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# Extracts from "Greenhouse"! the impact of sea level rise on low coral islands in the South Pacific.

*by Dr. Peter Roy, Dept of Minerals and Energy & Dr. John Connel, University of Sydney & published by RIAP, University of Sydney, 1989*

**"For most coastal dwellers there will be the option of retreating inland to higher ground,...but the most extreme situation will be faced by small ocean island states occupying low coral islands or atolls. Here high land to escape to does not exist and whole populations may be displaced and left country-less. This paper focuses on ... the four Pacific atoll-states of Kiribati, Marshall Islands, Tokelau and Tuvalu, which are entirely composed of low-relief atolls."**

"To gauge the extent of the impact we adopt as a convenient scenario a sea level one metre higher than at present in 50 years time; it is not intended as a prediction of what will happen."

"Tide gauge records from around the world...show a small rise in relative sea level (1.0-1.5mm per year) over the past few decades. However, the results are variously interpreted. Factors that remain to be assessed include (i)the extent to which the distribution of the recording stations can be divorced from regional tectonic trends and local earth movements; (ii)whether the apparent sea level changes are due to the global greenhouse phenomenon (GE) or to local climate variability, and (iii)whether possible changes in river discharges to the oceans over the past century are due to the building of dams, irrigation schemes and land clearing for agriculture.

Because of uncertainly concerning the pattern and extent of future heating of the earth's surface and the rate at which heat will be absorbed by the oceans, rates of expansion of the oceans cannot be determined with any accuracy."

"The basic effect of a Greenhouse induced rise in sea level is for low lying lands to be inundated and for coasts to erode. Erosion, as opposed to inundation, is most severe on shorelines composed of unconsolidated sediment exposed to storm wave attack on high-energy coasts. Here, a gradual rise of mean sea level will progressively lift the zone of flooding, storm wave set-up and surge effects to new levels thus eroding levels hitherto considered safe....In Pacific atoll states where resources are very limited, the provision of expensive engineering works will not be a commonly available option."

"While the spectre of rising sea level in the future seems

to follow inevitably from a Greenhouse induced warming of the atmosphere, there is growing evidence that its impact will not be the same everywhere....past sea level changes have been influenced by local climate and oceanographic factors - factors whose variability may increase with the GE. The nature of existing coastlines - whether cliffed, sandy, swampy etc - will also determine the impact of the GE....A number of factors influence the size, morphology and position of islands around the atoll rim. Storm patterns control the size of gravel ridges and determine how frequently they are formed; tidal ranges transport reef flat material away from islands and into lagoonal sinks; rainfall affects cementation/dissolution processes within the coral rubble pile; and biological processes, such as particular coral or algal growth styles, influence the generation of material to form the islands. These dynamic factors operate within a broad framework determined by the local eustatic history and inherited geology of individual atolls or atoll groups."

"As erosion reduces island size, ground water lenses shrink beneath larger islands and virtually disappear under smaller ones causing all except the most hardy vegetation to perish. Sea levels rising at the rates contemplated under future GE conditions would outstrip the ability of islands to grow upwards thus leading to a reduction in island 'freeboard' (height above mean sea level). Storm overwash will therefore become an increasingly frequent occurrence, causing damage to buildings and vegetation and salination of the ground water lens (refer to Fig. 2 - a, b &c).

Probably the most severe situation is likely to occur on what are today the widest and most productive islands. These typically occur at bends in the reef crest where waves approach from two or more directions and series of recurved spits have formed around a central low area (refer to Fig. 3). Low areas are swampy and historically have been used to grow swamp taro and *Cyrtosperma taro*; many islands of this type... support relatively high population densities. ... Not only are productive food areas in the interior of the island destroyed by salt water, but the ground water lens is greatly reduced as is the productivity of coconut and breadfruit crops. The construction of expensive sea walls to protect low-lying areas from salt water intrusion would only be effective in the early stages. As sea level continued to rise, so would the ground water table until, eventually, the central parts of the island would become a shallow, and relatively unproductive, lake of fresh water becoming increasingly brackish as storms overwash the island surface."

## The Impact of Greenhouse

"Rising sea-levels can only worsen in a number of ways, the problems of achieving development in atoll states though the extent of the changes will vary over time and from place to place in ways that are not yet possible to predict."

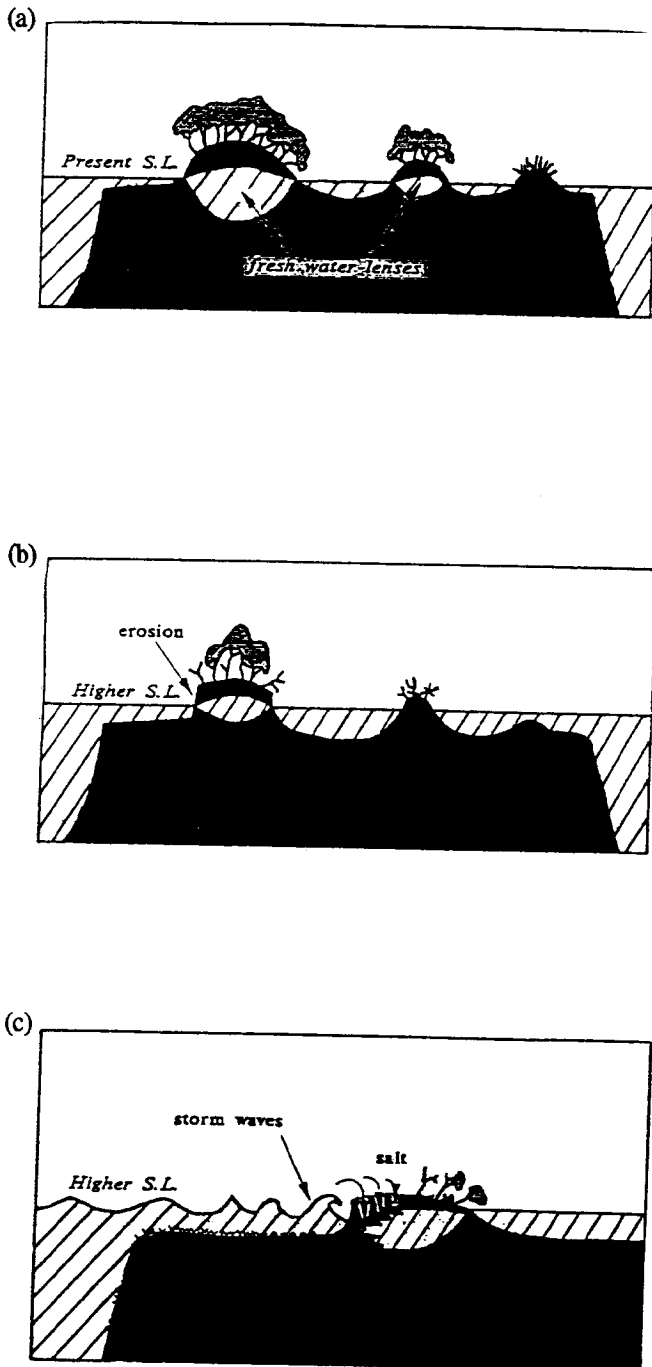


Fig.2 Freshwater lenses

"In some areas it will be extremely difficult to assess what the impact of GE will be. The intertropical convergence zone is likely to shift northwards, changing the distribution of zones of upwelling, and hence altering the distribution of fish stocks and thus fisheries."

"On atolls the relatively simple ecosystems enable some conclusions to be made with a greater degree of certainty, though nothing can be really certain on the timing and impact of GE.

A number of specific changes that affect atolls can be separately distinguished and examined in four principal areas. These are, firstly, the drowning of barrier reefs, secondly, the intrusion of saltwater into coastal groundwater supplies; thirdly, the erosion of areas of flat land, and fourthly, storm damage to coastal installations, such as port facilities. Tourism is not a source of income in any of the atoll states hence the disruption of tourist facilities, which is likely to occur elsewhere, will not be significant, though it will certainly discourage any developments in that area.

The intrusion of saltwater into ground lenses will have direct effects on agriculture and on the supply of potable water. The most obvious effects on agriculture will through increased salinity in taro pits, lower productivity of the taro and hence a greater disinclination to continue with this labour-intensive agricultural activity. Increased salinity is also likely to lead to the decreased productivity of all other crops, including coconuts, pandanus and breadfruits."

"Increased groundwater salinity will reduce the potability of groundwater...If increased salinity is combined with any long-term decline in rainfall, as is possible in some areas, the results will be even more serious, since the cost of water purification and desalination is extremely high...If and when groundwater becomes no longer potable human habitation will no longer be effectively possible. Significantly freshwater is most scarce on atolls after cyclones or tidal waves have swept the sea over the atoll, salting soils and wells, a situation which is likely to increase under GE."

"Erosion will both reduce the areas of land on atolls and, because of their minimal elevation, such losses may eventually be extremely severe and increase the swampiness and salinity of areas that remain above sea-level. Areas immediately at risk will be those areas that have previously been reclaimed from the seas, including parts of south Tarawa, and causeways such as those between Betio and Bairiki in Kiribati and in Majuro. This loss of land will directly affect agriculture, housing, roads etc. in these areas. Airstrips will also be substantially affected. Loss of land area will inevitably lead to a decline in agricultural production, increased competition of scarce land in urban areas and more disputes over land tenure...The loss of land will lead to a related decline in handicraft materials (wood, pandanus etc) and of firewood, which is already in extremely short supply in urban areas such as Tarawa. Such changes will further

threaten the already limited subsistence base.

The erosion of fringing reefs is likely to seriously disturb their ecology and reduce the distinctiveness of lagoon ecology as lagoons increasingly become indistinguishable from the surrounding ocean and mangrove habitats are damaged. This is likely to reduce the artisanal fishing potential of all atolls, but obviously especially those where large lagoons currently provide fisheries diversity.

The GE is likely therefore to lead to a substantial decline in agricultural production, a possible decline in fisheries production, and a loss of vital water, timber and firewood resources, thus reducing the potential of the few areas in which the atolls and atoll states currently demonstrate a degree of self-reliance. These problems will increase over time...Unless GE contributes to increased self-reliance in some other area...this will lead to an acceleration of the present process of dependence on metropolitan states. Within countries it is likely to further encourage rural-urban migration in search of the 'fast money' of wages and salaries rather than the increasing unpredictability of agricultural and fisheries incomes.

It is clear that much of what can be currently know about the impact of GE is derived from conjecture and speculation, since the order of magnitude of future physical events cannot be determined and there is no precedent for what is likely to follow...The causes and consequences are both complex and inter-related, involving changing natural processes and a variety of human adaptations to those changes. It is nonetheless apparent that GE offers nothing positive to atoll states and, because all their land is low-lying, the problems will certainly be considerable and more apparent than on high islands."

## Conclusion

"Atoll development options are naturally constrained by limited land (and sometimes lagoon) areas, and the simplicity of atoll environments (so that natural ecosystems may easily be disrupted). These options are

broadened by the increased availability of new plant varieties, fertilisers, technology, and so on, from outside, but limited by the fact that these may be expensive (and increasingly so) and far from simple to organise and maintain. Options have however been diminished by changes in aspirations that have resulted in changes in attitudes to traditional agriculture (resulting in a general decline of food cultivation) and some loss of skills and knowledge...that enable survival and success in environments often threatened by natural hazards. Options will be further reduced, even removed, by GE.

Questions central to the Greenhouse phenomenon are 'will climate really change in the next 50 or 100 years?', by how much? and what will be the impacts?' To expect mankind's past (and ongoing) massive degradation of the world's natural environments not to induce some future change in global climate, is to be irrationally optimistic. There may be geological precedents for different world climates in the past, but there is no precedent for the speed at which present changes to the environment are taking place. It is therefore unrealistic to expect present-day natural systems to compensate for, or accommodate, all these impacts without themselves changing to some extent. Inevitably, the world's climate will change; the extent of that change depends in large part on political, social and technological behaviour in the future.

Questions as to how much the climate will change and what will be the magnitude of the associated impacts are largely unanswerable at this time - at least in detail. Increasingly, it is apparent that simplistic models, predicting environmental factors (temperature, rainfall, cloud cover, sea level etc) changing progressively with time, at the same rate throughout the world are false. Changes will occur at differing rates and to a different degree from place to place...Specifically, in the context of atoll islands, it is likely that degradation of present day living conditions will come about through local factors - increased El Nino events, droughts, more storms, higher rates of coastal erosion. Impacts will vary from place

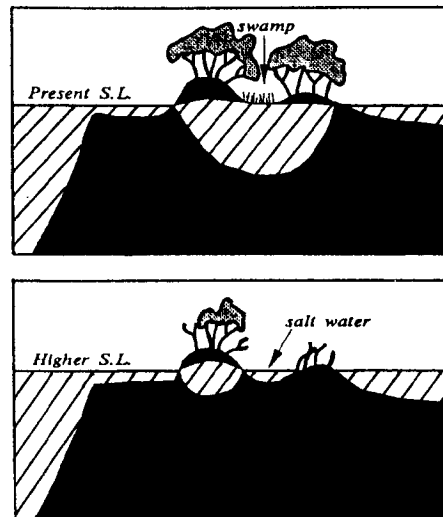
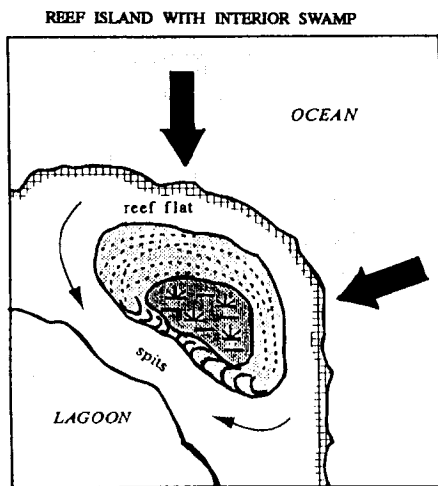


Fig.3

Wide islands with relatively large groundwater lenses form where converging waves (big arrows) build gravel ridges and recurved spits (small arrows) at bends in the reef crest.

to place not only because of environmental variability, but also because of inherited geological factors that have produced differences in island morphologies and compositions."

"Uncertainty over the outcome of GE has necessarily restricted ability and willingness, nationally and internationally, to respond to the problem through policy formation. Response is least likely in the atoll states where information is least adequate and where...planning remains in its infancy, finance, data, continuity and technical expertise are limited ...Atoll states, or other microstates, cannot act individually or collectively to remove or reduce the causes of GE, though they can call upon international organisations to act on these causes."

"GE will eventually overwhelm atolls since everything is coastal (in distance and altitude). Many conventional measures to reduce vulnerability (eg. transferring populations, infrastructure and economic activities to higher land) are impossible. Other conventional measures, such as the construction of dikes and pumping stations, are extremely expensive (especially when a small population is spread over a large number of islands) and because of the high porosity of coral sand would be unlikely to solve the problem since the continuous inflow of water underground would necessitate expenditure on land drainage whilst there would be no protection for the freshwater lenses. Similarly there would be no possibility for the transport of material to nourish island growth on the scale that would be required. Even defending the few urban areas, several of which are themselves spread over wide areas, would be a complex and costly operation, and in itself would be a pointless exercise. Moreover the finance for projects of this kind would be wholly absent within the atoll states and no aid donor would contemplate aid on the scale that would be necessary, even to strategically important states."

"In the meantime it is apparent that much more research is required on the physical, environmental and economic impacts of GE at the local level, especially in the atoll states (and in other low-lying areas). More detailed studies of the structure of atolls are required, to describe the physical environments of individual atoll groups, to indicate what proportion of the area of individual atolls, and what key installations, are particularly vulnerable to sea-level rises of different dimensions; remote sensing and geographical information systems (GIS) can play an important role here...It will also be crucial to strengthen the capacity of national planning offices, especially in relation to environmental matters, to ensure that there are more restrictions on planning in high-risk areas (a situation that will also be important for countries, such as Tonga, where a greater range of choice of locations is normally possible) and to enable better monitoring of local changes. Strengthening the ability of governments to undertake conventional planning, in areas such as population planning, become even more crucial than it already is. Ultimately, however, activities in these areas may turn out to be primarily holding actions, though

such actions will reduce risks and ensure greater awareness of the more long-term problem."

"Resettlement poses particular problems...Resettlement from atolls has...moved atoll dwellers into very different environments, imposing considerable social, psychological and sometimes economic costs, as they confront a very different economic, political and biological environment...By contrast voluntary individual and household migration...has been much more successful but has tended to result in selective migration of a youthful, more educated population, increasing the depending rate in the village and islands of outmigration. Resettlement will not occur without new problems emerging, especially if resettlement to metropolitan states occurs, and it is apparent that the experience of Tokelauans in New Zealand will be of some significance for future moves.

All the evidence suggests that the serious development problems experienced in the atoll states cannot adequately be met even now by internal policies or regional cooperation and that higher levels of aid will not contribute to economic growth (as opposed to improved welfare). This is certainly the case in Niue which has one of the highest levels of per capita aid in the world and also one of the highest rates of emigration. Whilst there is much evidence of widespread social and economic disadvantages to high levels of overseas migration, in the smallest states, such as Tokelau, there are substantial gains from migration that cannot be realised by other means. Where expectations of appropriate lifestyles continue to forge further ahead of South Pacific economic realities the migration response, especially under the impact of GE, becomes even more probable. In historic times atoll dwellers were extremely mobile and far from insular; men and women moved readily between islands in search of new land, disease-free sites, marriage partners, trade goods, and so on...Mobility itself was responsible for demographic survival; without mobility, adaptation and change were impossible. It is a phenomenon of contemporary times that South Pacific populations are growing, and political boundaries and policies minimise long-distance migration. Without the flexibility that this kind of resettlement migration provides, the uncertainties and limitations of atoll environments are emphasised and either more permanent migration (usually to urban areas elsewhere) or an uncertain dependence replaces it."

"Long before the contemporary implications of the Greenhouse Effect were recognised the choice of appropriate development strategies of atoll states had caused concern. Few world states have ever had such limited prospects for development, have gained so little from contemporary technological change but have nevertheless become so dependent on the outside world. Now it is even more crucial for there to be a focus on development issues in atoll states...Some of the most recently populated islands in the world may be depopulated. Some of the most recently formed islands may disappear."