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"GREENHOUSE": THE IMPACT OF SEA LEVEL RISE ON LOW CORAL ISLANDS IN THE SOUTH PACIFIC

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"GREENHOUSE": THE IMPACT OF SEA LEVEL RISE ON LOW CORAL ISLANDS IN THE SOUTH PACIFIC

Peter Roy and John Connell

If the greenhouse effect raises sea levels by 1 metre it will virtually do away with Kiribati...if what the scientists say now is going to be true. In 50 or 60 years my country will not be there' (President I. Tabai, Kiribati, September 1988)

'The environmental change caused by industrial progress in the developed world may slowly drown this unique paradise in its entirety' (President M. Gayoom, Maldives Islands, 1987)

'We are an endangered nation' (President M. Gayoom, 1988)

No environmental issue has captured public and private imaginations throughout the world in the past twelve months more than the 'Greenhouse effect'. Indeed, perhaps no environmental issue has ever stimulated such global interest and spawned such a variety of popular and academic accounts of future scenarios. Ironically however the term itself was coined even before the end of the nineteenth century. There are at least two reasons for this widespread interest: the cataclysmic effects forecast by the prophets of doom and, at the same time, the uncertainty over the actual effects and future rates of climate change. However scientific studies have increasingly begun to draw important and consistent conclusions about future trends, and point to the regions where the Greenhouse effect (GE) will cause the most severe problems. This paper examines some of these trends in the context of South Pacific Atoll states where the impact is likely to cause substantial social, economic and political problems, and where such problems may begin to emerge around the start of the next century.

For most coastal dwellers there will be the option of retreating inland to higher ground. In some countries, especially those with rich agricultural land and dense populations in low deltaic plains, enormous economic and social dislocations can be expected, but the most extreme situation will be faced by small ocean island states occupying low coral islands on atolls. Here high land to escape to does not exist and whole populations may be displaced and left country-less. This paper focuses on what are here referred to as the four Pacific atoll-states of Kiribati, Marshall Islands, Tokelau and Tuvalu, which are entirely composed of low-relief atolls (Fig. 1). It has recently been
Figure 1  Island regions in the Pacific that are composed principally of low coral atoll islands are shown here stippled.
stated that these states 'will be devastated if projected rises occur and consequently such states may cease to contain habitable land' (Pernetta, 1988:9). The focus is therefore appropriate.

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. In this scenario, average rates of sea level rise for the future (about 20mm per year) are similar to those documented by geologists during the Postglacial Marine Transgression (PMT), about 18000 to 6000 years ago, when the sea rose at an average rate of 12-15 mm per year (Thom and Roy, 1984; Devoy, 1987). Geological data from the past thus provides a basis for modelling future trends (Fig. 2).

The paper does not consider, in any detail, the issues that affect atolls when they are only part of larger multi-island states that include high islands, such as the Federated States of Micronesia (FSM), French Polynesia or the Cook Islands (Fig. 1), firstly, because it may be possible to divert resources from larger islands with stronger economies to provide special funds and strategies for atoll islands. This is the case in the French Polynesian atoll chain of the Tuamotus (Connell, 1986: 53-4). Secondly, and more importantly, the existence of high islands or much larger land masses such as in Papua New Guinea and the Solomon Islands provide atoll dwellers with migration options within states. In most cases these options have already been taken in part. Most of the discussion that follows, and particularly that concerning Kiribati and Tuvalu, is also extremely relevant for both the Maldives and Australia's Indian Ocean Territory, the Cocos-Keeling Islands, whose situations are very similar. The paper reviews past developments and problems in the atoll states and speculates on the potential impact of GE on future development strategies.

Island Populations

The four atoll states are quite different in language, culture, history and in their physical environment. Tuvalu and Tokelau are part of Polynesia; the Marshall Islands and Kiribati are in Micronesia. The state of Tuvalu consists of nine coral atolls and reef islands with a total land area of no more than 24 square kilometres, yet spread over 590 kilometres. Kiribati has twenty populated atolls (including Banaba) and a land area of 700 square kilometres but more than half of this (363 square kilometres) is on Christmas Island (Kiritimati) some 3500 kilometres away from Tarawa, the national capital. The Marshall Islands has 24 populated atolls, but the majority of the population live in the capital, Majuro, or on Ebeye, close to the American missile range on Kwajalein atoll. The
Figure 2

Following the last glaciation, Holocene sea levels rose rapidly (the PMT) to a maximum about 6000 years ago, then stabilised or fell slightly. Predicted GE may cause a renewed sea level rise at a similar rate to the PMT.
Table 1: Atoll State Populations

<table>
<thead>
<tr>
<th></th>
<th>Marshall Islands</th>
<th>Kiribati&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Tokelau&lt;sup&gt;b&lt;/sup&gt;</th>
<th>Tuvalu&lt;sup&gt;c&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Occupied atolls</td>
<td>24</td>
<td>16</td>
<td>3</td>
<td>9</td>
</tr>
<tr>
<td>Total population</td>
<td>43,335&lt;sup&gt;(1988)&lt;/sup&gt;</td>
<td>61,186&lt;sup&gt;(1985)&lt;/sup&gt;</td>
<td>1,690&lt;sup&gt;(1986)&lt;/sup&gt;</td>
<td>7,349&lt;sup&gt;(1979)&lt;/sup&gt;</td>
</tr>
<tr>
<td>Mean atoll population</td>
<td>1,805</td>
<td>3,284</td>
<td>563</td>
<td>817</td>
</tr>
<tr>
<td>Mean population</td>
<td>719&lt;sup&gt;b&lt;/sup&gt;</td>
<td>2,299</td>
<td>563</td>
<td>653</td>
</tr>
<tr>
<td>(excluding central atoll)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Population density (km&lt;sup&gt;2&lt;/sup&gt;)</td>
<td>242</td>
<td>227</td>
<td>56</td>
<td>287</td>
</tr>
</tbody>
</table>

Note: Areas are land areas. Since lagoons provide maritime resources, variable lagoon areas are also important. Populations have grown significantly since the censuses to which these data refer.

<sup>a</sup> These data refer to the Gilberts only, thus excluding Banaba and the Line Islands.

<sup>b</sup> This figure excludes the populations of both Majuro (including Laura) and Kwajalein (including Ebeye).

<sup>c</sup> In 1983 an informal census of Tuvalu was undertaken; this head count gave a total population of 8364 within Tuvalu, of whom 2620 were on Funafuti. A formal census is due to be held in 1989.
population density in Tokelau (Table One) is significantly less than in the other three states partly because of substantial migration to New Zealand where a majority of Tokelauans now live.

Kiribati is the easternmost and southernmost part of Micronesia. Tuvalu, once the Ellice Islands, is part of Polynesia, and there are indications that colonisation there may have been as recent as the sixteenth century (Munro, 1982:7) not long before the great Spanish explorer, Mendana, sighted at least one of the atolls in 1568. Further north Quiros sighted the Kiribati atoll of Butaritari in 1606 but it was not until the 1820s that European contact began to influence the trajectory of development. The Tokelau atoll of Atafu was first sighted by Europeans in 1765, when it was uninhabited, but at second contact in 1791 it was inhabited. Tokelau was severely affected by the Peruvian labour trade of the 1860s which led to a drastic reduction in the population (Maude, 1981). Spanish voyagers reached the Marshall Islands in the seventeenth century and there was considerable contact with traders, whalers and missionaries from the eighteenth century onwards. After the Second World War the Marshall Islands became part of the United States administered Trust Territory of the Pacific Islands. Tuvalu became independent in 1978 and Kiribati in 1979. The Marshall Islands has a degree of autonomy having achieved independence in association with the USA in 1984. Tokelau remains a New Zealand territory and Tokelauans are citizens of New Zealand.

The Greenhouse Effect

The build-up of industrial gases in the earth's atmosphere over the past 30 to 40 years is now well documented (Bolin et al., 1986; Pittock, 1988; Pearman, 1988). The resulting 'Greenhouse effect' is expected to raise temperatures over much of the earth's surface and lead to a rise in the levels of the world's oceans. Initially the latter will come about through expansion of surface waters in the oceans and melting of mountain glaciers (Bolin et al., 1986); not until much later will melting of the polar ice sheets significantly augment the ocean volumes (Budd, 1988).

Tide gauge records from around the world, analysed by a number of researchers (Gornitz et al., 1982; Barnett, 1984; Aubrey and Emery, 1983; Emery and Aubrey, 1986; Bryant, 1988) show a small rise in relative sea level (1.0 - 1.5 mm 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 or to local
climatic variability (Bryant, 1988); 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 uncertainty 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 (Pittock, 1988; Tucker, 1988), rates of expansion of the oceans cannot be determined with any accuracy. Extreme scenarios for the next 50 years range from virtually no change in mean sea level to an elevation many metres higher (Hoffman, 1984; de Robin, 1986). In Australia, values representing an intermediate range of 0.2-1.4 metres rise in the next 50 years have been adopted in order to consider possible implications of Greenhouse for the future (Pearman, 1988). The period of 50 years was chosen because it is the upper limit of most planning time-scales.

The basic effect of a Greenhouse induced rise in sea level is for low lying lands to be inundated and for coasts to erode (Short, 1988; Thom and Roy, 1988). 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 areas hitherto considered safe. Human responses will vary depending on the values of the coastal land under attack and the resources available to provide protective measures (Roy and Thom, 1987). In Pacific atoll states where resources are very limited, the provision of expensive engineering works will not be a commonly available option.

Origin of Atolls

Atolls are accumulations of the remains of calcareous reef-forming organisms usually arranged into a rim around a central lagoon. They are found in tropical ocean waters within $20^\circ$ latitude of the equator. Drilling results from a number of atolls essentially confirm the early speculations of Darwin (1842) and Davis (1928) that the reef deposits accumulated on the peaks of submerging mid-ocean volcanoes (Scott and Rotondo, 1983a and b). In Quaternary times the slow upward growth of the biogenic pile has been interspersed by glacio-eustatic fluctuations in sea level (Stoddart, 1973; Steers and Stoddart, 1977; Bloom, 1980; Wiens, 1962). For long periods when sea levels fell, the atolls were exposed to subaerial weathering and karstification of the limestone deposits (Brook and Ford, 1978; Emery et al., 1954). At times of high sea level they were submerged and corals recolonised the atolls' surfaces (Hopley 1982; Davies and Hopley, 1983). Thus, the
broad geological structure of coral atolls comprise a succession of old weathered limestones that form an irregular substrate on which the most recent (Holocene) deposits have accumulated (see Fig. 2 in Wheatcraft and Buddemeier, 1981). Intertidal and shallow subtidal areas that form the atoll rims and reef flats are composed mainly of coarse coral detritus; these deposits reach thicknesses up to 25 metres (Wheatcraft and Buddemeier, 1981; Davies and Hopley, 1983), but in some cases, such as Mataiva in French Polynesia (Pirazzoli and Montaggioni, 1986), may be as thin as 5 metres. Reef-rim detritus becomes finer towards the lagoon (e.g. Ayers and Vacher, 1986) where the main sediment types are biogenic sands and calcareous muds (Fig 3a and b).

Variations in coral assemblages and growth styles reflect exposure of atoll margins to prevailing trade winds (Wiens, 1962; Hopley, 1982). Typically, atoll rims are higher and narrower and reef flats are better developed on high-energy, windward coasts (Wiens, 1962). Here, storm waves deposit coral rubble that progrades lagoon-ward in washover lobes (Wiens 1962). Storm ridges and spits of coarse rubble that build above sea level act as nuclei around which grow small islands (motu) (Fig. 3c).

Radiocarbon dating studies (Davies and Hopley, 1983; Hopley, 1982; Hopley and Kinsey, 1988; Marshall and Jacobson, 1985) show that, in most cases, upward reef growth lags behind rising sea level during the Postglacial Marine Transgression (PMT). It was not until one or two millennia after sea level stabilised that reef building corals reached shallow sub-tidal depths; here living corals became vulnerable to storm erosion, at least on windward coasts. Much of the rubble that the storms generated is washed landwards. This rubble together with insitu reef becomes cemented in the intertidal zone to create reef flats (Fig. 3b), forming the foundation for islands of calcareous sand and coral rubble built above sea level (Hopley, 1987).

Precise radiometric dating of the time of formation of coral reef is made extremely difficult by the absence of in situ organic material and the rapidity with which diagenetic processes - chemical and bio-chemical dissolution, biological abrasion and accretion, reprecipitation and cementation - act on the detrital carbonate. The same phenomenon inevitably reduces the accuracy with which relative sea levels can be determined. Nevertheless, there is a large body of data to show that intertidal reef flats typically have radiocarbon ages less than 5000 years BP and coral islands are mostly younger than this age (Fig. 4). Atoll islands are therefore amongst the most recent of geological formations and are also the youngest in terms of human colonisation.
During the PMT, corals colonised old limestone surfaces, but in most cases their upward growth lagged behind the rapidly rising sea surface.

Shortly after sea level stabilised, coral reefs grew up into shallow depths and rubble accumulated to form planar reef flats in the intertidal zone.

A slight fall in sea level during the late Holocene promoted the formation of storm rubble mounds that became the nuclei for island growth.
Radiocarbon dated material from the supra-tidal parts of atoll islands are mostly less than 4000 years old. Here data from a number of sources is shown in relation to the sea level envelope for SE Australia (Thom and Roy, 1985). Data Sources: Curry et al (1970); Yonekura et al (1984); Montaggioni and Pirazzoli (1984) Schofield (1977) and Marshall and Jacobson (1985).
Atoll Islands

Islands on atoll rims vary enormously in size and shape but all are composed of mixtures of coral/algae rubble and calcareous sand and rarely rise more than 3 metres above mean sea level (Wiens, 1962). Cementation in the intertidal and even supratidal zone (Montaggioni and Pirazzoli, 1984) undoubtedly contributes to their stability. However, the occurrence of exposed and eroding outcrops of beachrock/coral conglomerate on the one hand and newly formed boulder ridges and sand spits on the other indicate that islands are constantly changing shape (Wiens, 1962; Hopley, 1987).

Island morphologies are diverse (Wiens, 1962) (Fig. 5). They include narrow, elongated land-forms aligned parallel and relatively close to reef crests, termed ‘motu’ by Stoddart and Steers (1977), series of small islets separated by tidal channels and relatively large ‘triangular’ land areas located at bends in the atoll rim where reef flats are particularly wide, termed ‘vegetated sand cays’ by Stoddart and Steers (1977). The triangular islands show beach ridge patterns that indicate the action of convergent waves. The significance of narrow, elongated islands and series of small islets (often located on the same atoll) is unclear. In some cases the small islets seem to be erosional remnants of a larger continuous island that has disintegrated (see Stoddart and Steers, 1977:65); in other cases, the islets appear to be accretionary and may eventually amalgamate to form a larger landmass. Measurement by Emery and others (1954) show that most reef islands in the Marshall Islands are less than 1000 metres long and 500 metres wide. But in other atoll groups, islands may reach considerable lengths (in Kiribati, islands more than 10 km long are common) but only triangular islands exceed widths of 1 km, and then rarely.

The building of atoll superstructures, especially islands, results from a combination of processes of small scale erosion and accretion, that can be observed on a day to day basis, interspersed by catastrophic changes caused by extremely violent storms (cyclones and hurricanes) that occur quite rarely. Wiens (1962) and McLean (1980) document a number of historical storm events in which waves passed across islands up to 8 metres above their land surfaces, hundreds of islanders died and whole island habitats were destroyed - either washed away or buried in rubble. Series of beach ridges and recurved spits show that islands with these features have undergone a net building or accretionary phase sometime during the last 2000-3000 years. It contrasts, features that indicate contemporary erosion include tidal channels intersecting islands and ‘makatea’ surfaces around island margins and on reef flats. The ubiquitous problems of dating the transported materials that make up the islands have delayed development of meaningful models of island evolution.
In plan view atolls rise steeply in the open ocean to relatively shallow depths. An outer rim of living coral grades lagoonwards into a sand and rubble zone bordering the lagoon. Where the rim is exposed to storm waves, reef detritus accumulates to form an intertidal reef flat. Islands are essentially storm deposits on this surface. Waves and currents transport detritus from the reef front across the reef flat to the islands and into the lagoon.
Patterns of island growth and decay related to storm activity have been documented for Ontong Java, Solomon Islands, by Bayliss-Smith (1988). In 1967 Cyclone Annie caused severe damage to vegetation, eroded coral from exposed reef fronts and formed large storm ridges or ramparts of coral rubble on the surface of windward reef flats. In subsequent years parts of the rubble ridges became welded to existing islands thus increasing their size. However the long-term trend was for the ridges to degrade as rubble was broken down and dispersed - the product of intermediate-intensity storms. Along lagoon shorelines, sandy beaches were initially cutback but then slowly recovered in the post-cyclone period probably with the addition of the finer breakdown products from the rubble ridges. It would seem therefore that very rare and large storms (hurricanes) are critical in generating the new stores of coral rubble on reef flats which are then redistributed to maintain islands and infill lagoons. Bayliss-Smith (1988) follows Stoddart et al. (1978) in interpreting these changes in terms of 'dynamic equilibrium' (rather than stages in an evolutionary progression) with periods of island accretion alternating with (and largely balancing) erosion. The periodicity of this cycle depends firstly on the 'relaxation time' or rate of recovery of the land form and, secondly, on the recurrence interval of major, rubble-generating storms. (Rates of coral regrowth may exert an independent control on rubble production). The recurrence intervals of these two processes are different with the former being shorter than the latter; in the case of Ontong Java they are thought to be in the order of 25 and 100 years respectively (Bayliss-Smith, 1988).

It is reasonable to propose that a particular equilibrium state or condition will vary from atoll to atoll and even within a single atoll and will be manifested in terms of island size and spacing. Clearly, not all islands are presently in equilibrium. Larger islands may approximate to this condition (quasi-equilibrium) but small sand and shingle cays on exposed reef flats probably do not. The latter are commonly remnants of large rubble ridges related to single storms; they are subject to constant fluctuations in size, shape and elevation and many have short life spans.

A state of disequilibrium may arise if environmental conditions, such as relative sea level or storminess change with time. For example, island morphologies can be expected to differ depending upon whether an atoll is undergoing slow submergence or emergence. The theoretical effect of slow changes in relative sea level can be predicted: negative movements would tend to promote the accumulation of sediment masses (Hopley, 1982:354-5) while positive movements should increase erosion. Many of the early observations of atoll islands did in fact infer a slight fall in sea level (Wiens, 1962:95). While this trend has been confirmed by C14 dating in some areas (Hopley, 1982; Chappell et al., 1982), it is disputed by others (Newell and Bloom, 1970; Bloom, 1980; Curry et al., 1970; Montaggioni and Pirazzoli, 1984). This is mainly because of the radiocarbon dating problems mentioned
above, but also because the eustatic changes are so slow (0.1 to 0.2 mm per year) as to be masked or modified by local tectonic trends (Spencer et al., 1987).

A major control on the quasi-equilibrium state of atoll islands is storm intensity and variations in this factor will almost certainly be reflected in island morphology. In a spatial sense, McLean (1980) shows that cyclone frequency varies latitudinally, generally increasing away from the equator; it is therefore conceivable that atoll islands will show progressive morphological changes in the same direction - an hypothesis that remains to be tested by careful documentation of island heights and morphologies over a wide range of latitudes.

In a temporal sense, Bayliss-Smith (1988) suggests that storms in the mid-Holocene were more frequent and intense than at present and, at this time motu islands slowly increased in size. He believes that the trend has reversed during the late Holocene and islands then slowly reduced in size. Regional studies to document island morphology, size and location on atoll rims and the nature of inter-island channels, reef flats etc., such as were undertaken by Wiens (1962) and other in the 1950s, need to be initiated to test the above relationships.

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. Bryant (1988) has shown how past sea level changes have been influenced by local climatic 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 (Short, 1988; Thom and Roy, 1988; Cocks et al., 1988). The diversity of coral island types has been recognised by Hopley (1982) in the Great Barrier Reef and by Wiens (1962:41-44) amongst Pacific atolls. 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.

Pirazzoli and Montaggioni (1986) document evidence from the northwest Tuamotu Islands, French Polynesia, indicating that relative sea level was about 1 metre higher for most of the mid to late Holocene (from about 5000 to 1000 yrs BP). The crust beneath the
atolls is quite ancient and remote from present centres of hot spot activity. Relative sea level changes are therefore thought to be eustatic rather than tectonic in origin and to have had important implications for human settlement of the atolls. Pirazzoli and Montaggioni argue that 'when the level of the oceans was nearly 1 m higher than at present, the reef islets (motu) either did not yet exist or were submerged frequently enough to inhibit any lasting colony on atolls' (1986:366). Clearly, continued habitation of the present islands will be threatened if future sea levels return to their former position.

**Island Ecology**

The general impression of the terrestrial flora (and fauna) of atolls is of a rather limited species diversity, especially in comparison with high islands, with only a few plant types predominating. Wiens (1962) points out that species numbers vary considerably between islands and there seems to be a direct relationship between diversity and island size and rainfall (Wiens, 1962: Table 21, Fig. 91). Some islands are reported to have more than one hundred plant species (including many that were introduced by Europeans) but only a few are commonly used for food. The main food crops are coconuts, breadfruit, taro and pandanus. In wetter conditions crops such as bananas are also cultivated.

Because of the relatively small size and the low elevation of atoll islands, virtually all plants have some tolerance to salt spray and brackish ground water conditions. Species such as the coconut and pandanus can withstand quite high levels of salt and even occasional inundation by storm waves. They survive (albeit unproductively) on downward percolating rain water in relatively exposed sites and quickly colonise even small rubble mounds that rise above high tide level. In contrast, swamp taro and Cyrtosperma are much more sensitive to salinity changes and grow in low areas, usually manually excavated (taro pits), in the central parts of islands; on occasion, notably after storms, salinity causes a substantial reduction in taro productivity (e.g. Levin, 1976; Bates and Abbott, 1958).

Island ecology, in terms of the capacity to support human habitation, is closely tied to the existence of a permanent ground water system (Wiens, 1962). Islands above a certain size, about 1.5 ha and 200 m in diameter (Cloud, 1952; Wiens 1962), contain a permanent lens of fresh water surrounded by salt water (Fig. 6a.). The lens-like shape of the fresh water body is governed by the Ghyben - Herzberg principal which is primarily a function of density differences between salt and fresh water. The volume of the lens is roughly proportional to the surface area of the atoll. Other factors influencing the character and behaviour of the freshwater lens include annual rainfall, permeability of the rocks
The Ghyben-Herzberg freshwater lenses vary in size under present-day islands (a). They will be significantly reduced or even disappear if sea level rises and island shorelines erode (b). Because of the loss of "Freeboard", storm overwash of the islands will cause salt intrusion into the groundwater to occur more frequently (c).
beneath the island and mixing due to storm or tide induced pressure gradients (Buddemeier and Holladay, 1977; Ayers and Vacher, 1986; Jacobson and Taylor, 1981).

For example, during droughts, water table levels fall and the ground water may become brackish. Environmental stress is manifested by trees loosing leaves, not fruiting and even dying. In Kiribati, where ground water is the main source of drinking water on most islands, populations have been forced to migrate temporarily to areas with higher rainfall. On small islands especially, ground water reserves are particularly vulnerable to the vagaries of rainfall, storms etc. On Eauripik cyclone disruption of groundwater supplies has forced bathing in salt water (Levin, 1976). However, the most severe threat to permanent water supplies is not from climatic factors directly, but rather from marine processes that cause coastal erosion and increase the frequency of storm overwash. Figure 7 shows in generalised form, the relationship between the dimensions of the ground water lens and island size, expressed in terms of width, and illustrates the dramatic effect of a 20 per cent reduction in island width which reduces by half the volume of freshwater. Thus any decline in island area has a very dramatic influence on the availability of freshwater supplies.

While coastal erosion is closely linked to raised sea levels in general theories such as that proposed by Bruun (1988), quantitative relationships have yet to be established for coral islands. Clearly, for a given rise in sea level, the amount of erosion will depend on the composition and height of a particular island, its exposure to wave attack and current erosion and the frequency and intensity of storms. Conceivably, in the next 50 years or so, GE shoreline erosion rates in the order of 1-2 metres per year could reduce the dimensions of some presently inhabited islands to the point where their ground water supplies would no longer support viable ecology or permanent habitation.

Figures 6b and c illustrate the type of changes that might accompany a Greenhouse induced rise in sea level. 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 Greenhouse 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 (Fig. 6c).

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
The maximum thickness of the Ghyben-Herzberg lens of freshwater beneath atoll islands increases in direct proportion to island width but the volume of freshwater increases semi-exponentially. Thus changes in island width due to erosion or accretion have a disproportionately large impact on freshwater reserves.
central low area (Fig. 8). Low areas are swampy and historically have been used to grow swamp taro and Cyrtosperma taro; many islands of this type, such as Eauripik, support relatively high population densities. The effect of a marine incursion on this type of island is illustrated in Figure 8. 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 Atoll States

Coral reefs with their low sandy islets provide the most limited range of resources for human existence and the most tenuous of habitats for man in the Pacific...The soil is infertile, lacking humus, and fresh ground water is very limited...Maintaining a livelihood is a considerable task for man (Thomas, 1963:36).

The standard perception of atoll life, albeit without reference to marine resources, points to situations where subsistence production was often extremely difficult and the tasks of generating any real surplus even more difficult (Bayliss-Smith, 1977:327-8). Atoll life was always far from that portrayed in images of the supposedly idyllic Pacific islands. For many generations of schoolchildren the South Pacific is an area best known from the books of Sir Arthur Grimble, especially *A Pattern of Islands*, a romantic, entertaining account of the Gilbert Islands (Kiribati) that remains a perpetual bestseller. The images that it evokes of almost idyllic settings for untroubled social life in harmony with a benign environment have been thoroughly pervasive. Yet, just as Grimble had previously been, in Banaba, one instigator of a period of the most repressive and rapacious colonialism in the Pacific, so his retirement images distort not only his own activities but the whole nature of society and economy in island groups where hazard, hunger and disease punctuated periods of well-being and where warfare, abortion and infanticide also served to reduce population numbers. Population growth was carefully controlled and wars in pursuit of both land and power were common, especially in Kiribati, the Marshall Islands and Tokelau.

Atolls vary enormously in size, both of land and lagoon areas, and in rainfall, and hence so do their flora and fauna, their ability to support human populations and, most recently, in their ability to provide some form of diversified development. Some atolls are
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. Lower areas in their interiors are highly productive but, if sea level rises, inundation and salt intrusion could destroy their productivity and the island's groundwater reserves.
small, arid, drought-prone and overpopulated, as in the central Gilbert Islands chain, but where such conditions do not occur the potential for development is often quite different. Nonetheless, in comparison with high islands, the diversity of resources is limited and natural hazards are usually but not always, more severe in their impacts; recurrent hazards of droughts, hurricanes and tsunamis have had an important demographic and cultural role in the four atoll states (Vayda, 1959). The basic constraints were such that, in past times, many atolls have been depopulated and repopulated, following hazards and migration movements of various kinds (Alkire, 1978:28-30). In recent times Osborne has provided a vivid description of the dying phases of the small community on Merir atoll, Palau: 'the island is dying...the women are too old to cultivate taro in any quantity and the men cannot keep the coconut groves clear' (Osborne, 1966:49). Five years later the island was depopulated with the few survivors moving to the mainland of Palau, an option open to atoll dwellers in some form of political liaison with larger islands and states. More generally atoll populations often developed cultural ties with other atolls so that, during periods of population-resource imbalance, their proximity to each other enabled economic exchange, personnel mobility and, on the negative side, warfare and raiding (Alkire, 1978:94). Thus atolls were usually part of coral clusters or complexes.

Beyond these inherent constraints to subsistence production, the modern era has increasingly demonstrated the tyrannies of distance that have restricted contemporary development. Atolls are tiny, with limited resources, often distant from each other and remote from more substantial land masses. Atoll states consequently face a host of development problems, often in more accentuated form than in other island micro-states (Connell, 1988a), which include limited skills, small domestic market size, high cost of imports and exports, restricted diversity of exports and substantial administrative costs. These have usually led to large trade deficits, balance of payments problems and considerable dependence on foreign aid and technical assistance. For example in 1984 exports from Tuvalu were valued at A$312,000 and imports cost A$3,965,000; the same figures for the Marshall Islands in 1987 were US$3.61 million and US$32.25 million respectively. In Kiribati in 1985 the same figures were A$6,06 million and A$21.58 million and in Tokelau in 1984 were A$28,000 and A$145,000 respectively. In each case this discrepancy is worsening. Atoll states have moved rapidly into situations of extreme dependence, on the outside world, primarily for aid, concessional trade and migration opportunities.

Atoll populations may be small. Only the few urban centres have substantial populations and the four atoll states are some of the smallest island micro-states in the world. At a very early stage in colonial history these resource-poor islands became quite significantly dependent on the outside world for consumer goods, including foodstuffs (eg
Munro, 1989). By the 1890's for both Kiribati and Tuvalu, pacification, population growth and changing aspirations had resulted in overseas labour migration being described as 'the only alternative to starvation' (Macedonald, 1982:53) in the sense that population and domestic resources were already recognised to be in some degree of imbalance. Indeed in Kiribati and Tuvalu the Malthusian spectre has been sighted most frequently in the South Pacific; mid-nineteenth century Tuvaluans 'were genuine Malthusians. They feared that unless the population was kept down they would not have sufficient food' (cited by Bedford and Munro, 1980:3). A century later 'few countries of the South Pacific serve to remind one so well of the so-called 'Malthusian dilemma' as the two countries under consideration with their rapidly expanding population pressing against a limited and non-expanding stock of natural resources' (Fairbairn, 1976:1). The situation was and is marginally better in the less densely populated Marshall Islands and Tokelau.

In every case modern health facilities and medicines have resulted in more rapid natural increase of population in most atoll situations; infants are more likely to survive, and diseases are less likely to be fatal while modern family planning is largely absent in the atoll states. Even during the early 1940s, at a time when the resettlement of Gilbertese islanders in the Phoenix Islands appeared successful, its instigator, H.E. Maude, noted that 'colonization measures are in fact palliatives only and for more permanent means of population control we must look elsewhere. The ultimate hope for the Gilbertese people probably lies in drastic population control' (Maude, 1968:342). For a time, in the late 1960s, Kiribati appeared to have a successful family planning scheme but it was all too shortlived. Much the same was true of Tuvalu. The Marshall Islands now has one of the fastest growing populations of any state in the world; widespread adoption has reduced the perceived need for family planning. Kiribati and Tuvalu are not far behind. As atoll populations increase, the problem of satisfying basic needs (e.g. housing, water and food) from local resources also increases. Although there has been little research on the human carrying capacities of atolls (and it is invariably true that there are possibilities of agricultural intensification, varietal improvement, and fishing development), in a number of cases population densities have reached extremely high levels (Table 1) and development prospects are limited. All atoll residents now demand some cash income (for clothes, fish hooks, kerosene, etc). In some exceptional cases, where population densities, as on Eauripik in FSM, have increased to the extent that all coconuts produced are eaten rather than marketed as copra (the only possible agricultural export), the constraints are particularly severe (Levin, 1976). In this case, locally generated income is earned almost entirely from handicraft production. Eauripik may be extreme (with a population density of 950 per km² in 1980), but its limited development options reflect the essential problems of atoll development.
Throughout the atoll states, and atolls elsewhere, the limited agricultural base of the traditional economy has further declined in colonial and post-colonial times. The most dramatic decline has been in the dominant base of that economy, the taro pits, one of the more labour-intensive agricultural systems in the world and indicative of the inherent difficulty of local agricultural production. In every case there has been a transition away from taro pits. In urban areas, notably in Majuro, relatively few are now left. Artisanal fisheries have experienced a similar but less dramatic transition, which has followed the depletion of in-shore and lagoon species, indirectly contributing to the necessity for more labour-intensive fishing practices. In every case there appears to have been a decline in local production per capita, paralleled by a transition to imported food, especially rice, which has followed changing tastes, preferences, convenience and so on. This transition has been so substantial that in each state, imported foods and drinks now constitute about 35 per cent of all imports by value, a substantial drain on domestic resources. This is most extreme in the Marshall Islands where a recent reliable estimate suggests that 75 per cent of all food consumed in the country is imported (Marshall Islands Journal, 13 January 1989).

Limited subsistence agricultural production has been dramatically emphasized since the nineteenth century by the ‘coconut overlay’ (Bedford, 1980:48) that has transformed the economy of atolls by enabling participation, however limited, in the international economy through copra production and sales. In the Tuamotu atolls of French Polynesia the coconut overlay was directly responsible for the complete disappearance of the former agricultural economy (Ravault, 1982). This sole historic domestic source of income, copra production, has continued into the present, although in recent years production does not appear to have grown significantly. Nonetheless, even on the more urbanised islands, including Majuro, copra is still produced because of its capacity for directly generating some cash income. However the relative significance of copra incomes for household and national incomes has declined, especially in the post-war years, as atoll dwellers have discovered that they have a one-crop economy and that this single crop has a falling price on the world market. Necessary activities, such as coconut replanting, are often postponed indefinitely and copra production offers an increasingly fragile basis for the construction of a modern economy.

Though fish and other marine resources have often been domestically marketed, albeit on a very small scale, marine resources have rarely been exported from the atoll states. In recent years, however, there has been some expansion of domestic fishing fleets, often through joint venture operations, and fish have become a growing source of national income, principally in Kiribati and Tuvalu. Much more important has been the leasing of fisheries waters for the fleets of overseas fishing vessels, including, for a brief period, the
leasing of Kiribati waters to the Soviet Union (Doulman, 1987). Through various bilateral and multilateral agreements fisheries lease now represent a major source of domestic income for the atoll states, though substantially less than the value of those fisheries. However, even the combination of fisheries and copra incomes does not provide high incomes for the atoll states, most of whose national incomes are now externally generated in a non-trade manner.

All atoll states are part of the international economy, and the aspirations of atoll people are generally those of people elsewhere, including improved services (health, education), remunerative employment opportunities, and consumer goods (imported food, clothes, outboard motors, motorbikes, etc.), although wants are somewhat less than those of occupants of larger islands where imported goods are more familiar. Everywhere, real and perceived differences between places in life-styles, economic opportunity, and the range of available services and facilities have increased, especially since the 1950s (Bedford 1980:47). It is a truism that new aspirations can be less easily satisfied in atoll environments; it is equally a truism that, as these aspirations increase, the degree to which they can be satisfied on atolls falls.

The Migration Option

The combination of higher postwar rates of population increase, the increased desire for consumer goods, the location of higher education facilities and hospitals either on one central atoll or on a high island, and the concentration of formal sector employment there has, in many cases, resulted in outmigration from atolls, especially where there is a central high island (Connell 1986:45). Although the populations of many, perhaps most, atolls are growing at a slower rate than that of the atoll state as a whole, few are actually losing population, and then only the smallest atolls. Throughout the atoll states there have been three migration trends, firstly, the tendency for there to be a growing concentration of population at one point on each atoll, usually the point where there has been some development of services, perhaps in association with a mission station, school etc. Much more important trends have been, secondly, the steady increase of the urban population of atoll states and, thirdly, international migration, both temporary and permanent from these states. These two latter trends can now be discussed in greater detail.

On small atolls especially, there are very few prospects of formal sector employment; as population and education levels increase and demand for employment also increases, this is further emphasized. The extent of emigration in youthful age groups especially is often substantial (Connell, 1986:47) as little local wage employment is
available and almost all of this is in the public sector. In these states the private sector, beyond stores, is conspicuous by its absence. In every case public sector employment rapidly expanded in the 1970s. In Tokelau this rapid expansion caused widespread social changes, disrupted traditional activities and also disrupted the fiction of egalitarianism as, by 1981 on Fakaofo, public service salaries accounted for 82 per cent of all cash income (Hooper, 1982). The impact of the general transition to bureaucratic employment, now the principal target of rural-urban migrants, is discussed in detail elsewhere (Connell, 1983a, b, c, d). Since many atolls are remote from capitals, the costs of transportation (either of commodities or medical services) have rapidly increased as oil prices have increased, and transport services have declined substantially in some areas. Migration becomes a cheaper alternative than remaining. When both population and wants have grown together in environments where local production possibilities are limited, the export of labour has become an important means of meeting some basic subsistence requirements, especially food. For example, in 1971,

The people of Butaritari and Makin [two atolls in northern Kiribati] are becoming increasingly dependent on remittances to pay their taxes and their children’s school fees, to buy corned beef and rice for feasts, and to purchase even moderately expensive items at the store. Most of the durable goods on Makin - planks for canoe hulls, canvas for sails, bicycles, sewing machines, radios and even clothing - were brought by returning workers. The export of labour has become the principle means of maintaining the local standard of living (Lambert 1975:220-221; our emphasis)

Migration has thus increasingly become a quest for essentials rather than luxuries.

While outmigration may solve the immediate population and welfare problems of some small, densely populated atolls, it may also increase the problems of destination areas in the atoll states. Some of the most difficult and intractable development problems in the South Pacific are experienced in the atoll states (and, to a lesser extent, in those where atolls predominate). Since aspirations to migration are much the same in these countries, and infrastructure (principally for health and education) is often highly centralised, migration has been concentrated in a very limited number of areas. The most extreme examples of this are the Marshall Islands and Kiribati. Tokelau has no ‘centre’ and much of the administration is actually undertaken from the Office for Tokelau Affairs in Apia, Western Samoa. In the Marshall Islands, the 1988 census recorded a total population of 43,335 of whom 19,695 were on Majuro (at a density of 2,188 persons per km²); less than 36 per cent of the population were on ‘rural’ atolls. In Kiribati, the 1985 census recorded a total population of 63,883, of whom 21,392 (33%) were on South Tarawa at an average density of 1,357 persons per km². The only other atoll state approaching these kinds of
urban concentrations and densities is Tuvalu where the 1979 census recorded a total population of 8,730 (of whom 7,349 were actually in Tuvalu); Funafuti had a population of 2,120 (28.9%) at a density of 770 persons per km² and this is now substantially greater; Funafuti now has about a third of the national population. In each of these cases urbanisation has been both recent and rapid. The reasons for these urban concentrations are many and, until quite recently, have followed growing economic and social differentials between one central atoll and the remaining atolls. A centralised administration has spawned the centralisation of the service sector hence most formal sector employment is concentrated in the centre. In Tuvalu, 78 per cent of all those employed in the cash economy in 1983 were in Funafuti; in Kiribati 60 per cent in 1985 were in South Tarawa. The figure for the Marshall Islands (for the two centres) is likely to be even higher than that for Tuvalu. In each case these proportions have grown between the last two census dates, indicating the continued concentration of both the population and contemporary economic activity. This centralization of wage employment suggests that even where urban unemployment, however recorded, is growing, the chances of obtaining wage employment appear to be greater at the centre. Since social services, the 'bright lights', and a significant proportion of relatives are also at the centre, there are powerful attractions to rural-urban migration. This centralization may be compounded by 'urban bias', where financial and technical resources are overwhelmingly concentrated in the urban area.

Inevitably this urban concentration has created problems. Many of these problems are no different from those of much larger urban centres elsewhere in the Third World: overcrowding in poor housing conditions with attendant health risks, pollution (to the extent that the lagoon in South Tarawa is a potential health risk and was one cause of a cholera outbreak in 1977), unemployment (even if disguised by sharing in extended families), the growth of squatter settlements (e.g. Itaia, 1987), worsened nutrition (as cash incomes are often inadequate to purchase diets based on imported foods), and sometimes higher crime rates and social disorganisation. Since migrants are not always successful in towns they may be unable, or unwilling, to contribute significantly to the needs of their rural kin. When urban jobs are hard to find, those who earn wages in town may be more likely to redistribute money there than remit to the home atoll. In Lae, in the Marshall Islands, the flow from Ebeye scarcely exceeded the rural-urban flow (Alexander, 1977). However more generally, throughout the Micronesian atolls, both ‘good’ and ‘bad’ times can usually be distinguished and in the bad times both money and foodstuffs flow to the towns (Alkire 1978:145) or kin may even migrate to urban centres to ensure access to the earnings of their relatives. If bad times in urban areas increase in the future, rural dependence on remittances may inadvertently prompt a reversion toward self-reliance.
These urban problems are not unique to atolls, but the small size of the land and lagoon areas, and the problems of achieving economic growth accentuate the basic difficulties.

In the atoll states of the Marshall Islands, Kiribati, and Tuvalu there are therefore two related problems: the relative depopulation and economic decline of the smaller, remote atolls and overurbanisation on the principal atoll. In the absence of overseas migration from atoll states, development prospects would be even more difficult. For Tokelau, migration to New Zealand is a right since Tokelau islanders are New Zealand citizens hence, in terms of ethnicity, a slight majority of Tokelau islanders now live in New Zealand.

the idea of permanent emigration, involving a severance of many ties with the home island and of seeking one's fortune elsewhere, is well established in Tokelau life and thought. For the past 70 years or so it appears to have been accepted...that some of nearly every group of siblings must tahe ("emigrate") simply because the local resources are seen as insufficient (Hooper and Huntsman, 1973:403-4).

Migration from the Marshall Islands (and from the Federated States of Micronesia) to the USA is possible under the terms of the Compact of Free Association; indeed the island states were anxious to ensure that such a clause be in the Compact. There are currently few Micronesians in the United States (Connell, 1988b) yet this may well change in the future to the extent that, as for Tokelau, Micronesian residents of the United States may outnumber "the folks back home" (Marshall 1979:10-11). For the former British colonies of Tuvalu and Kiribati only temporary labour migration to Nauru is possible at the moment, and this is currently constrained by fixed employment opportunities there and, in about a decade, by the eventual closure of the phosphate mine. Both countries have sought resettlement opportunities overseas and also new overseas employment by training seamen, and Tuvalu has formally located a handful of workers in New Zealand under existing short-term schemes. However, in the immediate future, these two countries do not have long-term overseas migration (or resettlement) opportunities.

Both Kiribati and Tuvalu specifically train a proportion of the national population for overseas migration through their Marine Training Schools. Apart from overseas seamen (representing 3 per cent and 1 per cent respectively of the de facto population of Tuvalu and Kiribati), there were almost 722 (8.2 per cent) Tuvaluans and 1,278 (2 per cent) I-Kiribati employed on Nauru at the time of the last censuses. The number of I-Kiribati on Nauru has declined between 1979 and 1985 and subsequently will decline further as employment opportunities contract. Movement overseas both reduces the pressure on local resources and provides a substantial cash flow from remittances. When phosphate mining
on Nauru ends, in the absence of alternative overseas opportunities, the development problems of Kiribati and Tuvalu will be considerably worsened, because of the loss of remittance income, the increased population pressure on resources as these workers (and sometimes their families) return, and the influence of these return migrants, hitherto employed in the urban-industrial sector, on the values and attitudes of the national population. Rates of extraction of phosphate are influenced by changing technology and prices, but there seems little doubt that commercial phosphate production will have finished before the end of the century.

The significance of international migration for Kiribati and Tuvalu is apparent not only in the flow of remittances but also in changing local attitudes to international migration. In pre-war years the colonial administration decentralised part of the population of the more densely populated Gilbert Islands to the Phoenix Islands group to the east (Maude, 1968; Knudson, 1977). At much the same time groups of villagers from Vaitupu in Tuvalu purchased land in Fiji for their own private resettlement (Koch, 1978). Local and colonial perceptions of population density and domestic development prospects were both quite similar. For various reasons settlement of the Phoenix Islands was unsuccessful and the settlers were again transplanted, this time to the then British colony of the Solomon Islands, where they and their descendants remain. In Kiribati these settlers are now viewed quite differently from in the past.

In earlier days they were the unfortunate ones who did not have sufficient land. Now our value have changed. Settling overseas beyond the oceans of our islands is something to be sought after. Why? Because our population is still growing. So now, many consider them, the resettled ones, the fortunate ones and they consider us to be the unfortunate ones (Schutz and Tenten, 1979:127)

Permanent international migration is increasingly viewed by many, though certainly not all, as a key solution to many development problems.

Toleration and encouragement of international migration in the Pacific is a function of its impact on the reduction of population pressure on scarce resources, attitudes to individual freedom of movement and, above all, the substantial flow of remittances that follows international migration. The flows of remittances to Kiribati and Tuvalu and, to a rather lesser extent, Tokelau are large and increasingly crucial to household and national welfare. Migration and remittances have tended to create an appetite for the import of consumer goods, and hence expensive imports, which has driven up wages. The remaining remittances are however mainly invested in stores or in the agricultural sector. However rural investment opportunities are normally so few that
migration is a more lucrative investment than anything available at home. In these conditions remittances can only be invested in increased, if not necessarily improved, consumption. The conservative use of remittances partially reflects the lack of productive investment opportunities. Although there are widespread assumptions that remittances emphasize dependency and produce rural stagnation (Connell 1980) their contribution to the generation of foreign exchange earnings and employment, especially in the service sector, in small islands where there are few other income-earning opportunities, ensures that there are many exceptions to this generalisation. Opportunities for emigration and remittances are extremely highly valued by islanders themselves and freedom of movement is given high priority. Migration is often linked or sponsored, with households or extended kinship units planning for and encouraging the migration of particular individuals, to the extent that in the smallest states, such as Tokelau and Tuvalu, Marcus has suggested the emergence of a new institution, the 'transnational corporation of kin', allowing kin groups to colonise and exploit economic opportunities across a wide range of environments (Marcus, 1981). Such behaviour is most apparent where domestic sources of income are least adequate. In all South Pacific states, including the atoll states, there have been no attempts to restrict international migration; rather have there been attempts to gain greater concessionary migration opportunities overseas.

In more dramatic form the growing perception of the household returns to migration has led to increasing fertility rates, as least as documented in the case of Nanumea atoll in Tuvalu, where parents actively hope to produce remittance earners and most feel that this necessitates having more than one son. As one woman said of her only son "One is not enough. If he goes away to work, there is no one to look after me here. If he stays and cares for me, no one earns any money overseas". Another woman recognised that her husband had been right to insist that they needed more children... "He said that if we had many children we might have a smart one who could go on to school and get good work. He will be our road to money and imported goods" (Chambers, 1986:2873-4).

This phenomenon has also been observed in other small islands that have become dependent on remittances from migrants (Connell, 1988a:29) and indicates not only that family planning is unlikely to be chosen as a solution to development but that population pressure on resources may worsen in the absence of international migration opportunities.

It is scarcely surprising then that individual migrants and households and also many observers have viewed the future of the atoll states in terms of increased levels of
international migration. A relatively recent review of the possibilities for economic growth in Kiribati and other larger, less remote and better endowed countries in the South Pacific concluded that sustained increases in incomes would essentially only be possible through greater dependence on migration:

The case of Kiribati exemplifies the dilemma in its starkest form. Even with the most optimistic view of the possibilities for fisheries or further development of the coconut industry, the conclusion must be that continued economic growth from its own resources is impossible... The acceptance of a no-growth option may be the only realistic option for the small countries... No-growth need not be synonymous with poverty if the possibility is established for people in stationary economies to migrate either temporarily or permanently... It is even more difficult when whole states are placed in the position of having to choose between, on the one hand, restricting opportunities for their nationals to those available within their own boundaries and, on the other, extending the range and choice of opportunities open to individuals by closer integration with larger economies at the possible cost of some attenuation of their national and cultural identity... [A policy of unrestricted temporary or permanent migration to metropolitan countries] would seem to be the only one that gives the people of the small island countries the chance to choose individual paths of development within the wider world community (Castle, 1980:135-6).

Specifically contrasting Tuvalu with Tokelau, where Tokelauans can move freely as citizens to New Zealand, Bertram has concluded

For Tuvalu, where the British and the local elite together managed to push through a transition to formal independence, the key role for the new state will now be to recruit a new patron and to seek out new opportunities for Tuvaluan labour and capital to penetrate the rest of the world. Closed country models, whether in the political or economic realm, simply do not fit the Pacific of the 1980s (Bertram, 1987:29).

Denied permanent overseas migration opportunities, unlike almost all other states in Micronesia and Polynesia, Kiribati and Tuvalu have hitherto found opportunities in Nauru and on foreign ships. A future in which these decline or even disappear poses immense problems, not only in rehabilitating and accommodating migrant workers but in coping without their remittances. As a former Australian Commissioner to Fiji and Tuvalu noted: the people of Kiribati and Tuvalu should be seen as 'economic refugees' (Keith-Reid,
1984). It is into that arena that the Jackson Review of Australian foreign aid (Committee to Review the Australian Overseas Aid Program, 1984) stepped.

The brief ‘Executive Summary’ of the Review attached sufficient importance to the problems of Kiribati and Tuvalu to give them a special significance denied to all other states except Australia’s former colony Papua New Guinea.

Kiribati with a population of 60,000 and Tuvalu with a population of 8000 have special problems. Their remote and minute land areas are heavily populated. They depend very much on remittances from their emigrants and on foreign aid. Their long term development prospects are discouraging. In view of structural problems which are beyond their control and beyond the reach of aid, Australia should make available limited opportunities for immigration from Kiribati and Tuvalu (1984:8).

The main body of the text scarcely extended on this summary although the Review singled out Tuvalu as having ‘a unique combination of minute size, tiny population and an almost total lack of resources. It is a state without internal economic viability, and it will have to remain dependent on remittances and aid’ (1984:171); it was also identified as having additional problems of land shortage, urban drift and high youth unemployment (1984:171). Kiribati was seen as exemplifying the problems of distance and communications; ‘the country consists of islands with a total land area of 690 square kilometres, spread over a sea area of 3.5 million square kilometres and remote from the nearest developed country market’ (1984:171). Although the Review specifically identified no other problems in Kiribati those listed for Tuvalu are equally apparent in Kiribati.

Urban migration is particularly serious in Kiribati and resulted in the unusual and rather dramatic response of formally allocating unskilled urban government employment by island quotas (Connell, 1983a). Likewise communications problems are at least as serious in Tuvalu, where the withdrawal in 1983 for financial reasons of a limited domestic seaplane service resulted in the departure of Peace Corps volunteers from every island except Funafuti, the capital. Though this aspect of the report was never debated or acted upon in Australia, and the more recent Fitzgerald Report (Australia, 1988) rejected the possibility of any concessionary scheme for Pacific Islanders, it is indicative of the growing perception of severe development problems in Kiribati and Tuvalu and the role that international migration might play in resolving them. Nonetheless a former Government Economist and Planning Officer of Kiribati has simply stated, ‘Emigration, as proposed by the ‘Jackson report’ is not an answer. This would result only in the removal of the best of one of the country’s few resources i.e. its skilled labour, to serve other countries and further frustrate Kiribati development’ (Pollard, 1987:6). Though there is some truth in
this view, migration from Kiribati already occurs and there is no obvious shortage of skilled labour that would be solved by reducing migration.

Alongside the contribution of remittances, a further substantial financial support for national incomes of atoll states is overseas aid, welfare payments, subsidies and compensation payments of different kinds. So substantial are aid funds that the atoll states of Kiribati, Tuvalu and Tokelau, alongside Niue and the Cook Islands, have been conceptualized as MIRAB states, where migrant remittances and aid are the most important bases of the economy and, through these flows, a government bureaucracy has become the principal source of wage and salary employment (Bertram and Watters, 1984). In the Marshall Islands direct external (US) support for the economy is even more substantial. Aid dependence has taken some unusual forms. In 1987 Tuvalu established an aid Trust Fund of A$27 million composed of direct cash donations from Tuvalu’s traditional aid donors. This fund is managed by a subsidiary of the Australian bank, Westpac, and if it is successful Tuvalu will be able to live off the annual interest, thus dispensing with conventional annual aid delivery. The money will be invested in a low-risk spread of assets, including fixed-interest funds, equities and property. The fund should enable Tuvalu to clear its recurrent deficit and contribute to long-term financial viability by earning an annual interest almost that of current aid receipts (Fisk and Mellor, 1986). The donors will have some ability to monitor the effectiveness of this fund in contributing to national development. In some respects the Trust Fund is based on the nearby success of the Revenue Equalisation Reserve Fund (RERF), derived from historic phosphate revenue in Kiribati (Bertram, 1986:820; Pollard, 1987). This fund is managed by a London merchant bank, supervised by a Kiribati committee chaired by the Finance Minister. In 1984 Kiribati received external aid of A$13.5 million (vastly in excess of its exports) and received A$5.5 million from the RERF; a further A$12,000 was generated from the lease of a tracking station on Christmas Island. Tokelau received New Zealand aid for the financial year 1985-86 to the value of NZ$3.1 million, and, in 1985, Tuvalu received aid of A$4.6 million. The Marshall Islands received a vastly greater sum than all of these from the United States alone. Only a very small proportion of the national income of atoll states is generated within those countries, through commodity, mainly copra and also postage stamp, exports but is dependent on concessionary external support. However the concessionary trade agreements of SPARTECA have proved of no use to countries that manufacture little (Tabai, 1987) and none of the states has any manufactured exports. Atolls and atoll states have moved a very long way from any semblance of self-reliance. Moreover they have gone beyond the traditional support of coral clusters to dependence on much more distant nations.
The Impact of Greenhouse

Previous sections have examined the difficulties of development in atolls and atoll states and noted how, over time, there has been increasing recourse to the option of migration as the preferred individual and household solution to the challenge of development, whilst the states themselves have tended to become more dependent on overseas aid. 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. As noted previously it is apparent that there will be climatic changes, in terms of differences in rainfall and storm frequency and rises in air and sea temperatures, and that coastal erosion will increase as sea-level rise accelerates beyond the upward growth of corals and that this erosion will probably be accentuated by the greater frequency of storms. Slowly but inexorably there will be critical environmental changes but of an unknown rate and dimension.

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. Some areas, including parts of Papua and Fiji, may experience a degree of desertification (Baines, 1988). At a local level future changes are even more difficult to assess.

The consequences of changed climate, including raised air and sea temperatures for the physiology of plants and animals and their ecological inter-relationships can only be guessed at at this stage. Ecological processes, too, will change. The fallen leaves and twigs which are the vegetation litter of forest and grassland, for instance, will decay even faster than now, exposing bare ground more readily to water erosion (Baines, 1988:9).

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 coastal 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 groundwater lenses will have direct effects on agriculture and on the supply of potable water. The most obvious effects on agriculture will be 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; though coconuts and pandanus are relatively salt-resistant increased salinity in other contexts, such as coastal areas of Thailand (Ealey, 1985), has reduced productivity and killed off palms. There appear to have been no studies of the relationship between salinity and agricultural productivity in the South Pacific region. No species of fauna or flora will however gain from increased salinity.

Increased groundwater salinity will reduce the potability of groundwater which, for most atolls, is currently of considerable significance, although preference is usually given to rainwater, and groundwater is a secondary source. In drought conditions access to groundwater on every atoll is crucial although, on some atolls of reasonably high rainfall, such as Nanumea (Chambers, 1984), construction of better cisterns may enable use of groundwater to be minimised or ended. 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. On some of the drier atolls, including urban areas such as Majuro, water supply is already a critical problem. (In the extreme case of Nauru water is intermittently imported). 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 sea, 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 for scarce land in urban areas and more disputes over land tenure. (Fortunately, the custom in many atolls, of land tenure being organised by strips across the atoll from lagoon to ocean, is likely to reduce the severity of such
conflicts). 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. One extremely pessimistic scenario even suggests that 'it is conceivable that some baselines for territorial seas and Exclusive Economic Zones would have to be altered, decreasing the area of exclusive rights for marine resources and reducing potential income' (Matos and Tiffin, 1988:51; cf. Pernetta, 1988). Long before this occurs there will have been many more obvious negative effects. These effects will occur alongside continued rapid population growth, and hence a substantial increase in population pressure on resources. Unless GE contributes to increased self-reliance in some other area (and it is remotely possible that deep sea fisheries potential might increase) 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 known 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. Indeed 'we do not really know what conditions were like around 8,000 years ago when global and regional temperatures were at levels that they might pass through within the next half century' (Brookfield, 1988:5); moreover the genesis of that situation was quite different from the contemporary set of circumstances. 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.
Development Alternatives

There are alternatives to the trends of population migration, dependency and overurbanisation in the atolls of the South Pacific but GE will make such alternatives exceptionally difficult to realise. Marshall has suggested one possibility, that 'outer-island communities may undergo a demographic revitalisation as educated migrants, longing to re-establish their cultural and ethnic roots, forego the urban centres and work towards building a new economic future in their home communities' (1979:11). While there have always been minority movements to reestablish cultural identity, these have not proved to be alone an adequate basis for development. Where solutions exist they must be in the area of economic development and job provision. Yet even now there are massive constraints.

In Kiribati, a series of policy choices have evolved in an attempt to achieve more balanced development, including, in the long term, improved rural education (including traditional and practical skills), increased copra prices (by subsidy), the development and expansion of district centres (involving decentralisation of government), and perhaps the resettlement of the distant and sparsely settled Line Islands. The development of the Line Islands, and especially Christmas Island, has recently been given new emphasis, in an attempt to decentralise population and development and reduce the high level of urbanisation. However moves to establish vocational education in both Kiribati and Tuvalu have been thwarted by opposition from parents demanding a curriculum that includes the academic training that offers some possibility of urban bureaucratic employment. In each of the atoll states there has been a focus on improved fisheries and agriculture, to increase self-reliance, but success has been minimal; attitudes have moved away from agriculture and marketing infrastructure is minimal. Development plans in each of the states have been exceptionally difficult to translate into practice.

It is improbable that atoll states can ever achieve a significant degree of self-reliance (unless they discover new sources of mineral wealth), yet they are currently capable of moving away from the present massive dependence on migration, aid and trade. The elements of such a policy redirection are clear: agricultural development policies that stress diversification and food crop production (while simultaneously encouraging the extension of new coconut varieties and replanting schemes to ensure some necessary cash income); land tenure reform and the taxation of unused agricultural land; increasing concentration on the exploitation and development of the marine resources that are the only obvious base of both export growth and improved nutrition; transport and energy policies that move away from the use of non-renewable resources; job decentralisation and allocation (along Kiribati lines); improved infrastructure (wharfs, aid posts etc); increased
emphasis on family planning, and so on. Self-reliance then entails reducing dependence on imported 'necessities' including foods, oil products, capital equipment, and also expertise. This involves changing consumption patterns as well as increasing local productive capacity. Policies would be needed to change living styles at given income levels - using taxes, price policies, advertising, and perhaps rationing. This might also involve increasing national ownership of assets and improving national capacity for negotiating with transnational corporations and metropolitan countries, especially, in this context, those with fishing fleets (cf. Seers, 1977). In short, self-reliance entails a more selective approach to external influences of all kinds. However for atoll states the problems of achieving a greater degree of self-reliance are extremely severe, fly in the face of the development trends of the post-war decades, are profoundly unattractive (Bertram, 1987:28), demand stable political authority in exceptionally 'soft' states and are inherently unlikely to occur. Many have been entrenched in advisory reports and development plans for years. They are even less likely to occur under the influence of GE.

In most of the atolls of the South Pacific, movement toward the self-sufficiency that reduction of aid and remittances implies would be difficult and painful especially for the young and as they run counter to perceived trends in metropolitan countries. In most places aspirations are firmly directed towards the acquisition of modern goods and, as has been argued for the small island of Rotuma, "with the prestige given to "foreign" goods, it is doubtful, therefore that Rotumans would want to be self-sufficient, even if that were a possibility" (Plant, 1978:174). In other small islands the same kind of situation exists; in Tikopia 'from such a level of dependence on imported goods it becomes difficult to retreat without unease and a sense of deprivation' (Firth, 1971:69). In Ponape, too, villagers are not interested in adequate subsistence, nor even 'the right to subsistence' but rather they desire 'continued and increased access to the goods and prestige provided by employment' (Petersen, 1979:37). While these statements refer specifically to small islands rather than atolls, such attitudes are becoming true of most areas within the Pacific and emphasize the reality of relative deprivation. Policy prescriptions that focus entirely on self-reliance, and not on interdependence, are unlikely to be taken in full for several reasons: the constraints of more than lingering demands for the the prestige associated with modernisation and westernisation, the difficulties attached to establishing rural projects (which are rarely prestigious), and the fact that concerted comprehensive policy formation in loosely structured, democratic states is difficult to achieve. Meanwhile self-reliance is steadily being eroded and the alternative, a more adequate interdependence, is as distant as ever.

The most detailed review of the development prospects of Kiribati and Tuvalu, undertaken a decade ago, was quite pessimistic in its conclusions:
The economic prospects for the Gilbert Islands and Tuvalu are not promising. No new economic resource other than the sea is likely to present itself...the islands' remoteness from markets will always create difficulties...The future appears to lie in maximising returns from existing resources, the export of labour, import substituting, the careful control of government spending and, for the Gilberts, the development of the resources of the islands without indigenous population (Geddes et al, 1982:5).

But the 'existing resources' of the islands are little more than coconuts and two major subsequent reports (Pitchford, 1981; Green, Bukhari and Lawrence, 1979) have cautioned against any real prospects for development in either the unpopulated Phoenix Islands or the even more remote Line Islands; it is a gloomy conclusion. Indeed the Team Report went on to note that:

Piecemeal tinkering with individual policies might alleviate some conditions but cannot possibly succeed as they are dealing with a complex whole; nothing less than a radical alteration of the whole political economy will suffice that will enable a new economic, social and political structure, firmly rooted in the real pattern of the islands, to emerge (Geddes et al, 1982:142).

This is, of course, too late and too improbable; the 'alluring options' of tourism and aid which may offer 'primrose paths' (ibid) on the road to 'westernisation' are found wanting. So too are the new leaders, with the notable exception of President Tabai of Kiribati, who 'show many of the signs that they may act in the same way as the elites of most other South Pacific governments in recent years - they will pursue the right wing, conventional economic policies of the former British administration and continue with an open laissez-faire economy, welcoming foreign investment capital' (Geddes et al, 1982:154). Advocations that they 'need to be austere and moderate in their own tastes and spending, practise restraint in public spending and be able to dampen down local expectations and aspirations that are no longer realistic (op cit:155; our italics) are likely to be met only in adversity. Transformation through tradition may provide some 'grounds for optimism that the islanders will eventually work out their own, indigenous model of development' (op cit:156) but this is more likely to be illusory. It will not be a self-reliant future; traditional pre-contact life presented its own problems that cannot now be diminished by appeals to the merits of self-sufficiency. And, as one report on the Tuvalu atoll of Nanumea well indicates, the 'poulioli myth', in which traditional Tuvalu culture is inferior to western culture and hence local customs belong to 'days of darkness' (Chambers, 1984:272), cannot now be erased. The prospects for greater self-reliance are exceptionally poor and slowly dwindling.
Some islanders are optimistic about the future, though many statements tend to be exhortatory and idealistic: in Kiribati, 'If there are going to be problems, dangers, or disaster, let us conquer them...The future is uncertain. But if we remain true to our kate ni Kiribati [Gilbertese way] we shall be able to see our way clearly through' (Itaia, 1979:182, 188). Likewise in Tuvalu, 'Tuvaluans have much to be proud of, and can face the future with confidence. They are masters in their own country...the Tuvaluans of the present, no less than those of the past, accept the challenge of providing as well as they can for those who are to come. Our history contains a message of hope' (Sapoago, 1983:181). No prominent leader has sought self-reliance with such determination as the President of Kiribati, Jeremiah Tabai.

...our fundamental conviction [is] that there is no alternative to developing our country so that we can at least stand on our god-given feet. We believe also that any other alternative is no alternative at all, because it would definitely condemn us to perpetual dependence on others - something that is inconsistent with our national objectives - something that obviously cannot be regarded as development (Tabai, 1987:4).

However throughout a series of detailed studies conducted in the 1970s there are several expressions of disappointment and pessimism; senior pupils at the Abemama Island School forecasted a future of hardship, insecurity, land shortage and overpopulation, exorbitant store prices and lack of wage employment (Watters and Banibati, 1982:247-9). Characteristically in Kiribati, where traditional attitudes emphasise luck and fate (Geddes et al, 1982:10), there was greater despondency than in Tuvalu. In Abemama this was accentuated by the emergence of island feeling of relative deprivation in contrast to Tarawa (op cit:14) and, in both countries, there was a healthy scepticism over the delusions and illusions of development plans.

The views of many island politicians are also much less sanguine. The former Tuvalu Minister of Finance, Henry Naisali, has stated: 'Viability? Never. It's no use pretending we can be, although I hope someone will find a better solution to our future than what I can see at the moment. Foreign investment? Honestly I don't see any foreign corporation investing in Tuvalu' (Islands Business, April 1984, p.62). In his inaugural speech after independence the Tuvalu President, Toaripi Lauti, proclaimed: 'All we have is sunshine, wind and a portion of the Pacific Ocean with which to build our nation's development'. Whilst in strikingly similar vein, the President of Kiribati opened the Seventh South Pacific Labour Ministers Conference in Tarawa in July 1981, with the
words, 'In Kiribati God was kind to us and blessed us with sunshine, the sea and the coconut'. What may appear pessimism elsewhere is realism here.

Some outsiders are less pessimistic about the future for small island states. Dolman, after an extensive review of development issues in small island states, has queried, 'Is it too much to suggest that small islands, for all the problems and constraints that confront them, could become the laboratory in which alternative development strategies, shaped by the notion of self-reliance, first see the light of day?' (Dolman, 1985:63). For most the answer would be that it is indeed too late, and that self-reliance in the past is very much a myth: 'dependency is sanctioned and encouraged by government action and is culturally a legitimate strategy that is effectively no different from former island network relationships' (McInnes, 1986:132-3). Pollard has reviewed some of the various discussions on the prospects for greater self-reliance in atoll states, concluding that most such states are now well advanced along the 'capitalist road' and 'for some countries perhaps it is too late to change these new ways' (Pollard, 1988:41). Theory does not conform to practice. Despite Kiribati's aim to achieve self-reliance, to the extent of divesting itself of overseas aid, it is apparent that 'countries such as Kiribati will require international assistance for many years yet' (Pollard, 1987:24). For the atoll states the future is increasingly one of dependence, or interdependence, a future that can only be accentuated and hastened by GE.

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, fertilizers, technology, and so on, from outside, but limited by the fact that these may be expensive (and increasingly so) and far from simple to organize 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 (principally as modern "school" knowledge replaces inherited traditional skills) 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. In the case of sea level change, it is probable, as Bryant (1988) points out, that local climatic change and oceanographic factors will have a bigger local impact than the transfer of heat from the atmosphere to the oceans and ice caps. 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 to place not only because of environmental variability, but also because of inherited geological factors that have produced differences in island morphologies and compositions.

There is little evidence that our present socio-political systems have the capacity or willingness to control global events such as the unique Greenhouse ‘experiment’. The majority of the various management options canvassed by Goodman and Jager (1988) recognise the improbability of governments implementing the radical changes needed now to significantly modify the GEs. Meyer-Abich, in a paper with the title ‘Chalk on the White Wall - On the Transformation of Climatological Facts into Political Facts’ (1980), suggested that there are three options for response: prevention, compensation and adaptation but concluded that, from a political point of view, prevention and compensation are much less practical than adaptation. Adaptation allows the least marginal action in the present and defers expenses into the future. In addition, adaptation does not require long-term international cooperation or agreement on long-range goals. If adaptation is the most rational political option, the climate problem tends to fade (‘Chalk on the White Wall’) compared to the already extremely serious problems of development confronting developing countries especially. Thus, at best, climate-oriented policies to cope with climate change would become part of development policies in general.
Judging by developments in the post-war years, the nature of technological changes in the future is hard to imagine. The best-case scenario for a technological 'fix' for the GE must entail the development of a non-polluting form of energy production, such as solar energy. Even if this was developed today, a new energy technology would still take many decades, even if it was economic, before it globally replaced the present sources of energy and pollution. Beyond technology and economics there are powerful vested political interests in those developed countries that export coal and uranium. Clearly, technology cannot avert, in the intermediate term, the inevitable consequences of a Greenhouse induced change in global climate.

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 offices are small and fully stretched to cope with standard recurrent activities. Planning remains in its infancy, finance, data, continuity and technical expertise are limited, environmental planning is almost non-existent and five-year plans (despite a history of 15-year plans in Micronesia) are the extreme limit of long-term planning. Though 'the decision process will not begin until there are more conclusive findings' (Titus, 1987:519) these findings are now sufficiently conclusive, despite their lack of specificity, for some forms of action to be taken now. Even so it is more likely that significant action will not be taken until there is consensus that some local (rather than global) change, can be definitely attributed to GE. 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. An international approach is essential to tackle this global problem though, even at an international level, climatic change is only one element in a complex and integrated set of population, resource, economic and environmental problems. The international context is not discussed here, it is important however to note that GE has now become a United Nations priority and UNEP is working towards an international convention for tackling the problem.

For a particular state options range from direct action to avoid or eliminate the risk (which is clearly not possible for GE), action to reduce vulnerability levels or action to move away from, or abandon, the most risk-prone areas. 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 and 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. Although present indications are that by far the most likely responses to the unprecedented historical occurrence of a possible global sea-level rise of one metre by the year 2045 will be high cost "technical fix" solutions' (Mercer and Peterson, 1988:709) these solutions will simply not be available to atoll states or even other micro-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. This kind of research is most likely to be undertaken with financial assistance from metropolitan states, though, in the past, metropolitan states such as Australia have been unenthusiastic about funding either research programmes or development programmes that strengthen environmental conservation (Durkin, 1988) because of their limited contribution to economic growth. There is some evidence that this is now slowly changing as the implications of GE become more apparent yet it is extremely difficult to get distant (in space and time) problems placed on the political agenda of any country (Mercer and Peterson, 1988:716). 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.

Increased emigration must therefore be inevitably seen as one response to GE, a response that builds on existing trends but that depends almost entirely on the policies of metropolitan states. Nevertheless as the title of a review of the possibility of a
concessionary Australian migration scheme implies - Australia's Next Boat People? (Howlett, 1985) - Islanders could ultimately take migration matters into their own hands. Based on the experience of existing migration from the South Pacific to Australia and New Zealand the bulk of potential migrants from Kiribati and Tuvalu would be young, with some education, and would find employment reasonably easily; moreover only a small proportion of the population would initially choose to migrate. Hastings (1984) has concluded that 'it should not be any great economic burden to this country to subsidise a substantial proportion of island peoples - perhaps all of them in a few instances - but should we do?' His concern was that there are grave dangers in selective migration policies and that much larger countries, such as Papua New Guinea and the Solomon Islands, might subsequently demand the same privileges. This was the principal concern of the Australian Department of Immigration and Ethnic Affairs in 1981 when migration policies were being reviewed, and probably of the FitzGerald Committee in 1988. There is then likely to be significant opposition to concessionary migration at the moment though, in time, when the impact of GE becomes apparent this may decline. Concessionary migration schemes may be granted in other potential destinations such as New Zealand or even the United States. They are unlikely within the South Pacific.

Resettlement poses particular problems. In pre-war times the resettlement of Gilbertese to the Phoenix Islands was eventually unsuccessful so that the resettled population was subsequently transferred to the Solomon Islands (Knudson, 1977). Resettlement from atolls has otherwise 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. The consensus of the few studies that exist of these kinds of resettlements is that a variety of problems occur: firstly, there are racial tensions, often as a result of the denigration of the settlers; secondly, migrants have few skills and some difficulty in obtaining formal employment; thirdly, land problems are often experienced, especially as the resettled community grows in size; fourthly, there are agricultural (and sometimes fishing) problems from converting skills appropriate to atoll situations to those appropriate to high islands. Finally, over time, the solidarity of the community breaks down with increasing individualisation and urbanisation often follows (Knudson, 1977; McKnight, 1977; Koch, 1978; O'Collins, 1988). These conclusions are drawn from resettlement movements within the tropical South Pacific and are quite different from the kind of long distance movements that took Tokelauans to New Zealand. Unfortunately, despite a wealth of data on the changing health status of Tokelauans in New Zealand (e.g. Prior, 1981), there is little detailed published information on the social and economic impact of resettlement. By contrast voluntary individual and household migration in otherwise similar circumstances has been much more successful but has tended to result in selective migration of a
youthful, more educated population, increasing the dependency rate in the villages and islands of outmigration. Resettlement will not therefore 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. In this way some islands were populated, depopulated, and latter repopulated. 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 minimize long-distance migration. Without the flexibility that this kind of resettlement migration provides, the uncertainties and limitations of atoll environments are emphasized and either more permanent migration (usually to urban areas elsewhere) or an uncertain dependence replaces it. The era of great Micronesian and Polynesian voyages may be over but the future may nonetheless lie on distant shores.

Long before the contemporary implications of the Greenhouse Effect were recognised the choice of appropriate development strategies for 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. Without further substantial external assistance, there is little doubt that people who were once described as real and potential 'economic refugees' will become, in less than fifty years, a new group of 'environmental refugees', or, as suggested elsewhere 'ecological refugees' (Pernetta, 1988). It is extremely unlikely that actions taken within the atoll states alone will allay this gloomy forecast. Some of the most
recently populated islands in the world may be depopulated. Some of the most recently formed islands may disappear.
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