A summary of reports assessing impacts and costs of the grounding and removal of the cargo freighter M/V Oceanus on the community of Satawal, Yap State, Federated States of Micronesia.

prepared by Leanne Fernandes

for Paul, Johnson, Park and Niles
on behalf of the People of Satawal

October 1995

Introduction

On 18 March 1994, the M/V Oceanus, a large cargo freighter, went aground on the reef terrace off the north east end of Satawal Island, Yap State, Federated States of Micronesia. After removal of some of her cargo of steaming coal, the Oceanus was successfully dragged off the reef on 3 May 1994. The community of Satawal suffered many dimensions of damage as a result of this accident and are presently seeking some form of compensation. To gain compensation for damages these damages must be assessed. For the purposes of a court of justice, all the damages should be translated into monetary terms. This is not possible for reasons discussed later. Most of the damages can, however, be identified and some of them can be quantified and a few of them can be assessed monetarily. This summary compiles information gathered on the qualitative and quantitative damages caused on Satawal and suffered by the Satawalese as presented in three reports:

A. Lopez. 1995. Satawal: A subsistence culture living on the edge. Report presented to Professor S. Gliessmand of the Environmental Studies Board, University of California, Santa Cruz, Mr. Ed King of the Law Corporation Paul, Johnson, Park and Niles and The San Jose/Evergreen Community College District.
J.E. Maragos, J.O.Fagolimul and M. Levine. 1995. Impact of the grounding and removal of the cargo freighter M/V Oceanus on the coastal resources of Satawal Island, (Yap State, Federated States of Micronesia). DRAFT report prepared for Paul, Johnson, Park and Niles on behalf of the People of Satawal.
M.A.McCoy. 1995. Report of the activities/interviews at Satawal, June 28 - July 5 1995. Report prepared for Paul, Johnson, Park and Niles.

The purpose of this summary is to gather the information in such a way as to clearly list the damages incurred by the community of Satawal and economically assess their value where possible.

Damages incurred by the Satawal community

Cultural values lost

Traditional authority of the chiefs has been undermined -

through the disruption caused by the ship grounding (e.g. orders to return to tending the taro were ignored) and through the loss of a medium through which to express power (i.e. previously manifested by permission to fish Wenimong reef but currently lost due to the absence of fish)(Lopez 1995)

Decrease in use of traditional foods and thus traditional food related practices -

of fishing/gathering seafoods, meal preparation and perhaps other culturally important activities (author's surmise from results in Lopez). This effects both men and women as the men traditionally do the fishing and the women gather seafood inside the reef and both these activities occurred frequently at Wenimong and involve traditional practices (Lopez 1995; McCoy 1995).

Loss of the ceremony of fishing at Wenimong reef.

In addition to the decreased fishing which occurs due to less fish being available at Wenimong there is the loss of ceremony and sacred tradition associated with fishing at Wenimong in particular (Lopez 1995; McCoy 1995). This loss would not have occurred, for example, if the ship had grounded elsewhere around Satawal.

Loss of cultural independence due to increased reliance on imported foods

This is especially true as this introduces a greater component of the money market into the, essentially, subsistence community (surmised from Lopez 1995)

Decrease in cultural integrity of one of the few remaining traditional subsistence societies -

globally speaking (Maragos et al 1995). This decrease has occurred due to the many reasons presented above and also, probably, simply due to the increased exposure of the people to the crew of the grounded ship, the salvage crews, the subsequent research teams. This value is not only lost to the people of Satawal themselves but is lost to the world (existence value)(author's surmise).

Loss of social values

Disruption of the normal functioning of the whole community.

During and since the time of the grounding various community activities were temporarily or permanently disrupted: taro farming was stopped or decreased; local fishing decreased; fishing at other islands increased; decision making was disrupted (due to loss of power of chiefs; eating habits changed; schools were disrupted) (Lopez 1995, McCoy 1995)

People feel a new insecurity with regard to their source of food.

There is worry with regard to having sufficient sources of food (Lopez 1995) and with regard to whether the seafoods they gather from or near Wenimong is poisoned (Lopez 1995, McCoy 1995).

People were angry that their sacred reef area was damage (Lopez 1995)

People felt that they were being violated by this intrusion upon their resources and community (Lopez 1995)

Loss of nutritional value

Decrease in taro (and perhaps other) cultivated food production.

During the time when the ship was grounded women were distracted or afraid to tend their gardens. They tended to discuss and watch the activities of the ship and/or were afraid that they would be harassed by the foreigners if they went to their gardens. Furthermore, the harvest of taro is believed to have been less due to excessive amounts of sea spray which were directed across the part of the island with gardens (Lopez 1995, McCoy 1995).

Decrease in fish

Approximately 10 times per year about eight canoe loads of fish used to be caught on Wenimong reef (Lopez 1995, McCoy 1995). This supplied a good sized fish to every person on the island. Now, less than one canoe can be caught there supplying only one smaller fish per household. Furthermore, women used to catch smaller fish as well as other marine animals) behind Wenimong reef in tide pools. This practice is no longer conducted as these animals are no longer available there(Lopez 1995).

Decrease in octopus

Increased amounts of rubble inside Wenimong reef have decreased available habitat for octupii (McCoy 1995). Further, the octupii which have been caught and eaten have caused illness (diarrhea) among the population. There is concern that this is associated with the grounding (ciguatera). In any case, this fear of poisoning is genuine and thus octupii are eaten less frequently.

Ciguatera poisoning in food sources

Preliminary analysis of algal samples taken from Satawal indicate low concentrations of *G. toxicus* the causative agent of ciguatera poisoning. Analysis of fish samples is pending.(Lopez 1995)

Increased stress on remaining food sources.

Due to the decrease in seafood available from Wenimong reef area, alternative protein sources from other locations and islands are being used more intensively and the stocks of organisms available there are also coming under stress (Lopez 1995).

Increased numbers of people to feed.

There have been excessive numbers of “visitors” to Satawal over the last year in connection with the grounding and tradition has required that whatever food and drink is available be shared (McCoy 1995).

Loss of medicinal value

Loss of medicinal ingredients.

Ingredients for specific medicines used to be mainly available behind Wenimong reef. The large amounts of coral stone and sand deposited on top of the reef mean that there ingredients can no longer be obtained (Lopez 1995, McCoy 1995).

Loss of biological value

Physical damage occurred to the reef community of Wenimong due to the grounding.

The damaged area is estimated to be 36,476 m^2 including 12,600m^2 of major damage. Due to the excess sediments this area almost no recolonization of corals or, consequently, fish is occurring (Maragos et al 1995). An excess of sediments can be detrimental for reef benthos in four ways: they scour the substrate thus removing any potential coral or algal recruits; sediment can cover substrate normally available for settlement of young benthic organisms but itself provides no substrate for settlement; suspended sediments decrease availability of light to existing benthic organisms and settling sediments can smother benthic organisms.

Pollution of the reef occurred.

Coal, coal dust, oil and bilge water, garbage and waste were all released into the water around Wenimong from various of the vessels at Satawal in connection with the grounding of the Oceanus(Maragos et al 1995)

Potential introduction of alien species occurred via the release of ballast water (Maragos et al 1995).

Potential dispersal of the negative effects of the sediments -

could occur especially if high winds cause waves to transport the sediments further (Maragos 1995).

Increased environmental pressure on two uninhabitated neighbor islands -

in the form of increased harvests of birds, eggs, clams, other shell fish and green turtles (listed as a threatened species in the U.S. Endangered Species Act).

Loss of aesthetic value

Temporary fouling of Satawal's beaches with coal, coal dust and oil occurred which was aesthetically unappealing and (possibly) interfered with the normal recreational activities of the locals (Maragos et al 1995).

Potential loss of shoreline protection.

If the living reef benthos is not re-established then the reef substrate will erode and expose the windward side of the island to increasing amounts of wave action and storm surge. The erosion of reef substrate will be exacerbated by the presence of excess amounts of sediment (surmise by author only).

For the purposes of seeking compensation for these damages, it would be ideal if they could be assessed in monetary terms. This is difficult if not impossible for a subsitence community without an operational market system. One of the more tangible, measurable damages is the loss of nutritional value.

Value of loss of nutritional value of fish from Wenimong reef

Estimating this value requires three basic steps:
1. Estimating the weight of fish harvest lost due to the ship grounding at Wenimong.
2. Estimating a cost per unit weight of that fish.
3. Estimating the net present value of the lost fish product.

An extremely rough estimate can, theoretically, be made of the weight of fish which were caught at Wenimong prior to and after the grounding of the Oceanus based upon the estimate of the numbers of fish caught per year (Lopez 1995 and McCoy 1995) and their average length at the grounding site and elsewhere on the island (Maragos et al 1995). It is assumed that the size of fish caught before the grounding is more like the size of fish sampled at the control sites. Note that the data indicate only very small sizes of fish at either control or damaged sites suggesting that the data do not include size of pelagic fish which were important at Wenimong.

Calculation:

The weight of fish the average fish caught at Wenimong pre-grounding: 4.47 grams
The weight of the average fish caught at Wenimong post grounding: 2.98 grams
These weights were calculated using an estimate of the length-weight relationship for the Threadfin bream (*Nemipterus marginatus*). The parameters should be replaced with more appropriate estimates.
Weight = 0.0125 Length ^{3} (from Pauly 1983 in P.Sparre et al 1989).

The numbers of fish which used to be caught annually can be estimated by the fact that approximately every person on the island used to get a fish each of the ten times per year that Wenimong reef was fished (Lopez 1995, McCoy 1995).
800 people x 4.47grams x 10 fishing trips per year= 35760 grams or 35.76 kilograms
One eighth of that annual catch is merely 4.47 kilograms per year.

These weights are too low to be realistic and are not supported by the many statements that 8 canoe loads of fish used to be caught at Wenimong about ten times every year. The weight of fish which used to be caught can perhaps better be calculated using estimates of the volume of the “8 canoes which came back filled with fish from Wenimong” (Lopez 1995) before the grounding. The volume of fish (in cubic cm) is approximately equal to it’s weight (in grams)(Sparre et al 1989).

Another estimate can be made by multiplying the damaged reef area by the average sustainable yields of coral reef and tropical pelagic fisheries measured around the world (Marten and Polovina 1982). Marten and Polovina (1982) present nine estimates of sustainable fish yield levels for coral reefs. The average is 6.38 metric tonnes per kilometer^2 of reef ($\pm$ 95% confidence limits of 4.58 metric tonnes per kilometer^2). For pelagic fisheries the sustainable fish yield was estimated at 2.732 tonnes/km^2 /yr (n=12, 95% confidence limit is 0.962). Maragos estimated that 36476 m^2 of reef was damaged, including 126000 m^2 of major damage. Given these figures, the potential loss of fish catch associated with these amounts of reef damage can be calculated (Table 1).

Table One. Estimates of potential fish yield lost based on a world wide average.

Area of reef	Reef fish yield (kilograms)	Upper and lower bound of 95% confidence limits for reef fish (kg)	Pelagic fish yield (kilograms)	Upper and lower bound of 95% confidence limits for pelagic fish (kg)
36476 m^2	233.72	65.66 - 399.78	99.65	64.56 - 134.74
12600 km^2	80.388	22.68 - 138.1	34.42	22.3 - 46.54

A problem lies in the fact that the islanders harvested pelagic fish from this area (jack, akule) as well as reef fish (Lopez 1995, Mc Coy 1995). Harvest of both types of fish has been stated to have decreased and are presently forbidden. If we assume that the harvest of pelagic fish at Wenimong is also connected to the area of substrate damaged at Wenimong, then the estimated in Table One provide indications of both types of fishery loss in units of weight.

McCoy (1995) indicates that carangid jack and Akule used to be caught in the area of the grounding. Lopez's (1995) work showed that Spam and corned beef were stocked as potential protein substitutes for the islanders. Ideally, market prices of these goods would be available for Satawal. Until this occurs, I substitute Oahu prices in their place simply to give an idea of the analysis we are working towards. For the carangid jack I have used prices of skip jack tuna/trevally jack which are similar. In fact, it is doubtful that jack or Akule could be imported to Satawal at any price.

Table Two. Estimating the replacement cost of the nutritional value lost (data from Table Two used). C.L. = confidence limits. Prices based on Oahu Safeway prices, October 1995.

Prices used to estimate cost of nutritional damage	Estimate based on 100% yield loss from 36476m^2 damage (95%C.L.)	Estimate based on 100% yield loss from 12600m^2 damage (95%C.L.)
Spam/corned beef equivalent of reef and pelagic fish ($1.79/12 oz)	US$1754.06($532.69 - $2812.44)	US$625.51 ($236.66-$971.51)
Spam/corned beef equivalent of pelagic fish only ($1.79/12oz)	US$524.32 ($339.69 - $708.95)	US$202.54 ($117.33 - $244.88)
Spam/corned beef equivalent of reef fish only($1.79/12 oz)	US$1229.74 ($193.00-$2103.49)	US$422.97 ($119.33 - $726.63)
Jack (average ± $6.50/lb)	US$1426.71 ($924.32 - $1929.10)	US$492.80 ($319.27 - $666.32)
Akule (average ± $5.00)	US$1097.47 ($711.01 - $1483.92)	US$379.07 ($245.59 - $512.56)
Reef fish (average ±$5.00/lb)	US$2574.01 ($723.13 - $4402.86)	US$885.33 ($249.78-$1520.93)
Average total cost summing reef fish and pelagic fish (using the mean price of akule plus jack for the pelagic fish)	US$3836.10	US$1321.27

NB. 1oz = 28.35g; 1 lb. = 0.454 kg.

If it is assumed that the Satawalese were harvesting around sustainable yield levels (and not substantially below or above) then it is reasonable to estimate that the maximum sustainable yield was the sum of the 8 canoes they harvested each of the 10 visits to Wenimong each year. Thus, the value of the fish lost should be about the value described above, if not for the Oahu prices used.

The decrease in catch was described as less than 1/8 the previous catch and presently no fishing is allowed at all. We have no data on the frequency that fishing occurred after the grounding but we could assume that fishing on Wenimong occurred at the same frequency as before during the year following the grounding and not since. A ban on fishing Wenimong has been put in place by island chiefs (McCoy 1995). Without implementation of restoration activities Maragos et al (1995) state that re-establishment of previous fish stocks is unlikely. If we assume that this remains true for the next 15 years then, even if the ban on fishing Wenimong is lifted, the poor catch recorded could be expected to be repeated. The village chiefs might be expected to realize that the area has not yet recovered sufficiently and thus re-instate the ban. In this scenario then, we could assume that essentially no fishing occurs at Wenimong over the next 15 years. It is assumed that, if not for the ship grounding, catch levels would have been sustained.

Table Three. Net present value (PV) in loss of the productive asset of the fish catch (d.r. = discount rate discussed below)

Year	Value of lost output	5% d.r.	PV @ 5% d.r.	10% d.r.	PV @ 10% d.r.	20% d.r.	PV @ 20% d.r.
1994	(Weight of fish usually caught - fish actually caught) x price per unit weight = $3356.59	1.0	$3356.59	1.0		1.0	
1995	Weight of fish usually caught x price per unit weight = $3836.10	1.0	$3836.10	1.0		1.0	
1996	this figure is the same as above = $3836.10	0.952	$3651.97	0.909		0.833	
1997	$3836.10	0.907	$3479.34	0.826		0.694	
1998	$3836.10	0.864	$3314.39	0.751		0.579	
1999	$3836.10	0.823	$3157.11	0.683		0.482	
2000	$3836.10	0.784	$3007.50	0.621		0.402	
2001	$3836.10	0.746	$2861.73	0.564		0.335	
2002	$3836.10	0.711	$2727.47	0.513		0.279	
2003	$3836.10	0.677	$2597.04	0.467		0.233	
2004	$3836.10	0.645	$2474.28	0.424		0.194	
2005	$3836.10	0.614	$2355.37	0.386		0.162	
2006	$3836.10	0.585	$2244.12	0.350		0.135	
2007	$3836.10	0.557	$2136.71	0.319		0.112	
2008	$3836.10	0.530	$2033.13	0.290		0.093	
2009	$3836.10	0.505	$1937.23	0.263		0.078	
2010	$3836.10	0.481	$1845.16	0.239		0.065	
Total			$44 771[12]				

This same analysis can be repeated for different, and hopefully more accurate, estimates of fish catch lost and of the monetary value of the fish.

Note that any values derived in this way, at the most, represent only the value of the nutritional loss associated with the fish which are no longer caught at Wenimong. This does not include the nutritional value lost due to other species or lost due to decreased fish catches elsewhere on the island which may be connected to the grounding.

This is only costing the loss associated with one of the twenty two different types of damage incurred by the people of Satawal.

Costing the damages

The economic impact of all the damages incurred through the grounding of the ship "Oceanus" is extremely difficult to assess for a community which is basically subsistence (Winpenny 1991). This society has almost no monetary market measures of the multiple benefits which were derived from Wenimong as it was or monetary measures of the damages incurred. Further, the lack of a monetary market means that the generation of such measures is extremely difficult. This creates a potentially unfair situation wherein compensation for damages may be denied simply due to logistical measurement constraints. Fortunately economics does provide some tools which can be applied even in Satawal. It remains true that any estimate will be conservative as many of the lost benefits and costs incurred cannot be valued in today's rigid economic system of the western world.

Replacement cost

The cost of replacing (or restoring) productive and other physical assets damaged by the ship grounding on Satawal can be taken as a minimum estimate of the presumed benefits of those assets (Hufschmidt et al 1983 p.266). The benefits of the restoring the reef community and other productive assets potentially include some degree of restoration of various nutritional values, medicinal ingredients, traditional authority, cultural independence, traditional ceremony, the physical damage to the reef, use of traditional food and food preparation practices and security of food sources. This does not include most of the other benefits derived from Wenimong which are not strictly "economically productive" but may be still be important. For example, the stress and sense of violation experienced by the Satawalese is not compensated for by this replacement cost method. Two projects are suggested which, together, could lead to the temporary replacement and ultimate restoration of the damaged reef of Wenimong.

The <u>Fish Aggregation Device (FAD) project</u> aims, temporarily, to replace the benefits previously derived from the natural function of the reef as fish habitat (Maragos et al 1995). The idea is to install fish aggregation devices in the area of Wenimong to temporarily replace the natural function of the original reef as fish habitat. This project may, in addition, provide for the interim restoration of the cultural value of the Wenimong reef area as important and ceremonial fishing ground and as a medium of the expression of authority by the local chiefs.

Concurrently, the environment should be restored to a more natural condition, in terms of sediment levels, to enable recolonization of the reef by coral recruits and other benthic organisms initially, and reef fish consequently. This restoration could occur if the <u>excess sediments are removed</u> by mechanical means (Maragos et al 1995).

Calculating net present value of the repairing some of the damages incurred

The net present value of re-introduction of fish to the area and restoration of the benthic reef community over the next 15 years is calculated by evaluating the costs associated with the FAD project and the sediment removal project which are both assumed to begin in 1996.

The timing and tasks required to conduct the FAD project are likely to include:
1. Organizing for purchase and installation of FAD (including field trip for installation) 1996.
2. Purchase of FAD 1996.
3. Transportation and installation of FAD at Wenimong, Satawal 1996.
4. Monitoring of effectiveness of FAD 1997, 1998, 1999, 2004, 2009 (check frequency and dates with Jim).

The components of the FAD project which must be costed include:

Experienced personnel	- for organizing logistics including field trips 1 to 6 (time x wage);
	- for supervising installation of FAD (necessary?)(field trip 1) (time x wage);
	- for monitoring the effectiveness of the FAD after installation (time x wage for field trips 2 to 6)
Manual labour for	- for assisting with installing the FAD (time x hourly wage x # people field trip 1);
	- for assisting with monitoring (time x hourly wage x # people for field trips 2 to 6).
Cost of the FAD (including parts and labour for building it)(in 1996 only)	
Transportation costs (cost	- of FAD, of labour and of expertise for installation and monitoring of flights x #trips; cost of boat time x # days for field trips 1 to 6).
Communication costs	- for organizing the project (for field trips 1 to 6).

The timing and possible tasks required to conduct the sediment removal project are likely to include:
1. Hire or perhaps build/adapt machinery to remove sediments (1996)
2. Organizing the logistics of the field trip including transport of suction dredge (or other sediment removal mechanism) 1996.
3. Field trip to conduct the dredging at Wenimong, Satawal 1996.
4. Monitoring of effectiveness of sediment removal in promoting recruitment 1997, 1998, 1999, 2004, 2009 (check frequency and dates with Jim).

The components of the sediment removal project which must be costed include:

Experienced personnel	- for building/adapting dredging machinery if necessary.
	- for organizing logistics including field trips (time x wage for field trips 1 to 6);
	- for supervising and conducting dredging (time x wage for field trip 1);

- for monitoring the recruitment of benthic and fish species after the sediment removal and for writing a report (time x wage for field trips 2 to 6)

Manual labour trip - for assisting with dredging (time x hourly wage x # people for field 1);
- for assisting with monitoring (time x hourly wage x # people for field trips 2 to 6).

Cost of the hire of the dredge (or other sediment removal apparatus) (field trip 1)

Transportation costs - of dredge, of labour and of expertise for dredging and monitoring (cost of flights x #trips; cost of boat time x # days for field trips 1 to 6).

Communication costs - for organizing the project (field trips 1 to 6).

In point of fact, the field trips required to carry out the two projects can be combined and since they are both addressing the restoration of damages incurred by the one grounding incident they can be combined for the purposes of estimating the lost benefits of that incident. Choice of use of a discount rate for Satawal is fairly arbitrary thus the net present value of the replacement costs is calculated for three commonly used discount rates. As a monetary economy is less relevant to Satawal, the social rate of time preference might be the best guide to choice of an appropriate discount rate. As the community of Satawal appears to have a great concern for the future of their people a lower discount rate might be more appropriate for their situation.

Table Four. The present value (PV) of the replacement costs. [d.r. means discount rate]

Year	Replacement cost	5% d.r.	PV at 5% d.r.	10% d.r.	PV at 10% d.r.	20% d.r.	PV at 20% d.r.
1996 (trip 1)	Add all the costs of the dredging /FAD trip	0.952		0.909		0.833	
1997 (trip 2)	Add all the costs of a monitoring trip	0.907		0.826		0.694	
1998 (trip 3)	this figure is the same as above	0.864		0.751		0.579	
1999 (trip 4)	"	0.823		0.683		0.482	
2004 (trip 5)	"	0.645		0.424		0.194	
2009 (trip 6)	"	0.505		0.263		0.078	
Total							

One assumption of this analysis is that the prices associated with the required project resources correctly reflect their scarcity. In actual fact, their true scarcity is probably better reflected using a shadow price but the data and time resources are not available to calculate a shadow price, thus actual price is used to represent the shadow price.

Uncertainty

There is a degree of uncertainty associated with the likely success of these projects in achieving their aims. This uncertainty has been minimized through choice of the most appropriate reef recovery actions from a range of possible alternatives. Beyond this, any uncertainty in the success of the projects is irrelevant.

The value of the projects is estimated for the purpose of considering the appropriate amount of compensation which should be awarded for the benefits which have been and could be lost due to the grounding of the Oceanus. The costs of these projects are being used to estimate the value of the benefits lost (if no recovery projects occur) or the value of benefits to be retrieved (if the recovery projects are implemented) . This method of estimating value of lost benefits is a standard economic approach called replacement or restoration cost method. The precise likelihood of success of these projects if implemented, while high, is also irrelevant at this point. The uncertainty becomes relevant when choosing, for example, between different types of FAD which have different prices and success rates. It is true, however, that the greater the uncertainty of a successful recovery, the greater the stress experienced by the Satawalese regarding the insecurity of a previously reliable source of sustenance. Greatest insecurity for the Satawalese lies in no action.

Concluding remarks

In economic project evaluation, the costs of not conducting these restoration activities would be compared with the cost of implementing them to decide if the project is economically desirable. This was not the purpose of the present exercise but can be conducted based upon the available information. If the enumerated costs are comparable or if it is "cheaper" to conduct the restoration activities then choosing this option is most economically efficient. This is extremely unlikely to be the case here. If the restoration activities are far more expensive, in monetary terms, than simply leaving the status quo situation as it is, then serious consideration must be given to the weight of the non-quantified costs. If the less tangible costs of not undertaking restoration activities are very important or large then restoration would be justified despite the discrepancy in the relative value of the quantifiable costs. Such an evaluation can be conducted once the cost of replacement and restoration activities are estimated.

Another important consideration is the continuing impact of foreign visitors associated with both the status quo situation and a situation where restoration activities would be occurring. In the latter situation, the impact can be expected to be greater and potentially more negative in some ways. To some degree then, a restoration project will cause more harm as well as repair other damages. To minimize this effect the project should be carried out in such a way as to minimize negative impact of foreign visitors on the island.

References

M.M. Hufschmidt, D.E. James, A.D. Meister, B.T. Bower and J.A. Dixon. 1983. Environment, natural systems and development: An economic evaluation guide. Johns Hopkins University Press: Baltimore.

G.G. Marten and J.J.Polovina. 1982. A comparative study of fish yields from various tropical ecosystems. In. D.Pauly and G.I. Murphy (Eds) Theory and Management of Tropical Fisheries. ICLARM/CSIRO: Manila.

P. Sparre, E. Ursin and S.C. Venema. 1989. Introduction to tropical fish stock assessment Part I. - Manual. FAO Fisheries Technical Paper 306/1.

J.T. Winpenny (1991) Values for the environment: A guide to economic appraisal. London: Overseas Development Institute.