Economic Issues Relating to Coral Reef Damages From Submarine Fiber Optic Cables Permitted Across the Sovereign Submerged Lands of the State of Florida

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Executive Summary

Coral reef resources in southeast Florida are of considerable value. Within Broward County alone they contribute over $2 billion to the economy each year. Direct use welfare values associated with Southeast Florida corals are also estimated to be over US$ 250 million per year. However, Florida's hard coral cover is declining. A recent comprehensive study of 160 reef-monitoring sites indicated a drop from 10.3% in 1996 to 6.4% in 2000. This is likely due to a multitude of predominantly human induced stresses. Added to these stresses is the laying of submarine fiber optic cables over reefs. This results in further damage to corals and associated reef organisms during cable laying operations and in subsequent years through cable movement. Although attempts have been made to mitigate and compensate for cable laying impacts through coral transplantation and construction of artificial reefs, recent biological investigations suggest the latter may be inadequate. Little is known about the long-term impacts of these cables and the relative success and appropriateness of providing artificial reefs as compensation. Before further submarine fiber optic cables are laid across reefs in Florida, it is perhaps time to take stock and draw more heavily upon recent experiences and perform more stringent and thorough Environmental Impact Assessments and Natural Resource Damage Assessments. A more informed approach may also justify a higher and more appropriate cable laying license fee.

INTRODUCTION

The importance of coral reefs

Over the past decade, numerous studies and reviews have clearly demonstrated that coral reefs have a significant economic value (Spurgeon, 1992; Cesar, 1996, Berg, 1998, Cesar 2000). The values relate to the beauty, productivity and structure of the corals, which give rise to a variety of important "goods" and "services". These include, for example, benefits relating to associated fisheries, tourism, coast protection and conservation value.

Recent studies focusing on the economic importance of coral reefs in the USA have revealed some considerable values. For example, according to Hazen and Sawyer (2001), reef related expenditure generated over US$ 2 billion total sales in the period June 2000 to May 2001 in Broward County, Florida. This resulted in a total income of over US$ 1 billion to Broward residents during the same period, supporting 19,000 jobs. Annual reef use values for southeast Florida for the same period were estimated at US$ 255 million (Hazen and Sawyer, 2001).

Declining coral cover in Florida

Coral reefs in Florida have lost much coral cover over the past few decades (Porter and Meier, 1992). Due to the intensification of human development and activities in the area, damage to corals and associated organisms on Florida's nearshore reefs is getting worse. A recent comprehensive study in Florida Keys National Marine Sanctuary revealed that at 160 monitoring stations, hard coral cover declined from 10.3% in 1996 to 6.4% in 2000 (Causey et al, 2002). Much of the loss is related to increased incidences of coral disease and coral bleaching. Although hard to pinpoint specific root causes, increased pressure from wastewater discharges, agricultural run-off, sedimentation, fishing, recreation, and global warming are all likely to contribute to this decline (Causey et al, 2002; Smazant, 2002).

Impacts from submarine cable laying

On top of the above threats, laying of marine telecommunications cables across reefs in Florida poses a significant threat to corals and associated organisms such as sponges and gorgonians (Sultzman, 2002). Damage can occur as a result of direct destruction during the cable laying operation, as well as from the long-term swinging movements of unsecured cables. The latter may result naturally from currents and storms, but also from fishing gear and anchors snagging the cable. Furthermore, indirect damages occur to reef organisms from sedimentation and turbidity caused by the cable laying operations. These issues are discussed in more detail in Sultzman (2002).

The current approach to submarine cable licensing and compensation

The current approach to licensing of submarine cable laying operations in Florida with respect to environmental impacts relies on obtaining various permits, which have environmental requirements. For example, permits are needed from the Florida Department of Environmental Protection, from the local County (e.g. Department of Environmental Resource Management in Miami-Dade County) and from the US Dept of the Army, Corps of Engineers. In addition, under the

US National Environmental Policy Act, it should be up to Federal agencies to ensure that a suitable environmental impact statement (EIS) is produced which details the likely environmental impacts and alternatives to the proposed actions.

As a result, recent submarine fiber optic cable laying activities have been accompanied by environmental assessments and restoration Mitigation Plans. The latter have tended to follow guidelines developed and accepted by the Department of Commerce, National Oceanic and Atmospheric Administration (NOAA) for Natural Resource Damage Assessment (NRDA) claims. This process is meant to ensure that impacts (injury) to the environment are adequately compensated.

Approaches to Natural Resource Damage Assessments

As our understanding of the economic value of corals has developed, so too has the number and size of compensation claims for incidents causing damage to coral reefs. Over the past decade, numerous ship-grounding incidents in the Red Sea (Spurgeon, 1992) and in Florida, USA (e.g. NOAA, 1997a, 1999) have resulted in multi-million dollar compensation claims and payments.

There is no internationally agreed approach to assessing the economic value of anthropogenic impacts to coral reefs, or indeed to any natural resources. However, various international manuals and books do provide guidance on impact assessment valuation techniques (e.g. Dixon et al, 1997) and in some countries, such as USA, there is specific legislation and guidance for NRDAs (e.g. Department of Interior, 1995; NOAA, 1995, 1996, 1997b and 2000).

In the USA, NRDAs focus primarily on restoration of the type of habitat injured. On the other hand, in international cases of coral reef NRDAs, claims have tended to be based on an “average value” damages approach, whereby the overall economic value of a reef is converted to a per meter square value per year which is then applied to the area of impacted coral for the time period until recovery. In some cases, however, in the international arena, there is a trend towards compensation based on estimated costs of restoration.

Comprehensive evaluation of impacts

When investigating the significance of impacts on coral reefs, in theory, several different perspectives should be considered. These include determination of:

- **ecological impacts**, associated with the loss or impairment of biological features such as habitat integrity and species. This should also include estimation of the period for full recovery, and the extent to which the resources lost can be restored.

- **chemico-physical impacts**, associated with the effect on the physical structure, water circulation patterns, sedimentation, turbidity and chemical changes.

- **financial impacts**, associated with direct monetary losses to individuals and organizations (e.g. loss of private tourism and fishery revenues).

- **social impacts,** associated with how humans are affected, through for example, changes in quality of life, nutrition levels and employment opportunities.

- **economic impacts**, associated with how human welfare (e.g. satisfaction) and their economies (e.g. expenditure levels and jobs) are affected.

Economic and environmental economic valuation techniques can account for the majority of the above impacts if undertaken appropriately and with suitable assumptions.

Contents of this paper

This paper begins by providing an overview of the economic "welfare values" and "economic impacts" associated with coral reefs, and briefly outlines how these can be measured. Alternative approaches to coral reef damage assessment and compensation claims are then discussed, in particular highlighting the US "restoration" based approach and the international "economic value" based approach. Finally the paper reviews the approach to impact and damage assessment adopted in Florida for fiber optic cable operations, and provides recommendations for the future.

ECONOMIC VALUES OF CORAL REEFS

Introduction

Economic values associated with coral reefs can be split into **"economic welfare values"** and **"economic impacts".**

Welfare values relate to the overall "utility" (enjoyment or satisfaction) derived by individuals from consuming goods and services, and are commonly measured in terms of individual's "willingness to pay". They can also be considered as the "net" economic benefits and losses accruing to individuals and organizations, whereby resource costs are subtracted from revenues gained. They are often the focus of cost:benefit analyses, which attempt to assess the overall net welfare contribution of a project to a national economy.

Economic impacts on the other hand relate to impacts to regional economies, for example, in the form of total sales, incomes and employment generated as a result of a resource.

Economic welfare values of coral reefs

Coral reefs provide a vast array of benefits to mankind in the form of goods (products) and services (functions). However, because few of the goods and services are traded in the market-place, they rarely have a readily observable monetary or financial value. Despite this, they can have a considerable economic welfare values, particularly when utilized on a sustainable basis.

A useful framework to help understand the full range of economic welfare benefits afforded by coral reefs is the concept of Total Economic Value (TEV) as shown in Figure 1, and further detailed in Spurgeon (1992) and Cesar (2000).

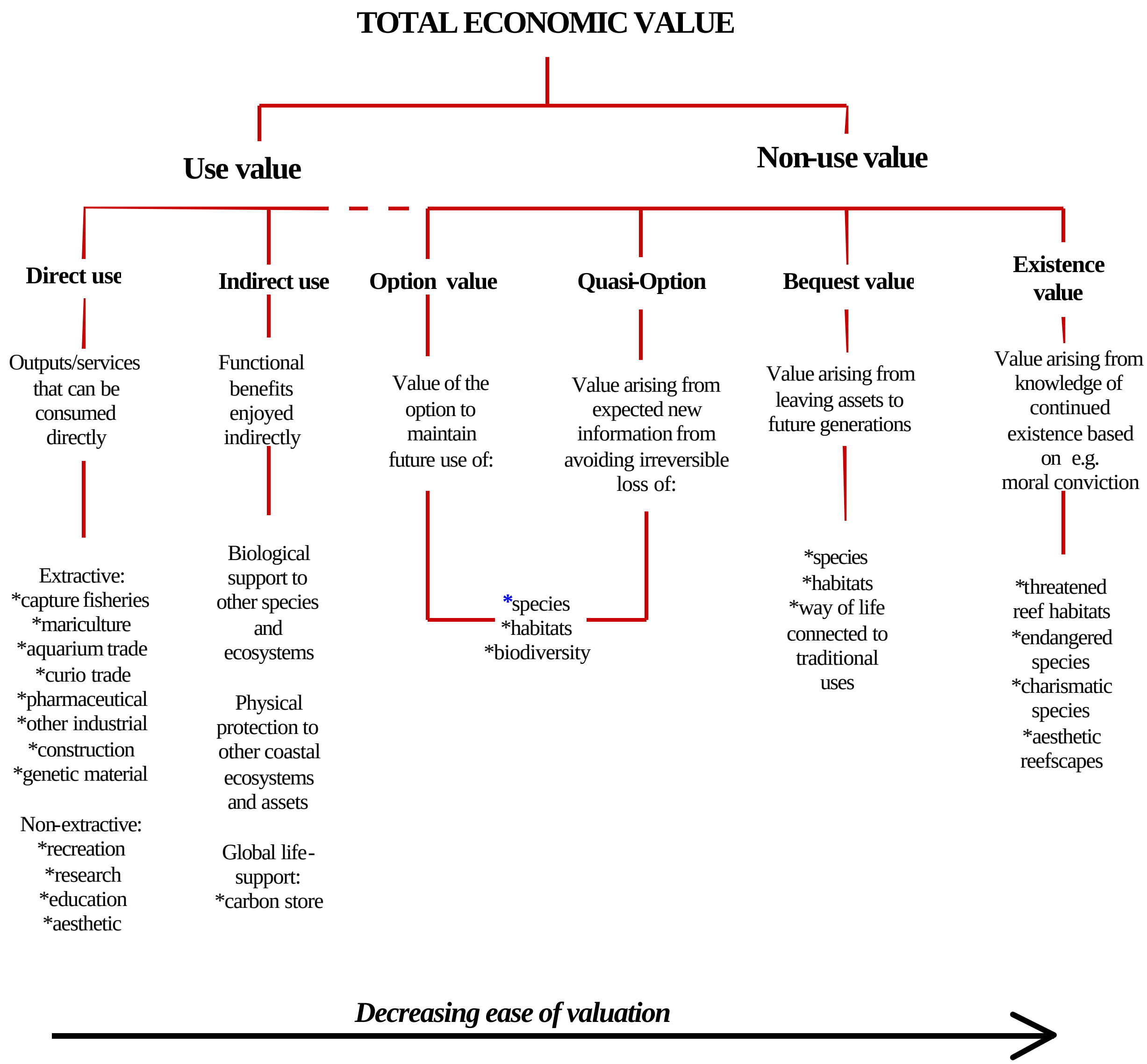
TEV is based on the theory that environmental assets give rise to a range of economic values that include direct use values, indirect use values and non-use values. The latter are also referred to as "passive-use" values, which comprise option, existence and bequest values. As based on World Bank definitions (Munasinghe, 1993):

- **Direct use value** is determined by the contribution an environmental asset makes to current production or consumption. Such values may comprise net economic returns (i.e. market revenues less "opportunity costs", the cost of inputs in their next best alternative use) and "consumer surplus" (i.e. the amount of satisfaction gained over and above the amount paid for).

- **Indirect use value** includes the benefits derived from functional services that the environment provides to support current production and consumption (e.g. coral reefs providing biological support to near-shore fisheries, and a coast-protection function to shoreline assets).

- **Option value** is the premium that consumers are willing to pay for an unutilized asset, simply to avoid the risk of not having it available in the future;

- **Non-use (passive) value: Existence value** arises from the satisfaction of merely knowing that the asset exists, although the valuer has no intention of using it. Part of the motive can be for future generations, in which case that element of value is known as "**bequest value**". These values capture some of the social value afforded by corals.



Note: Organisms, habitats and ecosystems also have an **'intrinsic value'** or worth of their own regardless of human perceptions. This is, by its very nature, impossible to give a monetary value.
Source of Figure: Based on Barton (1994) and Spurgeon (1992)

Figure 1 – Total Economic Value of Coral Reefs

Due to the fact that economists tend to determine values based on observing market behavor, the value of non-traded environmental goods and services needs to be measured in some other way. Over the past few decades, various economic techniques have been adopted which now enable the value of all habitat uses and non-uses (but excluding intrinsic value) to be estimated (see Hufschmidt et al., 1983 and Pearce and Turner, 1990). Note that to determine values for the above requires detailed understanding of biological, physico-chemical, financial and social aspects. Examples of welfare values for coral reefs are given below; the valuation methodologies are described briefly later.

Examples of coral reef welfare values

Coral reefs provide direct and indirect economic benefit in terms of **fishery** output from supporting finfish, shellfish and a range of other organisms. Net economic fishery benefits from coral reefs in Indonesia are in the order of US$ 50/acre/year (Cesar, 1996), however, values for reef fisheries in the USA are likely to be considerably greater.

Reefs provide significant benefits from **recreation**, particularly for visitors to the area. Recreational values of between US$ 12 to US$ 2,024 /acre/yr have been estimated for reefs in Indonesia (Cesar, 1996), and up to US$ 12,150/acre in Jamaica (Gustavson, 1998).

In south-east Florida, US$ 256 million per year of direct use value is estimated to accrue to resident and visitor reef users from diving, snorkeling and fishing (Hazen and Sawyer, 2001). This is broken down to US$ 126 for Broward County, US£ 47 million for Miami-Dade, US$ 52 million for Monroe County and US$ 31 million for Palm Beach County.

An earlier study (Leeworthy and Bowker, 1997) estimated a non-market user value of US$ 376 million per year for visitors (non Monroe County residents) undertaking diving, snorkeling and fishing in the Florida Keys/Key West. This equates to around US$ 1,100/acre per year based on there being 1,400km^2 of coral reef and hard bottom habitat.

Coral reefs can provide valuable **research and educational** sites. The true value of this is difficult to determine, but includes an element of expenditure in the vicinity of the reefs, as well as a multitude of potential spin-off values arising from the research and education (Spurgeon, 1992).

Reefs can yield large benefits from **pharmaceutical uses,** for example, an estimated US$ 215,000/acre in Bahamas (Ruitenbeek and Cartier, 1999) and for **ornamental** and **aquarium products** such as fish, corals and shells. The latter use of reefs is of course illegal in the US.

Coral reefs provide a valuable **coastal protection** service or function. Values in Indonesia have been determined which can be in the order of US$ 36/acre/yr for sparsely populated sites to US$ 45,000/acre/yr for areas with major infrastructure (Cesar, 1996). The coast protection function value of corals in Florida is likely to be substantially greater, particularly protecting the Keys and sandy beaches.

Coral reefs yield other benefits in terms of **supporting other ecosystems** (e.g. other reefs, seagrass beds and mangroves) and species (e.g. turtles) as well as possibly acting as a carbon sink (Spurgeon, 1992). These values are currently little explored.

Coral reefs are of great interest and attraction to many people throughout the world and consequently can have significant **non-use** (passive) values, which include option, existence and bequest values. Values have been calculated ranging from US$ 4.5 million for reefs in Curacao, US$ 19.6 million for reefs in Montego Bay, Bahamas (Spash *et al*, 1998), and US$ 79 million for the Great Barrier Reef (1997 prices, in Hundloe, 1990). The former two values are based on average individual willingness to pay values of around US$ 2 - 3 for both locals and visitors.

Non-use values for the reefs in Florida are likely to be of considerable value. Given that potentially much of the population of the USA may hold these values for the protection of the USA's mainland corals, such values are likely to be in the order of many millions or billions of US$. In countries such as the UK, non-use values are increasingly being incorporated in the Government decision-making process relating to use of natural resources (Spurgeon, 2001).

Economic impact values of coral reefs

There are several types of "economic impacts" or "economic contribution" that coral reefs provide that can be measured. These are useful measures to show the extent to which coral reefs contribute to and support local and regional economies. However, they are different from the net economic welfare values detailed above, and cannot be added to each other. Types of economic impact include:

Total sales: This is the value of additional output produced in a region due to reef related expenditures.

Total income: This is the sum of employee remuneration and property income, including interests, rents and profits generated as a result of reef related expenditures.

Employment: This is the number of full-time and part-time jobs created due to reef related expenditure.

Direct economic effects. This is the initial spending activity and comprises the increased purchase of inputs used to manufacture or produce the final goods and services purchased that are directly associated with reef activities.

Indirect economic effects. This is the value of inputs used by firms that are called upon to produce additional goods and services for those firms affected directly by the initial expenditure.

Induced economic effects. This is related to the added income received by individuals and businesses as a result of the original expenditure, spent in the local economy, which increases demand for goods and services and, in turn, results in increased production and sales of output.

Examples of coral reef "economic impact" values

When one considers the full market value of sales associated with reef tourism and fisheries, it is a measure of the "economic impact" to the region that will be affected.

In 2000/2001, the annual sales contribution to the economy associated with natural and artificial reef related expenditure was estimated to be over US$ 2 billion in Broward County, US$ 1.3 billion in Miami-Dade and US$ 0.5 billion in both Monroe and Palm Beach Counties, Florida (Hazen and Sawyer, 2001). The sales contribution can be defined as "the value of additional output produced", and include direct, indirect and induced effects of visitor expenditure and the direct effects of resident expenditure.

These sales supported around 35,500, 18,600, 10,000 and 6,300 jobs respectively (Hazen and Sawyer, 2001). The sales also resulted in an annual income (e.g. salaries and profits) to the County residents of US$ 1,094, 614, 140 and 194 million respectively.

More recently, the coral reefs in Hawaii have been estimated to contribute around US$10 billion, or US$ 378 million per year, to the economy based on reef related tourism, property values, research and fisheries (Cesar et al, 2002).

ECONOMIC VALUATION TECHNIQUES

Welfare valuation techniques

Various valuation techniques are available for placing estimated monetary values on natural resources (see Hufschmidt et al, 1987, Munasinghe 1993, Dixon et al, 1997, Bennett and Blamey 2001, Bateman et al, 2002). The techniques are not perfect, but they are continually improving. As indicated in Figure 1, valuation becomes more difficult for indirect use values and particularly so for non-use values. The techniques do, however, enable order of magnitude benefits to be determined for nearly all types of value. Key techniques appropriate for valuing impacts to coral reef are as follows:

- **Change in Productivity/Production Function:** This technique is well suited for damage assessments because it is based on 'cause-and-effect' (i.e. dose-response) relationships between the loss of an environmental resource and associated direct and indirect changes in economic output. Either market prices or **"substitute prices"** are used, less costs incurred in production. Substitute prices are adopted when the value of a non-marketed good or service is approximated by the value of similar goods or services that are marketed.

- **Replacement/Relocation Cost:** The value of a habitat is assumed to be at least equivalent to the cost of replacing or relocating it elsewhere.

- **Avertive/Preventative Cost:** The value of a habitat is assumed to be at least equivalent to previous expenditure used to avert/prevent damage to that habitat type.

- **Travel Cost Method:** Travel time and costs of a sample of visitors to a site are used to determine a "demand curve" (to reflect their "willingness to pay") and hence the recreational value for that site. Changes in visitor patterns before and after an impact could theoretically be use to calculated a loss in recreational value for a coral reef impact.

- **Stated preference surveys: i) Contingent Valuation Method (CVM)** is a questionnaire survey technique whereby a representative sample of individuals are asked their 'willingness to pay' to ensure or prevent a specific environmental change. The responses are interpreted and aggregated to produce an overall value**.** **ii) Choice modeling** is a similar questionnaire surveys approach whereby individuals are asked to choose their preferred set of goods (described in terms of key attributes, one of which is cost) from a selection of options. Complex econometric analysis is then undertaken to estimate values for different levels of each attribute. These are the only techniques capable of valuing option and non-use values.

- **Benefit Transfer:** This is not so much a recognised valuation technique in itself, but has recently developed as a cost-effective means of estimating ballpark values. The principle is that the value of a natural resource or impact calculated in one location can be used to estimate the value of a similar resource or impact elsewhere. Considerable care is needed in its application, for example to adjust the values appropriately, because most "site" and "impact" specific details are likely to vary considerably. Unfortunately, at present few thorough valuation studies exist for coral reefs that can be effectively transferred. Despite this, benefit transfers have commonly been used in NRDAs internationally (Spurgeon, 2001).

Economic impact assessment techniques

Direct, indirect and induced economic impacts associated with coral reefs can be measured using one of four levels of analysis (Stynes, 1999). They are as follows, listed in order of increasing data requirements:

Judgement: Using expert judgement to estimate expenditures and appropriate multipliers. Multipliers are needed to assess indirect and induced expenditures.

Transfers from other studies: Use can be made of other expenditures and multipliers calculated for other similar studies.

Segment/sector analysis: expenditures can be estimated through disaggregation of particular spending categories and segments (e.g. through use of satellite accounts).

Primary data: Undertake questionnaire surveys targeted at local residents, visitors, and organizations (e.g. businesses) to determine actual expenditure patterns. Input:output models of regional economies can be constructed to determine multipliers to assess indirect and induced expenditures.

APPROACHES TO CORAL DAMAGE ASSESSMENTS

The international "value based" approach

The many coral reef damage assessments undertaken for ship-groundings in Egypt generally focus on estimating the economic value of impacts, based on both welfare values and expenditures. What has tended to happen is that the party claiming ownership of the corals has calculated a damage estimate to represent the cost of restoration and loss of economic value. The shipping insurance company, who puts forward their own estimate, usually disputes this value. An agreed value is ultimately settled between parties either in or out of court.

In addition to the costs of restoration, the valuations also include predicted loss of recreational and fishery values. Benefit transfer values have often been adopted, for example, where estimates of recreational expenditures per m^2 calculated in the US are used (e.g. US$ 15.75/m^2 for direct revenues and US$ 85/m^2 for indirect revenues, as in Mattson and DeFoor (1985)). However, increasingly, recreational losses are based on current and potential revenues generated on a location specific basis and averaged out per m^2 of coral. The "present day" value of damages is then calculated using:

$$PV = \Sigma B_t/(1 + r)^{-t}$$

where (B) is the benefit lost, (t) is the predicted time horizon for coral recovery and (r) is the discount rate. The latter is used to adjust future values to lesser present day values by accounting for the "social time preference" for money.

Example of the international approach

An example is the M/V Mayflower grounding 1991, which caused damage to 340m^2 of coral reef. The Egyptian Government claimed US$ 30 million in compensation based on their calculations of lost diving revenues. An independent assessment put the value at US$ 250,000 based on using benefit transfer of values from Florida's reef. It was finally settled out of court for US$ 600,000 (Spurgeon, 1992). The money from such compensation claims in Egypt is put towards Government environmental funds to pay for a range of conservation projects throughout Egypt. Only limited restoration of damaged sites seems to be undertaken. The approach is thus more of a much needed revenue generation mechanism.

The USA "restoration-based" approach

In the USA, as the principal Federal trustee for natural resources in the coastal and marine environment, NOAA generally evaluates injuries to coral reefs. Such damages may be caused by the release of oil and hazardous substances, under the Oil Pollution Act (OPA) of 1990 and Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) of 1980, or from ship groundings in National Marine Sanctuaries, under the National Marine Sanctuaries Act. NOAA tends to act on behalf of the public to restore injured natural resources by holding the parties that caused the injury responsible for restoring the resources. The damage assessment and restoration process provides the framework for determining:

- What resources have been injured?
- What is the loss to the public?

- How can the resources be restored?
- What type and amount of restoration is appropriate?

The damage assessment and restoration process involves three steps: pre-assessment, restoration planning and restoration implementation.

Pre-assessment: NOAA and other trustees evaluate whether injury was sustained by examining the resources at risk, the nature of their exposure, and direct observations of injury. Trustees begin by coordinating with response agencies to determine whether response actions are sufficient to eliminate the threat of ongoing injury. If injuries are expected to continue, and feasible restoration alternatives exist to address such injuries, trustees proceed to conduct an assessment.

Restoration planning: Efforts during this phase are directed at evaluating potential injuries to determine the need for, and scale of, restoration actions. Two closely coordinated activities take place during this phase: **i) injury assessment**, to determine the nature and extent of injuries to natural resources and services; and **ii) restoration selection**, to select a preferred action(s) from a reasonable range of restoration alternatives. The responsible party is liable for paying the cost of restoration plus reasonable assessment costs.

Restoration implementation: NOAA works with co-trustees and responsible parties to design and implement restoration actions. Restoration plans are developed and presented for public comment before implementation. All restorations include monitoring provisions to allow for corrections, measure progress and determine the restoration effort's overall success. In many cases, the responsible party assumes responsibility for implementing the restoration with trustee oversight.

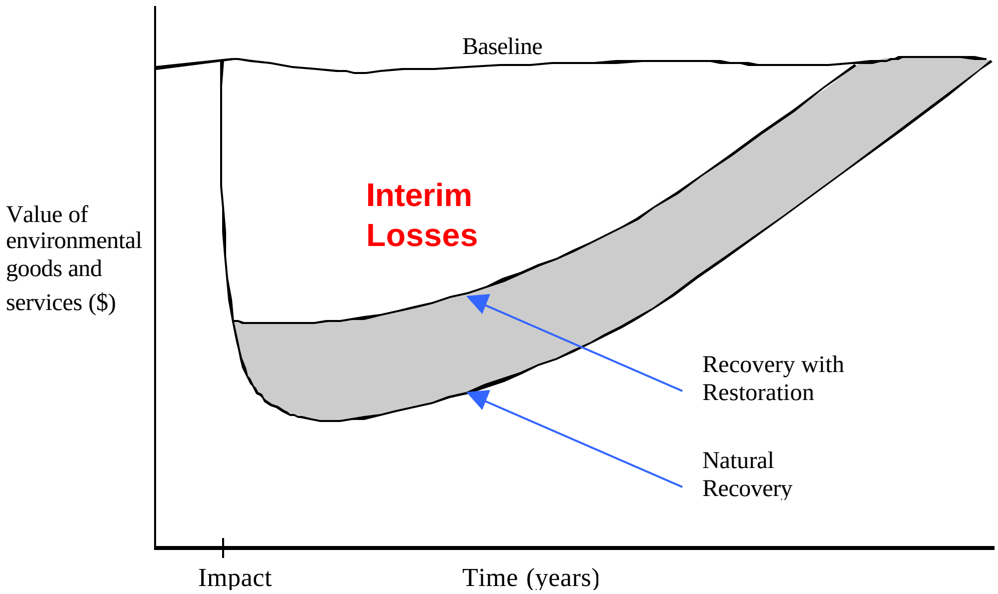
Natural resource damage claims have three basic components:

1) the cost of restoring the injured resources to baseline (i.e. the primary restoration);

2) compensation for the “interim” loss (see Figure 2) of resources from the time of injury until the resources recover to baseline, taking into account the enhanced recovery from primary restoration (i.e. the value of compensatory restoration needed); plus

3) the reasonable costs of performing the damage assessment.

Figure 2 – Concept of Interim Losses Following an Impact



The current statutory requirements are that all recovered damages are used to restore, replace, rehabilitate or acquire the equivalent of the injured resources (or to cover the costs of assessment). The compensatory restoration schemes need to be "scaled" to provide the equivalent level of interim natural resources and services from the time of the incident until the full recovery of resources. The process of scaling involves adjusting the size of a restoration action to ensure that the present discounted value of project gains equals the present discounted value of interim losses.

There are two possible approaches to scaling:

1) Service-to-service approach, for example using habitat equivalency analysis (HEA).

2) Valuation approach, where HEA is not appropriate, for example because like-for-like services cannot be restored at any compensatory restoration site.

The principal concept underlying **habitat equivalency analysis** is that the public can be compensated for damage to habitat resources through habitat replacement projects yielding an equivalent level of ecological goods and services. The basic steps for HEA implementation are:

1) **Quantify the losses from the injury.** Document and estimate the duration and extent of injury, form the time of injury until the resource recovers to baseline, or possibly to a maximum level below baseline:

2) **Quantify the gains from the habitat replacement project.** Determine and estimate the services provided by the compensatory project, over the full life of the habitat;

3) **Determine the size of the replacement project.** Calculate the size of the replacement project for which the total increase in services provided by the replacement project equals the total interim loss of services due to the injury; and

4) **Calculate the cost of the replacement project.** Calculate the costs of the replacement project or specify the performance standards in cases where the responsible party will be implementing the compensatory habitat project.

Strictly adhering to the NOAA guidelines, it is unlikely that the valuation approach would ever be considered appropriate for a coral reef damage assessment. Given the current status of coral reef restoration, in most instances suitable compensatory restoration schemes should be possible. However, whether the implementation of compensatory restoration schemes is the most suitable and cost-effective means of compensating for the damages is another matter. Spurgeon (1999) suggested a similar approach to damage assessment, but including a final step to investigate the optimum investment use of any interim damages for the overall benefit of coral reef conservation in the area damaged. For example, it may be better to spend additional funds on something other than expensive restoration and coral transplantation works, especially if corals are at risk from other controllable impacts.

Examples of the USA approach

When the M/V Elpis ran aground on a reef in the Florida Keys National Marine Sanctuary (FKNMS) in 1989, restoration funds of US$ 1.66 million (1991 prices) were awarded to restore 2,605 m^2 of totally destroyed reef and 468 m^2 of partially destroyed reef. The rehabilitation involved removing debris, stabilizing the reef substrate, importing new substrate, transplanting corals and sponges, and monitoring (NOAA, 1997a).

A similar example is the grounding of R/V Columbus Iselin in FKNMS in 1994 (NOAA, 1999). Compensation of US$ 3.76 million was paid for the destruction of 345 m^2 of reef area. Some of the money was used for compensatory restoration and grounding prevention elsewhere in the sanctuary. The rehabilitation included removal of debris, reinforcement and rebuilding to prevent further disintegration of the cracked reef, as well as transplantation of reef biota to the impacted site.

RECENT SUBMARINE FIBER OPTIC CABLE DAMAGE ASSESSMENTS

This section highlights a few “economics” related issues arising from a review of several coral cable impact assessment and mitigation plan reports made available (Coastal Planning and Engineering, 2001; Mathers Engineering Corporation, 2001; Post, Buckley, Shuh, and Jernigan, 1999 and 2001).

Damage to coral reefs resulting from cable laying operations is not officially covered by the OPA or CERCLA damage assessment regulations. Despite this, as part of the assessment process, the regulations have been followed (e.g. using Habitat Equivalency Analysis) in some cases to help determine an appropriate level of mitigation and compensation for damages to coral reefs. For example, Habitat Equivalency Analysis has been used to determine how many artificial reef modules should be installed. In other cases, a more subjective approach has been adopted, with cable operators required to provide a compensatory reef comprising limestone boulders.

In principle, such approaches are to be encouraged. However, the brief review of reports did reveal a few potential flaws.

- The damage assessment investigation and restoration plans are sometimes focused purely on hard corals. However, the cables also severely impact other important and slow growing sessile organisms such as gorgonians and sponges.

- A significant proportion of damages to reef biota occurs well after the cables have been placed, as a result of the cable swinging due to natural (e.g. currents and storms) and human induced effects (e.g. fishing gear and anchors). This is not picked up in the original damage assessment. The issues may be picked up during the later monitoring of sites, although this is restricted to 5 years. The impacts may well occur long after the 5 year period.

- The amount of “resource services lost” has in some damage assessments been underestimated, using a 30 year recovery period whilst claiming to use a 35 year recovery period.

- The reports using the HEA approach end up recommending a single artificial reef module per cable laid across a reef, which seems to be a poor trade off.

- The artificial limestone boulders installed for compensation do not appear in some cases to be providing an equivalent level of resources, particularly with respect to barrel sponges and gorgonians. The latter struggle to attach and survive on the generally vertical boulders (Sultzman, 2002).

- The current fee for laying cables across reefs is perhaps rather low bearing in mind the value of the "public property" reefs they cross. The application processing costs should also cover the full administrative costs required to review the damage assessment and monitoring processes associated with each cable.

CONCLUSIONS AND RECOMMENDATIONS

Key conclusions from this paper are that:

- Corals and their associated organisms have extremely high welfare values and contribute significantly towards local and regional economies.

- The value of corals can be estimated with a reasonable degree of accuracy using a range of continuously improving valuation techniques.

- The status of coral reefs in Florida is rapidly declining as a result of numerous different threats.

- Vulnerable coral reefs of significant value are being impacted by cable laying operations in Florida.

- Not only are hard corals are being affected, but many other important sessile organisms too.

- Impacts arising from cable laying operations are not restricted to the actual cable laying operation, but can occur continually for many years.

- Current impact assessments and damage mitigation and compensation packages may be inadequate.

- In other countries, damage assessments for coral reefs take into account the value of corals damaged and result in compensation packages that can be used to fund appropriate conservation initiatives.

- The current fee for cable companies to lay cables across reefs in Florida may be too low.

Key recommendations are that:

- Impact assessments should broaden their scope to include quantification of significant sessile organisms other than hard corals.

- Where feasible, alternative approaches to laying submarine cables should be adopted to minimize impacts to large corals and sponges.

- Longer term monitoring programmes should be implemented to record impacts occurring over time.

- The long-term effectiveness of mitigation measures implemented (e.g. coral transplantation and deployment of artificial reefs) should be fully explored.

- If the mitigation measures are found to be inadequate, additional appropriate compensation should be provided.

- The existing situation with respect to the above should be fully investigated so that future decisions made concerning cable laying operations and any the necessary mitigation and compensation can be improved.

- The basis for setting cable fees should be re-examined to take into account all aspects of the cable laying process, including assessment of impacts and damages; the mitigation and compensation packages; and the overall monitoring and administration required.

REFERENCES

Barton, D. N. (1994) *Economic Factors and Valuation of Tropical Coastal Resources*, Report 14/94, University of Bergen, Norway.

Bateman I et al (2002) Economic Valuation with Stated Preference Techniques: A Manual, *Edward Elgar Publishing Ltd.*

Bennett J and Blamey R (eds.) (2002) The Choice Modelling Approach to Environmental Valuation, Cheltenham: *Edward Elgar Publishing Ltd.*

Berg, H. M. C. Öhman, S. Troeng and O. Linden (1998) "Environmental Economics of Coral Reef Destruction in Sri Lanka", *AMBIO*, Vol. 27, No. 8, pp. 627 - 634.

Causey, Billy, Joanne Delaney, Ernesto Diaz, Dick Dodge, Jorge Garcia, Jamie Higgins, Brian Keller, Ruth Kelty, Walter Jaap, Cruz Matos, George Schmahl, Caroline Rogers, Margaret Miller and Donna Turgeon. Status of Coral Reefs in the U.S. Caribbean and Gulf of Mexico: Florida, Texas, Puerto Rico, US Virgin Islands, Navassa. In *Status of coral reefs of the world: 2002.* Edited by Clive Wilkinson.

Cesar, H (1996) *Economic Analysis of Indonesian Coral Reefs*, Environment Department, World Bank, Washington, D.C.

Cesar (2000). Collected Essays on the Economics of Coral Reefs. CORDIO.

Cesar, H. van Beukering P., Pintz, S and Dirking, J. (2002). Economic valuation of the coral reefs of Hawaii. Final Report to NOAA.

Coastal Planning and Engineering (2001). Atlantica U.S.A., L.L.C fiber optic cable installation, Boca Raton (Palm Beach County), Florida; Atlantica-I system cables 1 and 2, stony coral impact six months post-construction monitoring report, and Artificial reef colonization six-month post-monitoring report. Unpublished report submitted to Florida Department of Environmental Protection, West Palm Beach, Florida.

Department of Interior (1995). CERCLA NRDA Regulations.

Dixon, J. A., Scura, L. F., Carpenter, R. A., and Sherman, P. B (1997) Economic Analysis of Environmental Impacts. Published in association with the Asian Development Bank and the World Bank. Earthscan Publications Ltd, London.

Fonseca, Mark, S., B.E. Julius, and W.J. Kenworthy. 2000. Integrating biology and economics in seagrass restoration: How much is enough and why? Ecological Engineering, 15: 227-237.

Gustavson, K. (1998) Values associated with the local use of the Montego Bay Marine Park. Study prepared by for the World Bank. World Bank, Washington.

Hazen and Sawyer (2001). Socio-economic Study of Reefs in Southeast Florida. Final Report to NOAA, October 2001.

Hufschmidt, M.M., James, D. E. Meister, A.D., Bower, B.T. and J.A. Dixon (1983) *Environment, Natural Systems and Development: an Economic Valuation Guide,* John Hopkins University Press, Baltimore.

Hundloe T.J. (1990). Measuring the value of the Great Barrier Reef. Australian Parks and Recreation 26(3), 11-15.

JacobsGIBB (2002) Public preferences for low flow alleviation on the River Mimram, Report prepared for the UK Environment Agency.

Leeworthy V. R. and Bowker, J. M. (1997) Nonmarket economic user values of the Florida Keys/Key West. Linking the Economy and Environment of Florida Keys/Florida Bay.

Mathers Engineering Corporation (2001). Caribbean Crossings Ltd. – Bahamas Internet Fiber Optic Cable System, BICS post lay final report. Unpublished report submitted to Florida Department of Environmental Protection, West Palm Beach, Florida.

Mattson, J.S. and J.A. DeFoor (1985) "Natural Resource Damages: Restitution as a Mechanism to Slow Destruction of Florida's Natural Resources", *Journal of Land Use Environmental Law*, Vol. 1, No. 3, pp. 295-319.

Munasinghe, M (1993) Environmental Economics and Sustainable Development. World Bank Environment Paper Number 3. The World Bank, Washington D.C.

National Oceanographic and Atmospheric Administration (NOAA) (1995/2000) Habitat equivalency analysis: An Overview.

NOAA (1996) Guidance document for Natural Resource Damage Assessment Under the Oil Pollution Act of 1990: Injury Assessment.

NOAA (1997a) "Elpis Coral Reef Restoration", http://www-orca.nos.noaa.gov/darp/seregion/elpis.htm

NOAA (1997b) Guidance document for Natural Resource Damage Assessment Under the Oil Pollution Act of 1990: Scaling Compensatory Restoration Damages.

NOAA (1997c/2000). Habitat Equivalency Analysis: an overview. Policy and Technical Paper Series. No. 95-1.

NOAA (1999). Web page: http://www.sanctuaries.nos.noaa.gov/special/columbus/project.html

Pearce, D. W. & Turner, R. K. (1990). Economics of Natural Resources and the Environment. Wheatsheaf Publications.

Post, Buckley, Shuh, and Jernigan. (1999). Mitigation plan for the deployment of telecommunication cables in the nearshore waters off Hollywood, Florida. Unpublished report submitted to Florida Department of Environmental Protection, West Palm Beach, Florida.

Post, Buckley, Shuh, and Jernigan. (2001). Arcos-1 north and south cable Sunny Isles, Dade County, Florida coral assessment and restoration report. Unpublished report submitted to Miami-Dade County Department of Environmental Resources Management, Miami-Dade County, Florida.

Porter. J. W. and O. W. Meier (1992) Quantification of loss and change in Floridian reef coral populations. American Zoologist 32:625-640.

Smazant A.M. (2002) Nutrient enrichment on coral reefs: is it a major cause of coral decline? Estuaries. Vol 25, No 4b, p743-766.

Spash C. L., Van der Weerff, J. D., Westmacott, S. and Ruitenbeek, H. J., (1998) Lexicographic preferences and the contingent valuation of coral reef biodiversity in Curacao and Jamaica. Study prepared for the World Bank. World Bank, Washington.

Spurgeon J.P.G. (1992) "The Economic Valuation of Coral Reefs", *Marine Pollution Bulletin*, Vol. 24, No. 11, pp. 529-536.

Spurgeon J P G (1999). Economic Valuation of Damages to Coral Reefs. Coral Reefs: Marine Wealth Threatened. Conference organised by National University of Mexico. Cancun, Mexico, 1999.

Spurgeon J.P.G. (2000) Spurgeon J P G and Lindahl U (2000). Economics of Coral Reef Restoration. In Cesar (Ed) Collected Essays on the Economics of Coral Reefs. CORDIO.

Spurgeon et al (2001a) Economic Evaluation of Inland Fisheries, Module B: Indirect economic values associated with fisheries, R&D Project Record, W2-039/PR/2 prepared for the Environment Agency.

Spurgeon J.P.G. (2001b) Valuation of Coral Reefs: The Next 10 years. Paper prepared for an International Consultative Workshop on “Economic Valuation and Policy Priorities for Sustainable Management of Coral Reefs”. ICLARM, Penang Malaysia, December 2001.

Stynes D.J. (1999) Economic Impacts of Tourism. Bulletin report for Dept of Park Recreation and Tourism Resources, Michigan State University.

Sultzman (2002) A Professional Jury Report on the Biological Impacts of Submarine Fiber Optic Cables on Shallow Reefs off Hollywood, Florida. Report to PEER.

Ruitenbeek H. J., and Cartier C. M. (1999) Prospecting for marine biodiversity: a case study in Montego Bay, Jamaica. (Chapter 13). In Turner K, Bateman, I, Adger N (eds) Economics of coastal and water resources: valuing environmental functions. Kluwer Academic Press, Dordrecht.