.E. and Kay, R. 1993: Possible future directions for integrated coastal zone management in the eastern hemisphere: a discussion paper. In: McLean, R. and Mimura, N. (eds.) *Vulnerability Assessment to Sea Level Rise and Coastal Zone Management*. Proceedings of the IPCC/WCC '93 Eastern Hemisphere Workshop, Tsukuba, 3-6 August 1993. Canberra, Department of Environment, Sport and Territories: 351-366.
- He, C., Chung, Q. 1999: Resurvey of Bikenibeu beach profiles, South Tarawa, Kiribati. *SOPAC Preliminary Report 116*.
- Holthus, P.F. 1991: SPREP coastal management planning and awareness activities in the South Pacific Region (extended abstract). In: Workshop on Coastal Processes in the South Pacific Island Nations, *SOPAC Technical Bulletin 7*: 59-61.
- Holthus, P.F. 1996: Coastal and marine environments of Pacific islands: ecosystem classification, ecological assessment, and traditional knowledge for coastal management. In: Maul, G.A. (ed.) *Small Islands: Marine Science and Sustainable Development*. Coastal and Estuarine Studies, Vol. 51. American Geophysical Union, Washington, D.C., pp. 341-365.
- Howorth, R. 1985: Atlas of beach profiles monitored on Betio-Bairiki, Tarawa Atoll, Kiribati: Jan. 1982 – July 1985. *CCOP/SOPAC Technical Report 50*. 4p, 26 figures and appendix.

- Howorth, R. 1991: Beach profile monitoring programmes in Kiribati and Tuvalu (abstract). In: Workshop on Coastal Processes in the South Pacific Island Nations, *SOPAC Technical Bulletin* 7: 201.
- Howorth, R. 1995: Kiribati in-country seminar on beach monitoring; 22-26 January 1995. *SOPAC Preliminary Report* 77.
- Howorth, R. 1998: Islanders, oceans, and coastal environment problems: an approach towards the third millennium. *SOPAC Miscellaneous Report* 290.
- Howorth, R. and Woodward, P. 1995: Kiribati in-country seminar on beach monitoring. *SOPAC Preliminary Report* 77. 7p.
- Huang, J.C.K. 1997: Climate change and integrated coastal management: a challenge for small island nations. *Ocean and Coastal Management* 37, 95-107
- Kaluwin, C. and Smith, A. 1997: Coastal vulnerability and integrated coastal zone management in the Pacific island region. *Journal of Coastal Research* Special Issue No. 24, 95-106.
- Kay, R. & Hay, J. 1993: A decision support approach to coastal vulnerability and resilience assessment: a tool for integrated coastal zone management. In: McLean, R. and Mimura, N. (eds.) *Vulnerability Assessment to Sea Level Rise and Coastal Zone Management*. Proceedings of the IPCC/WCC '93 Eastern Hemisphere Workshop, Tsukuba, 3-6 August 1993. Canberra, Department of Environment, Sport and Territories: 213-225.
- Le Borgne, R. 1993: JGOFS activities in the SPREP region. In: Hay, J.E. and Kaluwin, C. (eds.) *Climate Change and Sea Level Rise in the South Pacific Region*. Proceedings of the Second SPREP Meeting, Noumea, New Caledonia, 6-10 April 1992, Apia, Western Samoa, South Pacific Regional Environment Programme: 76-82.
- Liu, S.P. 1993: Appropriate coastal zone management (CZM) for Western Samoa: cultural aspects determining implementation. In: McLean, R. and Mimura, N. (eds.) *Vulnerability Assessment to Sea Level Rise and Coastal Zone Management*, Proceedings of the IPCC/WCC '93 Eastern Hemisphere Workshop, Tsukuba, 3-6 August 1993. Canberra, Department of Environment, Sport and Territories: 273-280.
- McLean, R.F. 1991: Weather and climate interactions with coastal environmental systems in the South Pacific. In: Hay, J.E. (ed.) *South Pacific Environments. Interactions with Weather and Climate*. Environmental Science, University of Auckland, Auckland, pp 49-56.
- Nunn, P.D. 1987: Fiji. In: Walker, H.J. (ed.) *Artificial Structures and Shorelines*. Dordrecht Kluwer Academic Publishers for International Geographical Union, Commission on Coastal Environments, pp 435 -442.
- Nunn, P.D. 1998b: Recent and future coastal changes in the Pacific islands: management implications.[Based on a plenary address given at Inaugural START-Oceania Workshop]. *Proceedings of the joint coastal zone management and climate change*

- workshops*. 5-9 October 1998. The University of the South Pacific, Marine Studies Programme Facility, Suva, Fiji, 111-120.
- Reti, I. 1990: Environmental problems in the South Pacific region: an overview. *Regional Workshop on Environmental Management and Sustainable Development. Country Reviews and Technical Papers*. United Nations Development Programme, Suva, pp 149-154.
- Shea, E.L. and Dyoulgerov, M. F. 1997: Responding to climate variability and change: opportunities for integrated coastal management in the Pacific rim. *Ocean and Coastal Management* 37, 109-121.
- Sherwood, A. 1994: Coastal protection in the South Pacific. *SOPAC Technical Report* 190. 43p.
- South, G.R. and Veitayaki, J. 1998: Capacity building in the South Pacific and the role of the marine studies programme at the University of the South Pacific. *Ocean & Coastal Management* 41, 103-113.
- SPREP 1988: *Action Plan for Managing the Natural Resources and Environment of the South Pacific Region*. South Pacific Regional Environment Programme: Noumea, New Caledonia.
- Thaman, R.R. 1990: Coastal reforestation and agroforestry as immediate ameliorative measures to address global warming and to promote sustainable habitation of low-lying and coastal areas. In: Streets, D.G. and Siddiqi, T.A. (eds.) *Responding to the Threat of Global Warming: Options for the Pacific and Asia*. Argonne National Laboratory, Argonne, IL. pp 4:33-4:57.
- Thaman, R.R. 1993: Climate change, forestry and agroforestry in the Pacific islands: impacts and appropriate responses. In: Hay, J.E. and Kaluwin, C. (eds.) *Climate Change and Sea Level Rise in the South Pacific Region*. Proceedings of the Second SPREP Meeting, Noumea, New Caledonia, 6-10 April 1992, Apia, Western Samoa, South Pacific Regional Environment Programme: 119-136.
- Veitayaki, J. 1997: Traditional marine resource management practices used in the Pacific Islands: an agenda for change. *Ocean and Coastal Management* 37, 123-136.
- Vellinga, P. and Klein, R. 1993: Climate change, sea-level rise and integrated coastal zone management: an IPCC approach In: McLean, R. and Mimura, N. (eds.) *Vulnerability Assessment to Sea Level Rise and Coastal Zone Management*. Proceedings of the IPCC/WCC '93 Eastern Hemisphere Workshop, Tsukuba, 3-6 August 1993. Canberra, Department of Environment, Sport and Territories: 27-47.
- Watling, R. 1985: *A Mangrove Management Plan for Fiji, Phase 1*. Government of Fiji and South Pacific Commission, Suva, Fiji.
- Woodward, P. 1997: Beach monitoring in Dud and Laura, Majuro Atoll, Republic of the Marshall Islands. *SOPAC Preliminary Report* 88.
- Xue, C. 1995: Coastal sedimentation and coastal management of Fongafale, Funafuti Atoll, Tuvalu. *SOPAC Technical Report* 221. 54p.

- Xue, C. 1996a: Coastal erosion and management of Amatuku Island, Funafuti Atoll, Tuvalu. *SOPAC Technical Report 234*. 34p.
- Xue, C. 1996b: Coastal sedimentation, erosion and management of Southwest Nukufetau Atoll, Tuvalu. *SOPAC Technical Report 238*. 40p.

## APPENDIX 2

### APN WORKSHOP ON RECENT SEA-LEVEL CHANGE AND COASTAL MANAGEMENT IMPLICATIONS FOR ATOLL STATES IN OCEANIA: WORKSHOP PROGRAM

Day 1 Thursday 15 February

12:00	<p>Official Opening</p> <p>Welcome Address- Associate Professor Nick Harvey</p>
12:30	Lunch
14:00 - 15:15	<p><b>Session 1: Theme – Current Coastal Issues for Atoll States</b></p> <p><i>Chair: James Aston</i></p> <p>James Aston <i>Recent Regional Initiatives Addressing Sea Level Rise</i></p> <p>Abraham Hicking <i>Coastal erosion issues in The Marshall Islands</i></p> <p>Seluka Seluka <i>Tuvalu: coastal change and protection strategies</i></p> <p>SYNTHESIS AND DISCUSSION</p>
15:15 – 15:40	Coffee
15:40-16:30	<p><b>Session 2: Theme – Current Coastal Management in Atoll States Relevance for Sea-Level Change</b></p> <p><i>Chair: Seluka Seluka</i></p> <p>Komeri Onorio <i>The use of EIA in coastal management in atoll states with particular reference to sea-level change</i></p> <p>Karness Kusto <i>Developing an integrated coastal management approach for atoll states</i></p> <p>SYNTHESIS AND DISCUSSION</p>



**Day 2 Friday 16 February**

9:00 – 12:30	<b>APN Field exercise</b>
12:30-13:30	<b>Lunch</b>
13.30 – 15:00	<p><b>Session 3: Theme – Relating Coastal Impacts Resulting From Level Change to Policy and Management</b></p> <p><i>Chair: Deidre Hart</i></p> <p>Karness Kusto <i>The role of education in awareness raising of sea-level change coastal management issues</i></p> <p>James Aston <i>Technologies for coastal management</i></p> <p><b>SYNTHESIS &amp; DISCUSSION</b></p>
15:20 – 16:30	<p><b>Session 4: Theme – Monitoring and Measuring Coastal Changes in Atoll Environments</b></p> <p><i>Chair: Komeri Onorio</i></p> <p>Tupulaga Poulasi <i>Monitoring, fisheries and coasts in Tuvalu</i></p> <p>Tekena Teitiba <i>30 years of recent record of temperature and rainfall data in Kiribati techniques and recording</i></p> <p><b>SYNTHESIS &amp; DISCUSSION</b></p>

**Day 3 Saturday 17 February**

**Field Training Day (see Section 3.4 of this report)**

**Day 4 Sunday 18 February**

**No sessions held**

**Day 5 Monday 19 February**

9.00 – 10.30	<p><b>Session 6: Theme - Climate Change and Sea-Level Issues</b>  <i>Chair: Paul Kench</i></p> <p>Nakibae Teuatabo  <i>Policy issues relating to sea-level change for atoll states with particular reference to Kiribati</i></p> <p>Abraham Hicking  <i>Climate Change policy for The Marshalls and implications for sea-level issues</i></p> <p>Seluka Seluka  <i>Climate Change policy and sea-level issues for Tuvalu</i></p> <p><b>SYNTHESIS &amp; DISCUSSION</b></p>
10:30 – 11:00	Coffee
11.00 – 12.30	<p><b>Session 7: Theme - Understanding and Modelling Coastal Responses to Sea-Level Change</b>  <i>Chair: Naomi Atauea</i></p> <p>Nick Harvey  <i>Local effects on sea-level change</i></p> <p>Deirdre Hart  <i>Sediment sources, paths and sinks on atoll reef flats</i></p> <p>Paul Kench  <i>Sediment budgets and sea-level change for atoll islands</i></p> <p>Naomi Atauea  <i>Coastal survey data and program for Kiribati</i></p> <p><b>SYNTHESIS &amp; DISCUSSION</b></p>
12:30 – 13:30	Lunch
13:30 – 15:00	<b>Concluding Session and Action for the Future</b>

### APPENDIX 3

#### APN WORKSHOP ON RECENT SEA-LEVEL CHANGE AND COASTAL MANAGEMENT IMPLICATIONS FOR ATOLL STATES IN OCEANIA:

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