Technology Fact Sheet for Adaptation

Restoration of Coral Reefs [i]

23. Sector: Coastal

24. Technology characteristics

24.1 Introduction to establishment of artificial reefs by transplanting corals:

Coral reefs are underwater structures made from calcium carbonate secreted by corals which are biologically classified as Cnidarians (coelenterates). **Corals** are marine organisms in class Anthozoa of phylum Cnidaria typically living in compact colonies of many identical individual "polyps". The group includes the important reef builders that inhabit tropical oceans and secrete calcium carbonate to form a hard skeleton. Coral forming organisms construct the reef by secreting hard skeletons of aragonite (a fibrous, crystalline calicium carbonate). Most coral reefs are built from stony corals, which in turn consist of polyps that cluster in groups. The polyps are like tiny sea anemones, to which they are closely related. But unlike sea anemones, coral polyps secrete hard carbonate exoskeletons which support and protect their bodies. Reefs grow best in warm, shallow, clear, sunny and agitated waters. Garison, 1995; http://en.wikipedia.org/wiki/

Coral reefs often called "rainforests of the sea" and they form some of the most diverse ecosystems on Earth. They occupy less than one tenth of one percent of the world's ocean surface, about half the area of France, yet they provide a home for twenty-five percent of all marine species (Dali et al. as quoted in http://en.wikipedia.org/wiki/Coral_reef) including other marine vertebrates and invertebrates] Paradoxically, coral reefs flourish even though they are surrounded by ocean waters that provide few nutrients. They are most commonly found at shallow depths in tropical waters, but deep water and cold water corals also exist on smaller scales in other areas.

Coral reefs deliver ecosystem services to tourism, fisheries and shoreline protection. The annual global economic value of coral reefs has been estimated at $US375 billion. However, coral reefs are fragile ecosystems, partly because they are very sensitive to water temperature. They are under threat from climate change, ocean acidification, blast fishing, cyanide fishing for aquarium fish, mining for lime industry and overuse of reef resources, and harmful land-use practices, including urban and agricultural runoff and water pollution, which can harm reefs by encouraging excess algae growth. (http://en.wikipedia.org/wiki/Coral_reef; Kumara 2008)

The two main variables determining the geomorphology, or shape, of coral reefs are the nature of the underlying substrate on which they rest, and the history of the change in sea level relative to that substrate.

The approximately 20,000 year old Great Barrier Reef offers an example of how coral reefs formed on continental shelves. Sea level was then 120 metres (390 ft) lower than in the 21st century.(Veron, 2000; Toller et al., 2001) As sea level rose, the water and the corals encroached on what had been hills of the Australian coastal plain. By 13,000 years ago, sea level had risen to 60 m (200 ft) lower than at present, and many hills of the coastal plains had become continental islands. As the sea level rise continued, water topped most of the continental islands. The corals could then overgrow the hills, forming the present cays and reefs. Sea level on the Great Barrier Reef has not changed significantly in the last 6,000 years (Veron, 2000), and the age of the modern living reef structure is estimated to be between 6,000 and 8,000 years (Barnes & Hughes, 1999). Healthy tropical coral reefs grow horizontally from 1 to 3 cm (0.39 to 1.2 in) per year, and grow vertically anywhere from 1 to 25 cm (0.39 to 9.8 in) per year; however, they grow only at depths shallower than 150 m (490 ft) due to their need for sunlight, and cannot grow above sea level (Hatta, et.al., 1999).

24.2 Technology Characteristics/Highlights

As an adaptation for expected sea level rise as a result of climate change, this natural reef building mechanism continued during the evolutionary process, should be artificially enhanced by providing hard substrata attached with relevant samples of temperature tolerant live corals to produce artificial coral reefs. At University of Ruhuna, transplanting of corals on concrete blocks and tiles have been successfully implemented by a group of marine scientists led by Dr. Terney Pradeep Kumara, under the financial assistance under the SIDA (Sweden) coastal & Marine Science Project of University of Ruhuna and the Tsunami rehabilitation programme funded by CIDA (Canada) (Plates 1 2 & 3).

Plate 1: Tiles used to transplant corals & a tile with corals grown within 1 year

Plate 2: *Transplanted corals on cement tiles in situ. Initial stages (left) and after the growth of corals (right)* Photographs by P.B.T.P. Kumara

Plate 3: *Transplanted corals on wire mesh.* Photographs by P.B.T.P. Kumara

This includes propagation of corals using small pieces of live coral attached to larger peces of coral rbble (dead coral) which are fixed to different types of artificial material such as concrete tiles, clay tiles or to wire mesh. These methods have been successfully adopted by a group of marine scientists at University of Ruhuna led by Dr. Terney Pradeep Kumara and have been identified as a promising method for restoration of reefs degraded due to natural and anthropogenic disturbances and for development of artificial reefs for ecotourism. This technique could be adopted to reinforce the effect of hard technologies such as sera dikes, sea walls, etc. used (Figure 1) for minimising coastal erosion or to reduce impacts from coastal inundation that may occur as a result of sea level rise due to climate change.

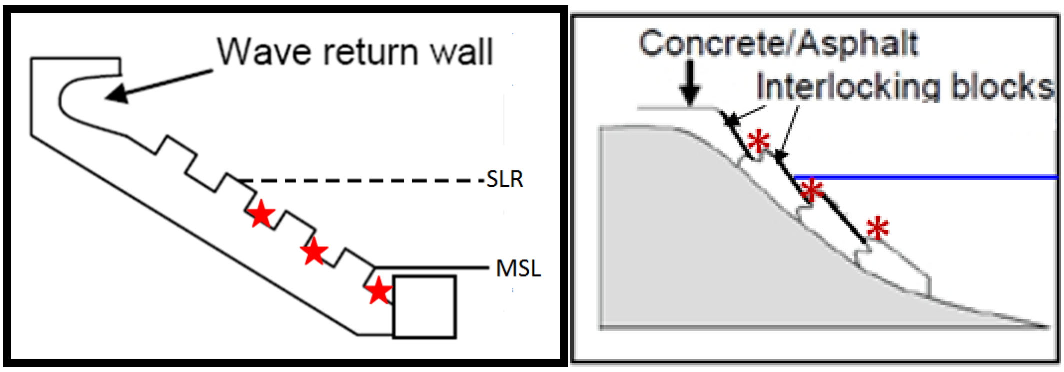

Figure 1: *Modified drawing of a sea wall with a structure that helps the return of the waves could be used as a hard substratum to establish artificial coral beds. Places within an irregular faced sea walls (★) and on the revetments with interlocking blocks (*) sea walls suitable to fix the tiles with transplanted corals or plots with sea grasses considering the water level due to sea level rise. MHWS- MSL- Mean sea level; SLR- Water level at sea level rise. (Source: Adopted from French, 2001)*

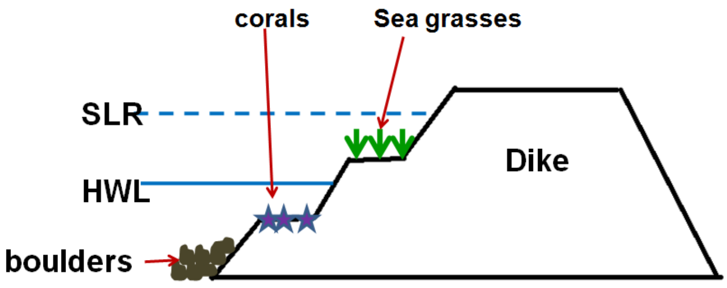

Figure 2: *Proposed design of a dyke with the landward aslope having a terraced structure to enable transplanting corals and establishing seagrass plots during high water levels (HLW) and sea level rise (SLR). This would gradually enhance the settlement of more adaptive temprature tolerant marine benthic organisms*

In areas where there is no impact from river sedimentation corals could be grown on tiles (Plates 1 & 2) and in those affected by sedimentation wire meshes placed above the natural or artificial substratum could be used (Plate 3). Corals can be grown as rock coltures and small pieces of rocks attached with coral plyps could be fixed on to the hard defense structures as shown in Figure 1. As an adaptation for climate change coral species used for transplanting should be the species with high tolerance for upper limits of temperatures prevailing in coastal areas. Transplanting should be done when the sea is calm in order to get the coral polyps established on tiles and a considerable growth is resulted prior to rough conditoions appear during monsoon seasons.

For successful implementation of the above programme carefully monitored research programmes are essential to identify the following

- Temperature tolerant species of corals available in different parts of the coastal belt of Sri Lanka
- Other coastal species found in association of coral forming organisms, that would enhance the growth and existance of natural & transplanted coral forming organsms.

24.3 Institutional/ organisational requirements

Facilities for snorkeling and facilities for construction of cement tiles attached with coral rubble should be provided to academic and research institutions and also to local societies and hoteliers who are involved in coral reef conservation, rehabilitation & management and located in the vicinity of the sites selected within the existing coral reefs that needs restoration and transplanting of corals.

25. Operations and maintenance

25.1 Endorsement by experts

Coral transplanting is a technology accepted worldwide for restoration of coral reefs and to establish artificial reefs

25.2 Adequacy for current climate

Currently coral reefs are existing in Sri Lanka and there are species which can stand higher temperatures than most others and they are found in Sri Labnkan coastal waters. In the Southern coastal belt of Sri Lanka. Coral genera most commonly observed in shallow coastal reefs are *Pocillopora, Acropora* and *Montepora* (Kumara, 2008). Therefore species of these genera which are commonly occurring could be used for transplanting purposes.

25.3 Size of the beneficiary group

Coastal communities depending on reef communities, such as tourist guides, ornamental fish collectors, tourist industry within the coastal belt, etc. could be considered as beneficiaries and to quantify the numbers of beneficiaries detailed surveys should be carried out with respect to the coastal belts associated with different coral reefs. Location of the coral reefs are given in the Map given in figure 2.

Figure 2: Distribution of coral reefs along the coastal belt of Sri Lanka, Each orange coloued patch indicates one fringing reef (Rajasooriya & White, 1995)

In addition to the above establishment of artificial reefs will improve the status of the coastal biodiversity and hence the fish populations depending on reefs for food, shelter, etc. This will enhance the coastal fish production.

26. Costs

4.1Cost to implement adaptation options

Costs up to the Phase 4 will be given herein because the area to be included for the Phase 5 will be decided on the success of the project up to phase 4.

Activity	cost

	Unit cost (US$/m)	Total cost (US $)
Field surveys to decide the suitable sites (duration 6 months)		10,000
Training workshops 10 Nos	3,000	30,000
Material for prepare substrata for transplanting 10 sites of 1 ha (100,000m^2)	40/m^2	4,000,000
Allowances for persons (10) involved in trasplanting and taking care of the transplants for 2 years		40,000
Transport & other miscellaneous costs		8,000
Contigencies		202,000
Total cost up to phase 4	14.3/m^2/yr	4,290,000/10 ha/3yrs

26.1 Additional costs to implement adaptation option, compared to "business as usual"

This technology could be coupled with the construction of hard defenses such as sea walls and dykes as shown in Figure 2 and in such occasions cost for such hard structures also should be taken in to consideration.

To receive maximum benefits from this technology, awareness & sensitivity on the importance of coral reefs should be improved among all stakeholders, who are depending on reefs. Therefore, awareness among coastal communities, school children, hoteliers, industrialists, should be improved. Thus there is a need for conducting awareness programmes whenever necessary.

Development impacts, indirect benefits

26.2 Economic benefits

26.2.1 Employment

This project will provide employment opportunities to person involved in coastal construction sector, coastal zone management sector, tourism industry, etc. Indirectly income of the fishermen will be improved

26.2.2 Investment :

- Improvement of foreign exchange earnings through tourism.
- Income to fisher communities due to improvement of coastal stocks
- Provision of protection to coastal infrastructure
- Opens up recreational sites for holiday makers

26.3 Social benefits :

- **Income**
  - 26.3.1.1.1.1 Improvement of economy as the expenditure on repairing the damages caused to their properties due to coastal erosion.
  - 26.3.1.1.1.2 Socioeconomic status of coastal communities due to reduced risk of coastal inundation and erosion
  - 26.3.1.1.1.3 Increased income to persons involved in tourism (especially in eco-tourism), coastal resource management and hotel sectors.
  - 26.3.1.1.1.4 Increased income to fisher communities
- **Education**
  - o Improvement of awareness on the importance of conservation, management and restoration of coral reefs
  - o Improvement of scientific knowledge on the sensitivity and complexity of reef building and reef associated biotic communities
  - o Adaptation to natural phenomena by scientifically maneuvering the natural coastal ecosystems
  - o Knowledge on the establishment of artificial structures within the coastal belt, with least impacts on sensitive ecosystems
  - o Transplanted structures could be used for field training
- **Health**
  1. Improved security of coastal dwellings will naturally improve the health & mental conditions of coastal communities
  2. Proper management of coastal ecosystems by controlling harmful anthropogenic activities such as pollution, coral mining, illegal fishing, etc. to protect the reefs will provide the coastal communities a healthy atmosphere and a better income through proper management of coastal fish communities, which will also help them to maintain healthy families.

26.4 Environmental benefits

- Restoration of corals and their transplanting will form a more effective barrier with respect to wave action, inundation, erosion, etc. which will reduce the negative impacts to coral reefs from natural phenomena.
- Provision of shelter for other reef associated organisms will improve the stability of reef ecosystems and also will improve the biodiversity
- Utilisation of CO_2 for internal & external hard skeletons (corals, shellfish such as mollusks, crustaceans, etc will reduce the CO_2 concentration in coastal habitats, reducing its impacts on global warming

27. Local context

27.1 Opportunities & Barriers

27.1.1 Opportunities

- For coastal scientists, coastal engineers and coastal zone managers will get a very good opportunity to use their knowledge and experience to find solutions for global warming and for sustainable management of coastal resources & coastal ecosystems to be adapted for climate change at the local level
- Coastal resource utilisers and those who were involved in destructive activities harmful to coastal ecosystems will get an opportunity to obtain a training to sustainably manage the coastal resources for their own benefit.
- Academics and researchers will get an opportunity to conduct useful scientific research to reduce the impacts of climate change to coastal ecosystems and communities
- Sri Lanka will get an opportunity to make possible contributions to find solutions for local regional and global problems that may faced due to climate change.
- More fish will be available
- Reduce pollution levels

27.1.2 Barriers

- High cost incurred on coastal constructions, coral transplanting, training personnel and to provide security against harmful anthropogenic activities against coral transplants and other associated artificial structures
- Lack of or insufficient political commitment for coastal resource conservation and management.
- Low inputs by the government on coastal & marine science education, due to ignorance of the importance of marine science education and the cost incurred to provide facilities (capacity building) for marine science education.
- Insufficient or lack of motivation and knowledge of the coastal & marine resource utilisers on the importance of sensitive coastal marine ecosystems and their sustainable utilization.
- Reluctance of older generation of the coastal communities to acquire new knowledge and to accept that certain practices adopted by them for fishing and other socio economic activities could cause serious threats to sensitive coastal ecosystems and their biodiversity.

27.2 Status

Technology for coral transplanting has been successfully implemented in the southern coastal belt by a group of scientists led by Dr. P.B.T.P. Kumara (dept. of Oceanography & Marine Geology, Faculty of Fisheries and Marine Sciences & Technology, University of Ruhuna. Such technologies should be adopted in a larger scale at other reef sites independently and in combination with hard defense technology.

Studies on Coral diversity & distribution has been conducted during the past decade and there is sufficient knowledge with respect to their biology, sensitivity & their resilience.

27.3 Time frame

	Year 1 divided to 4 quarters				Year 2 divided to 4 quarters				Year 3 divided to 4 quarters			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Survey for selection of sites	X											
Awareness/training		X										
Preparation of transplant material			X									
Transplanting/monitoring				X	X	X	X	X				
Transplant coupled with hard defense structures							X	X	X			
Monitoring								X	X	X	X	
If successful adoption to wider area										X	X	
Evaluation of success						X			X			X

27.4 Acceptability to local stake holders:

- Younger generations with secondary & tertiary education will accept this technology and also during the transplanting programmes carried out by the University of Ruhuna their assistance was obtained and some received an allowance on days of involvement and a few worked voluntarily
- School children showed enthusiasm during workshops conducted on school science day programmes
- Adult male members of the coastal communities involved in fishing and other coastal activities did not show much interest in participating in workshops conducted.
- Hotel owners and diving training institutes of Hikkaduwa offered fullest cooperation.
- CCD & MEPA has continuously provided necessary assistance.

28. References

- Barnes, R. and; Hughes, R. (1999). *An Introduction to Marine Ecology* (3rd ed.). Malden, MA: Blackwell Science, Inc.. pp. 117–141. ISBN 0-86542-834-4.

- Daly, M., Fautin, D.G., and Cappola, V.A. (March 2003). "Systematics of the Hexacorallia (Cnidaria: Anthozoa)". *Zoological Journal of the Linnean Society* **139**: 419–437.

- Garrison, T. (1995). Tropical Oceans in Oceanograpy: An introduction to Marine Science. Wordsworth Publishing Company, New York. 456- 465 pp. ISBN -534-25728-3

- Hatta, M., Fukami, H., Wang, W., Omori, M., Shimoike, K., Hayashibara, T., Ina, Y., Sugiyama, T. (1999). "Reproductive and genetic evidence for a reticulate evolutionary theory of mass spawning corals" (PDF). *Molecular Biology and Evolution* **16** (11): 1607–1613.

- **http://water.epa.gov/lawsregs/guidance/wetlands/definitions.cfm (browsed on 09-10-2011)**

- **http://www.water.ncsu.edu/watershedss/info/wetlands/definit.html (browsed on 09-10-2011)**

- **http://www.water.ncsu.edu/watershedss/info/wetlands/class.html (browsed on 12-10-2011)**

- **http://en.wikipedia.org/wiki/Coral_reef**

- Kumara, P.B.T.P. (2008). Patterns of coral production and distribution in Southern Sri Lanka :P Reef resilience in an environment affected by major disturbances. Ph.D. Thesis School of Pure & Applied Natural Sciences, University of Kalmar, Sweden
- Linham, Mathews M. & Robert J. Nicholls((2010). Technologies for Climate Change Adaptation –Coasta Erosion & Flooding- (Xaanil Zhu ed.). UNEP Riso Centre, University of Southhampton. ISBN978-87550-3855-4
- Rajasuriya, A., & White, A.T., (1995) 'Coral reefs of Sri Lanka: Review of their extent, condition and Management status'. *Coastal Management* 23: 70 – 90.
- Toller, W. W., R. Rowan and N. Knowlton (2001). "Repopulation of Zooxanthellae in the Caribbean Corals *Montastraea annularis* and *M. faveolata* following Experimental and Disease-Associated Bleaching". *The Biological Bulletin* (Marine Biological Laboratory) **201** (3): 360–373.
- Veron, J.E.N. (2000). *Corals of the World. Vol 3* (3rd ed.). Australia: Australian Institute of Marine Sciences and CRR Qld Pty Ltd.. ISBN 0-64232-236-8.

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[i] **This fact sheet has been extracted from TNA Report – Technology Needs Assessment Reports For Climate Change Adaptation – Sir Lanka. You can access the complete report from the TNA project website http://tech-action.org/**