Coral Reefs (1999) 18:393–402

REPORT

L. Fernandes · M. A. Ridgley · T. van't Hof

Multiple criteria analysis integrates economic, ecological and social objectives for coral reef managers

Accepted: 20 July 1999

Abstract Managing a coral reef in a small island state is a difficult task. Apart from having conflicting objectives and few data there is the added problem of how to evaluate the less tangible benefits of management. This study reports the successful use of multiple criteria analysis to help the managers of a coral reef to make "good" decisions. "Good" decisions are consistent with the community's desires to, in this case, preserve social and ecological values while simultaneously maintaining the economic benefits of dive tourism and maintaining the park as a global model of successful management. Multiple criteria analysis provides a systematic framework for evaluating management options. This study presents one of the first times multiple criteria analysis has been used in coral reef management, let alone in a non-industrialised setting. The results suggest that the method may be more widely useful than previously thought.

Key words Coral reef management · Policy evaluation · Multiple objectives · Participation · Coastal zone management · Marine park · Multiple criteria analysis

L. Fernandes (✉)
Program on Environment, East West Center, EWC Box 1037, 1777 East West Rd. Honolulu, HI 96848, USA
mailing address: Great Berrier Reef Marine Park Authority, PO Box 1379 Townsville, Q. 4810, Australia.
e-mail: leanef@gbrmpu.gov.au
Fax: +61-7-4772-6093

M.A. Ridgley
Department of Geography, University of Hawaii at Manoa, Porteus Hall 445, 2424 Maile Way, Honolulu, HI 96822, USA

T. van't Hof
Saba Conservation Foundation, The Bottom, Saba, Netherlands Antilles

Introduction

Decisions in natural resource management are frequently made without good quantitative data or the involvement of local user groups, and even without explicitly addressing the multiple objectives inherent in the process (McAllister 1986; Wells and Brandon 1992; van Pelt 1993). Evaluations of projects or policies are often dependent on sparse quantitative data using a single criterion, such as environmental quality, social acceptability or, commonly, economic efficiency (Munasinghe 1992; Force and Machlis 1997). Such evaluations, rather than highlighting the spectrum of strengths and weakenesses, have sometimes contributed to management failures (Wells and Brandon 1992; van Pelt 1993; White et al. 1994). In response, assessment of management options is becoming more integrated, more accepting of qualitative information and more participatory (van Pelt 1993; White et al. 1994; Johannes 1998).

Management of coral reef resources is particularly challenging. Coral reefs have complex marine environments where relevant scales in time and space are many and varied (Kenchington 1990); Consequently complete and detailed quantitative data are never available. Furthermore, coral reef management must also account for the subsistence use, and the social and cultural values of the reef to local people. Such people number in their millions globally (Richmond 1993).

This paper describes a systematic framework for evaluating coral reef management options. The framework, which can accommodate economic, social and environmental objectives, was tested for use in a participatory manner in a developing island state where quantitative data are limited and where people's preferences matter.

The multiple criteria analysis (MCA) framework was designed to conduct integrated, systematic program or policy evaluations (Korhonen et al. 1992). It can be used to inform decision-makers and involve user groups in situations where there are many conflicting

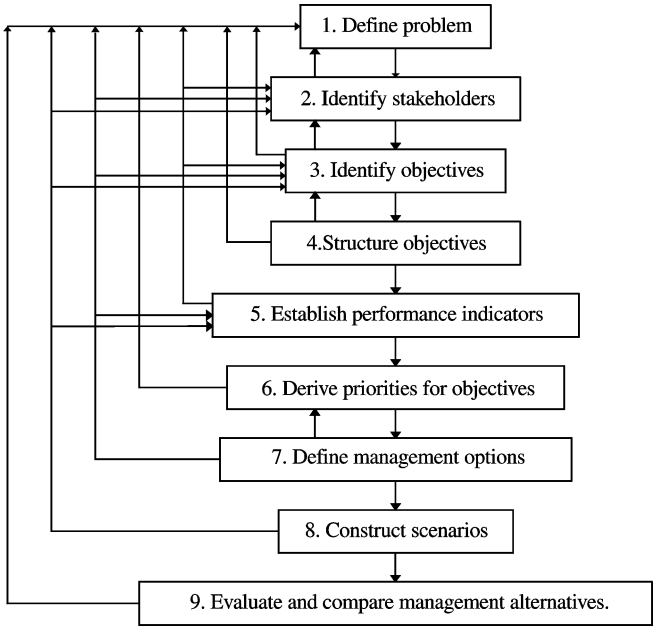

Fig. 1 Tasks and iterations involved in a multiple criteria analysis

objectives and limited data (Rietveld 1980; Marttunen and Hamalainen 1995; Yoon and Hwang 1995). MCA can incorporate both social and environmental issues into management decisions (Goicoechea et al. 1982; van Pelt 1993). Essentially, it helps decision-makers assess management strategies *a priori* based upon the relative extent to which they are likely to achieve a variety of management objectives. Part of its strength comes from its ability to represent human values and preferences directly and explicitly (Hamalainen 1992; Ridgley and Rijsberman 1994). The tasks that comprise a complete MCA are shown in Fig. 1.

To date, MCA has been applied mainly to business and terrestrial environments in industrialised countries (Goicoechea et al. 1982; Ballestero and Romero 1996; Salminen et al. 1996). Our case study demonstrates that it is a far more flexible tool than its previous uses suggest, and that it can be applied to help coral reef management where multiple objectives, human values and preferences must be taken into account.

Background

Saba is a small Caribbean island in the Netherlands Antilles (63°14′W, 17°38′N). Over the last 25 years, the 1200 inhabitants of Saba have seen the introduction of roads, an airport, a reliable electricity supply and a port (Mol 1989). The community has traditionally used its coastal resources for subsistence, sport fishing and recreation.

Saba's multiple-use marine park was established by the government in 1987 to help develop the potential for profit from visiting scuba divers while protecting their coral reef and other marine resources. The park surrounds the island to a depth of 60 m. Between 1962 and 1994, the number of tourists increased from about 1300 to about 23000 a year (Mol 1989; Saba Tourist Bureau, unpublished data), raising concerns among some Sabans that the marine environment might suffer as a consequence (van't Hof 1985; Saba Government Planning Office, unpublished data).

The marine park manager and Saba Conservation Foundation chairperson both had long associations with Caribbean marine resource management in general, and Saba in particular. They were perceived as credible, well-respected and acceptable expert advisors to government and the community on marine resource management issues. However, they were concerned at the lack of awareness of the values that might be associated with Saba Marine Park. Value exists in the achievement of desirable marine park objectives. We were invited to assess the values of the marine park in the eyes of the government and the wider community. Saba Marine Park's decision-makers considered that a formal assessment could help raise awareness of those values and of how the marine park could enhance those values. Multiple criteria analysis (Fig. 1), the methodology we chose, was applied in a participatory manner so that stakeholder input would define the objectives, priorities and management options against which the value of Saba Marine Park was assessed.

Methods and results

Identifying the problem, stakeholders and objectives

The marine park manager and the Saba Conservation Foundation chairperson, who were in charge of day-to-day park management, identified their major problems as, on the one hand, a lack of community and government appreciation of Saba Marine Park, and, on the other hand, insufficient awareness among the marine park staff of the community's needs and desires (Task 1). The managers identified the key stakeholders as all levels of marine park decision-makers, park users, educators, and people selling goods or services to marine park users (Task 2).

Views on what the marine park objectives should be were collected from respondents through a pre-tested, open-ended, semi-structured survey (Fernandes 1996). We chose a qualitative method of data collection because the purpose of this questionnaire was to collect the diversity of opinions rather than to generalise them. To reduce interviewer bias, questionnaires were personally administered by the one person (the first author) who expressed no personal opinions during the interviews. The standard social science techniques of "snowballing", combined with purposeful sampling, were used to identify and select respondents (Bernard 1988). By these methods, the first author's contacts on the island introduced her to other stakeholders, who introduced her to still other stakeholders, and so on until the people she met had no connection with the original contacts. She requested introduction to people with divergent viewpoints. Written responses to the same survey were also collected from 33 school children.

Table 1 Summary of most frequent responses of the Saban community to questions about Saba Marine Park (SMP). For public $n = 48$; for students $n = 33$

Summary of responses:	Frequency mentioned:	
Environmental Issues	Public	Students[a]
Maintenance of ecosystem (e.g., protecting the fish and/or coral, **maintaining water quality**[b])	43	28
Require a carrying capacity	20	4
Decreased anchor damage associated with mooring system	15	10
Patrolling and enforcement is important and/or should increase	13	
Impact per diver decreased by education	11	
Monitoring is important	10	
Fishers are being excluded and people fish less now	8	
Oil spill from St. Eustatius is of concern	8	
Expand the size or authority of SMP with regard to protection against future development	7	
Fish abundance is and should be increasing	5	10
Social Issues		
Education of local children	24	14
More communication/interactions with community	27	10
SMP attracts a desirable type of visitor	21	
Minor conflicts between SMP and SMP users	16	13
More support for SMP now, especially from fishers, as the economic benefits become apparent	16	
There is more appreciation and understanding of marine environment now	14	5
There is no conflict between fishers and SMP now	13	
No social impact of SMP	12	
Minor conflict exists between different SMP users	10	
Local access to resources is important	9	
Sabans are not interested and/or do not now about SMP	9	
Dive operators co-operate with SMP	6	3
Economic Issues		
Increased development on Saba is associated with SMP via divers and yachts	37	11
SMP is financially independent of Saba	11	
People are in better paying jobs partly because of SMP	9	
Political Issues		
Want SMP to continue advising government on developments that could impact the marine environment	14	

[a]"Students" refers to school students
[b]The **issues in bold** were also mentioned at least once at the public meeting

Data on objectives were collected from interviews to the point where new interviews provided no new objectives. This ensured comprehensive results. Respondents ($n = 88$) reflected the diversity of stakeholder groups, ages (mean = 39, range: 10–65), villages (all five villages) and sexes (M : F = 47 : 53) and were also people who were willing and able to participate.

Objectives for the marine park (Task 3), as well as actions that the park management should undertake (Task 7), were identified from the oral and written responses to the questionnaires (Sudman and Bradburn 1983; McCracken 1988; Sommer and Sommer 1991). Management actions were often identified in lieu of management objectives. For example, "putting in moorings" was identified in lieu of "minimising physical damage to the benthic community". "Objectives" are defined here as final outcomes that are of value to community and government. They were identified by determining *why* issues, management actions and concerns were raised. The validity of the interviewer's interpretations were checked by asking respondents to review her translation of their input into objectives. The most frequent responses, gathered from 6.6% of the total population of Saba, identified a variety of issues (which implied values) that the marine park should address (Table 1). All responses were used for identifying objectives and management actions, even if they were mentioned only once (therefore not in Table 1). For example, an objective that was originally identified only three times became one of the principal objectives due to support at all the review meetings: maintenance of Saba Marine Park as a global model of marine park management.

Two focus-group meetings were held to ensure that the management objectives, as extracted from written and verbal responses, were correct and complete (Morgan and Krueger 1993). A public meeting was also held to review the final objectives. Attendance was, according to locals, impressively high, with 50 participants (about 4% of the population). These multiple meetings and high levels of attendance meant that the output of this work was more likely to reflect stakeholder's needs and thereby increase its acceptability and appropriateness.

Structuring the objectives

Through an iterative process, a hierarchy of objectives for Saba Marine Park was generated (Task 4; Fig. 2). The first author structured objectives into groups of related objectives, each of which

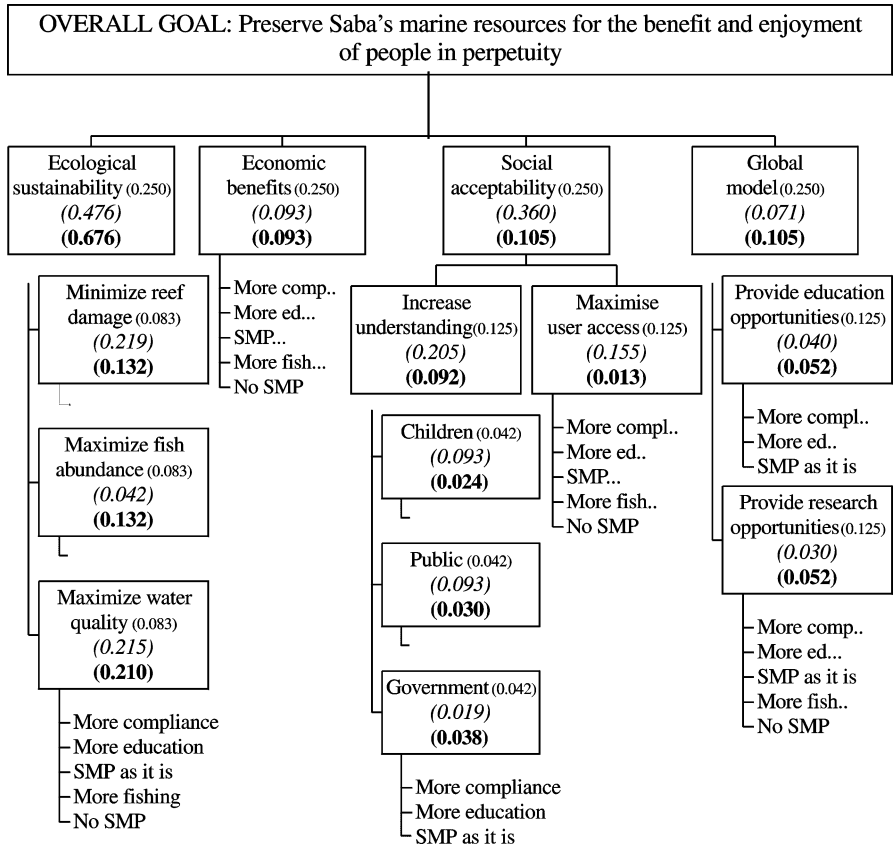

Fig. 2 Community-derived objectives hierarchy for Saba Marine Park (SMP). All objectives are in *boxes*. Management options come under each lowest level objective. There are three sets of numbers in *brackets*. The numbers in the *small font* directly after the objectives are default weightings: all objectives are equally important to achieving the overall goal. These are given for comparison purposes only. The weightings in *italics* are those of one of the experts; the weightings in *bold* are those of the other expert

contributed to a higher-level objective. An objectives hierarchy places the most generic objectives at the highest level of the structure and the most specific ones at the bottom-most level (Keeney et al. 1987). For Saba Marine Park, the overall goal was to "Preserve Saba's marine resources for the benefit and enjoyment of people in perpetuity". The main objectives within the goal were to achieve ecological sustainability, economic benefits and socially acceptable management, and to maintain Saba Marine Park as a global model of marine park management. Each of these top-level objectives was composed of more detailed, lower-level objectives, all of which had been identified by stakeholders.

Both the structure and content of the objectives hierarchy changed as a result of input from focus group and public meetings. For example, "maintain the material quality of life" was considered beyond the scope of Saba Marine Park, so was changed to "maintain economic benefits derived from Saba Marine Park". "Education" was recognised as a means by which to achieve an end, not an end in itself, so it became "increase awareness about the marine environment and marine park".

Prioritizing the objectives

The relative importance of each objective in the entire hierarchy was assigned by applying the "analytic hierarchy process", a multiple criteria method based on pairwise comparisons (Task 5; Saaty and Kearns 1985; Saaty 1980). In this method, each pair of objectives at the same level and in the same cluster of the hierarchy is compared in terms of their relative importance for achieving the "parent" objective immediately above them. Comparisons are made along a nine-point scale marked off both numerically (from 1 to 9) and with descriptions (from "equally important" to "extremely more important"; see Appendix 2).

At the highest level of the objectives hierarchy, the relative importance of each objective was assessed by individuals from all stakeholder groups, as indicated in Table 2. For example, they were asked to evaluate how important economic benefits were in comparison to social acceptability. In 60% of responses, the highest priority was given to maintaining the ecological sustainability of the marine environment of Saba. The lower-level objectives (the sub-objectives) were compared by the two managers: the local experts. They made pairwise comparisons of, for example, maximising water quality and fish abundance (Task 5). Individuals from all stakeholder groups were asked whether the managers would provide credible, unbiased input or whether other sources should be sought; all agreed that the nominated experts would provide unbiased assessments. Since there was not complete agreement between the experts, they provided two sets of weights for the subobjectives (shown in Fig. 2 in italics and bold). Both of the resulting base models were used in the analyses.

Establish performance indicators

Performance indicators and their ranges (Task 6) were defined by the Saba Marine Park manager and the chair of the Saba Conservation Foundation. They used the best available data whether qualitative

Table 2 Relative importance (priorities) of top-level Saba Marine Park objectives in contributing to the overall goal of "preserving the marine resources of Saba for the benefit and enjoyment of the people in perpetuity". The priorities given here are as judged by one individual from each stakeholder group. Each row sums to 1

	Objective			
Stakeholder groups	Ecological sustainability	Economic benefits	Social acceptability	Global model
Local government 1	0.323	0.221	0.285	0.171
Local government 2	0.309	0.388	0.249	0.054
Local government 3	0.290	0.470	0.200	0.040
Saba Conservation Found'n	0.476	0.093	0.360	0.071
Saba Marine Park	0.676	0.114	0.105	0.105
Recreational fishers	0.525	0.168	0.177	0.129
Gift/souvenir shops	0.401	0.126	0.277	0.197
Hotel/restaurants	0.293	0.285	0.260	0.163
Grocery stores	0.344	0.094	0.143	0.419
Dive shops	0.683	0.111	0.150	0.056
Tourist bureau	0.225	0.349	0.315	0.111
Educators	0.600	0.230	0.057	0.114
Politician	0.181	0.151	0.605	0.064
Art galleries	0.404	0.131	0.207	0.259
Developer	0.283	0.529	0.095	0.093
Default value (for comparison only)	0.250	0.250	0.250	0.250
Maximum value	0.683	0.529	0.605	0.419
Median value	0.344	0.168	0.207	0.111
Minimum value	0.181	0.093	0.057	0.040

or quantitative (Table 3). Ranges were standardised on a scale of 0 (undesirable) to 1 (desirable).

From Roberts (1994), and Polunin and Roberts (1993), sufficient data existed to detect biomass changes of 15 fish species from, in all, five families. If all five families increased in biomass, this was considered desirable; if all five decreased in biomass, this was considered undesirable. Coral damage was assessed from the level of damage detected at Hawkins et al's (1993) "low use" sites on Saba: if $\leqslant 2.4\%$ of the colonies were broken this was considered desirable. As there were no data as to what might be an undesirable level of damage for Saba, we chose 9.3% damaged colonies as undesirable based upon Hawkins and Roberts' (1997) assessment in Egypt. Thus, the current average level of damage at Saba, 2.8% (Hawkins et al. 1993) is 0.95 along the 0–1 scale of undesirable to desirable levels of damage.

All the performance indicators can be upgraded when new or better data become available.

Formulating management options

Suggestions for Saba Marine Park management actions were extracted from the surveys (from Task 3) and compiled into five distinct management options (Task 7), including the "Park as it currently is" and "No park". A third option, "More fishing access" involved the abolition of the existing "No fishing" zone. The fourth management option encompassed a larger education, communication and public interactions component ("More education about the park"). The final option, "More compliance with park rules", would require stronger enforcement and greater authority.

Constructing the scenarios

Scenarios describe conditions outside the control of the system under analysis (Task 8). For simplicity, this paper only offers the results of the "no change" scenario. For analyses under different scenarios see Fernandes (1996).

Measuring performance of the management options

Guided by the performance indicators, the two experts used the analytic hierarchy process to estimate the relative degree to which each lowest-level objective would be achieved under each of the five options being considered (Task 9). The evaluation was facilitated with the use of *Expert Choice*, software designed to implement the analytic hierarchy process (Expert Choice 1983). Management options were compared under "no change" conditions and along the same nine-point scale used in Task 6.

The relative value of each management option depended on the weighting of different objectives and sub-objectives (Task 5) and estimates of the degree to which each management option might achieve those objectives. The five management options (from Task 7) were evaluated under the priorities given by 15 different stakeholders (Task 2). As both managers' base models were used, thirty cases were analysed in total for the status quo scenario. The ranges of values for different management options are the result of different stakeholders ascribing different levels of importance to each objective (Fig. 3). For details on the calculations used, see a description of the analytic hierarchy process (Saaty 1980, Saaty and Kearns 1985, Appendix 2).

Comparing the management options

In all cases, the analysis showed that Saba Marine Park as it currently exists was far more valuable in achieving the overall goal than either no marine park or a marine park that allowed fishing everywhere (Fig. 3). This conclusion was reached regardless of the range of values held by various stakeholders and the different opinions of the two experts who defined the base models (see error bars, Fig. 3). The analysis demonstrated that the existing marine park was better able to achieve economic, social, environmental and global learning objectives than the less restrictive management regimes. If the marine park were abolished, a number of undesirable consequences would ensue. For example, the amount of diver spending would decrease, there would be less understanding and

Table 3 Performance indicators chosen to help estimate degree of achievement of each of the lowest-level objectives of the Saba Marine Park (SMP, in Fig. 2)

Objective	Abbreviation[a]	Performance indicator
Minimize reef damage	Minimize reef damage	Physical damage (breakage and abrasion per number of coral colonies (Hawkins and Roberts 1997)
Maximize fish stocks	Maximize fish abundance	Changes in biomass of fish families (Roberts 1994; Polunin and Roberts 1993)
Maximize water quality	Maximize water quality	Qualitative estimate of pollution from oil, nutrients, sediment and garbage
Contribute positively to the income of the Saban community	Economic benefits	Amount of annual spending by divers
Increase children's understanding of marine environment and SMP	Children	Number of lessons per year including the marine environmental and/or SMP
Increase public awareness of marine environment and SMP	Public	Number of locally available media exposures per year
Increase government awareness of marine environmental impacts and SMP	Government	Degree of satisfaction in SMP-government interactions as assessed by SMP and Saba Conservation Foundation
Minimizing conflicts of access and interest between users	Maximize user access	Qualitative assessment of degree of conflict by SMP based on number of warnings, complaints
Global education about marine biology and management using SMP as a model	Provide education opportunities	Satisfaction felt by SMP and Saba Conservation Foundation in degree of hands-on education and textual exposure
Scientific research into marine biology and management using the SMP as a model	Provide research opportunities	Satisfaction felt by SMP and Saba Conservation Foundation in amount and type of research conducted

[a]Abbreviations as used in the objectives hierarchy (Fig. 2)

awareness about marine ecology or management, and there would be increasing conflicts among users.

The evaluation also showed where there was room for improvement (Fig. 3). A marine park with a greater education and communication component was deemed by all stakeholders to be more valuable in achieving the desired objectives than the park as it was at the time. Similarly, all objectives could be better met by the option of "More compliance with park rules" than by keeping the status quo (Fig. 3). Recommendations arising from the analyses encouraged the implementation of specific management activities to increase education and improve compliance. The recommendations adopted included: retain the "no fishing" zone; enhance policing powers; put more effort into responding to community needs; increase involvement in curriculum development at schools; and convey more positive news about the marine parks to the government.

Discussion

While the outcomes of the analysis were, in this case, not surprising to workers in the field of coral-reef management, the exercise demonstrated convincingly that the analysis can provide:

1. A successful way to handle multiple objectives, facilitate community participation, and incorporate both qualitative and quantitative data;
2. A feasible method for evaluating coral-reef management strategies even on a small, and rapidly developing, island; and
3. A structured and systematic assessment of management options which is valuable for convincing the more sceptical stakeholders and decision-makers.

On Saba, the multiple criteria analysis helped meet the marine park managers' needs for:

1. Evidence that the park has value to the community in many ways
2. Clear and understandable bases for justifying government support for the park
3. Means to explicitly consider the potential impacts of decisions upon marine park objectives
4. Greater understanding of what the community wanted their marine park to achieve

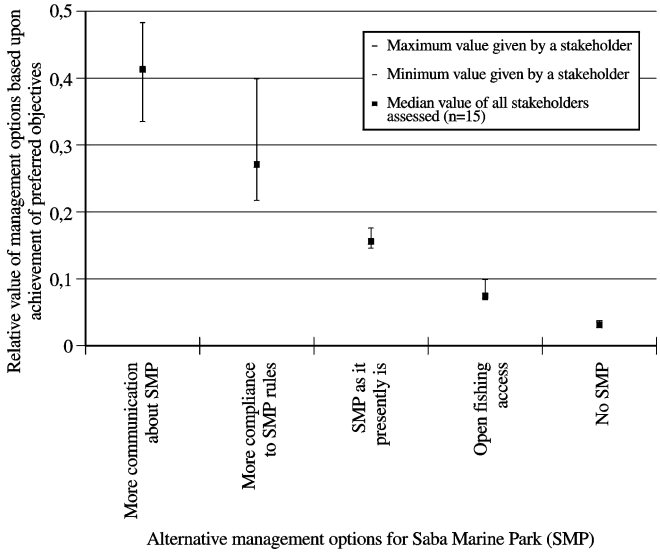

Fig. 3 Relative value of management options to decision-makers and stakeholders under status quo conditions. The range of values for each management option reflects the different preferences people had for the many management objectives combined with the degrees to which those objectives could be achieved

5. Maximum use of existing information
6. Greater community awareness about the benefits and functioning of the park and
7. Insights into future management directions.

All these factors are crucial both for maximising the utility of research to decision-makers and for successful resource management in general (Lisk 1985; Patton 1986; Robinson 1993; White et al. 1994; Beinat 1995; Alder 1996).

The process of multiple criteria analysis provided a forum for tabling, discussing and documenting the community's concerns and allowed the unexpected degree of general agreement to become apparent. Creating this common ground from apparent conflict can provide a basis to generate support for natural resource managers as they work to enhance community benefits (Keeney et al. 1987; Keeney 1988; GBRMPA 1994). This multiple criteria analysis also showed that the value of a marine park, as measured by achievement of desirable objectives, can be enhanced by more education or more enforcement. While these results may be obvious to some, other stakeholders, such as governments or developers, can be antagonistic to such moves, so it is helpful to have a clear, well-structured assessment that supports increases in education or regulation efforts (Lucas 1989; Le Maitre et al. 1997).

Specific recommendations to increase education and regulation efforts came from the community and were adopted after this analysis had been conducted. That these recommendations were acted upon provides encouraging evidence that, while the analysis may not have initiated all these actions directly, it did provide impetus and support for them.

Multiple criteria analysis is, however, no panacea. While a complete critique of the method is beyond the scope of this paper, it should be noted that the analytic hierarchy process used in this research has flaws: the hierarchical organisation of objectives is not always suitable (Pitz and Riedel 1984); it requires relatively well-educated users; it does not require definition of performance indicators which can lead to ambiguity in eliciting preferences (Belton and Gear 1984, Dyer 1990); its linear aggregation rule may not be appropriate; and the ranking of options can be reversed when new options are introduced (Dyer 1990). Weber and Borcherding (1993) summarises many MCA studies that have shown that the description of the objectives, the components of the objectives hierarchy, and the procedure used to elicit weights influence the weights generated

Table 4 Scale of relative importance used in the analytic hierarchy process

Intensity of relative importance	Definition	Explanation
1	Equal importance	The two objectives contribute equally to the higher level objective
3	Moderately more important	Experience, judgement and/or data slightly favour one objective over another
5	Strongly more important	Experience, judgement and/or data strongly favour one objective over another
7	Demonstrated importance	One objective is of dominant importance over another in order to achieve the higher level objective
9	Extreme importance	All experience, knowledge and data indicate that one objective is so important, the other hardly matters
n 2, 4, 6, 8	Intermediate values	When the relative importance falls between the intensities listed above

Table 5 Manager's priorities for increasing understanding and awareness about the marine environment. Values in italics are reciprocal for the reverse comparisons

Understanding	Children	Public	Government	Priority
Children	1	1	1/2	**0.260**
Public	*1*	1	1	**0.327**
Government	*2*	*1*	1	**0.413**

although in theory, they should not. The analytic hierarchy process in the Saba study, however, was applied with relatively well-educated users, required definition of performance indicators, and did not introduce new options. In addition, this process: does not invoke Arrow's impossibility theorem (see French 1988); can handle deviations of people's preferences from strict axioms of rationality (for example, preferences are allowed to be inconsistent); uses a linear aggregation rule that is relatively robust; and it allows direct incorporation of qualitative or quantitative data. Studies to date have not proved either the superiority or inferiority of the analytic hierarchy process to other multiple criteria analytic techniques, or of multiple criteria techniques to other evaluation tools. All have advantages and disadvantages; which method to choose depends on the conditions under which it will be used.

Conclusions

This case study has illustrated the potential strengths of an integrated, data-flexible process for evaluating reef-management options. In tropical, less-developed countries (where most coral reefs are found) there are often strong market distortions, limited quantitative data and significant cultural, social and subsistence use values (Bleakley and Mouldoon 1994; Alder 1996). These factors compound problems associated with the more popular, but data-intensive and uni-dimensional, assessments used to support management decisions (e.g., benefit-cost analysis and environmental impact assessment; Sagoff 1988; Winpenny 1991; van Pelt 1993). The multiple criteria analysis of Saba Marine Park addressed these factors in a way that other project evaluation methods usually do not. The case study proved that MCA can be used to elucidate and structure a variety of objectives for a marine park including ecological, social and economic objectives (Yin 1994). The relationships amongst, and trade-offs between, objectives can be clarified. Using multiple criteria analysis, quantitative and qualitative data can be compiled into a format that decision-makers can use. People's values are important to the success of any management strategy and those held by stakeholders in the case study were explicitly considered in this analysis, thus creating important involvement in, and understanding of, the issues at hand (White et al. 1994).

When evaluating options for marine resource management, managers and users should consider their needs and limitations and choose an appropriate evaluation tool (Hwang and Yoon 1981; Janssen et al. 1984). As multiple criteria analysis may often meet their needs, managers and users should add it to the list of tools available to support marine resource management in coastal communities.

Acknowledgements The authors acknowledge the support of the East West Center and WWF The Netherlands. We thank the people of Saba and Saba Marine Park for their willing cooperation, colleagues who critiqued this paper and the three anonymous reviewers.

Appendix 1. Questionnaire

1. a. What do you think should be the objectives in managing Saba's marine resources?
   b. Have you noticed any positive or negative impacts/changes on Saba due to SMP? Why have you noticed these impacts/changes?
   c. Have you noticed any conflicts associated with SMP?
   d. What impacts/changes/conflicts do you anticipate in the future with regard to SMP?
2. a. What do you think should be the main environmental objectives associated with managing Saba's marine resources?
   b. Have you noticed any positive or negative environmental changes associated with SMP?
   c. Do you anticipate any positive or negative environmental changes associated with SMP?
3. a. What do you think should be the main economic objectives associated with managing Saba's marine resources?

Table 6 The relative degree to which different management alternatives can increase the awareness and understanding the government has about the marine environment. Estimates made by the manager of Saba Marine Park. Values in italics are reciprocal for the reverse comparisons

Management alternatives	No SMP	Open fishing access	SMP as it is	More compliance to SMP rules	More communication about SMP	Priority
No SMP	*1*	1/5	1/7	1/8	1/7	**0.027**
Open fishing access	*5*	1	1/5	1/7	1/5	**0.058**
SMP as it is	*7*	*5*	1	1/5	5	**0.244**
More compliance	*8*	*7*	*5*	1	7	**0.548**
More communication	*7*	*5*	*1/5*	*1/7*	1	**0.123**

b. Have you noticed any positive or negative economic changes associated with SMP?
c. Do you anticipate any positive or negative economic changes associated with SMP?

4. a. What do you think should be the main social objectives associated with managing Saba's marine resources?
b. Have you noticed any positive or negative social changes associated with SMP?
c. Do you anticipate any positive or negative social changes associated with SMP?
5. Is there anything else you would like to say?

Appendix 2. Example of calculations

For full details of the mathematics and justification of this method see Saaty (1980) or Saaty and Kearns (1985).

In Fig. 2 the numbers in bold are the weightings which reflect the priority the Saba Marine Park manager places upon the different objectives. The analytic hierarchy process uses a 1–9 scale of intensity of relative importance which can be used directly as numbers (A is three times as important as B) or it can be used on a verbal scale (A is moderately more important than B; Table 4).

For example, in aiming to increase the general understanding and awareness about the marine environment, the manager's priorities were as listed in Table 5. The data on priorities were collected on the verbal scale listed in Table 4 and translated to the corresponding numerical value. The mathematical appropriateness of translating these verbal priorities into ratio level data has been tested (Saaty and Kearns 1985).

From Table 5, increasing the awareness and understanding of children, the public and government were all equally important except that increasing the awareness of the government was slightly more important (twice as important) as increasing the awareness of the children. The data are collected for one set of comparisons and the matrix is completed by entering reciprocal values for the reverse comparisons (in italics). The priorities listed above are calculated from the eigenvector of the matrix which is then normalised to unity.

Through similar assessments, the relative importance of all the objectives in the hierarchy are calculated. The data are presented in Fig. 2 in a distributive model, for example, the weightings are applied to the relative importance of increasing people's awareness and understanding about the marine environment overall (0.092). Of this total weighting:

$0.260 \times 0.092 = 0.024 =$ local priority for increasing awareness of children;

$0.327 \times 0.092 = 0.030 =$ local priority for increasing awareness of public; and

$0.413 \times 0.092 = 0.038 =$ local priority for increasing awareness of government.

Using data to guide judgements, similar assessments are made, for example, as to the relative degree to which different management alternatives are likely to achieve different objectives. For example, the Saba Marine Park manager estimated the degree to which management alternatives could help increase government awareness about the marine environment (Table 6). In particular, the manager strongly prefers (that is, thinks it is five times better) to have a marine park with open access to fishing than not to have a marine park at all.

In distributive mode, this means that the relative value of the alternatives in terms of increasing the awareness of the government about the marine environment is:

$0.038 \times 0.027 = 0.001$ for having No SMP;

$0.038 \times 0.058 = 0.002$ for having open access fishing in SMP;

$0.038 \times 0.244 = 0.009$ for SMP as it is;

$0.038 \times 0.548 = 0.021$ for more compliance to SMP rules; and

$0.038 \times 0.123 = 0.005$ for more communication about SMP.

These kinds of estimates are made explicitly for every objective by both the manager or SMP and the Chair of the Saba Conservation Foundation who administers SMP. The individual estimates sum to total relative values for the management alternatives. The range of relative values shown in Fig. 3 is due to the relative importance different stakeholders place upon the top level objectives (Table 2).

References

Alder J (1996) Have tropical marine protected areas worked? An initial analysis of their success. Coast Manage 24:97–114

Ballestero E, Romero C (1996) Portfolio selection: a compromise programming solution. J Oper Res Soc 47:1377–1386

Beinat E (1995) Multiattribute value functions for environmental management. Institute for Environmental Studies, Vrije Universiteit, Amsterdam

Bernard HB (1988) Research methods in cultural anthropology. Sage Publications, London

Bleakley C, Mouldoon J (1994) A representative system of marine protected areas for the East Asian Seas region. Coast Manage Trop Asia 3:1–5

Dyer JS (1990) Remarks on the Analytic Hierarchy Process. Management Science 36(3):249–258

Expert Choice (1983) Expert Choice. Expert Choice, Pittsburgh

Fernandes L (1996) Evaluating proposed uses of coral reef: comparison of economic and multiple criteria approaches. University of Hawaii, Honolulu, Hawaii. Unpublished PhD Dissertation

Force JE, Machlis GE (1997) The human ecosystem Part II: social indicators in ecosystem management. Soc Natur Resource 10:369–382

Goicoechea A, Hansen DR, Duckstein L (1982) Multiobjective decision analysis with engineering and business applications. John Wiley, New York

GBRMPA (1994) The Great Barrier Reef, keeping it great. A 25 year strategic plan for the Great Barrier Reef World Heritage Area. Great Barrier Reef Marine Park Authority, Townsville, Australia

Hamalainen RP (1992) Policy and politics. Decision analysis makes its way into environmental policy in Finland. Oper Res Manage Sci Today June 1992:40–43

Hawkins JP, Roberts CM (1997) Estimating the carrying capacity of coral reefs for SCUBA diving. Proc. 8th Int Coral Reef Symp. Panama 2:1923–1926

Hawkins JP, Roberts CM, White S (1993) Effects of recreational scuba diving on a Caribbean coral reef. Eastern Caribbean Center, St. Thomas, US Virgin Islands

Herwijnen M van, Rietveld P, Thevenet K, Tol R (1993) Sensitivity analysis with interdependent criteria for multicriteria decision making. The case of soil pollution treatment. Faculteit der Economische Wetenschappen en Econometrie, Research Memorandum 1993–51. Vrije Universiteit, Amsterdam

Hof T van't (1985) Saba Marine Park: a proposal for integrated marine resource management in Saba. Netherlands Antilles National Parks Foundation, Netherlands Antilles

Hwang, C and K. Yoon. 1981. Multiple attribute decision making: methods and applications. Springer-Verlag, Berlin Heidelberg New York

Janssen R, Nijkamp P, Voogd H (1984) Environmental policy analysis: which method for which problem? Revue d'Economie Regionale et Urbaine 5:839–855

Johannes, RE (1998) The case for data-less marine resource management: examples from tropical nearshore finfisheries. TREE 13(6):243–246

Keeney RL (1988) Structuring objectives for problems of public interest. Oper Res 36(1):396–405
Keeney RL, Renn L, von Winterfeldt D (1987) Structuring West Germany's energy objectives. Energy Policy August: 352–362
Kenchington RA (1990) Managing marine environments. Taylor and Francis, New York
Korhonen P, Moskowitz H, Wallenius J (1992) Multiple criteria decision support – a review. Europ J Opera Res 63:361–375
Le Maitre D, Gelderblom C, Maphasa L, Yssel S, van de Belt M, Manuel T (1997) Communicating the value of fynbos: results of a survey of stakeholders. Ecol. Econ 22:105–121
Lisk F (1985) Popular participation in planning for basic needs. Gower Publishing Company, Hampshire
Lucas PHC (1989) Resource conservation and biological diversity: how they contribute to sustainable development. Proc Fourth South Pacific Conf Nature Conserv Protected Areas. Volume II. South Pacific Regional Environment Program, Apia, Western Samoa
Marttunen M, Hamalainen RP (1995) Decision analysis interviews in environmental impact assessment. Europ J Oper Res 87:551–563
McAllister DM (1986) Evaluation in environmental planning. MIT Press, Massachusetts
McCracken G (1988) The long interview. Sage Publications, California
Mol R (1989) Doctor on Saba. Eburon, Delft
Morgan DL, Krueger RA (1993) When to use focus groups and why. In: DL Morgan (ed) Successful focus groups: advancing the state of the art. Stage Publications, California
Munasinghe M (1992) Environmental economics and valuation in development decision making. World Bank, Washington DC
Patton MQ (1986) Utilization-focused evaluation. Sage Publications, Beverly Hills
Pelt MJF van (1993) Ecologically sustainable development and project appraisal in developing countries. Ecol Econ 7:19–42
Polunin NVC, Roberts CM (1993) Greater biomass and value of target coral reef fishes in two small Caribbean reserves. Mar Ecolo Prog Ser 100:167–176
Richmond RH (1993) Coral reefs: present problems and future concerns resulting from anthropogenic disturbance. Amer Zool 33:524–536
Ridgley MA, Rijsberman FR (1994) Multicriterion analysis and the evaluation of restoration policies for a Rhine estuary. Socio-Economic Plan Sci 28(1):19–32
Rietveld P (1980) Multiple objective decision methods and regional planning. North Holland Publishing Company, Amsterdam
Roberts CM (1994) Rapid build-up of fish biomass in a Caribbean marine reserve. Conserv Biol 9:815–826
Robinson D (1993) Public participation in environmental decision making. Environ Planning Law J October 1993: 320–340
Saaty TL (1980) The analytic hierarchy process. McGraw-Hill, New York
Saaty TL, Kearns K (1985) Analytical planning. Pergamon, Oxford
Sagoff M (1988) The economy of the earth. Cambridge University Press, Cambridge
Salminen P, Teich JE, Wallenius J (1996) A decision model for the multiple criteria group secretary problem. J Oper Res Soc 47:1046–1053
Sommer B, Sommer R (1991) A practical guide to behaviour research: tools and techniques. Oxford University Press, New York
Southgate D, Hitzhusen F (1987) Economic analysis of renewable resource conservation in the Third World. In: D Southgate, J Disinger (eds) Sustainable resource development in the Third World. Westview Press, Boulder
Sudman S, Bradburn NM (1983) Asking questions. Jossey-Bass Publishers, San Fransisco
Wells M, Brandon K (1992) People and parks. Linking protected area management with local communities. The World Bank, Washington DC
White AT, Hale LZ, Renard Y, Cortesi L (1994) Collaborative and community based management of coral reefs. Lessons from experience. Kumarian Press, Connecticut
Winpenny JT (1991) Values for the environment: a guide to economic appraisal. Overseas Development Institute, London
Yin RK (1994) Case study research. Design and method. Sage Publications, London
Yoon KP, Hwang C-L (195) Multiple attribute decision making. Sage Publications, Thousand Oaks, USA