MDV/SLR/12

SMALL STATES CONFERENCE ON SEA LEVEL RISE
MALE', 14 – 18 NOVEMBER 1989

STRATEGIES FOR THE FUTURE AND THE IMPORTANCE OF COASTAL ZONE MANAGEMENT IN THE CONTEXT OF SEA-LEVEL RISE

By
Dr Alasdair J. Edwards

Centre for Tropical Coastal Management Studies
Department of Biology, University of Newcastle upon Tyne
Newcastle upon Tyne NE1 7RU, United Kingdom

Conference Coordinator: Hussein Shihab, Director of Environmental Affairs, Ministry of Planning and Environment, Male' 20-05, Republic of Maldives. Tel: (960) 323825 Telex: 66013 RADHUN MF Fax: 325500 RIYAASATH

Small States Conference on Sea Level Rise.
Maldives: 14th-18th November 1989.

Strategies for the future and the importance of coastal zone management in the context of sea-level rise

by

Dr Alasdair J. Edwards

Centre for Tropical Coastal Management Studies
Department of Biology, University of Newcastle upon Tyne
Newcastle upon Tyne NE1 7RU, United Kingdom

STRATEGIES FOR THE FUTURE AND THE IMPORTANCE OF COASTAL ZONE MANAGEMENT IN THE CONTEXT OF SEA-LEVEL RISE.

Introduction

Predictions of global warming and consequent sea-level rise have given rise to a number of problems and issues which are of particular concern to small low-lying countries. In this presentation I will address three sea-level rise issues from a coastal management viewpoint. These are:

1) How long is there before action needs to be taken?

2) The need for careful coastal management now to reduce the economic burdens of the next generation.

3) The role of science and education in preparing society for the consequences of sea-level rise. (Maldives case study).

1. How long before action needs to be taken?

Clearly any decisions on this issue must be based on a study of predictions of both the amounts of sea-level rise which will be experienced by various dates in the future and the rates at which sea-level will be rising at those dates.

Figure 1 shows various predictions for sea-level rise until the year 2100. The ones on which most discussion in this paper is based are those of Wigley (1989), which like the middle projection in Jaeger (1988), show a more or less linear increase. The earlier predictions of Hoffman et al. (1986) show an accelerating rate of sea-level rise whilst van der Ween (1988) just provides an upper and lower estimate for the rise by 2085.

As can be seen from Figure 1, although there is an envelope inside which most projections fall, there is considerable uncertainty in projections and this uncertainty becomes greater and greater the further into the future one goes. This is not surprising given the various levels of uncertainty involved. The first level of uncertainty involves the projections for greenhouse gas emissions. The use of chlorofluorocarbons (CFCs) is already being curbed following the signing of the Montreal protocol and the central issue is how fossil fuel (coal, oil, gas) burning - the primary source of greenhouse gases - will develop over the next decades. The second level of uncertainty involves how much warming will accompany a given increase in greenhouse gas concentrations and how long this warming will take to reach a steady state. The third level of uncertainty involves how fast heat will be transferred vertically downwards through the ocean and how glaciers and polar ice sheets will respond to global warming. As research progresses and political initiatives are taken in respect of CFCs, fossil fuel use and deforestation, so the amount of uncertainty at all levels is reduced and it is important to realise that the projections available should become significantly better year by year.

How does the level of uncertainty affect planning? Clearly to plan effectively, planners and policy makers need well-defined projections, preferably with some indication of the confidence which can be placed in the projections. Research currently in progress at the Climatic Research Unit of the University of East Anglia seeks to do just this and attach confidence limits to projections. To date this does not appear to have been done in any systematic way.

A difference in sea-level of a few centimetres can have profound effects on small low-lying states and it is clear from Figure 1 that beyond about 15-20 years in the future the various sea-level rise predictions we have at present begin to diverge so much as to be of little use to decision makers. For 2010 the 'best estimate' of Wigley (1989) is 11.4 $\pm$2.5 cm; by 2030 the uncertainty in the 'best estimate' is twice as large.

On the one hand one can argue that this does not matter since most economic and development planning is for 3-5 years or at most 10 years ahead. On the other hand it is clear that sea-level rise is a problem that requires strategic planning over a longer timescale and that some decisions which need to be taken now must take account of what may occur 25 years or more into the future.

I will argue that the benefits of taking some of these long-term decisions are such that they seem very cost-effective insurance policies. Conversely I will argue that failure to tackle the problems now will pass additional and unnecessary costs down to the next generation(s) who will have to bear the brunt of paying for sea-defences and other economic burdens consequent on sea-level rise.

Returning to Figure 1, there are various key points I would like to discuss:

By the year 2000 predictions from the various models show sea-level rises of between about 2 cm and 12 cm above a 1985 baseline. The global network of tide-gauges established under the GLOSS and TOGA programmes will allow scientists to test these predictions against what actually happens. Thus in 10 years time we should have a fairly clear idea of which of the models match reality closest. It will then be clearer whether sea-level is rising much as it has done over the last century (low estimate from Wigley, 1989), is rising almost ten times as fast (high estimate from Wigley, 1989), is rising about 3 to 5 times as fast ('best estimates' from Wigley, 1989), or is doing something unpredictable. These comparisons between observed and predicted rises, developments in climatology and improvements in the models will together make predictions for the next 10 years (to 2010) far better than they are now. Meanwhile if the 'best estimates' are accepted as probable and provisions made for such rises in coastal planning, the decision maker can be reasonably sure that vast sums of money will not be sunk into developments which will shortly be swallowed up by the sea.

The first major decision is thus to accept that sea-level may be rising. The second decision is to establish a working envelope of projections which can provide a useful basis for planning.

As an initial working envelope, the 'best estimates' of Wigley (1989) could be adopted. The working envelope can be updated and refined from time to time as new data become available; the important thing is that there is an accepted basis for planning and action. Without it, resources will inevitably be wasted.

Two important conclusions which I drew in my study of the impications of sea-level rise for the Maldives (Edwards, 1989) and which may have a wider application are that if action is **taken now:**

(a) Before sea-level rises sufficiently to cause major problems, there is enough time a) to gather the necessary data to allow planning for sea-level rise, b) to develop the governmental infrastructure and manpower to implement plans, and c) to build up social awareness of the demands that sea-level rise will place on society.

(b) It should be possible to spread the economic demands, that combatting sea-level rise to 2030 will entail, over 25 years or so <u>if</u> forward planning capabilities are developed, national political will is strong and international aid is forthcoming.

In summary, much needs to be done to prepare for sea-level rise. If preparation begins immediately, the economic burdens can be spread, the key personnel trained, and the governmental infrastructure developed in time. Since the developments proposed will in any case have long-term benefits to the countries concerned whilst delays will progressively reduce the abilities of countries to respond adequately to the threat of rising sea-level, there seems no excuse to procrastinate. Aid agencies should take on a catalytic role in promoting training, coastal zone management and other initiatives directed at developing the capabilities of small states to respond effectively.

2. The need for coastal management.

The Commonwealth Expert Group on Climate Change and Sea level Rise (Holdgate et al., 1989) recommend:

> "First, all governments should endeavour to identify - and developing countries should be helped to identify - areas of vulnerability to the effects of sea level rise based on detailed survey data and plausible global assumptions about the likely rise. Second, all governments should take initiatives to develop national coastal zone management policy. This should include consideration of sea level rise analysis leading to a full range of options (including land use regulation, engineering works, managed flooding) that could be implemented to deal with the future threat."

In this section I will argue that for small island states, civil engineering solutions may not always be appropriate and should perhaps be viewed as a last resort, whilst careful management of coastal resources such as coral reefs may be a better option.

2.1. Civil engineering solutions

If sea-level is going to rise the instinctive response is to build sea-defence works to protect the land. Unfortunately, sea defences (seawalls, breakwaters etc.) are expensive and may often just provide a temporary respite or not be a cost-effective option.

Not only are small low-lying island nations very vulnerable to rising sea-level, they are also less easy to protect with sea-defence works and the costs per hectare of land protected are likely to be higher.

The Maldives lie almost entirely within 3.5 m of mean sea-level and have their human habitation, industry and vital infrastructure within 0.8-2.0 m of mean sea-level. The islands are made up of porous coral rock and sand. Groundwater, where present, consists of a freshwater lens floating on seawater which penetrates the island's foundations from the surrounding ocean. On Male', the capital island, the freshwater lens was probably up to 20 m thick originally in the middle of the island. As the freshwater has been used up so the lens has thinned and seawater has moved inwards and upwards to take its place so that wells on the periphery of the island are too salty to use. On Male' the water table (top of the freshwater lens) is on average only about 1.2 m below ground level. Although coastal sea defence structures may keep waves from sweeping onto the land, because the island is porous the water table will rise at the same rate as sea-level. In the long-term this problem must also be addressed (by for instance raising the level of the whole island surface) and the building of dikes or seawalls alone can only be regarded as temporary measures. The cost-effectiveness of building expensive sea defences which may only be of temporary use will make such investment difficult to justify.

Thus the porous nature of most low-lying small islands casts severe doubts on the efficacy of certain civil engineering "solutions".

The other problem that small island states face is that the cost per hectare of defending small islands is much greater than that for defending large islands, even if the overall cost may be less (Figure 2). Further, it is significantly more costly to defend long thin islands of a given area than round (or square) ones of the same area (Figure 3). Unfortunately the islands that form along atoll rims are quite often long and thin, further increasing the cost per unit area of sea-defence.

<u>Costs of being small</u>: as an example one can consider the costs of building a seawall around a 200 m diameter island as compared to a 2 km diameter island. Assuming cheap construction using largely local materials, such a wall might cost $400 per metre. Although the total cost for the larger island will be ten times that for the smaller, the cost per hectare of land protected will be one tenth of that for the smaller. Thus the cost-effectiveness of

sea-defence appears to be directly proportional to the diameter of an island.

Costs of being long and thin: as an example one can consider the cost of defending 100 ha of land and compare the costs of building a seawall around a 1 km square as opposed to a 200 m x 5 km strip of land. In the latter case the cost will be 2.6 times that in the former case. Thus the longer and thinner an island is the greater the costs of defending a given area of land and the greater the difficulty of justifying expenditure on sea-defence.

Low-lying coral island states thus appear to have the worst of all possible worlds. They are porous and composed of small islands which are often long and thin. Thus although particularly vulnerable to sea-level rise they are about the least cost-effective places to defend by civil engineering means.

It is appropriate to reiterate here a recommendation of the Commonwealth report Climate Change: Meeting the Challenge (Holdgate et al., 1989).

> "We recommend therefore that small island states consider proposals for major sea defence systems with extreme caution and only proceed when all other options are exhausted and a positive social and economic benefit-cost outcome is demonstrated."

2.2. The response of coral reefs to rising sea-level

In the context of sea-level rise, most tropical islands have the important asset of living growing coral reefs. These reefs in the case of low-lying sediment based islands are the primary reason for the existence of the islands in the first place. It is their wave energy absorbing capacity which has allowed sediments derived from their own erosion to accumulate and be shaped by waves and currents into dry land. Once islands are established it is primarily the offshore protection provided by the reefs which maintains the islands' integrity. Due to the dynamic nature of the system, although the coastlines of the islands may appear fixed they are likely to be continually moving if looked at over periods of tens to hundreds of years. On small islands even seasonal changes will be apparent.

Coral reefs tend to grow up to just below mean low water level and as global mean sea-level rises they will tend to grow vertically upward to keep pace with it. In the Maldives they have grown 10-20 m upwards within the last 10,000 years as sea-level has risen following the last glaciation (Woodroffe, 1989). A key question is how reefs will respond to the increased rates of sea-level rise predicted.

In this context it is the rates of sea-level rise which matter rather than the actual amounts that sea-level is predicted to rise by a given time. The rates of sea-level rise from the predictions of Wigley (1989) are as follows:

High	11 mm per year
Best estimate - High	6 mm per year
Best estimate - Low	3.7 mm per year
Low	1 mm per year

Over the last century the rate of sea-level rise has been about 1.2 mm per year.

Individual corals, particularly branching species like those in the genus <u>Acropora</u>, can grow up to 15 centimetres in a year. However, what is of interest in the context of rising sea-level is net vertical accretion rates averaged across whole coral reefs. References to growth and growth rates that follow are to such vertical growth by whole reefs.

The predicted rates of sea-level rise listed above are compared graphically in Figure 4 with net rates of vertical accretion by coral reefs deduced from a variety of studies.

The important points to emerge from this comparison are as follows:

a) Coral reef flats should be able to accrete fast enough to keep up with sea-level rise if the rate of rise falls in the 'Low' or 'Best estimate - Low' projections of Wigley (1989).

b) If sea-level rises according to the 'Best estimate - High' rate then although some reef flats (such as those dominated by branching corals) may be able to keep up, it is likely that others (such as those on very exposed coasts) may lag behind. However, since the the energy of waves increases as the square of wave height, even if reef flats grow upwards at only half the 'Best estimate - High' rate they may still reduce the likely adverse effects of sea-level rise as far as erosion is concerned to one quarter of what it might have been.

c) The highest rate of sea-level rise predicted by Wigley (1989) corresponds to the highest rates of reef growth recorded. It is however, improbable that reef flats will respond by vertical growth at these high rates and thus the sea-defence services offered by reefs will steadily decline.

In summary, it appears that tropical islands surrounded by healthy growing reefs should benefit considerably from the sea-defence offered by the reef flats unless rates of sea-level rise are towards the top end of those predicted.

Another service provided by coral reefs is that their constant erosion by waves and currents generates sediments (coral sand) which maintain beaches and sandy island coastlines. If reefs are healthy and growing then this sediment production will continue. As sea-level rises a steady supply of new sediment created from the breakdown of coral, calcareous algae, shellfish, and foraminiferans will be needed to maintain beaches. If reefs are degraded or dead, not only will their sea-defence function be lost but also their sediment supply function.

Thus, if you take care of your coral reefs they may take care of you. If you don't, they certainly won't.

3. The role of science and education in preparing society for the consequences of sea-level rise - Maldives case study.

In the Maldives, which can perhaps be considered as a reasonably representative small island developing nation, two separate but linked issues which need action have been identified. Firstly, there is no effective mechanism for environmental impact assessment (EIA) so that environmentally unsound projects which may prejudice the integrity of islands are allowed to go ahead every year. Secondly, there is neither adequate data nor adequate governmental manpower to cope with the challenges posed by sea-level rise. The first issue requires immediate action and is under study, the second issue can be dealt with over the 15-20 years which will hopefully elapse before serious problems develop.

Details of the action plans recommended to the Republic of Maldives (Edwards, 1989) will not be reiterated here but a few of the key points which may have general applicability will be discussed.

3.1. Skilled manpower

Firstly, the government departments which would be in the forefront of the additional research, planning, sea-defence engineering and decision making which sea-level rise would generate were identified. In the Maldives these are the Ministry of Public Works and Labour, the Marine Research Section and the Agriculture Section of the Ministry of Fisheries and Agriculture, the Ministry of Planning and Environment, the Office of Physical Planning and Design and the Department of Meteorology.

It was clear that all these departments of government would need strengthening to be able to deal with the additional burdens and that if enough indigenous skilled personnel were to be available within 15 years, education and training would need to begin immediately. The fields in which training was identified as necessary were: engineering, planning, economics, marine biology, oceanography, agriculture and geology. The need for highly skilled manpower in government has implications both for education - an increased demand for expensive university education overseas - and for public sector salaries - a need to remunerate adequately highly skilled public servants (or lose them to the private sector at the first opportunity).

In small developing nations with relatively small populations this acute shortage of the necessary skilled manpower is likely to be a widespread problem. Although external consultants have a role to play, in the long term it will clearly be more cost-effective to train local personnel in the skills needed. Aid agencies should give every encouragement to such training.

3.2. Uncertainty - convincing the people

Uncertainty about sea-level rise is not just a problem to planners but affects society as a whole. In Maldivian society I found some people who were unduly alarmed by wild estimates of sea-level rise, others who were convinced that sea-level was not going to rise, and others who expected it would rise but awaited unequivocal evidence. For politicians to be able to take the hard decisions which will need to be taken, they need societies who are convinced of the reality of sea-level rise and are united in their determination to deal with the problems arising from it. In the Maldives the Department of Meteorology already operates tide gauges under the Tropical Ocean - Global Atmosphere (TOGA) programme and has thus taken the first steps to allowing the reality of sea-level rise in the Maldives to be demonstrated unequivocally. Local data on mean sea-level and the rate of change in mean sea-level are fundamental to all planning, and when it comes to convincing Maldivian society of sea-level rise, these data, collected in the Maldives by Maldivians, will be critical.

The need for local tide gauge data and adequately staffed Departments of Meteorology and Oceanography which can participate in international programmes on climate monitoring will be common to all small island states.

3.3. Environmental databases

Obtaining data on local rates of sea-level rise, which may differ from global mean rates if land is locally sinking or rising, is a first step. However, such data can only be used by planners if there is detailed information on land topography, status of coastal resources (coral reefs, seagrasses, mangroves, etc.), population and settlement patterns, agricultural land use, geology, groundwater resources, meteorology, etc. This sort of information is often not available or is incomplete. In the Maldives and probably in many other developing countries establishing an adequate environmental database may take several years. Without such information it is very difficult to assess vulnerabilities and decide priorities.

For the Maldives it was suggested that a radically strengthened Environment Section in the Ministry of Planning and Environment should undertake the task of compiling an environmental database for the country.

3.4. Coastal zone management legislation

Meanwhile, as was emphasised in section 2, it is important to protect those resources that help protect coastal land from the sea. In particular, activities such as coral mining, dynamiting of coral, uncontrolled sand mining, ill-considered dredging operations, land reclamation, discharge of nutrient rich sewage onto reefs, and building of coastal structures (causeways, groynes, jetties, breakwaters, etc.) which alter water movements along the coast, need to be carefully controlled. If legislation does not already regulate these activities, such legislation needs to be drafted and enforced. Usually such legislation will take the form of regulations to ensure that developments on the coast are subject to environmental assessment or environmental impact assessment.

In the Maldives it was suggested that the Environment Section should assume responsibility for drafting adequately wide ranging environmental legislation and ensuring its implementation through environmental impact assessment requirements.

Environmental legislation places additional burdens on those public bodies concerned with construction and development. In the Maldives, it is the Ministry of Public Works and Labour and Office of Physical Planning and Design which would have to bear the brunt of complying with such legislation. Environmental assessment or environmental impact assessment require highly skilled people. Such skilled personnel may be lacking locally so either education and training may be required and/or expensive foreign consultants have to be hired. This seems a key area where aid needs to be made available to small states.

3.5. Public awareness

Another key area is to ensure that the public are well-informed on environmental issues and the impact that sea-level rise may have on their country. Long-term public awareness campaigns need to be instigated by Environment Departments in cooperation with Ministries of Education to facilitate this. Such campaigns can also help to make people understand the need for environmental legislation and reshape attitudes to certain natural resources. Also, if in the long term some resettlement of the populations of particularly vulnerable small islands is likely to have to take place, then the societies on such islands can be educated about the necessity well in advance.

3.6. Research

To adjust to sea-level rise and global warming there will be a need for research in fields such as agriculture, hydrology and oceanography. Also it will be necessary, if any reliance is being placed on the response of coral reefs to sea-level rise, to determine local rates of accretion and monitor the state of reefs. Such research will need funding. Although much of the work will need to be carried out at the local level, exchange of ideas and techniques between countries with similar problems will help ensure the best use of limited manpower. Interdisciplinary meetings of scientists and planners involved in sea-level rise issues should be encouraged to promote this.

Summary

1) Forward planning to cope with the demands of sea-level rise needs to begin now so that costs can be spread over time and nations will be capable of responding effectively when sea-level rise becomes serious.

2) Training of personnel in appropriate subject areas and gathering of topographic, demographic and environmental information necessary for planning, needs to start now.

3) Local tide gauge data must be collected in order to establish an accepted basis for planning and action as early as possible.

4) Civil engineering solutions may not be appropriate except as a last resort for small island states.

5) Currently available figures on coral reef growth indicate that reefs should be able to keep up with rising sea-level if slower sea-level rise scenarios are correct.

6) Damage to the coastal environment will exacerbate the problems of sea-level rise. If not already in existence, national coastal zone management plans should be developed.

References

Edwards, A.J. (1989). The implications of sea-level rise for the Republic of Maldives. Report for Commonwealth Secretariat. 137 pp.

Hoffman, J.S., Wells, J.B. & Titus, J.G. (1986). Future global warming and sea-level rise. pp. 245-266, in Sigbjarnarson (ed.), Iceland Coastal and River Symposium, Proceedings. National Energy Authority, Reykjavik.

Holdgate, M.W. et al. (1989). Climate change: meeting the challenge. Commonwealth Secretariat: London. 131 pp.

Jaeger, J. (1988). Developing policies for responding to climatic change. World Climate Programme: Impact Studies. WCIP-I. WMO/TD-No.225. 53 pp.

Van der Ween, C.J. (1988). Projecting future sea level. Surveys in Geophysics 9: 389-418.

Wigley, T.M.L. (1989). Scientific assessment of climate change and its impact. Presentation to Downing Street Seminar, UK Department of Environment.

Woodroffe, C. (1989). Maldives and sea-level rise: an environmental perspective. Report to Ministry of Planning and Environment, Republic of Maldives. 64 pp.

FIGURE 1. Various projections of sea level rise until 2100.

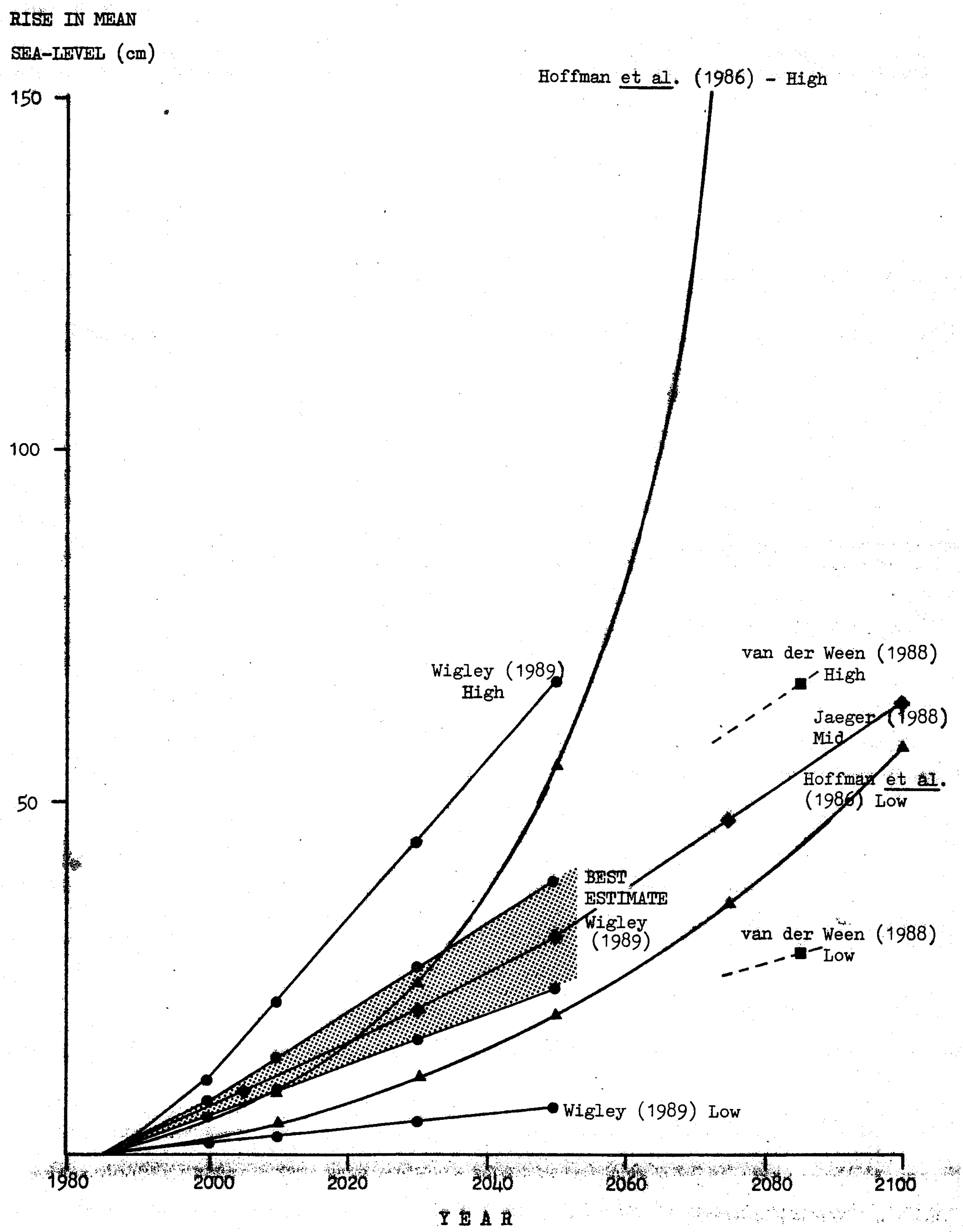
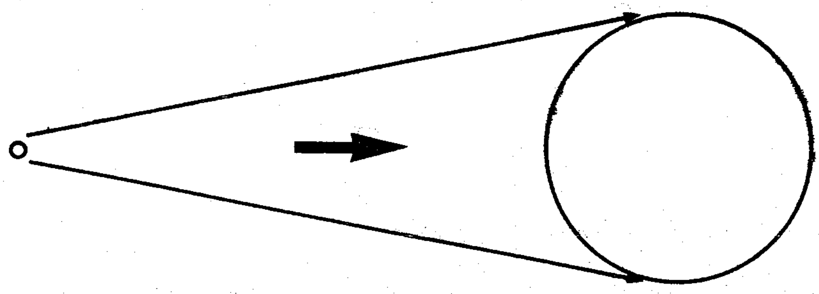


FIGURE 2.



COSTS OF BEING SMALL

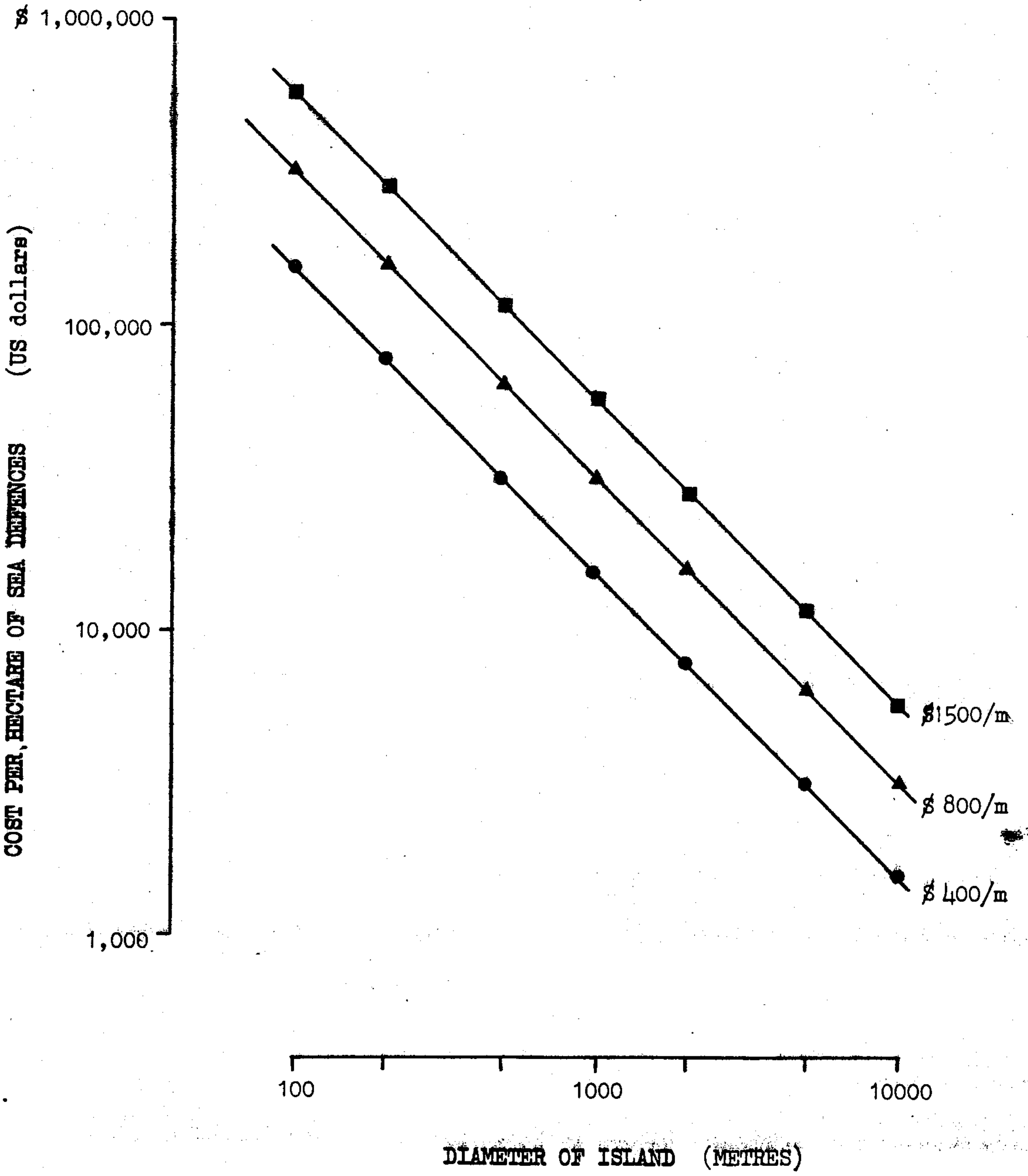
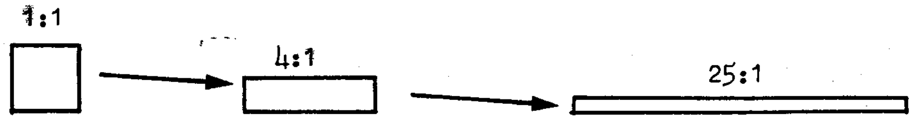


FIGURE 3.



COSTS OF BEING LONG AND THIN

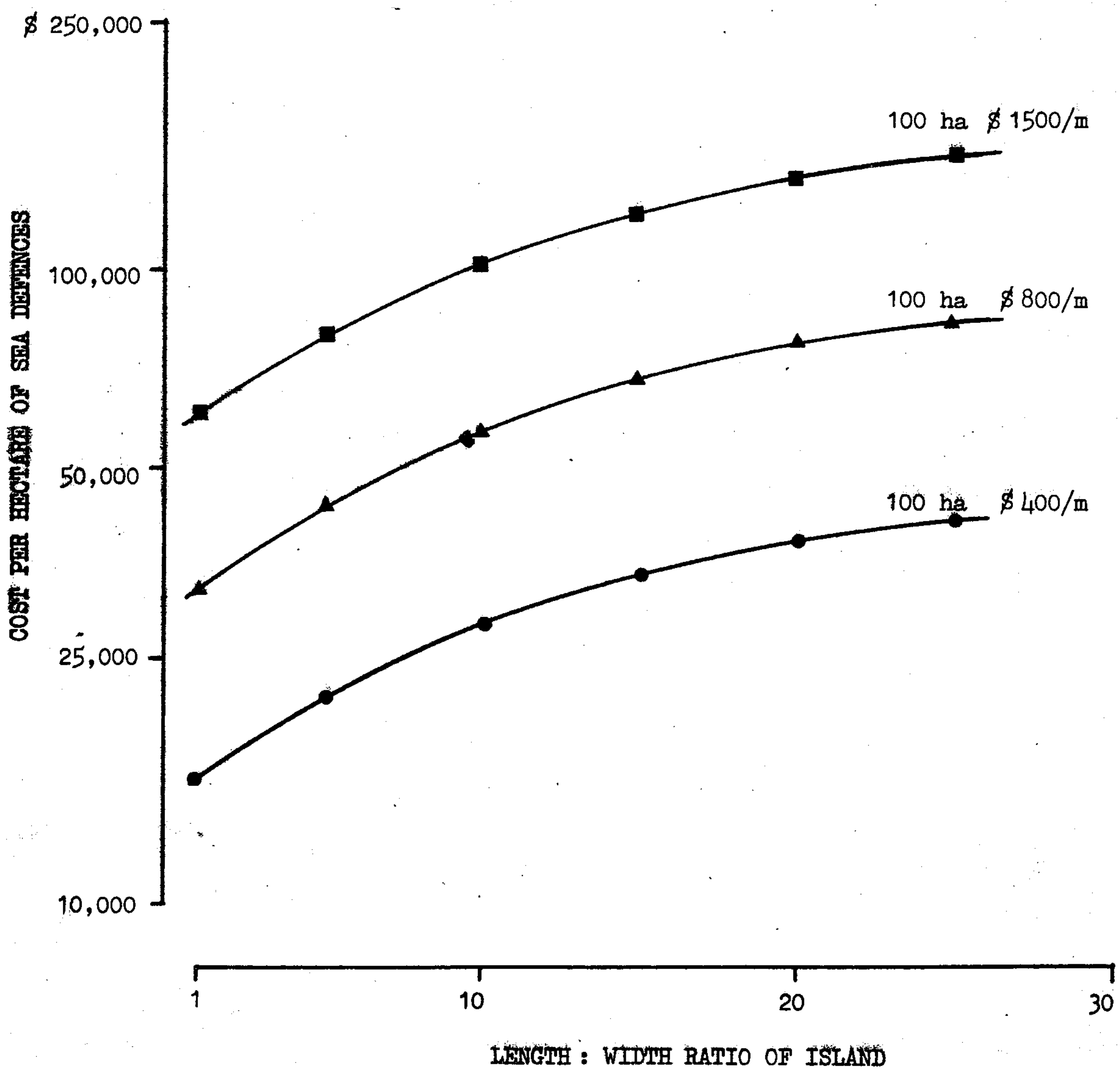
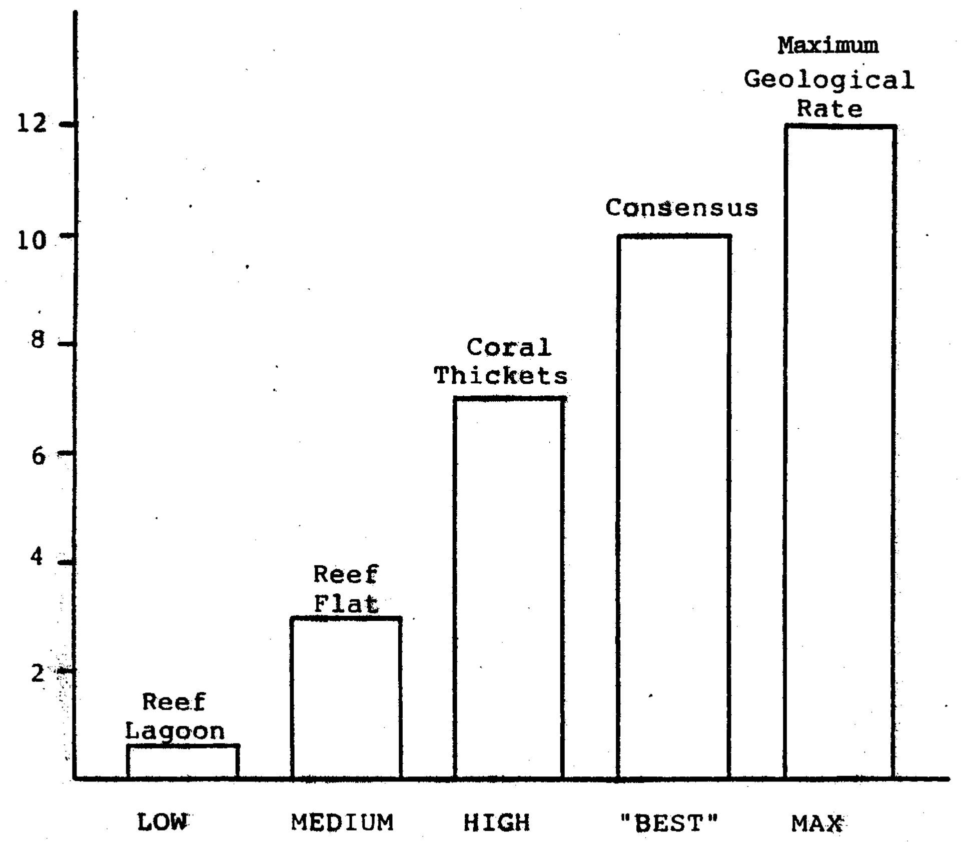
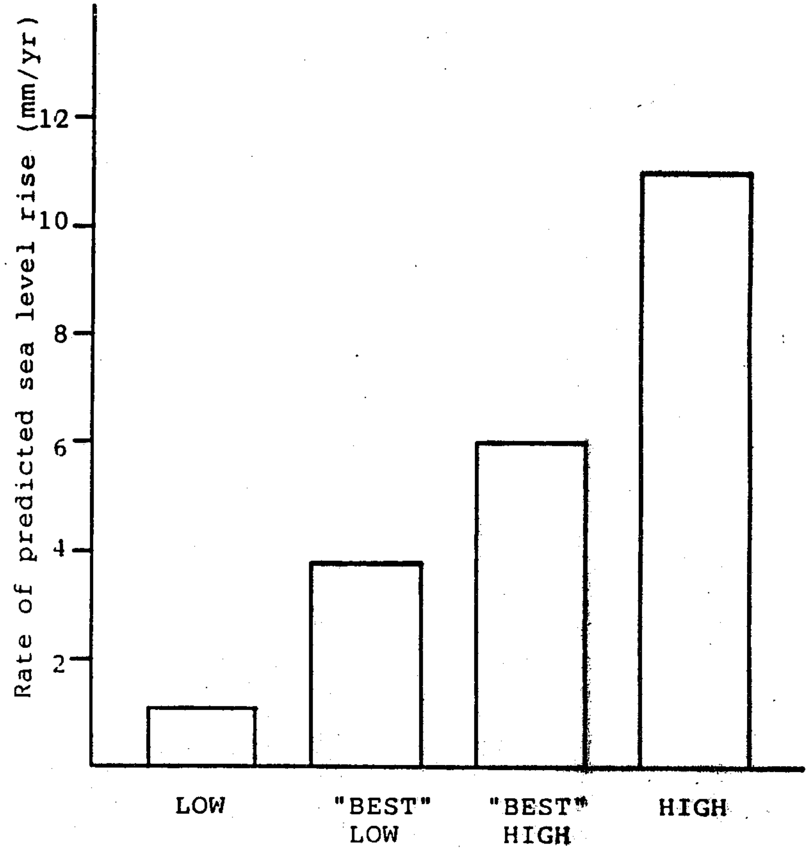


FIGURE 4.

RATES OF VERTICAL GROWTH OF CORAL REEFS **VERSUS** **PROJECTED RATES OF SEA-LEVEL RISE**



Growth of various reef communities



Various scenarios of predicted sea level rise, after Wigley (1989)