SEA LEVEL RISE IN THE SOUTH PACIFIC REGION: ASSESSING COASTAL AREA VULNERABILITY AND DETERMINING PRIORITY AREAS AND ACTIONS

Background/Rationale

Sea level rise

A rise in the level of the world's oceans is expected as a result of the global warming associated with the buildup of "greenhouse gases" (carbon dioxide, methane, nitrous oxide, chloroflourocarbons) in the earth's atmosphere (Barth and Titus, 1984). A series of sea level rise scenarios have been developed which range from conservative projections of about a 20 cm increase by the year 2050 to projections of a greater than 1 m rise by 2050. Mid-range low and high scenarios project a sea level rise of about 50 to 80 cm by the year 2050 (Hoffman, 1984). The data and modelling from which global sea level rise projections are made are subject to considerable uncertainity and are continually being refined (Robin, 1986).

Although global sea level rise is a certainity and is already occuring, the implications for any given location are influenced by regional and local tectonic, lithospheric, oceanographic and atmospheric factors. It is therefore neccesary to analyse the potential impacts of sea level rise and develop appropriate responses at the regional, national and local scale.

Sea level rise in the South Pacific region

The South Pacific region is composed of over 20 small island states in the status of either independent nations or states which are territories of, or are in "free association" with, metropolitan countries. The total land area of the South Pacific region is 550,000 sq km (84.1% of which is in Papua New Guinea) with a population of only 5.2 million (57.7% of which is in Papua New Guinea) (Dahl, 1984). All of the Pacific Island states, with the possible exception of PNG, would be classified as "small island nations", that is, they are coastal oriented, with large coast to land ratios, a strong dependence of their economies on coastal resources, a concurrent lack of an inland economic base and with their populations conentrated along the coast (Sorensen, et. al., 1984). In spite of this, coastal management planning programmes are virtually non-existant outside the U.S. Pacific territories, especially in the atoll countries (Holthus, in prep.).

The island peoples of the South Pacific region are thus intimately linked to and dependent upon their coastal and nearshore marine areas and resources. They are therefore likely to suffer severe consequences from projected sea level rise. The potential impacts of sea level rise in the South Pacific region have been initially outlined as:

- coastal innundation
- increased coastal flooding from storms
- changes to coastal morphology due to altered sediment budgets and nearshore dynamics
- saline intrusion of coastal groundwater
- raising of water tables
- compression of the marine/terrestrial transition zone
- increased turbidity due to increased rainfall and erosion (Anon., 1988).

The South Pacific region is not homogeneous and the islands can be classified into several different types (volcanic, metamorphic, raised coral, atoll/reef island and mixed), each of which have different susceptibilities to various aspects of sea level rise. The island states of the South Pacific region are composed of different combinations of these island types, although it is important to note that several states are entirely made up of atolls and reef islands. Thus all states in the region, and all islands within a given state, are not equally vulnerable to the potential impacts of sea level rise and it should be possible to determine this difference in order to identify priority areas for response action.

Relative susceptibility to sea level rise

A relative ranking system, based on insularity, island type, altitude and land area, was used to classify Pacific Island states according to their susceptibility to the impacts of climatic change (Pernetta, 1988). This resulted in the following groupings, beginning with those states most likely to suffer severe, widespread impacts and ending with those likely to suffer major local impacts:

A) Tokelau, Marshall Islands, Tuvalu, Kiribati
B) Federated States of Micronesia, Palau, Pitcairn, Nauru, Niue French Polynesia, Cook Islands, Tonga
C) American Samoa, Fiji, New Caledonia, Northern Marianas, Solomon Islands
D) Vanuatu, Wallis and Futuna, Papua New Guinea, Guam, Western Samoa.

There is now a need to more precisely identify which islands, and even which parts of islands, within a given state are most vulnerable to sea level rise. In evaluating the potential impacts of sea level rise in Kiribati, McLean (1989) described some of the factors which might be used to determine which atolls or reef islands are most vulnerable and concluded that "the derivation of quantitative measures and indices of island vulnerability should be possible using relatively simple office and field survey techniques". However, this could be extended beyond an assessment and determination of the natural vulnerability of coastal areas to sea level rise to also include an assessment of their human use and natural resource importance, conditions and potential. This comprehensive evaluation of island coastal areas in the context of sea level rise would provide the means to determine the priority islands and coastal areas for response actions. It could further indicate specific response activities required to maintain or enhance the priority value of these areas in relation to sea level rise.

Assessing vulnerability and determining priorities

The development and testing of a methodology to assess vulnerability to sea level rise and determine priority areas for response action should first focus on those Category A countries identified as critically at risk. Not surprisingly, these countries are composed of atolls and reef islands (with the exception of the raised limestone island of Banaba in Kiribati). However, a methodology to assess the vulnerability of Category A countries will also obviously be applicable to the atolls or reef islands in any other Pacific Island state. Subsequent to developing and applying the methodology to the relatively simple atoll/reef island context, the system could be adapted to the other island and coastal types found in the South Pacific region.

The system would be used to determine which islands within a Pacific Island state are most at risk to the impacts of sea level rise and which are priority areas for response action. Such an evaluation could be employed, for example, to identify the less vulnerable, more habitable atolls within an atoll country (or outer island group) where infrastructure development is best directed or to assess the viability of islands targeted for population resettlement schemes. Within the context of an individual island, the system could identify the most appropriate areas for infrastructure development (e.g. the site of an emergency evacuation airstrip), areas safe to develop housing for refugees from more vulnerable outer islands or prefered areas for more intensive agricultural production. The system will be able to

indicate actions required to maintain or enhance the value of priority islands and coastal areas, such as eliminating activities which are degrading or destroying the ability of natural systems in priority areas to adapt to sea level rise (e.g. reef dredging, mangrove removal, waste water discharge).

Additional applications

The development of the methodology proposed here could be modified for application to other small island coastal areas, such as in the Caribbean and the Indian Ocean. In addition, the development of a classification system for the coastal and nearshore marine areas in the South Pacific region will also be adaptable to analysing conservation needs and priorities (e.g. identifying representative and unique habitats, determining adequacy of protected area coverage).

Methods/Workplan

Assumptions

It is assumed that coastal areas of Pacific Island states can be evaluated on the basis of various physical, biological and socio-economic factors, almost all of which will be affected by sea level rise to some degree. (See Appendix A for an initial list of factors potentially useful in assessing atolls/reef islands). For a given coastal area, each of these factors will have a certain value. These may either be absolute values from direct measurements in the field or from secondary sources (maps, air photos) or relative values assigned from a range of indices developed to evaluate that factor. Some factors will be more important to the evaluation of a coastal area in relation to sea level rise than others. Also, the effort to obtain values for some factors (not necessarily the most important ones) will be much less than for others. Finally, the values for some factors will be more valid than for others (e.g. absolute field measurements vs. relative indices for parameters which are difficult to quantify).

System development

The development of a system to assess the vulnerability of coastal areas in the South Pacific region to sea level rise and indicate priority areas and actions would initially focus on atoll and reef island environments. The system would be developed along the following steps:

1. Develop a comprehensive list of factors which could be considered useful in assessing: a) the natural vulnerability of a given atoll/reef island area to sea level rise, b) the importance of that area to human populations and c) the type, importance and condition of the natural resources in that area. (See Appendix A, for example).

2. Indicate the information sources and means of measuring, obtaining or assigning values for each of the factors. (See Appendix A, for example).

3. Determine the optimum set of factors to use in the assessment, based on: a) their importance in relation to sea level rise, b) the ease or difficulty in obtaining meaningful values for them, and c) the validity of the values.

4. For each of the selected factors, more fully define the methods for measuring, obtaining or assigning values.

5. Develop the methodology to synthesize the various factors and their values into the three ratings for the coastal area under consideration:

a) Vulnerability Rating - combining biological, physical, climatic, oceanographic and hydrologic factors

b) Human Importance Rating - combining past, present and potential human use and socio-economic factors

c) Natural Resource Rating - combining natual resource type,importance and condition factors

6. Develop the methodology to synthesize the vulnerability, human importance and natural resource ratings into an overall evaluation index for comparative ranking.

Following the application of the system to a group of atolls/reef islands (described below), the suite of factors, their value types and ranges, the methods for determining values and the process of developing ratings will be evaluated and the necessary improvements made. The system would then be applied to two or three more atoll/reef island groups and reviewed and revised, as appropriate, after each application.

Subsequent to its thorough development and testing in the low island context, the system would be redeveloped to suit the high island types found in the South Pacific region. This would require listing, considering and developing methods for a series of factors not included in the initial process as developed for low islands. Of particular importance will be the need to delineate an inland limit to the detailed assessment procedure and incorporate terrestrial parameters and processes (e.g. geology, ecology, land use, natural resources, freshwater runoff, sediment delivery, pollutant discharge).

System application

The system will primarily be applied at two scales, that of: a) the whole island and b) the individual coastal units which make up the island coastal area. Most islands can be divided into a series of fairly discrete coastal sections, primarily based on physical features and orientation. On atolls, these sub-divisions would often be based on the individual islets (motus) which make up the land area.

The system would be applied through the following process:

1. Select a pilot group of atolls/reef islands. This could be an entire atoll country, but would preferably be a group of not more than 6 islands for the initial system testing.

2. Divide the islands into coastal sections based on existing information, particularly maps and air photos, finalising the sub-division delineation during reconaissance visits.

3. Apply the assessment methodology to each of the coastal sections of each of the islands to determine the vulnerability, human importance and natural resource ratings and overall evaluation index for each coastal section.

4. Combine the ratings for all coastal sections of each island to determine the whole island vulnerability, human importance and natural resource ratings and overall evaluation index.

5. Compare the results for the group of islands analysed and develop a relative ranking of the islands based on the vulnerability, human importance and natural resource ratings, as well as the overall impact index.

6. For the high ranking islands (i.e. those with relatively low vulnerability, high human importance and valuable natural

resources) reanalyse the detailed coastal section assessments and develop a relative ranking of the coastal sections which make up each of these islands.

7. Based on the information assembled for the assessment of each coastal section, recommend actions to a) maintain or enhance the characteristics or conditions contributing to low vulnerability, high human importance and valuable natural resources (especially for high ranking coastal sections and islands) and b) reduce the conditions contributing to increased vulnerability, reduced human importance and degraded natural resource systems.

The system can also be applied at a national scale by amalgamating the ratings determined for all the islands in a country and comparing these with the results from another country. This will allow the international priorities in the South Pacific region regarding sea level rise to be revised, if necessary.

Outputs

The following products will result from this project:

1. A detailed system which includes the methodology for assessing and rating:
a) the natural vulnerability of atolls and reef islands in the South Pacific region to sea level rise,
b) the human importance of these areas,
c) the type, importance and conditions of natural resources in these areas and the means for combining these ratings to determine an overall index to identify priority areas and actions for response to projected sea level rise.

2. Reports presenting the results of applying the above system to two to three groups of atolls/reef islands, including the information assembled, values obtained and ratings determined, with conclusions and recommendations identifying priority areas and responses.

3. An adaptation of the above system to high island coastal environments of the South Pacific region.

4. Reports presenting the results of applying the modified system to a number of high island types.

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APPENDIX A

INITIAL LIST OF POTENTIAL FACTORS FOR USE IN ASSESSING THE VULNERABILITY, HUMAN IMPORTANCE AND NATURAL RESOURCE VALUES OF ATOLLS/REEF ISLANDS IN RELATION TO SEA LEVEL RISE

(Material in brackets indicates value types to be used for that factor)

I. VULNERABILITY FACTORS

1. Island Type
   - 1.1. Atoll
   - 1.2. Reef island
   - 1.3. Intermediate

2. Island Platform
   - 2.1. Area
     - 2.1.1. Land (ha and % ot total)
     - 2.1.2. Reef (ha and % of total)
     - 2.1.3. Lagoon (ha and % of total)
     - 2.1.4. Total island platform (ha)
   - 2.2. Shape
     - 2.2.1. Outline (shape descriptor index)
     - 2.2.2. Irregularity (uneveness index)
   - 2.3. Orientation (platform axis alignment)

3. Land
   - 3.1. Area
     - 3.1.1. Area (ha)
     - 3.1.2. Relative area (% of platform)
     - 3.1.3. Relative area (% of reef top, i.e. land + reef area)
     - 3.1.4. Continuity (no. of motus)
     - 3.1.5. No. of motus/land area (ratio)
   - 3.2. Coastline
     - 3.2.1. Length (km)
     - 3.2.2. Coastline/land area (ratio)
   - 3.3. Topography (profiles)
     - 3.3.1. Elevation
       - maximum (m above sea level)
       - average (m above sea level)

- elevation/area (ratio)

3.3.2. Ridge/swale features
- location
- area (ha)
- height (m above ocean reef flat level)

3.4. Land location and persistence

3.4.1. Position on platform

3.4.2. Persistence over time (air photo analysis)

3.4.3. Erosion
- location
- area (ha)
- loss of vegetated land (ha)
- recentness (years of increased erosion)

3.4.4. Accretion
- location
- area (ha)
- stability (revegetation index)
- recentness (years of increased accretion)

3.5. Shoreline

3.5.1. Sediment type (standard descriptors)

3.5.2. Sediment size
- range (standard descriptors)
- average (standard descriptors)

3.5.3. Exposed beachrock
- location
- extent (km of shoreline)
- relative extent (% of shoreline)

3.5.4. Subaerial beachrock
- location
- depth (cm below surface)
- extent (km of shoreline)
- relative extent (% of shoreline)

3.5.5. Shoreline storm banks
- location
- materials (standard desriptors)
- extent (km of coastline)
- relative extent (% of shoreline)
- height (m above reef flat)
- recentness (year of formation)

3.5.6. Artificial shoreline
- type (descriptive index)
- location
- extent (km of shoreline)
- relative extent (% of shoreline)

3.6. Land materials

3.6.1. Sediment type (standard descriptors)

3.6.2. Sediment size
- range (standard descriptors)
- average (standard descriptors)

3.6.3. Across island variation (relative variability index)

3.6.4. Conglomerate
- location
- area (ha)
- depth (cm below surface)

3.6.5. Phosphatic rock
- location
- area (ha)

3.7. Vegetation

3.7.1. Shoreline vegetation type (descriptive index)

3.7.2. Mangroves
- location
- area (ha)
- average width (km)
- density (trees/ha)

3.7.3. Inland forest
- location
- area (ha)

3.7.4. Taro pits
- location
- area (ha)
- no. of pits/area (ratio)

4. Reef Flat

4.1. Width

4.1.1. Ocean side
- average (km)
- maximum/minimum (km)

4.1.2. Lagoon side
- average (km)
- maximum/minimum (km)

4.2. Topography

4.2.1. Elevation - ocean vs. lagoon (difference in cm)

4.2.2. Exposed reef substrate, i.e. features of former high sea level
- location
- area (ha)
- height (cm above present reef flat)

4.2.3. Reef blocks
- location
- size
- number

4.2.4. Topographic complexity (profile, roughness index)

4.2.5. Boat channels
- location
- number

4.3. Non-living substrate areas

4.3.1. Sediment
- type (standard descriptors)
- size (standard descriptors)
- area (ha)
- relative area (% of reef flat)
- average depth (cm to solid substrate)

4.3.2. Solid substrate
- area (ha)
- relative area (% of reef flat)

4.4. Living substrate areas

4.4.1. Coral communities
- area (ha)
- relative area (% of reef flat)
- community type (descriptive index)
- density (% cover/sq m)

4.4.2. Seagrass
- area (ha)
- relative area (% of reef flat)
- community type (descriptive index)
- density (% cover/sq m)

4.4.3. Algal beds
- area (ha)
- relative area (% of reef flat)
- community type (descriptive index)
- density (% cover/sq m)

5. Outer Reef

5.1. Reef crest

5.1.1. Characteristics
- width (m)
- height (cm above reef flat)
- composition (descriptive index)

5.2. Outer reef slope

5.2.1. Reef edge type (descriptive index)

5.2.3. Reef terrace
- width (m)
- depth (m below sea level)
- coral community type (descriptive index)

6. Lagoon

6.1. Size

6.1.1. Area (ha)

6.1.2. Relative area (% of platform)
6.2. Depth
6.2.1. Maximum (m)
6.2.2. Average (m)
6.2.3. Depth/area (ratio)
6.3. Interior openess (descriptive index)
6.4. Non-living substrate areas
6.4.1. Sediment
- area (ha)
- relative area (% of lagoon)
- sediment type (standard descriptor)
- sediment size (standard descriptor)
- depth (m below sea level)

6.4.2. Hard bottom
- area (ha)
- relative area (% of lagoon)
- depth (m below sea level)

6.5. Living substrate areas
6.5.1. Halimeda beds
- area (ha)
- relative area (% of lagoon)
- density (% cover/sq m)

6.5.2. Coral communities
- area (ha)
- relative area (% of lagoon)
- community type (descriptive index)
- density (% cover/sq m)

6.6. Lagoon passes
6.6.1. Deep passes
- number
- location
- depth (m)
- width (m)

6.6.2. Shallow passes
- number
- location
- depth (m)
- width (m)

6.6.3. Artificial passes
- number
- location
- depth (m)
- width (m)

7. Sea Level Record
7.1. Recent sea level change (tide guage and microatoll record)

7.1.1. Direction (stable, rising , lowering)
7.1.2. Rate (mm/year)
7.1.3. Duration (years)
7.1.4. Variation (noise index)

7.2. Historical higher sea level incidents (pumice lines, interviews)
7.2.1. Location
7.2.2. Height (m above sea level)
7.2.3. Area innundated (ha)
7.2.4. Relative area innundated (% of land)
7.2.5. Recentness (year)

7.3. Geological higher sea level
7.3.1. Exposed reef communities
- height above present ref flat (cm)
- area (ha)
- relative area (% of reef flat)
- coral community type (descriptive index)

8. Oceanographic and Climatic Factors

8.1. Tides
8.1.1. Normal range (m above and below mean sea level)
8.1.2. Variation (cm out from average)

8.2. Sea level fluctuation
8.2.1. Seasonal variation
- duration (months)
- frequency (occurence index)
- amount (cm difference from mean sea level)

8.2.2. ENSO events
- duration (months)
- frequency (occurence index)
- amount (cm difference from mean sea level)

8.3. Wind, current and wave patterns
8.3.1. Winds
- direction
- strength
- seasonality

8.3.2. Currents
- direction
- strength
- seasonality

8.3.3. Waves
- direction
- strength
- seasonality

8.4. Storm and cyclone patterns
8.4.1. Historical patterns

- seasonality
- frequency (no./year)
- direction
- strength
- duration (no. of days)

9. Hydrologic Factors
    9.1. Rainfall patterns
        9.1.1. Average amount (mm/year)
        9.1.2. Seasonality
        9.1.3. Annual variability
    9.2. Freshwater lens
        9.2.1. Characteristics
            - size (ha)
            - potability (salinity index)
            - durability (resistance to drought index)
        9.2.2. Uses
            - no. of wells
            - well depths
            - well locations

II. HUMAN IMPORTANCE FACTORS

1. Population
    1.1. Characteristics
        1.1.1. Size
        1.1.2. Distribution
        1.1.3. Density
    1.2. Trends
        1.2.1. Growth rate
        1.2.2. In/out migration
2. Settlement patterns
    2.1. Cities
        2.1.1. Characteristics
            - size
            - location
            - growth rate
            - in/out migration
    2.2. Villages
        2.2.1. Characteristics
            - size
            - location
            - growth rate
            - in/out migration
3. Economic activities

3.1. Subsistence economy
  3.1.1. Types of activities
  3.1.2. Number of people involved
    - full-time
    - part-time
  3.1.3. Location of activities
    - land based
    - reef/lagoon based
    - ocean based
3.2. Money economy
  3.1.1. Types of activities
  3.1.2. Number of people involved
  3.1.3. Location of activities
  3.1.4. Income/export earnings earned

4. Resource control
  4.1. Land or reef/lagoon tenure
  4.2. Land or reef/lagoon resource rights
5. Coastal infrastructure and development
  5.1. Transport
    5.1.1. Type of infrastructure
    5.1.2. Value
  5.2. Urban development
  5.3. Tourism development

III. NATURAL RESOURCE FACTORS

1. Activities degrading coastal ecosytem
  1.1. Type of activites
    1.1.1. Extractive activities
      - beach mining
      - reef dredging
      - lagoon sand mining
      - coral harvesting
      - mangrove clearing
    1.1.2. Coastal water polluting activities
      - solid waste dumps
      - sewage discharge
      - non-point waste discharge
      - excessive runoff/sedimentation
2. Special habitats
  2.1. Sea turtle nesting beaches/feeding grounds
    2.1.1. Location
    2.1.2. Seasonality
  2.2. Dugong feeding/resting grounds
    2.2.1. Location