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Maintaining coastal and lagoonal ecosystems and productivity

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The paper discusses issues that should be addressed through an integrated process of strategic planning and design to ensure proper consideration of environmental, social and economic impacts in any proposal for island protection works.

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Introduction

Global attention was drawn to the threat of sea level rise to low lying islands in a dramatic presentation by the President of the Republic of Maldives to the 1992 World Summit on Sustainable Development in Rio de Janiero. The Maldives and other low-lying island and atoll states are especially vulnerable to climate change and associated sea-level rise. In many cases (e.g., the Bahamas, Kiribati, the Maldives, the Marshall Islands), much of the land area rarely exceeds 3-4 m above present mean sea level. Indeed the highest land in the Maldives is 2.4 metres at a point on Wilingili Island in Addu Atoll. (http://zhenghe.tripod.com/m/maldives/index.html).

Global attention has been particularly focussed on the issues of loss of land due to sea level rise and vulnerability of land to increasing frequency and severity of storms. Low lying islands face the prospect of losing most if not all of their land mass. The situation is particularly critical where the islands are coral cays formed from the accumulated limestone skeletons of corals, coralline algae and other shallow marine life. It can be similarly critical for steep-sided rocky islands surrounded by fringing coral reefs and lagoons where the reef and lagoonal structure supports and sustains beaches and coastal land.

The maintenance and growth of such islands depends on the health of the marine environment. They exist because of the accumulation of skeletal carbonate debris produced by calcification in a healthy coral reef community. In a period of stable sea-level, if carbonate production stops or is significantly reduced for a long period, islands are likely to decrease through failure to replace beach materials washed away in severe storms. In a period of sea-level rise the capacity of reefs to grow upwards and to supply sand to maintain and grow existing islands will generally require very high levels of reef health.

The issues of coral island protection present an extreme and sensitive subset of the global issues that identify the need for an integrated and ecosystem-based management approach to management of coastal and marine ecosystems. In a situation with few if any alternatives, human coral island communities and nations depend on the productivity of goods and services by marine ecosystems. As the impacts of the human community reduce the health or productivity of the ecosystem through single or combined impacts such as pollution, unsustainable exploitation and habitat destruction, the health of the marine ecosystem becomes a priority socio-economic issue. As the combined impacts of the human community exceed the productive capacity of the marine ecosystem, the local supply of goods and services reduces. In a situation with few internal resource alternatives, such communities become increasingly dependent on external support and service-based economic activities.

The purpose of this paper is to provide a multidisciplinary introduction to issues of coral island growth and maintenance and some lessons of management experience. This may provide a contribution to developing effective nationally and locally appropriate approaches for integrated management to sustain coral reefs, islands, associated ecosystems and the human communities that depend upon them.

The formation of coral islands

Corals build skeletons through deposition of calcium carbonate in an association with symbiotic algal cells as do some other reef animals including giant clams. Coralline algae also deposit calcium carbonate and some corralline algal species builds reefs by cementing rubble into substantial structures.

As reef structures mature and consolidate they attract species including worms, shellfish and sponges that make secure shelters by burrowing or boring into the reef structure. This and the action of grazing species and physical impacts such as severe storm waves remove carbonate materials and erode reefs. The extent to which a reef consolidates and grows is determined by the extent to which calcification exceeds erosion.

Hutchings and Hoegh -Guldberg (2008) discuss estimates of carbonate production through calcification in the range 1 – 2 metres per century. This is consistent with Pandolfi and Kelley (2008) who suggest that during rising seas healthy coral reefs can grow upwards at rates exceeding 10 metres per thousand years.

Smith and Kinsey (1976) reported carbonate accumulation in shallow, seaward portions of modern mature coral reefs equivalent to a maximum vertical accretion of 0.5 to 5 metres per thousand years. Hutchings and Hoegh-Guldberg (2008) discuss rates of long term reef growth of 0.1-0.2 metres per thousand years calculating that reflects rates of calcification 3 – 10 times higher than the rate of calcium carbonate removal by biological and physical erosion.

Whether sea-level is stable or rising, the extent to which calcium carbonate production exceeds loss through erosion is critical for the maintenance of coral cays, lagoons and beaches. Recently DeAth et al (2009) have reported a calcification decline of 14.2% since 1990. from an analysis of cores from 328 colonies of massive *Porites* corals from 69 reefs of the Great Barrier Reef (GBR) in Australia. They note that the cause or causes are unknown but comment that such a severe and sudden decline in calcification is unprecedented in at least the past 400 years.

The reported calcification decline reported by De'Ath et al (2009) comes on top of other reports of reef condition discussed in a synthesis by Jackson (2008) who commented that many scientists believe that the cumulative forces of overfishing, pollution and climate change are so great that coral reefs may virtually disappear within a few decades.

From the information available for his synthesis, Jackson (2008) found encouragement in the fact that unpopulated, unfished and unpolluted reefs in the central Pacific were healthy with coral cover in excess of 50% but noted that other Pacific reefs had half that coral cover. Where they occur, such declines in coral cover and reef health have major implications in terms of reef island maintenance and decline even in the absence of sea level rise.

Coastal engineering to secure islands and beaches

Coastal engineering has a long history of works to create and protect harbours and to reclaim low lying areas and protect them from salt water incursions. Horikawa (1996) cites reports of harbour works and artificial island construction at Ohwada Domari in 1172 as the first evidence of coastal engineering in Japan. Bijker (1996) discusses the long and continuing history of Dutch engineering to reclaim and protect low lying and subsiding lands from the sea for agriculture and settlement. He cites monastic records of 1105 as the first directly documented evidence and archaeological evidence from 2200 to 2400 years before present. Bijker noted that the archaeological evidence is supported by references in the writing of the Roman Pliny (AD 23-79) to people in living on man-made islands in a low lying coastal area on the northern border of the Netherlands with Germany.

The ongoing history of coastal engineering includes measures to protect existing coastlines from marine flooding and from erosion of coasts and beaches. In low lying areas it includes creation and protection to retain new land. Rising sea-levels give urgency to such works.

There are four basic approaches to securing and developing islands and beaches.

The first involves construction of sea walls of concrete or rock, typically along the extreme high water mark to block the reach of waves that would otherwise remove supratidal sediments or sand dune.

The second involves reclamation by dumping solid material, or fill, comprising rocks, rubble, gravel or sand to build up areas of intertidal or subtidal seabed to a level beyond the reach of the highest tides. The fill is often contained by sea walls to protect it from erosion. This approach is often favoured on economic grounds because, with appropriate design, a reclaimed area can serve as a sea wall while the created land creates an economic asset to offset at least some costs.

The third involves building groynes which are wall-like structures projecting outwards from high tide to below low tide level to slow or prevent long shore movement of intertidal sediments and reduce loss of shallow sediment to deeper water.

The fourth involves construction or placement of intertidal or subtidal structures that can absorb sufficient energy of incoming storm waves so that they do not scour, undermine or erode other protective structures or the area being protected.

Any such works have an immediate local impact by alienating habitat in the area in which they are placed but may have much wider impacts that are not intuitively obvious. These include altering lagoonal water circulation and the flow of nutrients, organic matter and sediments in ways that reduce carbonate productivity; blocking fish migration routes; and destroying breeding or nursery areas of fish or species important to them. Such impacts may be very significant where carbonate sand and rubble from coral reef communities provide the primary source of natural sediment for sustaining islands or beaches. They can also be very significant if they reduce the habitat and productivity of species that are important natural food resources of island people.

The physical dynamics of sediment supply and transport are critical factors in the context of management of rocky and sedimentary oceanic islands. Both are likely to be significantly changed by expected climate-related changes and may be further affected by measures intended to secure islands in the face of such changes.

There is a history of unfortunate and sometimes very serious unintended consequences of coastal and island protection and development initiatives. They include:

- altered flow regimes causing unintended erosion or sand bar accumulation;
- sea walls that trap overtopping water on the “protected” land;

- large scale reclamations removing wetland areas that are important breeding or feeding areas for fished species; and
- impacts of deep foundations and heavy equipment compressing fragile carbonate soils and disrupting natural freshwater flows and storages.

Design and construction of works on coral islands require special skills and understanding of their fragile nature and their linkage to the reefs that formed them.

Strategies for island protection

The prospect of further deterioration of shallow marine environments, whether from expected global climate change, continuing of human impacts or from measures designed to protect land in the face of those impacts, has major implications for island people. There are related economic, social and strategic implications for most nations within or bordering the Pacific and Indian Oceans and the South-East Asian Sea.

Coastal engineering measures are often large scale, costly and disruptive. It is important that all reasonable steps are taken to ensure that they are competent and effective. The risks of unintended social, environmental and economic consequences and costs should be systematically considered and addressed in planning such measures.

There is growing understanding and experience of the interactions of marine and terrestrial ecosystems and of the costs, benefits and unintended consequences that can flow from interventions to address island and coastal protection. The developing practice of integrated coastal and marine resource management (eg Cicin Sain and Knecht, 1998, Rais et al 1999, Lawrence et al 2002, Kay and Alder, 2005) provides a basis for systematic consideration of the social, environmental and economic interactions that should guide selection of the best option for a particular situation.

The concept of ecosystem-based management is particularly relevant in management of coral cays and other islands associated with coral reefs. The core concept is sustainable management designed and conducted within the constraints of the processes and biological diversity of ecological systems. The politics and socio-economics of ecosystem based management of marine resources are complex when maintenance of environmental services constrains or adds significant costs to socio-economic objectives. This is well discussed in a special issue of Marine Ecology Progress Series (Browman and Stergiou KI (eds) (2005))

Each island has a specific set of interactions of social, environmental and economic factors that should be evaluated at a number of scales to select the most appropriate protective strategy. Key considerations are: the health of the marine ecosystem, its role in supplying sediments and protecting the island beaches from storm waves and the socio-economic importance of and community dependence upon local marine resources.

In many islands where protective measures are likely to be needed in the face of sea-level rise, environmental damage has already compromised carbonate productivity. Current economic activity has typically been associated with the growth of human population and, in multi-island nations, migration of people from outlying islands. The development that has occurred to provide homes, health and sanitation services, employment and food for a growing population is often associated with declines in nearshore environments and productivity of natural resources through pollution, overfishing and reclamation.

Development of an appropriate strategy for island protection requires evaluation of the short and longer term social, environmental and economic implications of many linked considerations including:

- The need for and location of and most appropriate form of engineering works needed to protect or build up island level;
- Current impacts on the environment, natural resource productivity and ecosystem services;
- Options for repairing past damage and new construction damage and restoring environmental condition, productivity and resilience;
- Current and likely future socio-economic dependence on local marine resources and environmental services;
- Potential impacts of construction on environment, human amenity and natural resource productivity and ecosystem services on site and more distantly; and
- Requirements for maintenance of completed works

Such issues are most effectively evaluated in the context of development and ongoing implementation of an ecosystem-based plan for ocean and island resources. A key strategic issue in such a plan is to establish specific objectives and a mandatory process of regular review of performance and future prospects in the light of experience and the results of monitoring and research

Restoration and repair of tropical marine ecosystems

In the light of Jackson’s (2008) reflections that undeveloped reefs in the Pacific have twice the coral cover of those that are subject to resident human populations, pollution and overfishing, restoration and repair to bring reefs back to good health must be a priority consideration in any sustainable management regime.

Substantial research has been carried out to develop methods for repair or restoration of coral reefs damaged by ship groundings or by events such as coral bleaching or predation by Crown of Thorns starfish. In 2005 the International Coral Reef Initiative (ICRI) became concerned that repair and restoration methods that are effective at small scales were being inappropriately promoted and regarded as means for widespread rehabilitation and replacement of coral reefs. ICRI had two major concerns. The first was that governments and agencies might be induced to spend substantial sums in the expectation that wide-scale accelerated recovery of coral reefs could occur after major and widespread phenomena such as coral bleaching. The second was that a false view was being promoted that coral reefs were easily restored or created so their destruction could be regarded as a minor and reversible cost of development or public works.

Following an ICRI resolution on this topic (ICRI 2005), guidelines intended to inform managers and political decision-makers on reef restoration were prepared by Edwards and Gomez (2007). These guidelines are basd on an authoritative overview of the scientific literature and experience from field applications to advise on the strengths, weaknesses, costs and coverage of restoration options.

In the context of discussion of island conservation and revival the guidelines of Edwards and Gomez (2007) are important because they emphasise that:

- Coral reef restoration is in its infancy.
- We cannot create fully functional reefs.
- Active coral reef restoration has been carried out with some success at scales of up to a few hectares only.
- Although restoration can enhance conservation efforts, restoration is always a poor second to the preservation of original habitats.
- Coral reefs that are relatively unstressed by anthropogenic impacts can often recover naturally from disturbances without human intervention.

Widespread reef restoration of damaged reefs would be required at a scale of tens to hundreds of square kilometres in order to recreate functional carbonate exporting reef systems at the scale needed to sustain islands during modest sealevel rise. This is at best a distant prospect but measures to produce carbonates through local mariculture may develop to play an important role in maintaining islands in the face of rising sea level. Plans for island protection should be based on maintaining healthy coral reefs by reducing or removing human impacts upon them. This is essential to sustain islands and beaches in the face of ocean warming, acidification and sea level rise associated with climate change.

Existing technologies can be rapidly applied to reduce human impacts on reef health. These include advanced land ,liquid and solid waste management to prevent further pollution from silts, agricultural and industrial pollutants, nutrients, and toxic materials.

Engagement and involvement of human communities from the individual to the national level are needed to develop understanding of the issues and personal commitment to actions that may reduce old freedoms of action in order to protect natural resource systems for the future. Education and communication programs that engage different groups within the communities are important in successful introduction of new management approaches.

A further important component of ecosystem based management and community involvement is the establishment of marine sanctuaries or reserves in which human activities of fishing and collecting are prohibited. Other uses may be allowed only if they are consistent with the protection objective. There is typically resistance to the establishment of such areas but when properly managed, they rapidly serve as sanctuaries where people can see large fish and more life than on impacted reefs. When fully established they usually become popular with fishermen who can catch more fish near the borders of protected areas than elsewhere and this can lead to community support for more extensive protection (Ward, 2004).

Measures to reduce and halt human impacts on reef ecosystems should be a central element of planning for island protection. These can rarely be imposed from outside and usually require culturally appropriate engagement of people who will be affected with consideration and consultation on issues at a number of scales from national to individual. Such engagement should be openly undertaken as part of a systematic process to develop an ecosystem-based management plan.

A current example of such a process is the plan being developed for Addu Atoll by the Republic of Maldives through a local process being mentored by the Centre for Maritime Studies of the University of Queensland (CMS, 2009). An example of the range of scales and objectives is provided in Table 1.

Table 1. Scale of planning for the Addu Ecosystem-based Management Plan

Scale	Objectives	Process	Outputs	Verification
Atoll	- Coordinated government approach - Cooperation with local communities	- Policy, institutional design and strategic development	- Agreement and policy contained in economic, marine and land use policies - Climate change adaptation policies	- Vision Addu 2015 - Millennium Goals 2002
Island groups	- Sustainable use of the resources - Minimisation of cumulative impacts	- Strategies planning (government documents)	- Strategic land use plans - Waste management strategy - Infrastructure development strategy - Ground water management strategies	- 7th National Development Plan - National Biodiversity and Action Plan
Lagoon areas	- Specific targeted intervention to off-set impacts from some human activity	- Tactical planning (sustainable resource management planning	- Marine protected areas	- Environmental Protection and Preservation Act - Fisheries Law of Maldives
Near shore oceanic region adjacent to the atoll	- Recognise the impacts from actions outside the atoll	- Tactical planning (marine resource use)	- Regional and international agreements recognised	- Environmental Protection and Preservation Act - Fisheries Law of Maldives
Village	- Targeted management of specific biophysical and	- Site planning (environmental management plans (EMPs))	- Ecosystem reserves - Resource use or harvest plans	- National Solid Waste Management Policy for the Republic

	cultural impacts as a result of human development		- Business and project plans - Site tenure / management plans	of Maldives - Environmental Impact Assessment Regulations 2007 - Population Policy of the Maldives
Households	- Reduction in waste, sediment run-off, coral and sand loss, noise and visual pollution through individual actions	- Promote "best practice" in environmental management and conservation	- Prevention of impacts and pollution at the source	- National Solid Waste Management Policy for the Republic of Maldives - Environmental Impact Assessment Regulations 2007 - Population Policy of the Maldives
Individuals	- Better understanding of actions and individuals on the environment	- Education on the cause and effects of environmental damage	- Better informed community -	

Source CMS (2009)

Synthesis and conclusion

The development and implementation of integrated ecosystem-based coastal and ocean management are probably the most urgent issues facing small island nations that have no significant resource base other than the productivity of their marine ecosystems. The protection of coral islands and maintenance of the health and productivity of coral reefs and associated ecosystems are critical to the wellbeing of many people in small island nations in the Pacific and Indian Oceans and the East Asian and Caribbean Seas.

The protection of islands should be approached as a component of overall integrated ecosystem-based management, drawing upon global experience to develop capacity and planning and management regimes that engage and involve local communities in solutions that are effective and appropriate to the significant and troubling problems predicted from climate and other global change.

References

Bijker E W History and Heritage of Coastal engineering in the Netherlands *History and Heritage of Coastal Engineering* American Society of Civil Engineers,. New York USA pp 390 412

Browman HI, Stergiou KI (eds) (2005) Politics and socioeconomics of ecosystem-based management of marine resources. *Mar Ecol Prog Ser* 300:241–296

Centre for Marine Studies, (2009). *Framework for an Ecosystem-based Management Plan for Addu Atoll in the Republic of the Maldives.* 30pp Centre for Marine Studies, University of Queensland. Web source http://www.gefcoral.org/Portals/53/downloads/EBM%20Framework-Addu%20Atoll.pdf

Cicin Sain, B. and Knecht, R. (1998). *Integrated coastal and ocean management:Concepts and practices*. Island Press Washington USA. 517pp.,

De'ath, G., Lough, J.M. and Fabricius, K.E. (2009). Declining coral calcification on the Great Barrier Reef. *Science* **323**: 116-119.

Edwards, A.J., Gomez, E.D. (2007). *Reef Restoration Concepts and Guidelines: making sensible management choices in the face of uncertainty*. Coral Reef Targeted Research & Capacity Building for Management Programme: St Lucia, Australia. iv + 38 pp.

Horikawa K (1996) History of coastal engineering in Japan. *History and Heritage of Coastal Engineering* American Society of Civil Engineers,. New York USA pp 336 374

Hutchings and Hoegh -Guldberg (2008) Calcification, erosion and the estab;ishment of the framework of coral reefs. In *The Great Barrier Reef Biology, Environment and Management* (Hutchings, P., Kingsford, M. and Hoegh-Guldberg, O. eds) pp 74 – 84. CSIRO Publishing, Collingowood, Victoria Australia.

ICRI (2005) *Resolution on Artificial Coral Reef Restoration and Rehabilitation.* prog(http://www.icriforum.org/secretariat/pdf/ICRI_resolution_Restoration.pdf)

Jackson (2008) Ecological extinction and evolution in the brave new ocean. *PNAS* _ August 105 _ 11458–11465

Kay, R and Alder, J (2005). *Coastal Planning and Management 2nd Edition.* Taylor and Francis. 380pp.

Kraus, N.C. (Ed) (1996). *History and Heritage of Coastal Engineering* American Society of Civil Engineers,. New York USA ...603pp

Lawrence, D.R, Kenchington, R.A. and Woodley, S.J. (2002). *The Great Barrier Reef: Finding the Right Balance.* Melbourne University Press. Melbourne. 263pp

Pandolfi and Kelley (2008) The Great Barrier Reef in time and space: Geology and palaeobiology. . In *The Great Barrier Reef Biology, Environment and Management* (Hutchings, P., Kingsford, M. and Hoegh-Guldberg, O. eds) pp 17 - 27. CSIRO Publishing, Collingowood, Victoria Australia.

Rais, J., Dutton, I.M., Pantinema, L., Plauffe, J. and Dahuri, R. (Eds) (1999). *Integrated coastal and marine resource management. Proceeding of an international symposium* .Institute of Technology National (ITN), Malang, Indonesia. 375pp

Smith, S. V. [1] and Kinsey, D. W. (1976) Calcium Carbonate Production, Coral Reef Growth, and Sea Level Change *Science*194. no. 4268, pp. 937 – 939

Ward, T.J(2004) Marine protected areas in fisheries: Design and performance issues. Amer. Fish. Symp 42: 37-61