USE OF THE ANALYTICAL HIERARCHY PROCESS FOR DEVELOPING RANKINGS OF MANAGEMENT CRITERIA FOR THE BLADEN NATURE RESERVE

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SUMMARY

A workshop to provide input on the structure and content of a management plan for the Bladen Nature Reserve was held at the Belize Foundation for Research and Environmental Education field station June 28-30, 2006. One of the main focuses of the workshop was to apply the Analytical Hierarchy Process (AHP) to assist with development of a transparent management structure and to prioritize management actions. Because of the limited time available a preliminary structure to serve as a template for a final structure was developed prior to the workshop. Modification of the preliminary structure resulted in a final structure consisting of six main criteria (Level 2), twenty one Level 3 criteria, sixty four Level 4 criteria, and fifty one Level 5 criteria. Rankings of the six main criteria were done by 18 of the conference participants on June 29. Ranking of Level 3 and most Level 4 criteria were done by 12-13 participants on June 30. No rankings were done for Level 5 criteria, and the group decided not to identify specific management actions. Consequently, evaluation of the rankings was limited to the criteria at Levels 2, 3, and 4. Of the six main criteria, Resource Management was considered to have 2 to 6 times more importance than the other five main criteria. Research & Monitoring and Administration were of approximately equal importance, followed by Community Participation, Infrastructure, and Public Use, respectively. Each of the main criteria was dominated by one of the Level 3 criteria; Resource Management by poaching, Research & Monitoring by research & inventory, Administration by financial sustainability, Community Participation by ex situ programs, Infrastructure by building construction, and Public Use by involvement in research studies. Agreement within the group was greater for criteria with higher scores, while variation within the group decreased for criteria with higher scores. Recommendation is made to develop a management strategy based on the AHP that where the highest ranked subcriteria within each of the main criteria is selected, then specific management actions associated with each subcriteria are identified. When specific management actions are identified they can be integrated seamlessly into the AHP, ranked, and evaluated relative to uncertainty and sensitivity in the scoring.

INTRODUCTION

A common shortcoming of many management plans is that an often lengthy "laundry list" of targets, goals, and potential actions is presented in the plan, but no recommendations are made on how these should be prioritized. Without a system that assists managers in prioritizing management targets and actions much of the potential effectiveness of a plan is diminished. As part of the development of a management plan for the Bladen Nature Reserve (BNR), a workshop was held at the Belize Foundation for Research and Environmental Education (BFREE) field station from June 28 to June 30, 2006. The main purpose of the workshop was to broaden the level of input into development of the management plan using a structured approach known as the Analytical Hierarchy Process (AHP). Integration of the AHP into the management plan would result in a prioritized framework of management targets and actions. Doing this provides the critical link between management planning and implementation, and allows development of justifiable strategies for allocating limited financial and human resources.

The workshop had eight goals and four products. These included:

Goals:

1. Get people in the same room at the same time to exchange information and ideas on the Bladen Nature Reserve (BNR)
2. Identify management issues, needs and constraints in the BNR
3. Identify integration of the BNR management plan with the Chiquibul National Park management plan under the NPASP and CMM/KBA initiative
4. Prioritize management actions for the BNR
5. Determine scope and the conceptual and structural framework for the BNR management plan
6. Identify goals, objectives, and timeline for management actions to be covered under the BNR management plan
7. Identify measures of success for BNR management actions
8. Agree on procedure and timeline for evaluating success of management actions

Products:

1. Database of information (data, contacts, etc.) to be used in development of BNR management plan
2. Conceptual and structural framework for management plan
3. Diagram of decision-making process, including hierarchy of criteria, rankings of criteria, and ranking of management actions.
4. Explicit deadlines for delivery of management plan, implementation, review, and evaluation.

The objective of this report is to present the results of the AHP for the BNR Management Plan, and interpret the results in the context of development of useful management strategies for implementing management actions.

OVERVIEW OF AHP

AHP was developed in the 1970's as a decision-making tool to assist with selecting the best out of a set of potentially large alternatives (Saaty 1980, 1992). It has been applied frequently in business, economic, and political fields (Golden et al. 1989), but over the last 15 years has been seeing increased use in conservation and natural resource management (Anselin et al. 1989, Drechsler 2004, Herath 2004; see Moffett and Sarkar 2006 for a review of multi-criteria decision making methods in conservation and resource management).

AHP is based on a defined goal or outcome and a set of alternatives (i.e. management actions) with various likelihoods of contributing towards achievement of the goal. Between the goal and alternatives are different levels of criteria (Figure 1). The criteria are arranged in a hierarchy, with the most general and/or important criteria at the highest level and sub-criteria nested within the higher level criteria. The relative importance of the criteria and sub-criteria within each level are then weighted against each other in a series of pairwise comparisons (Table 1). Mathematical calculations based on matrix algebra are used to determine the weights assigned to the main criteria and lower level sub-criteria (weights are the eigenvectors associated with the single positive non-zero eigenvalue of the pairwise comparison matrix). The alternatives are linked to each of the lower level criteria with a direct score (continuous quantitative, discrete quantitative, ordinal, etc). The rank for each alternative is calculated as the normalized sum of the products of the weights for each level.

There are many advantages to using AHP as part of the development and implementation of management plans. Typically, a number of options must be considered when selecting among a large set of potential management actions, and AHP graphically structures the options (i.e. criteria) in an easily understood manner. It forces planners and managers to be disciplined in developing management plans, and allows a complex process to be partitioned into manageable parts. Because AHP is based on decision-theory and well understood mathematical methods it has good generality and flexibility. In a conservation planning context this gives it the potential to mitigate some of the inherent vagueness and uncertainty of the *ad hoc* scoring methods typically used when developing conservation strategies and management plans. Although AHP does not remove subjectivity (no decision-making process does unless all measures have legitimate quantitative measures), its mathematical foundation considerably reduces it. Using matrix algebra effectively integrates the influence of the various criteria and helps identify the most important elements in a management plan. A consistency ratio is calculated for the pairwise comparisons within a level, which help ensures rankings are logical and legitimate. Advances in software also allow measures of uncertainty and sensitivity analysis to be used in evaluating the rankings. Perhaps most important of all, AHP makes planners and managers explicitly confront the criteria they must base their decisions on, and leaves a record (graphical and text) of how and why one alternative or a set of alternatives was selected over another.

AHP does have disadvantages. As noted above, there is still subjectivity involved when scoring criteria against each other. And as with any multivariable (i.e. multicriteria) analytical technique it does not explicitly adjust for interactions among criteria. AHP can also become extremely unwieldy and tedious when there are a large number of nested criteria to score. Fortunately, these disadvantages can often be dealt with to various degrees. Relative to other decision-making methods (e.g. "vote counting", SMART), AHP has a rigorous mathematical foundation that reduces the subjectivity inherent when assigning scores. Interactions among criteria can be indirectly integrated into the decision model when selecting management actions (e.g. sequencing management actions that have dependencies). Rigor and critical selection of criteria can substantially reduce the potential size of the decision model.

METHODS

Workshop participants spent 1 ½ days scoring criteria for the BNR management plan. Depending on the size and complexity of a management area, an AHP is typically done over a period of 5 to 8 days. Although the BNR is a large area and has many management issues confronting it, the BNR Management Plan workshop was only scheduled for 2 ½ days. Many of the participants did not attend the meeting for the entire time, and the first day was devoted to talks and overviews of the BNR, conservation in Belize, and scientific research in the BNR. Therefore, to save the time of designing a decision model entirely "from scratch", Rob Klinger and Jacob Marlin drew up a preliminary model the week before the workshop. The preliminary model was based on issues, targets, goals, and action items described in BNR management plan progress reports, reports from other planning workshops, and proposals to Conservation International's CEPF program and PACT. The preliminary model consisted of five main criteria (Level 2), nineteen subcriteria (Level 3), nineteen Level 4 criteria, five Level 5 criteria, and 39 potential management actions; the overall goal of the preliminary model was effective and sustained management of the BNR (Level 1).

Following a 30 minute introduction to AHP on the morning of June 29, participants reviewed and modified the preliminary model. Once consensus was reached on the modified structure of the model, eighteen of the participants did the pairwise comparisons of the main criteria (Level 2). On July 29 and July 30 thirteen participants did the pairwise comparisons of all Level 3 criteria, and with the exception of the criteria nested under Infrastructure, all of the Level 4 criteria. There was not enough time to do the pairwise comparisons of the Level 5 criteria, and management actions were not included in the modified model. The Bladen Management Consortium (BMC) had identified some specific management actions to implement in the BNR, but the group felt that many of the management actions identified in the PACT and CEPF proposals were in reality goals, and that without more specificity from BMC potential actions were too numerous to effectively include in the model structure.

The pairwise comparisons were made by individuals writing their score and the higher ranked criterion of the pair on a piece of paper. The totals for each criterion were

summed, and the difference between the two criterions divided by the number of votes was used as the score (rounded to a whole number) for that comparison:

$$S = \frac{\left(\sum_{1}^{n} C_1 - \sum_{1}^{n} C_2 \right)}{N}$$

where S is the score on a 1-9 scale, C_1 are the scores given to the highest ranked criterion of the pair, C_2 are the scores given to the lower ranked criterion of the pair, n are the number of scores for C_i, and N is the total number of votes. The raw scores were retained for 143 of the pairwise comparisons to analyze the variability and concordance in the scoring. Variability was analyzed using the coefficient of variation (CV; standard deviation/mean). Concordance was the proportion of individuals in the group who ranked one criterion higher than the other.

The program Criterion Decision Plus (version 3) was used to design the AHP model structure and calculate weights for the pairwise comparisons. Systat (version 11) was used to analyze the variability and concordance in scoring.

RESULTS

The preliminary model was modified to include six main criteria (Level 2), twenty one Level 3 criteria, sixty four Level 4 criteria, and fifty one Level 5 criteria (Table 2). Because specific management actions were not identified and Level 5 comparisons were not made, evaluation of the rankings is limited to the criteria at Levels 2, 3, and 4.

Resource Management was considered to have 2 to 6 times more importance than the other five main criteria (Figure 2). Research & Monitoring and Administration were of approximately equal importance, followed by Community Participation, Infrastructure, and Public Use, respectively. Three Level 3 criteria were clearly ranked higher than others within that level; poaching, research & inventory, and ex situ community participation (Figure 3). Each of the main criteria was dominated by one of the Level 3 criteria; Resource Management by poaching, Research & Monitoring by research & inventory, Administration by financial sustainability, Community Participation by ex situ programs, Infrastructure by building construction, and Public Use by involvement in research studies (Figure 4).

Although the Level 4 pairwise comparisons under Infrastructure were not completed, cautious interpretation of the rankings at that level can still be made because the weight for Infrastructure was low and would have minimal influence on final rankings. There were three highly ranked Level 4 criteria under Resource Management; preventing poaching of non-timber plants (e.g. Xate), preventing poaching of animals, and patrols focused on preventing agricultural incursions near the BNR border (Figure 5). Biological research and inventory studies dominated Research & Monitoring. There were four Level 4 criteria of high importance under Administration; creation of an endowment fund, hiring more field staff, doing more grant writing, and advocating for no water

developments in the watershed. Developing outreach programs was the most highly ranked for Community Participation, although training and research programs were also considered to have some importance (Figure 5). There were no Level 4 criteria for Public Use.

Consistency ratios ranged from 0 to 0.083. The median score was 3 (mean = 2.9, SD = 1.6). Scores ranged from 1 to 8, but 72% were < 4 (Figure 6). With the exception of Research & Monitoring this pattern was consistent within each of the Level 2 criteria. Forty-two percent of the scores for Research & Monitoring were > 3 (mean = 3.6, SD = 1.5). This was due primarily to high scores given to the importance of monitoring threats and animals.

There was reasonably strong concordance within the group for the scoring (Figure 7). There was ≥ 70% agreement in 68% of the comparisons (N = 95). The greatest amount of concordance was for Research & Monitoring; there was ≥ 80% agreement in 86% of the comparisons (N = 95). Concordance increased for pairwise comparisons with higher scores (Figure 8).

Variation in the scoring was strongly skewed (Figure 9). Coefficients of variation ranged from 0.17% to 3.83, but over 62% of the CV's were ≤ 0.75. The mean CV was 0.883 (SE = 0.625) and the median = 0.632. There was no significant difference in the amount of variability in the scores among the main criteria (Figure 10). Coefficients of variation decreased for pairwise comparisons with higher scores (Figure 11).

DISCUSSION & RECCOMENDATIONS

Of the eight workshop goals four were not explicitly addressed in the workshop. Integration of the BNR management plan with the Chiquibul National Park management plan was discussed informally, but a specific process for achieving the integration was not identified. Because the most promising funding sources for the BNR are contingent on it being a part of a regional conservation, explicitly identifying a formal process for collaborating with Chiquibul is of critical importance.

No measures of success or a procedure and timeline for evaluating success of management actions stemming from the BNR management plan were discussed. Measures of success should be identified and an approach for evaluating management actions should be developed by the members of BMC and made an explicit part of the management plan.

All or parts of the other four goals were accomplished. Probably the most important of these was the conceptual and structural framework for the management plan. The AHP structure for the BNR was derived from the work that has been done on the management plan over the last year. Therefore, it can be easily incorporated into the final draft of the management plan, and it provides the BMC with a simple structure it can use for planning, implementation, and evaluation.

Specific management actions were not identified in the workshop. Some of this was because of time constraints, but one opinion was expressed that specific management actions were not important because these could be identified in annual operations plans. While this may be so, it is contingent on annual operations plans being written. It is also not as effective or efficient as identifying them in the management plan. Annually shifting *ad hoc* strategies and goals are not a wise use of limited time for planning, identifying needs and sources of money, or allocating human resources. Virtually all modern management plans identify specific actions structured around a well thought-out strategy, and there is no reason the BMC should not do this before the plan for the BNR is finalized.

The management plan structure that came out of the AHP was fairly large and complex. This reflects the many issues relevant to managing the BNR, as well as the evolving political landscape involving conservation in Belize and the southern Maya Mountains (e.g. NPAPSP, CEPF). Although the AHP structure is large, it is not unwieldy. Consistency ratios for the comparisons were all < 0.10, indicating that the group had a coherent sense of the relative importance of different criteria. For the most part, the structure gives a clear sense of what the BMC should focus on over the next 3-5 years. The weight given to Resource Management is a clear signal that conducting on-the-ground activities are considered very important, especially warden patrols focused on curbing poaching activities. But the rankings of the other main criteria are also a clear indication that management of the BNR will need to be pluralistic; the importance of scientific research, administration, and community participation were apparent. That management of the BNR is not dominated by just one or a few issues was also reflected in the distribution of pairwise scores; the mean and median scores were 3, indicating that in most comparisons one issue was considered to only have marginally more importance than the other.

The variation in the scores for the pairwise comparisons was generally moderate. With the exception of the six main criteria, the pairwise comparisons were done by only 12-13 individuals. This was a relatively small number of people, so moderate differences in scoring would lead to moderately high standard deviations. Variation would also be expected to be moderately high for statistical reasons; the scores are discrete values that would be expected to follow a Poisson distribution, where the variance is equal to the mean. Although the scores did fit a Poisson distribution (analysis not shown), the variance was about 15% less than expected. Given the statistical considerations and relatively small number of people in the group, the variation in scoring was very acceptable.

Some of the coefficients of variation for the pairwise comparisons were quite large. In general this appeared to more reflect an approximately equal split in opinion within the group that one criteria was more important than the other than extreme differences in scoring when most everyone agreed that one criteria was more important than the other (e.g. five or six people giving scores of 1 or 2 and the rest 8 or 9). Interestingly, when group opinion was split, each group gave their preferred criteria an approximately equal score as the other group did. Though it was difficult to quantify, the split often appeared

to be people leaning towards ecological issues and those tending to lean towards administration or social issues. The overall outcome was that the two groups effectively canceled each other out; when scores were low concordance often was as well. Not surprisingly, variation was consistently greater for the pairwise comparisons with low scores. Though arguments could be made otherwise, a reasonable conclusion from this pattern was that the criteria for the comparisons the group was split on were indeed of approximately equal importance when more than one perspective was incorporated into the decision. If true, this is an excellent example highlighting the importance of having a diverse group of knowledgeable individuals providing input into the development of management plans, and how the AHP objectively integrates different perspectives into the rankings.

There are several potential ways the BMC could use the AHP structure for developing a management strategy. One option would be to just focus on the top ranked criteria for either Level 3 or Level 4. Though appealing for simplicity alone, doing so is unlikely to be the most effective approach. Each of the main criteria (Level 2) had one strongly preferred subcriterion (Level 3), and many of the Level 3 criteria had one or two strongly preferred Level 4 criteria. Given this, a more systematic and justifiable strategy would be to select the highest ranked subcriteria within each of the main criteria, then designate specific management actions associated with each. The point was made several times during the workshop that there are contingencies among many of the criteria, and AHP does not explicitly handle interactions among criteria. Selection of several actions within each main criteria and phasing them in a logical fashion would be a reasonable way of handling contingencies and interactions.

The rankings of the criteria among Level's 2-4 give a great deal of insight into developing a management strategy for the BNR, including selection of management actions. Many of the Level 5 criteria are quite specific, and BMC doing a series of pairwise comparisons for them would be time consuming. Because of their relatively narrow focus, many or most of the Level 5 criteria could be translated into management actions, especially by evaluating them in the context of the CEPF and PACT proposals.

One of the most important strengths of using the AHP is that uncertainty and sensitivity in management actions rankings can be analyzed, and this can still be easily done for the BNR management plan. Once a set of management actions are decided on, they can be easily incorporated into the AHP structure and ranked, followed by an evaluation of the ranking based on uncertainty and sensitivity of the scores.

The time allotted to the AHP for the BNR management plan was about 25% of what is normally allocated for incorporating multi-criteria decision making into the development of management plans. Nevertheless, the BMC gained a useful tool to integrate into the management plan. Advantages associated with broadening the level of participation into the development of the plan were obvious, not least of which was developing a functional structure, priorities, and documentation of the process used to derive the structure and define priorities. Evaluating the management actions that stem from the plan will be extremely important. Lessons learned from this workshop that can be transferred to that

effort include the participation early on of a large and diverse number of individuals familiar with the BNR, allocating enough time to do a thorough evaluation, and commitment by the participants to devote a continuous block of time to the process.

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Table 1. (a) Nine-point scale used for making pairwise comparisons between criteria in the Analytical Hierarchy Process, and (b) the pairwise matrix for the six highest-level criteria in the draft management plan for the Bladen Nature Reserve, Belize. Numbers in the matrix are interpreted as the importance of the row relative to the column; e.g. Resource Management is marginally more important (score = 3) relative to Research & Monitoring.

(a)

Value	Interpretation
1	Criteria are of equal importance
2	
3	One criteria is marginally more important
4	
5	One criteria is definitely more important
6	
7	One criteria is markedly more important
8	
9	One criteria is critically more important

(b)

	Resource Management	Research & Monitoring	Administration	Community Participation	Public Use	Infrastructure
Resource Management	1	3	3	4	4	3
Research & Monitoring	1/3	1	1	2	3	3
Administration	1/3	1	1	2	3	2
Community Participation	1/4	1/2	1/2	1	3	4
Public Use	1/4	1/3	1/3	1/3	1	1
Infrastructure	1/3	1/3	1/2	1/4	1	1

Table 2. Analytical Hierarchy Process structure of a management plan for the Bladen Nature Reserve, Belize. Pairwise comparisons for the Level 5 criteria were not done, so no weights are shown.

Goal	Level 2	Level 3	Level 4	Level 5
Management of BNR	***Research & Monitoring***	Research/Inventory	Natural	Topography Climate Vegetation Soils Animals Hydrology Geology
			Cultural	Ethnobotany Archaeology History Attitudes/Beliefs
			Socioeconomic	Demography Current Land Use Livelihood Health Education
		Monitoring	Vegetation	Physical Structure Composition Climate
			Threats	Looting Fire Hunting Non-timber Logging Invasive Fauna Chytridomycosis Water Quality
			Animals	Species Of Concern Charismatic Game Species
			Visitor	Characteristics Impacts
			Socioeconomic	

Table 2 continued.

Goal	Level 2	Level 3	Level 4	Level 5
Management of BNR	***Resource Management***	Poaching	Timber	
			Non-Timber	Pacaya
				Xate
				Other Plants
			Animals	Fish
				Game Species
		Agriculture		
		Looting		
		Mineral Exploitation	Water	
			Oil	
			Minerals	
		Fire	Broadleaf Forest	
			Savanna	Rx Burn
				Suppression
	Community Participation	In Situ	Education	
			Research	
		Ex Situ	Local Advisory Concept	
			Outreach	
			PR	
			BMC Facilitation of Local Issues	
			Training	
			Alternative Livelihoods	
	Public Use	Research		
		Education		
	Infrastructure	Buildings & Services	Purchase	
			Maintenance	
			Construction	
		Access	Heliport	
			Roads	
			Bridge	
			Trails	
			River	
		Equipment	Maintenance	
			Transport	
			Communications	
			Safety	
			Field	

Table 2 continued.

Goal	Level 2	Level 3	Level 4	Level 5
Management of BNR	***Administration***	Advocacy	Mining	
			Oil	
			Water	
			De-reservation	
			NPAPSP	
			Legislation	
		Administration Policies		
		Collaboration/Alliances	National	Brit Army
				BDF
				Police
				MNRE
			Co-management Agreements	
			International	
			Local	BAS
				Las Cuevas
				BFREE
				FCD
				TIDE
				Communities
				FD
				YCT
		Public Communication	Radio	
			Newsletter	
			Marketing	
			Website	
			Brochures	
			Festivals	
			TV	
		Financial Sustainability	User Fees	
			Events	
			Enviro Services Payments	
			Endowment Fund	
			Grant Writing	
			Government In-kind	
			Volunteers & Interns	
		Human Resources	Office	
			Field	
			BMC Board	
		Reporting		

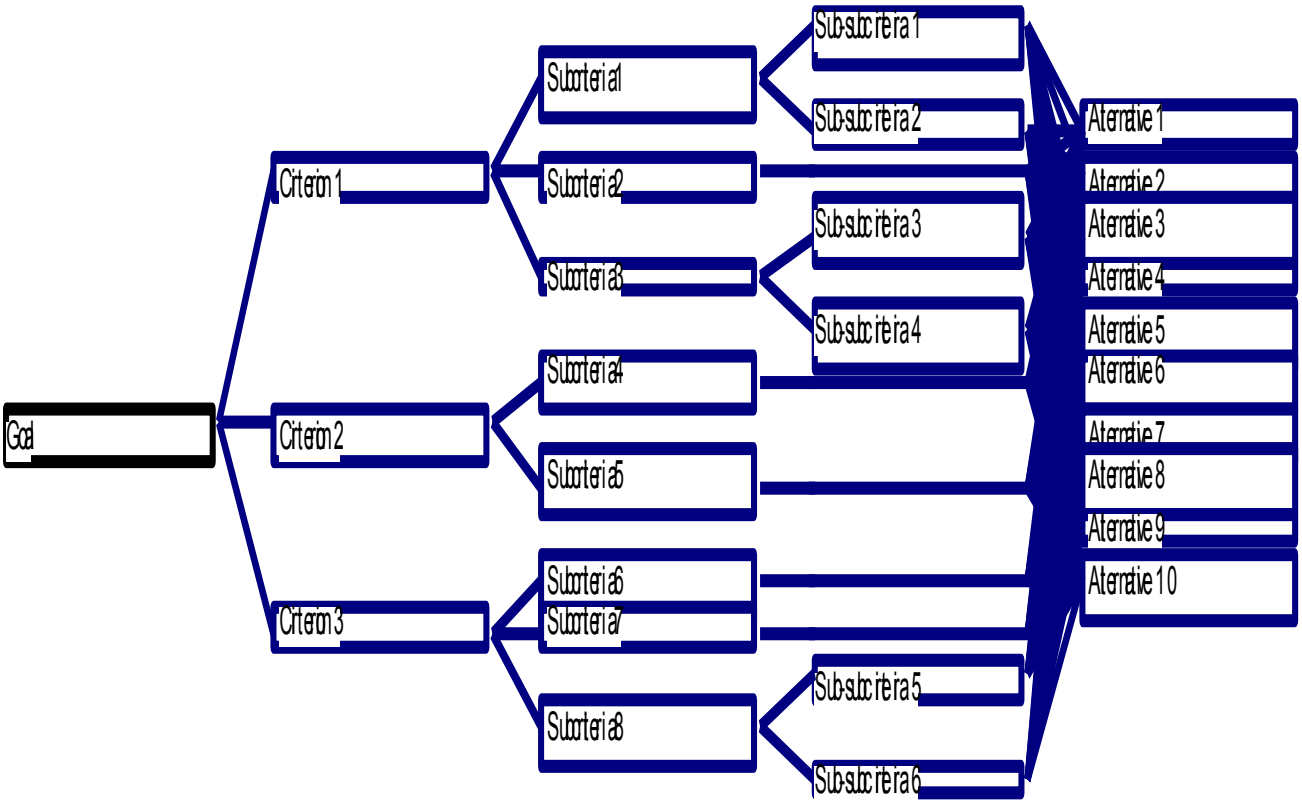

Figure 1. Example of AHP structure with a goal (Level 1), three main criteria (Level 2), eight Level 3 criteria linked to Level 2 criteria, and six Level 4 linked to Level 3 criteria. Each of the ten alternatives is directly linked to the criteria at levels 3 and 4.

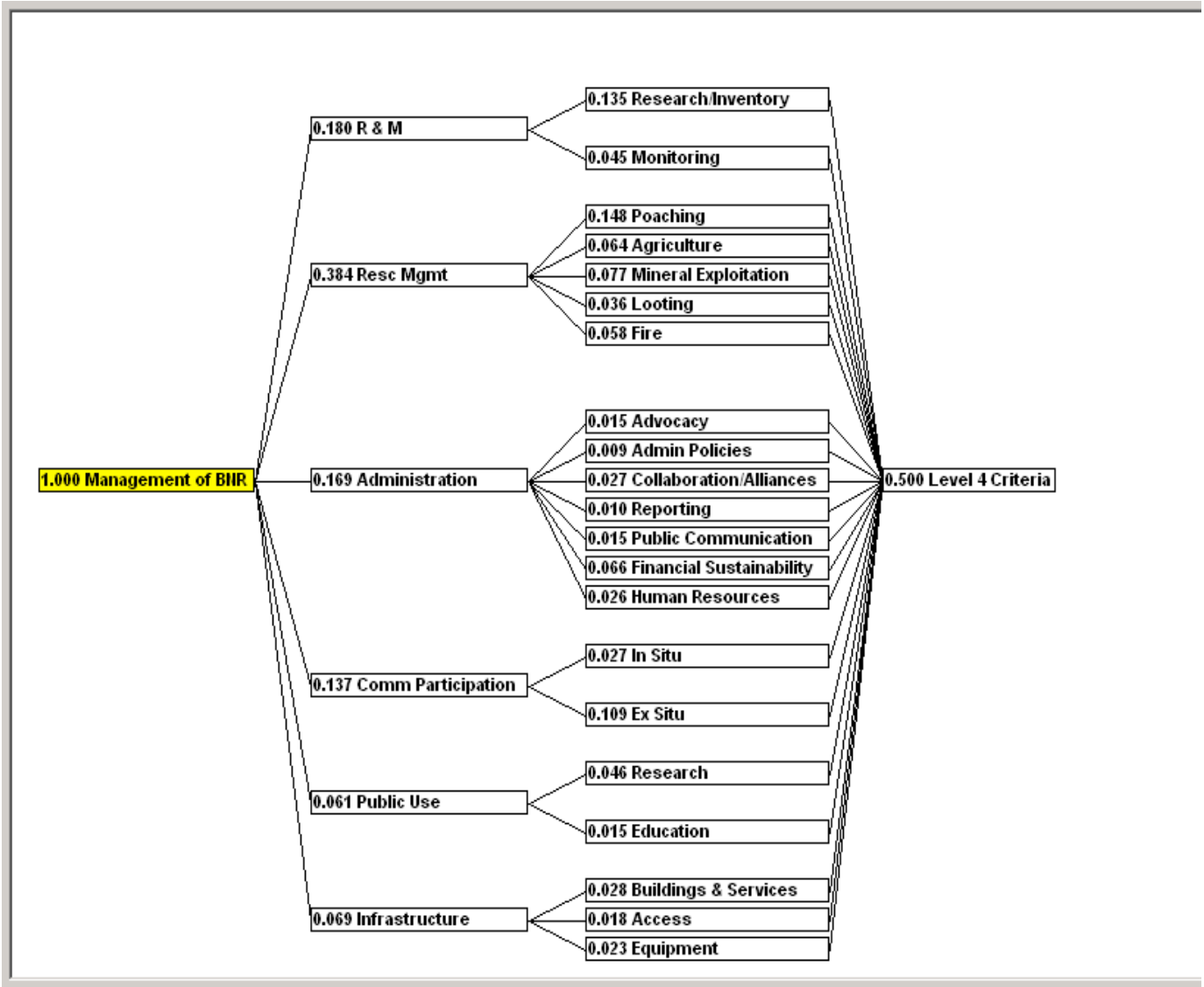

Figure 2. AHP structure of the management plan for the Bladen Nature Reserve, Belize. Levels 1 (management goal) through Level 3 are shown.

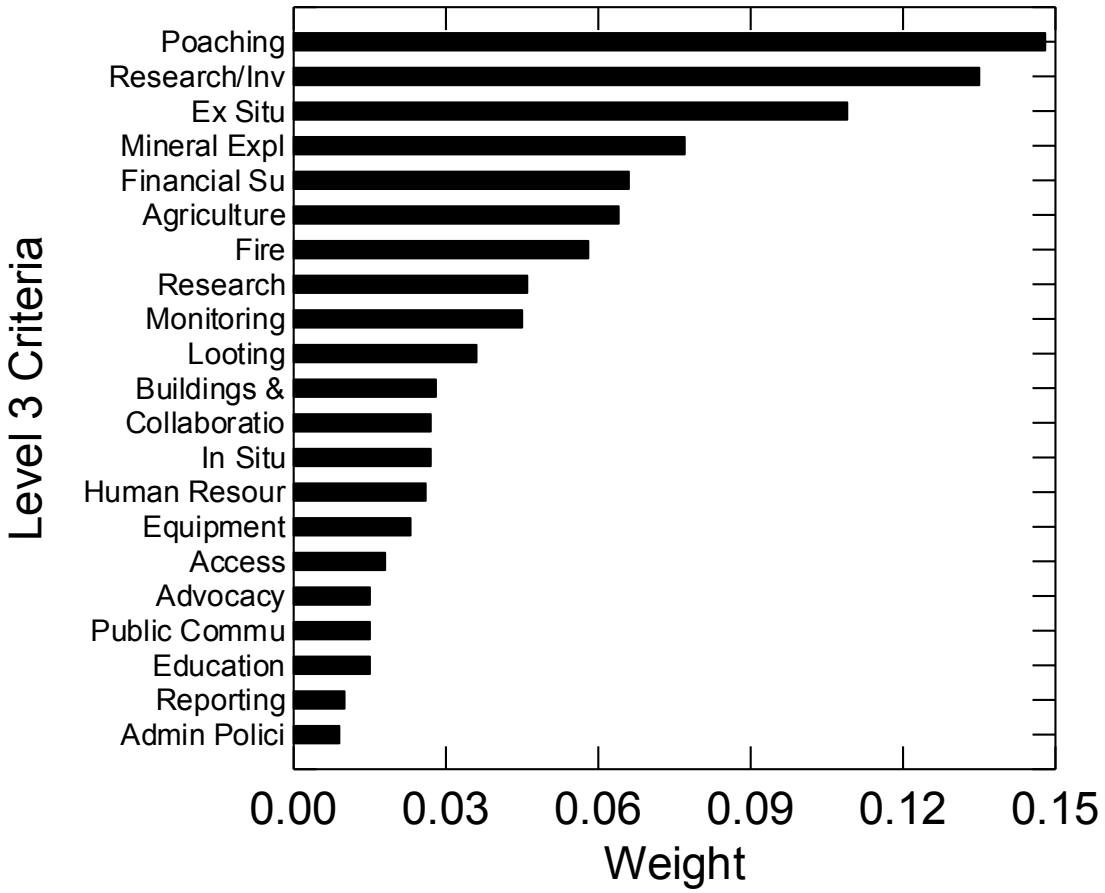

Figure 3. Ranking of Level 3 criteria based on the AHP structure of the management plan for the Bladen Nature Reserve, Belize.

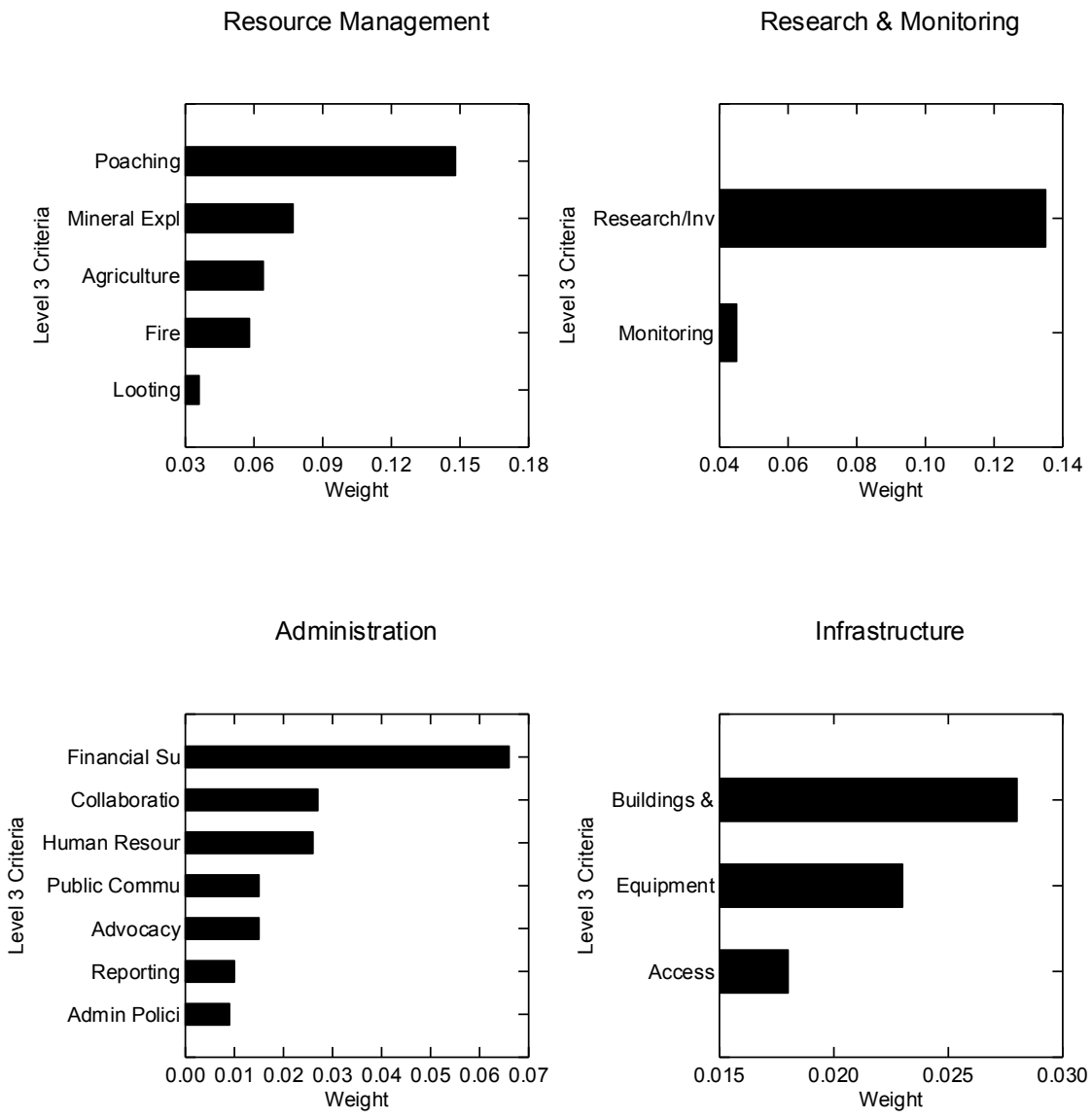

Figure 4. Ranking of Level 3 criteria within Level 2 categories for the Bladen Nature Reserve management plan (continued next page).

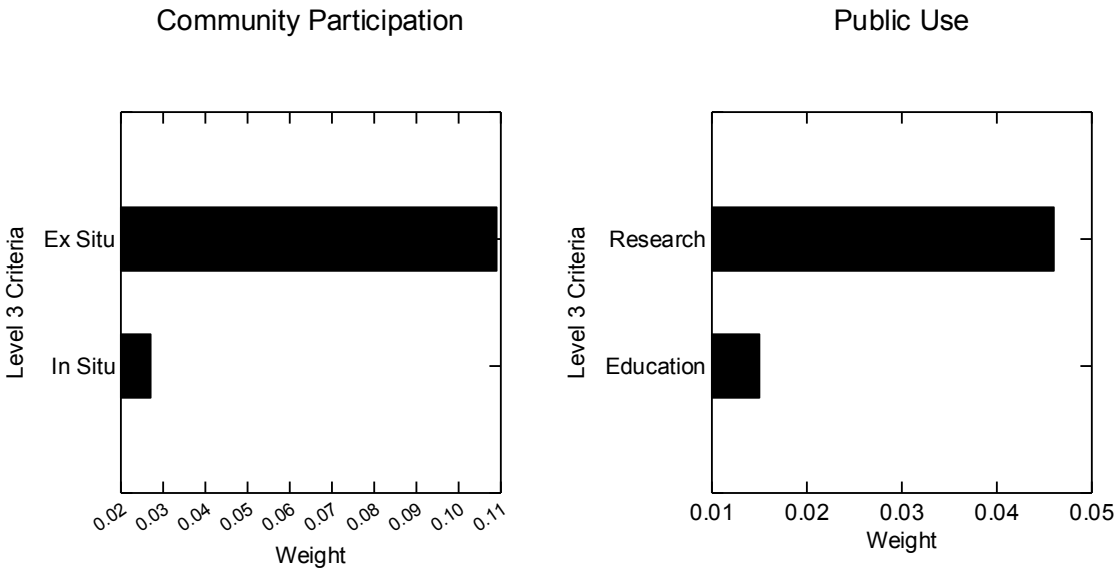

Figure 4 continued.

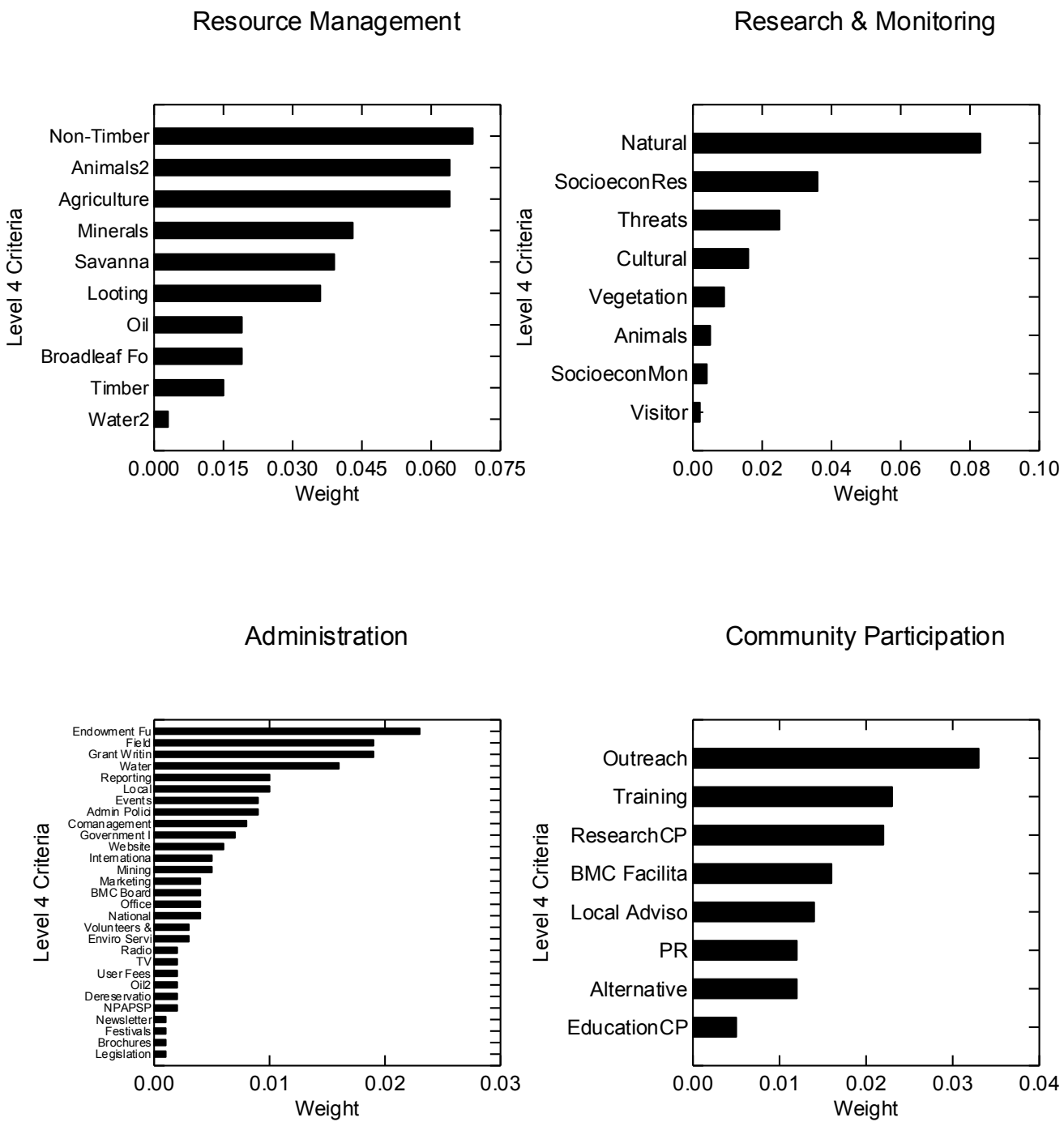

Figure 5. Ranking of Level 4 criteria within Level 2 categories for the Bladen Nature Reserve management plan.

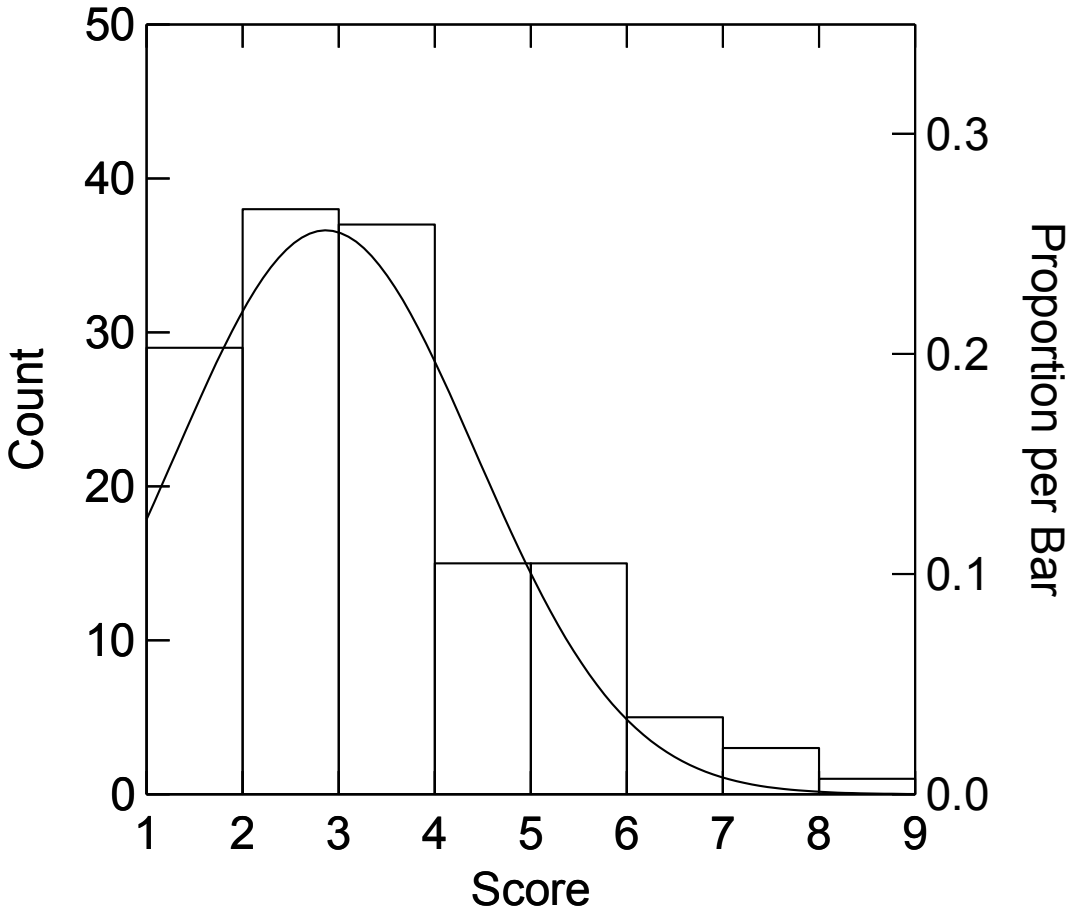

Figure 6. Distribution of scores for pairwise comparisons of Level 3 and Level 4 criteria. Infrastructure and Public Use (highest level criteria) were not included because there were < 3 comparisons within each category.

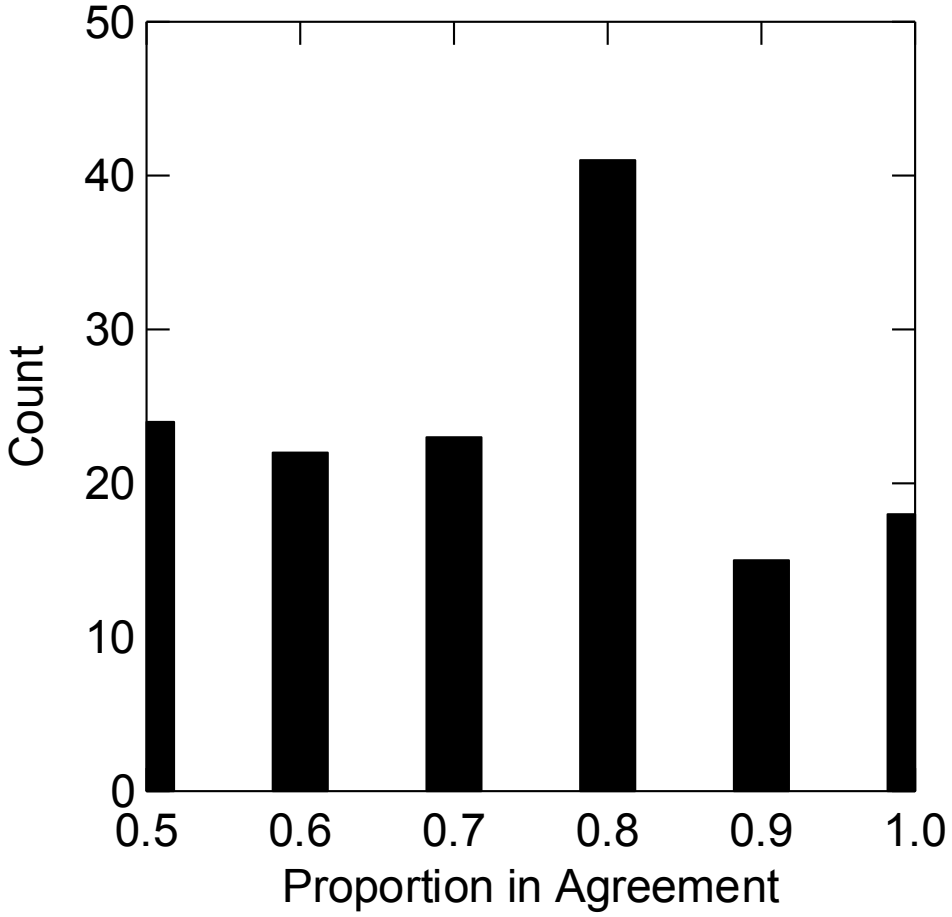

Figure 7. Agreement in scoring among participants for pairwise comparisons of Level 3 and Level 4 criteria. Infrastructure and Public Use (highest level criteria) were not included because there were < 3 comparisons within each category.

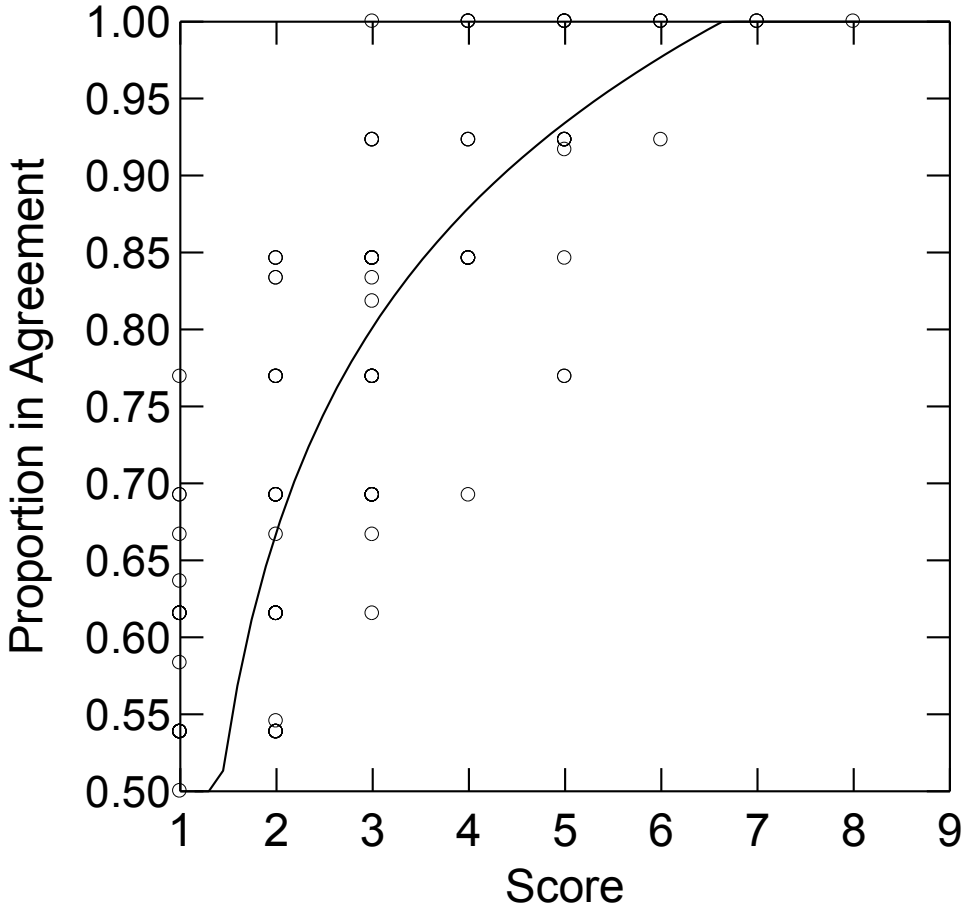

Figure 8. Non-linear regression analysis of the relationship between concordance in scoring (the proportion of participants agreeing one criterion was more important than the other it was being compared against) and the mean score for 143 pairwise comparisons. The regression equation was Concordance = constant + slope*(ln(score)). Regression statistics were: constant = 0.553 (SE = 0.014), slope = 0.221 (SE = 0.013; 95% CI = 0.195-0.247), corrected $r^2 = 0.67$, corrected r = 0.82.

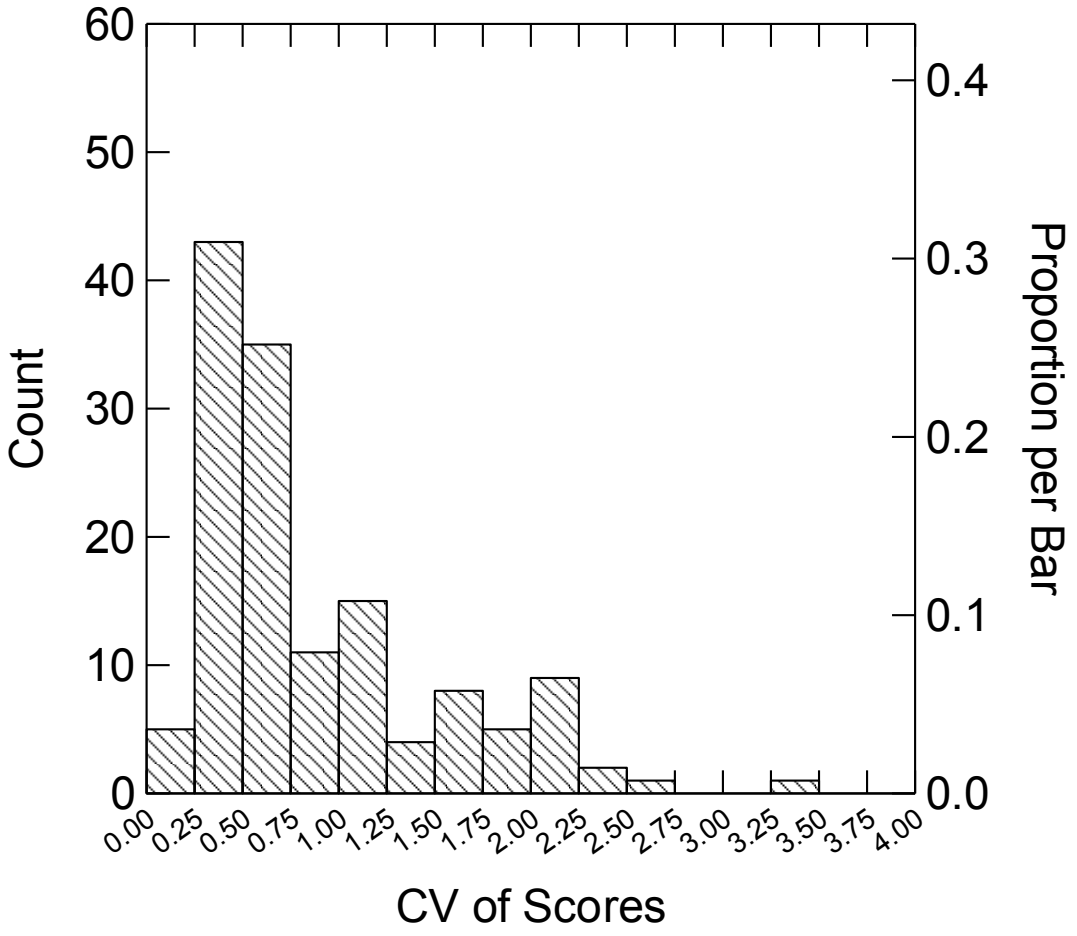

Figure 9. Distribution of the coefficients of variation (CV) for 139 pairwise comparisons of Level 3 and Level 4 criteria. Infrastructure and Public Use (highest level criteria) were not included because there were < 3 comparisons within each category.

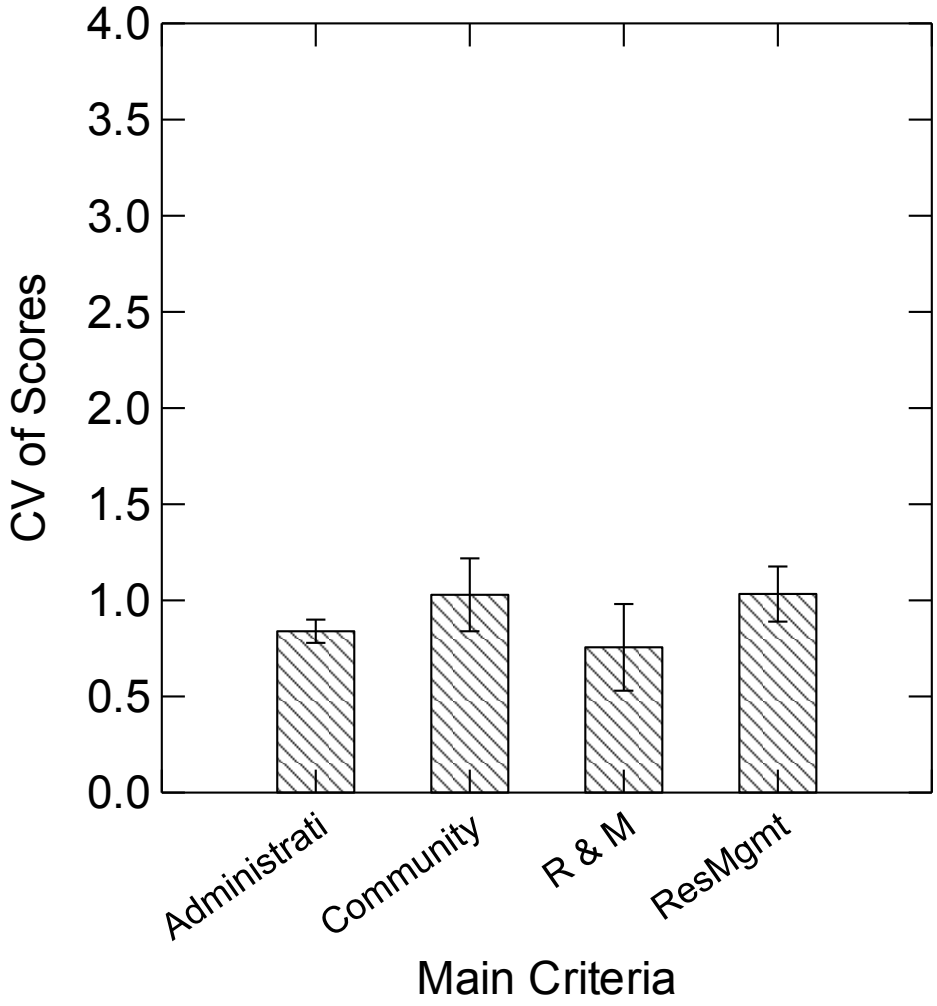

Figure 10. Coefficients of variation (CV) among the four main criteria. Infrastructure and Public Use (highest level criteria) were not included because there were < 3 comparisons within each category. Administrati = Administration, Community = Community Participation, R & M = Research & Monitoring, ResMgmt = Resource Management.

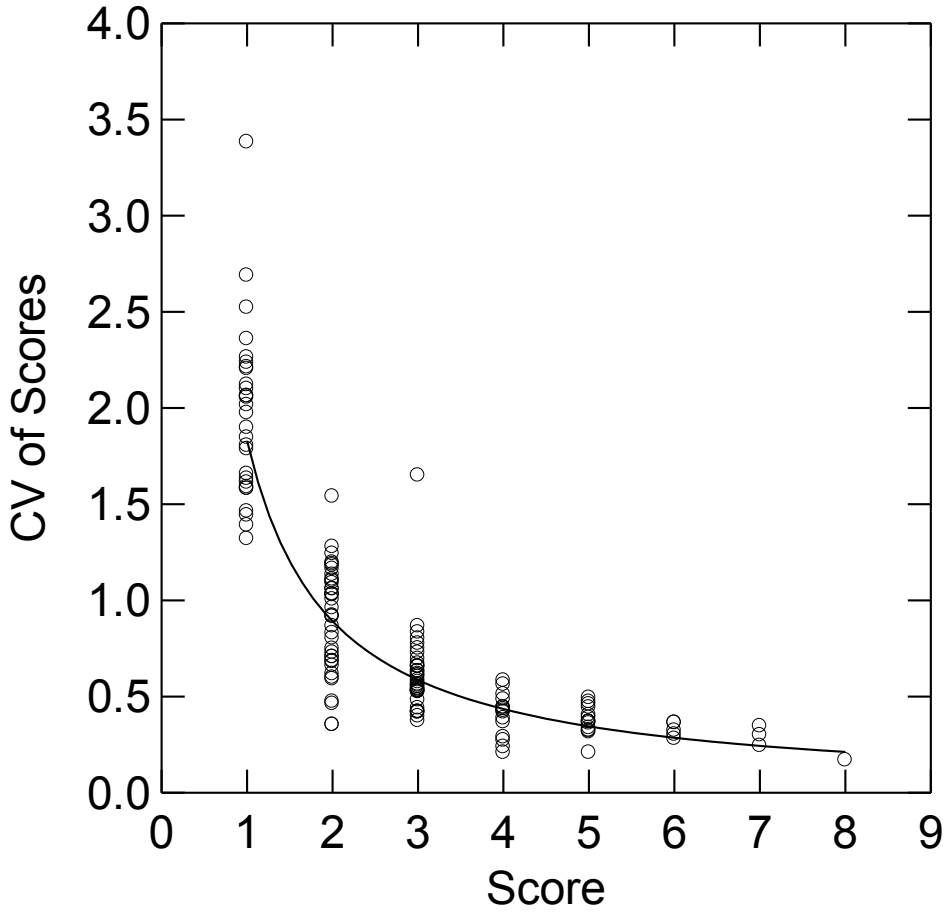

Figure 11. Non-linear regression analysis of the relationship between the coefficients of variation in scoring and the mean score for 143 pairwise comparisons. The regression equation was CV = constant*(score)$^{-slope}$. Regression statistics were: constant = 0.552 (SE = 0.018), slope = -3.422 (SE = 0.184; 95% CI = -3.059 to -3.786), corrected r^2 = 0.79, corrected r = 0.89.