

METHODOLOGY ON VALUATION OF ECOSYSTEM SERVICES OF CORAL REEFS

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Introduction

Natural resources are boon to mankind. Economic progress of any country depends on the extent, quality and availability of natural resources. Currently, these resources are fast depleting due to various natural processes and anthropogenic activities. Through ecosystem valuation, it is possible to get a fair idea on the rate of depletion of different natural resources over time. Valuation is an attempt to put a monetary value on a certain asset, which can be tangible or intangible. Valuation is the heart of environmental economics and is emerging as a very active and rapidly expanding field. The basic strategy for environmental valuation is the co-modification of the services that the natural environment provides. The need for valuation arises from the fact that most environmental goods and services are not traded in the market and hence don't have a price. Examples are air and water quality or forest preservation. This does not imply that these goods and services don't have a value; only that market fails to capture it directly ('market failure'). The purpose of environmental valuation is to reveal and translate into monetary terms the true costs and benefits of alternative decisions regarding public goods such as environmental resources. It provides important information to guide the allocation of scarce public resources.

Economic valuation of ecosystem services

Economic valuation is the process of identifying the relevant changes in consumer demand and producer supply arising from a (project-induced) change in environmental quality, or the change in the provision of an environmental resource. In brief, environmental valuation is concerned with the analysis of methods for obtaining empirical estimates of environmental values, such as the benefits of improved river water quality, or the cost of losing an area of wilderness to development. The most commonly used approach is based on the concept of total economic value (TEV). Environmental valuation is largely based on the assumption that individuals are willing to pay for environmental gains and, conversely, is willing to accept compensation for some environmental losses.

Importance of environmental valuation

Most of the environmental goods and services have no price but have value. These resources are so important to be valued as they perform a large number of ecological functions that a society enjoys like clean air, ecological balance nutritional recycling, aesthetic beauty etc. So, broad reasons for valuing these resources are:

- ❖ To ensure optimal & sustainable resource level.
- ❖ There is the situation of missing markets.
- ❖ Even if there are markets, they are not performing well.
- ❖ For environmental goods and services, it is essential to understand and appreciate its alternatives and alternatives uses.
- ❖ Governments may like to use the valuation as against the restricted, administered or operating market prices for designing natural resources conservation programmes.
- ❖ In order to arrive at environmental accounting for methods such as net present methods or cost- benefit

analysis, valuation is a must.

- ❖ Facilitate land use decisions.
- ❖ Limit or ban trade in endangered species.

With this background, various methodologies used to estimate the valuation of ecosystem services of coral reefs are given below:

Methodology for Valuation of Coral Reefs

Millennium Ecosystem Analysis (MEA)

Coral reefs are highly productive, diverse, and attractive ecosystems which provide a valuable range of goods and services for mankind. Valuation of goods and services generated by coral reef system had widely been attempted by researchers in different parts of the world. Millennium Ecosystem analysis (MEA) has conceptualized the ecosystem services framework as (1) provisioning services such as supply of food, building materials and medicines, (2) regulating services such as shoreline stabilization, flood prevention, storm protection, climate regulation and carbon sequestration (3) cultural and recreational services such as culture, tourism, and recreation and (4) supporting services such as habitat provision, nutrient cycling, primary productivity and soil formation. Therefore, complex valuation techniques are used to arrive at an economic value of coral reef services. To ascertain the Economic Value of coral reefs in study area, special attention had been given mainly to eight types of goods and services provided by coral reef systems:

1. Fisheries (Change in productivity method)
2. Tourism (travel cost method)
3. Coastal Protection (Replacement cost method)
4. Erosion prevention (Replacement cost method, Benefit transfer method)
5. Biodiversity (Bio prospecting) (Benefit transfer method) (Option value)
6. Research
7. Donations by NGO and various organizations (Bequest value)
8. Existence value (Contingent valuation method)

The main advantage of calculating the TEV is to obtain a figure of the value of the reef ecosystem, which will highlight to stakeholders and policy makers the importance of the conservation of the reef ecosystem.

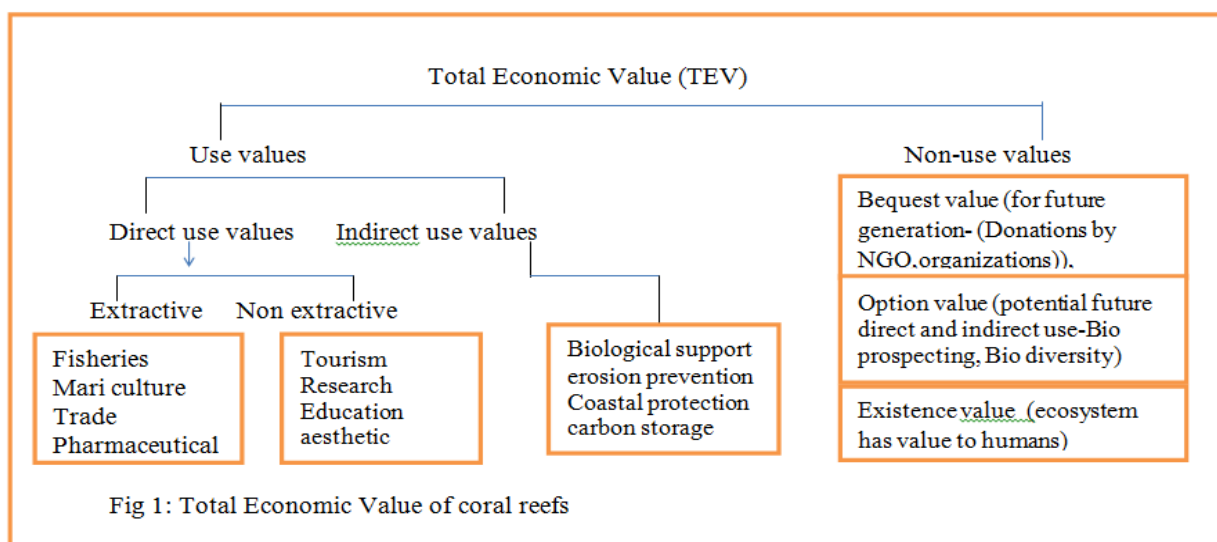


Fig 1: Total Economic Value of coral reefs

Valuation of Coral Reef Fisheries

In the context of present study, the value of coral reef-associated fisheries will be estimated using a financial analysis approach and involves calculating the revenue generated from fisheries of study area. Two major streams of fisheries related revenues will be considered. They include: (i) net revenue of fisheries at the landing centre (major part of this revenue is distributed among the fishermen) and (ii) the revenue generated from value added fisheries i.e. the export based revenue (major part of this revenue is distributed among fish traders and fish processing units)

Net revenue of fisheries at the landing centre

The fish catch data from 2000-01 to 2015-16 to be collected to study trend over the period of time in study area (Table 1). CPUE (catch per unit effort) also has to be studied to analyze the fishing pattern in the study area.

Table 1: Dummy table for species /group wise fish catch (in Tons) in study area

Local name	Common name	2012-13	2013-14	2014-15	2015-16
Total					

At fish landing centres, the gross revenue of fisheries is to be estimated based on species wise fish catch and their sale price. From this, the net revenue is estimated by subtracting operating costs. Literature suggests that on an average the operating cost (including the labor and non labour) in marine fisheries is around 25% of the gross revenue (Burke *et. al.* 2008). In addition to above overall fish valuation, the valuation specifically focuses on fisheries that depend directly on coralline area for at least a portion of their life-cycle. Therefore, any positive or negative changes in coral reef health (e.g. coral bleaching) will have significant impact on fish productivity and total revenue generation. Accordingly, average annual catch value for entire region and coral associated fishing areas is to be estimated. Out of this, contribution of coralline areas in annual fish catch in value and per cent has to be worked out.

Revenue generated from value added fisheries (Export)

To estimate the export value of fish catch, the total volume of fish export from study area is to be estimated and, along with the actual value addition done through fish processing for export purpose (Table 2). Since, fish processing and export units in the region may not share specific data on processing volumes and revenue, the cost of value addition is difficult to estimate. Similarly, the export volume would not be available at disaggregated level. Therefore, these values can be approximated based on available information and expert knowledge.

Export of various products of marine fish is one of the key revenue generators for the State of Tamil Nadu. A range of fish products are exported to different countries and regions. Export details of marine fish products of Tamil Nadu may be collected and compiled from MPEDA annual reports.

Further, the summary on coral associated fishery value may be estimated based on the various categories such as gross revenue, operating costs, value addition, etc. and adjusted for the coral reef area associated with the fishery (Table 3).

Table 2: Dummy table for state of catch & export (in tons) and value of fisheries products

Year	Marine Catch	Inland Catch	Total Catch	Total Export	Total Export Value (Million Rs.)	Unit Value (Rs./kg.)
2007						
2008						
2009						
2010						
2011						
2012						
2013						
2014						
2015						
2016						
Average						

Table 3: Dummy table on summary of coral associated fisheries values in study area

S.No	Parameter	Value (in lakhs Rs.)
1.	Commercial Fisheries – Gross Revenue (A)	
2.	Operating Costs (% of Gross Revenue)(B)	
3.	Commercial Fisheries – Net Revenue (i.e. A - B)(C)	
4.	Value addition (i.e. Export) (D)	
5.	Total Net Value (C+D)	
6.	Total coral reef area (km ²)	
7.	Coral Reef Associated Fish Value (lakh Rs. / km ² /year)	

Valuation of coral reef tourism and recreation

Tourism and recreation constitute the most highlighted economic benefits of the coral reef systems. The key tourism activities associated with coral reefs include the SCUBA diving, reef walking etc. They are the direct use values attributable to coral reefs and are usually estimated by accounting for the tourism revenue generated by a particular coral reef destination. Most of the studies focused on coral reef recreation/tourism estimate consumer surplus using a travel cost method (TCM) or Contingent Valuation Method (CVM).

In the present context, economic value of tourism and recreation related to coral reefs in study area can be assessed by using a travel cost method with main focus on the expenditure pattern of tourists associated with the coral tourism.

Also, the expenses incurred by students who attend nature education camps in the study area will also be considered and included as educational tourism. While, the estimate of numbers of tourists in the study area could be provided by park managers, to record expenditure pattern of tourists who visits different coral reefs locations of study area, a questionnaire-based primary survey of tourists can be conducted (Table 4). The extent to which tourism can develop depends on expansion of infrastructure, basic amenities and marketing linkages.

Based on the feedback from the respondents at different sites, the expenditure pattern during the stay at study area to visit coral reefs can be recorded. The expenditure is broadly classified into three major categories namely lodging, transport, food and official entry fees. Visitors may be differentiated as foreigners, domestic and local tourists. In addition, students visiting study area for viewing coral and other marine lives as part

of their environmental/nature education program may also be considered in the study. Per person expense related to coral associated tourism varies in different site. Also, the expense pattern varies between Indian and foreign tourists (Table 5).

Accordingly, based on the feedback from the respondents and assuming that each tourist visits the site once a year, per head expenses for study area could be estimated per year. In addition, students who visit the study area as part of nature education camps will incur for one day camp. These values could be added along with tourism value. Thus, by applying expenditure method, annual value of tourism and recreation can be estimated. The above values will be used to estimate the tourism value in terms of per unit area of coral reefs in study area (Table 6).

Table 5: Tourism related expenses for different coral reef sites in study area

Type of Tourist	Site	Total Tourists	Per person expenses incurred (Rs.)	Total Annual Value (Rs.)
Indian				
Foreigner				
Total (Tourism)				
Education				
Grand Total				

Table 6: Total annual tourism value of coral reefs in study area

Parameter	Study area
Coral Reef Area ² (sq. km.)	
Value of Coral Reefs (Rs./sq. km./year)	

Coastal protection value of coral reef

Preventive Expenditure on Salinity Control

Salinity ingressions in ground water of coastal areas is a growing problem in terms of huge monetary loss in agriculture production. Realizing the magnitude of this problem and to tackle this problem, concerned governments and various national and international organizations incur expenditure on various schemes. However, all of the above ‘mitigative expenditures’ cannot be ascribed to replacement for coral reef function, because as such most of the mitigation measures are simply to deter excessive pumping of ground water and facilitate ground water recharge. So the value of coral reefs in preventing the salinity ingressions is assumed as 15%. In recent years, TN Government and various organizations have undertaken artificial reef installation at various places of Tamil Nadu to increase biomass and protect the coastal wealth. The budget allocation for those schemes in the study area can also be included to estimate coastal protection value of coral reef (Table 7).

Table 7: Dummy table on total coastal protection value of coral reef

items	Value (In Rs)
Preventive Expenditure on Salinity Control	
Budget for artificial reef installation	
Total	

Value of coastal Erosion prevention by coral reef

Coral reefs act as wave breakers and thereby fulfill an essential function of coastal protection. They act as natural sea walls and in coastal areas that are devoid of coral reefs, authorities need to spend huge sums on manmade protection. In addition, the ability of the reef to act as an effective buffer zone depends on the state of the reef. The coastal protection prevention function of coral reefs will be valued by applying Benefit Transfer Method (BTM). In addition, preventive expenditure data by Govt. Agencies to control the coastal erosion problem can also be analyzed (Table 8).

Benefit Transfer Method (BTM) is used when values derived and used in other comparable studies are transferred and adjusted to find and estimate the values in the current study. The logic is that a study carried out in the similar circumstances and location can be used as a substitute and a proxy for another area, especially if the data is inadequate for the study site and the time for the study is also restricted. The BTM estimates the net benefit of a similar environment from an existing study and transfers it to a new context assuming that existing values can be used as an approximation.

To reduce the transfers errors, the adjustments and scaling up and down of the data have to be done with regards to site specific characteristics like socio-economic variables like per capita income and geographical differences etc. at the macro level. It is mostly used for site to site transfers of values and cannot be applied to the whole ecosystem. Thus, in this context, attempts need to be made to apply benefit transfer approach for valuation of biodiversity, coastal protection and ground water quality maintenance (control of salinity ingress). While, the outcomes of studies in differ parts of globe provide sufficient information that can be used in BTM approach, the results of those coral reef systems which are geographically and socio-economically closer to study area, actually provide greater power for value transfer.

Table 8: Dummy table on coastal erosion prevention values in other coral reef areas

Parameters	Unit	Other area 1	Other area 2
Estimated coastal erosion prevention value (eg.,2003)	Lakh Rs		
Adjusted coastal erosion prevention value (2016)	Lakh Rs		
Adjusted coastal erosion Prevention value (2016)	Rs per sq. km.		

The second level of adjustment (value transfer) has to be done using different ecological and economic parameters. Thus for the present purpose, (i) ratio of reef flat to coastal margin, (ii) population density (iii) per capita income and (iv) contribution of agriculture product in GDP may be adjusted to estimate the value by benefit transfer approach (Table 9).

Table 9: Dummy table on parameters and their values used for applying Benefit Transfer Method

Parameters	Unit	Other area 1	Other area 2	Study area
Reef Area	Sq. km.			
Length of shoreline	km			
Ratio of Reef Area to Coastal margin (shoreline)	Sq. km./km			
Population density	No. per sq. km.			
Per Capita Income	Rs			
Value Added in Agriculture	% of GDP			

Accordingly, using different parameters that are considered to have influence in defining the value of coral reef associated coastal erosion prevention in other regions the estimated values of coastal erosion prevention function for study area can be arrived at (Table 10).

Table 10: Dummy table on estimated coastal erosion prevention value of coral reefs in study area (Rs. Per km²)

Parameters Used for Benefit Transfers	Transferred Values from other region	Transferred Values from other region
Ratio of Reef Area to Coastal margin		
Population density		
Per capita income		
Value Added in Agriculture		
Average		

Preventive Expenditure on Coastal Protection

To analyze the economic contribution of shoreline protection services provided by coral reefs in study area, valuation of the shoreline protection services provided by the artificial reefs, are necessary based on the costs required to replace them by artificial means. In addition to that, central government funding for various schemes and projects for coastal protection are to be taken care of. It is also important to note that the entire estimated monetary value of artificial reef and schemes cannot be attributed to the coral reefs protection. Based on coral experts and literature, we can assign some per cent as preventive expenditure of coral reefs. If we have sufficient data on preventive expenditure, value can be directly estimated (Table 11). Or else benefit transfer approach will be more suitable for this purpose.

Table 11: Dummy table on total coastal erosion prevention value of coral reef

Items	Value (Rs)
Estimated Coastal Erosion Prevention Value by benefit transfer method	
Preventive Expenditure on Coastal Protection	
Total	

Coral reef biodiversity valuation by benefit transfer method

In terms of economic valuation, biodiversity is potentially the most significant value of marine products. Realizing the fact that the limited knowledge exist about the biodiversity pattern, its economic valuation is considered a difficult task. However, for the present study, maintenance of biodiversity function of coral reefs can be valued by applying Benefit Transfer Method (BTM) (Table 12).

Table 12: Dummy table on bequest value estimation of coral reef bio diversity

Donors	2011-12	2012-13	2013-14	2014-15	Average
Global Environment fund					
NGO					
Various organizations					
Private, Industries					
Indian govt.					
State govt.					
Total					

Bio-prospecting potential

Scientific research that looks for a useful application, process, or product in nature is called biodiversity prospecting, or bio-prospecting. Bio-prospecting (the exploration of biodiversity for new biological resources of social and economic value) has yielded numerous products derived from species in coastal and marine ecosystems (for example, antibiotics, antifreeze, fibre optics, and antifouling paints).

Table 13: Biological activities recorded from different marine species from Indian coast.

Animal group	Species	Location	Recorded Biological Activities
Soft Coral	<i>Heterogorgia flabellum</i>	Kanyakumari, Tamil Nadu	Antiviral (Encephalomyocarditis virus)
Soft Coral	<i>Lobophytum pauciflorum</i>	Havelock, Andaman	Diuretic
Hard Coral	<i>Acropora corymbosa</i>	Kadmal island, Lakshadweep	Cardiovascular effect
Hard Coral	<i>Acropora formica</i>	NA	Diuretic, Toxic
Hard Coral	<i>Acropora humilis</i>	Kadmal island, Lakshadweep	Antiviral (Ranikhet disease)

Coral reefs are exceptional reservoirs of natural bioactive products, many of which exhibit structural features not found in terrestrial natural products. The pharmaceutical industry has discovered several potentially useful substances, such as cytotoxicity (useful for anticancer drugs) among sponges, jellyfish and starfish. Some of the recorded biological activities of coral reefs are presented in Table 13. This exciting opportunity of bio prospecting is in its infancy in India. CMFRI has recently developed extracts from green mussel and seaweeds, which are reported to relieve pains from arthritis. The particulars for estimating the biodiversity and bio-prospecting value of coral reef are presented in Table 14.

Table 14: Dummy table on total estimated bio diversity and bio-prospecting value of coral reef

Items	Value (Rs)
Estimated biodiversity value by benefit transfer	
Bequest value estimation	
Bio prospecting option value by Benefit transfer method	
Total	

Valuation of coral reef research

The research value of reefs can be approximated by estimating the amount of money spent on reef-related research in study area. There is a number of other reef-related research activities in coral reef is being carried out. In addition to that, students pursue their research in coral reefs for their master's degree and doctorate. These study expenses of particular area can be considered for number of years and average research expense can be worked out as detailed in Table 15.

Contingent valuation method (CVM) (Existence value): Willingness to pay questionnaire can be developed to estimate existence value of coral reef in study area. Respondents are to be given number of questions on coral reef protection, based on which the existence value can be arrived at.

The data on tourism, fisheries, coastal protection, research, biodiversity and bio prospecting will together form the basis for the overall valuation of ecosystem services from coral reefs. A summary of the various valuation techniques and the estimates arriving out of them are summarized in Table 16.

Table 15: Dummy table on research expenses on coral reef (Rs.)

Particulars	Institutes	2012-13	2013-14	2014-15	2015-16	Average
Research organizations	CMFRI					
	Institute of Oceanography					
	Madurai Kamarajar university					
	Anna university					
	State government					
	Central govt. research					
	Others					
	Others					
Students research (Master, Doctorate, Post doctorate)	M Sc.					
	Ph. D.					
	Post doctorate					
Marine Protected areas (MPA)	Maintenance cost					
	Research expenses					
	Entry fee					
Private research	Medical research					
	Coral mining research					
	Foreign					
	Various organizations					
	NGO					
Total						

Table 16: Dummy table on total estimated economic value of coral reefs in study area by Millennium approach

S. No.	Goods & Services	Method	Total Annual value (Million Rs.)	Value per unit area of coral reefs (Rs. per sq. km. per year)
1.	Fisheries	Change in productivity method		
2.	Tourism & Recreation	Travel cost method		
3.	Coastal protection & Protection against Salinity Ingression	Productivity Change & Preventive Expenditure Measure		
4.	Protection Against Coastal Erosion	Replacement cost method & Benefit Transfer Method (BTM)		
5.	Maintenance of Biodiversity (Option value)	Benefit Transfer Method (BTM)		
6.	Research	Expenses by various organizations		
7.	Bequest value	Donations by NGO and various organizations		
8.	Existence value	Contingent valuation method		
	Total			

Constraints of valuation methods

Valuation methods developed so far are not entirely able to capture the exact value of natural and environmental resources. Non-market products of nature, which are largely used by indigenous people, are difficult to be valued since there does not exist a market for these products. There does not exist a clear ranking of methods of valuation. All methods are not equally relevant for all resources. Each technique requires a variety of assumptions depending upon the method being applied and of course the resource being considered for valuation. There is an unresolved methodological puzzle that still remains and relates to the consistency of different valuation techniques.

Conclusion

It is neither possible nor sensible to conserve everything. Since development activities are necessary for the country's progress even at the cost of natural resources, a pertinent question is: how much resources should be conserved? Which should be considered first? How should conservation be linked to development? We need to understand what is driving the present loss of environmental resources and what may be done to conserve it.

The advantage of an economic approach to the valuation of resources is that it provides a means of quantifying error and also indicates how markets might be reformed to remove the current sources of biases, and where it is not possible to reform markets, how government might intervene to correct the signals to private resource users. It also indicates how and where economic activity may be constrained so as to protect resources that are important for maintaining the options open to future generations. The valuation of environmental resources are much more than just 'getting the prices right'. So use of measurement is not to eliminate but to minimize adverse effects on environment.

Suggested Reading:

Dixit, A. M., Kumar, P., Kumar, L., Pathak, K.D. and Patel, M.I. (2010). Economic Valuation of Coral Reef Systems in Gulf of Kachchh. Final Report. World Bank aided Integrated Coastal Zone Management (ICZM) Project. Submitted to Gujarat Ecology Commission. 158 pp.