VISITOR IMPACT ASSESSMENT AND MANAGEMENT FOR PROTECTED AREAS IN CENTRAL AND SOUTH AMERICA

by,
Tracy Ann Farrell

Dissertation submitted to the faculty of the Virginia Polytechnic Institute and State University in partial fulfillment of the requirements for the degree of

Doctor of Philosophy
in
Forestry

Jeffrey L. Marion, Committee chair

Troy E. Hall, Committee member

R. Bruce Hull, IV, Committee member

James D. Fraser, Committee member

Muzaffer Uysal, Committee member

December, 1999
Blacksburg, VA

Keywords: protected area management, Central and South America, visitor impacts, visitor impact management, recreation ecology, decision making frameworks.

VISITOR IMPACT ASSESSMENT AND MANAGEMENT FOR PROTECTED AREAS IN CENTRAL AND SOUTH AMERICA

by,

Tracy Ann Farrell
Committee chairman: Dr. Jeffrey L. Marion
Department of Forestry

ABSTRACT

Ecotourism and protected area visitation have been steadily increasing in recent years in Central and South America, inevitably resulting in natural resource impacts. The consequences of such impacts may include natural resource degradation, diminished aesthetic qualities, or decreased functionality of certain facilities like recreation sites and trails. Recreation ecology and visitor impact management expertise and tools are available to help balance the potentially conflicting management goals of protecting natural resources and permitting visitation but such knowledge has not been widely used in Central and South America.

The goals of this research were to characterize certain visitor-related natural resource impacts and to determine how these impacts could be assessed and managed in Central and South America. The research included case studies of eight protected areas in Costa Rica and Belize, trail impact assessment research at Torres del Paine National Park in Chile, and development of a new visitor impact assessment and management framework, presented as three papers intended for journal submission.

The first paper had two objectives: 1) to identify visitor-related natural resource impacts at selected protected areas in Costa Rica and Belize to increase awareness about visitor impact problems, and 2) to apply and compare rapid trail and recreation site impact assessment procedures to provide study site managers with impact data and impact assessment procedures. A variety of natural resource impacts were reported by interview subjects and recorded by rapid assessment procedures. The management utility of the rapid trail and recreation site impact assessment procedures were compared and discussed and the need for developing additional rapid assessment procedures to evaluate other resource impacts reported by protected area managers was also identified.

The intent of the second paper was to investigate trail impacts at Torres del Paine National Park. Study objectives included measuring the frequency and magnitude of selected trail impacts, and comparing the relative impact contribution of the amount of use, vegetation type, trail position and trail grade on common condition indicators such as width and incision. Findings somewhat contradicted those of other studies, revealing that amount of use significantly contributed to trail width and incision. However, findings also indicated that vegetation type and trail grade contributed to number of informal trails and trail incision, respectively. A variety of management strategies were recommended and suggestions were provided for future monitoring studies.

The purpose of the third paper was to propose a new visitor impact assessment and management framework that would provide managers with a feasible means of addressing visitor impact management concerns for selected protected areas in Central and South America. The Protected Areas Impact Assessment and Management (PAIAM) framework was adapted from existing frameworks like carrying capacity and the Limits of Acceptable Change to provide a simple, cost-effective and relatively quick decision making process. PAIAM analyzes visitor impacts using an expert panel and incorporates stakeholders and local residents into decision making. This study experimentally applied the new framework in Mexico and compared PAIAM to existing frameworks.

The focus of this dissertation is on Central and South America since they are heavily visited ecotourist regions that could potentially benefit from applying recreation ecology and visitor impact expertise and tools to protected area management. This research demonstrated that a variety of visitor impacts are affecting natural resources and visitor facilities like trails and recreation sites at selected protected areas in Central and South America. This research also developed and applied rapid impact assessment procedures and visitor impact frameworks for use in Central and South American protected areas.

ACKNOWLEDGEMENTS

First, I would like to thank Dr. Jeffrey L. Marion for his support, assistance, mentorship and perhaps most importantly, his friendship. Without his faith, commitment and attention to my career development this document and the training that it took to produce it would not have been possible. I would also like to thank the remainder of my committee, particularly Troy Hall, for their extremely useful input into this document, and for their much appreciated assistance and support for other projects undertaken during my career at Virginia Tech. Finally, I would also like to thank Chad Dawson for his unwavering support and faith in my abilities. I look forward to working with all of you in the future.

I would like to thank my family and friends in such a manner that words cannot convey. They represent the true authors behind this document since I was able to produce it through their love, acceptance, affection and attention. To my mother and father, my eternal thanks for your never ending love, emotional support, for teaching me how to give the best of myself, and for your faith and intense interest in my work and career, giving them true meaning. To my sister, my gratitude for your strong shoulder to lean on, including me in your life and your exciting goings on, and for enabling our friendship and shared personal growth to continue from childhood to adulthood. To my grandmother Alice P. Welsh, I dedicate this document to you as my fellow traveler and soul-mate across time. To my long term friends who have watched me evolve over time and kept up with my personal and professional development, thank you for keeping me grounded and in good company. To my best friend Janice, thank you for keeping my sanity and your excellent advice. To my friends and housemates that I have been fortunate enough to share these past four years with, thank you for good times and for listening.

TABLE OF CONTENTS

LIST OF FIGURES .... **VII**

LIST OF TABLES .... **VIII**

CHAPTER I. INTRODUCTION **1**

PAPER CONCEPTS AND THEMES **1**
DEFINITION AND SIGNIFICANCE OF TOURISM, ECOTOURISM AND PROTECTED AREAS 1
IMPACTS RELATED TO ECOTOURISM AND PROTECTED AREAS 2
IMPORTANCE OF PROTECTED AREA VISITATION IMPACTS AND THE NEED FOR IMPACT MANAGEMENT 3
DEFINITION AND ROLE OF RECREATION ECOLOGY AND VISITOR IMPACT MANAGEMENT 4
Definition of Recreation Ecology and Visitor Impact Management 4
Need for Integration of Recreation Ecology and Visitor Impact Management into Protected Area Management in Central and South America 5
PROBLEM STATEMENT **5**
STUDY OBJECTIVES 6
DISSERTATION STRUCTURE 7

CHAPTER II. VISITOR IMPACTS AND THEIR MANAGEMENT AT SELECTED PROTECTED AREAS IN COSTA RICA AND BELIZE **8**

ABSTRACT **8**
INTRODUCTION **9**
VISITOR IMPACTS AND CONDITION ASSESSMENT METHODS 10
Trail and Recreation Site Impacts 10
Wildlife Impacts 11
Water Resource Impacts 11
Other Impacts 12
Condition Assessments methods 12
STUDY AREA AND METHODS **13**
STUDY AREAS 13
MANAGER INTERVIEWS 14
TRAIL AND RECREATION SITE SELECTION 14
CONDITION ASSESSMENT METHODS 15
Trail Assessment Procedures 15
Recreation Site Assessment Procedures 17
RESULTS **19**
INTERVIEW INFORMATION ABOUT VISITOR IMPACTS 19
TRAIL IMPACTS: CONDITION CLASS SYSTEM AND POINT SAMPLING METHOD 20
TRAIL IMPACTS: PROBLEM ASSESSMENT METHOD 20
Factors Influencing Trail Impacts 21
RECREATION SITE IMPACTS 22
Factors Influencing Recreation Site Impacts 22
DISCUSSION **23**
IMPACT INFORMATION AND UTILITY OF RAPID ASSESSMENT PROCEDURES 23

RAPID ASSESSMENT PROCEDURES FOR IMPACTS TO WILDLIFE, WATER, ATTRACTION FEATURES AND OTHER RESOURCES 25
CONCLUSION 26

CHAPTER III. TRAIL IMPACTS AND TRAIL IMPACT MANAGEMENT RELATED TO ECOTOURISM VISITATION AT TORRES DEL PAINE NATIONAL PARK, CHILE........28

ABSTRACT........ 28
INTRODUCTION 29
TRAIL IMPACTS 30
FACTORS CONTRIBUTING TO TRAIL IMPACTS 31
Use-Related Factors........ 31
Environmental Factors........ 32
Managerial Factors 32
METHODS........ 33
STUDY AREA 33
STUDY OBJECTIVES........ 35
SAMPLING 35
TRAIL CONDITION ASSESSMENT 36
ANALYSIS........ 37
RESULTS 38
TRAIL SUBSTRATE CONDITION CHARACTERISTICS........ 38
RELATIONAL ANALYSES 39
Implications of Multicollinearity 39
Amount of Use 40
Vegetation Type........ 41
Trail Position 41
Trail Grade........ 41
DISCUSSION........ 42
INFLUENCE OF CONTRIBUTORY FACTORS........ 43
Amount of Use 43
Vegetation Type........ 44
Trail Position 45
Trail Grade........ 46
IMPLICATIONS FOR MANAGEMENT........ 47
Management Implications........ 47
Future Research 48
CONCLUSION 48

CHAPTER IV. THE PROTECTED AREAS IMPACT ASSESSMENT AND MANAGEMENT (PAIAM) FRAMEWORK: A SIMPLIFIED PROCESS FOR VISITOR IMPACT MANAGEMENT 51

ABSTRACT........ 51
INTRODUCTION 52
VISITOR IMPACTS AND PROTECTED AREA MANAGEMENT 52
DECISION MAKING FRAMEWORKS AND PAPER OBJECTIVES........ 53
METHODS........ 53

DESCRIPTION AND CRITIQUE OF DECISION MAKING FRAMEWORKS 54
DESCRIPTION OF DECISION MAKING FRAMEWORKS.. 54
Carrying Capacity.. 54
Alternative Decision-Making Frameworks.. 55
Use of Decision-Making Frameworks in Central and South America 57
CRITIQUE OF EXISTING DECISION-MAKING FRAMEWORKS 57
Positive and Negative Attributes of Carrying Capacity 58
Positive and Negative Attributes of Alternative Decision-Making Frameworks....................... 59
JUSTIFICATION FOR DEVELOPING A NEW FRAMEWORK... 61
PROPOSING THE PROTECTED AREAS IMPACT ASSESSMENT AND MANAGEMENT (PAIAM) FRAMEWORK 61
THE PROTECTED AREAS IMPACT ASSESSMENT AND MANAGEMENT (PAIAM) FRAMEWORK 61
Public Participation and the Expert Panel.. 62
PAIAM Steps 63
PAIAM IMPLEMENTATION IN MEXICO 66
CRITIQUE OF THE PAIAM FRAMEWORK 66
Positive and Negative Attributes of PAIAM... 67
CONCLUSION 69

CHAPTER V. SUMMARY, DISCUSSION AND CONCLUSION 71

SUMMARY 71
DISSERTATION THEME AND INTENT 72
INTENT AND FINDINGS FROM THE THREE PAPERS 73
DISCUSSION.. 74
GENERAL CONTRIBUTIONS OF DISSERTATION RESEARCH 74
SIGNIFICANCE AND IMPLICATIONS OF SPECIFIC STUDY FINDINGS.............................. 75
STUDY LIMITATIONS 76
FUTURE RESEARCH... 78
CONCLUSION 79

REFERENCES 81

TABLES...95

FIGURES...104

APPENDIX I. CASE STUDY MANUAL FOR CONDUCTING INTERVIEWS AND APPLYING RAPID ASSESSMENT PROCEDURES..107

APPENDIX II. TRAIL MONITORING MANUAL 119

VITA...123

LIST OF FIGURES

FIGURE 1. Diagrams of alternative trail tread incision measurements 104

FIGURE 2. Schematic illustrating LAC, VIM and VERP planning and management Frameworks 105

FIGURE 3. Protected areas impact assessment and management framework (PAIAM) 106

LIST OF TABLES

TABLE 1. Examples of literature findings related to visitor activity impacts on natural resources........ 95

TABLE 2. Attributes and characteristics of protected areas selected for case studies in Costa Rica and Belize.. 96

TABLE 3. Condition class rating system applied to trails and recreation sites in case study protected areas in Costa Rica and Belize 97

TABLE 4. Summary of trail condition class and point sampling results for case study protected areas in Costa Rica and Belize... 97

TABLE 5. Summary of trail problem assessment results for case study protected areas in Costa Rica and Belize 98

TABLE 6. Summary of site condition class and multi-indicator impact assessment system for case study protected areas in Costa Rica and Belize 99

TABLE 7. Trail segment names, location of sub-segments sampled and use category for Torres del Paine trails. 99

TABLE 8. Means, medians, ranges and percentiles for trail substrate conditions stratified by amount of use for Torres del Paine trails.. 100

TABLE 9. Means, standard deviations and ranges for impact indicators stratified by amount of use for Torres del Paine trails... 100

TABLE 10. One-way analysis of variance (ANOVA) for impact indicators stratified by amount of use to compare impact indicator responses for Torres del Paine trails 101

TABLE 11. T-test for impact indicators for medium levels of use stratified by vegetation type to compare impact indicator responses for Torres del Paine trails 101

TABLE 12. Two-way analysis of variance (ANOVA) for impact indicators stratified by amount of use and trail position to compare impact indicator responses for Torres del Paine trails............................. 102

TABLE 13. Two-way analysis of variance (ANOVA) for impact indicators stratified by amount of use and trail grade to compare impact indicator responses for Torres del Paine trails. 102

TABLE 14. Significant effects for impact indicators after controlling for other variables for examining trail impacts at Torres del Paine. 103

TABLE 15. Critique of carrying capacity, alternative decision-making frameworks and the proposed framework using criteria developed from interview information and the literature. 103

CHAPTER I. INTRODUCTION

PAPER CONCEPTS AND THEMES

Definition and Significance of Tourism, Ecotourism and Protected Areas

Tourism is one of the largest multi-national activities. In 1996, almost 600 million international tourism trips occurred (WTO 1997). The highest rates of growth for international arrivals are in Asia/Oceania, Africa and the Americas. Increased tourist and ecotourist travel has been linked to a growing interest in experiencing less developed or more natural settings, and to worldwide trends of increased support for protecting the environment and natural resources (WTO 1991). Improved access, transportation and infrastructure have also facilitated tourism growth (Ceballos-Lascurain 1996).

Nature-based tourism and ecotourism are key sources of income for many developing countries, particularly in Latin America (Furze et al. 1996). Nature-based tourism is travel to any outdoor natural or cultural site for amenity and recreation purposes (Brown et al. 1997). Ecotourism includes travel to natural and cultural sites but also requires some attention to conservation or enhancement of the environment, a strong commitment to nature, and a sense of social responsibility (Nepal 1999). The Ecotourism Society (TES) defines ecotourism as "responsible travel to natural areas, which conserves the environment and improves the welfare of local people" (Lindberg et al. 1998: 8). Numerous definitions exist for ecotourism, with no clear resolution as to which is more suitable. Therefore, TES's definition is adopted for the purposes of this paper.

Protected areas are a particularly important component of nature-based tourism and ecotourism (Wight 1996). The International Union for the Conservation of Nature (IUCN) defines protected areas as areas of land and/or sea that are legally or otherwise effectively protected, and are especially dedicated to the protection and maintenance of biological diversity, as well as the protection of other natural and cultural resource values (Borrini-Feyerabend 1997). According to Shackley (1998), protected areas represent national symbols of culture and character, promote national identity and pride, protect natural resources in a world where such resources are increasingly threatened, safeguard the authenticity of treasured places, and preserve these areas for future generations. Additionally, protected areas promote intellectual and spiritual experiences for visitors who are interested in interacting with natural and cultural attractions in a relatively undisturbed state.

Protected areas are a critical component of maintaining a sustainable world, because they can maintain biodiversity, protect land from other more exploitative resources uses, and generate revenue for local people (Borrie et al. 1998). Recognition of the potential benefits of protected areas has recently occurred in Central and South America, where 76% of Central American protected areas and 37% of South American protected areas have been established within the last twenty years (Redford and Ostria 1995).

Impacts Related to Ecotourism and Protected Areas

Ecotourism has been heralded as a means of providing income for local populations, promoting cultural integrity, and protecting natural resources. Examples of such positive benefits are evident in Central and South America. First, many countries in Central and South America have mandated the development of national tourism and ecotourism strategies to obtain these benefits (Edwards et al. 1998). Second, several countries like Ecuador and Belize have begun to initiate massive efforts to facilitate the development and operation of ecotourism projects by local people (Epler-Wood 1998). Finally, in Costa Rica, ecotourism has become the largest income generating industry, resulting in strong incentives to protect natural resources, with more than 20% of the total land area already set aside as protected areas (Sweeting et al. 1999). Similarly, protected area designation and visitation may result in greater appreciation for natural resources and other benefits like promoting conservation activities and ethics, stimulating economic activity in nearby areas, and nature education (Nepal 1999).

Conversely, a variety of undesirable or negative impacts have occurred that diminish the benefits and values of ecotourism and protected areas. For example, many developing countries such as Nepal, Belize, Ecuador and Costa Rica are experiencing rapid, unplanned growth of ecotourism in remote, rural zones, resulting in exploitation of local cultures and environments (Epler-Wood 1998; Nepal 1999). Additionally, increased drug trafficking and improper sewage disposal have occurred in response to tourism development in Belize, foreign land speculation has drastically increased land prices in Costa Rica, and opportunities to earn tourism dollars in Ecuador have attracted numerous unqualified guides, resulting in conflicts with trained guides and diminished visitor experiences (Epler-Wood 1998). Similarly, negative economic, socio-cultural and environmental impacts can also result. For example, protected area designation has sometimes displaced local indigenous peoples, denied their traditional access to resources, or replaced their systems of decision making with agency bureaucracies (Pimbert and Pretty 1995). Additionally, protected areas do not always generate sufficient revenue for local residents to off-set financial losses related to previous resource uses (Furze et al. 1996).

Infrastructure, facility development and visitor activities also create environmental impacts, the latter of which is often overlooked by protected area managers (Marion and Farrell 1998). Protected area visitation can result in noise pollution, crowding, conflicts with local people or other visitors, trail erosion, campsite proliferation, wildlife disturbance, littering and inappropriate sewage disposal, among other impacts (Boo 1990; Buckley and Pannell 1990, Woodley 1993; Marion and Farrell 1998; Nepal 1999).

Importance of Protected Area Visitation Impacts and the Need for Impact Management

Visitor impacts are important management concerns because protected area mandates and other legislation commonly require managers to protect natural resources and provide for certain visitor experiences, ecotourists and other visitors may desire interaction with undisturbed resources, and because impacts may adversely affect local populations (Ceballos-Lascurain 1996).

Natural resource impacts are of particular concern because they may occur at initial or low levels of use, result in increased degradation of resources over time or create additional impacts, result in intense impacts in localized areas, affect larger landscape scales, decrease the functionality of facilities like trails and sites or increase safety concerns (Leung and Marion 1996; Hammitt and Cole 1998). Other visitor impact management concerns include increased conflict between visitors and/or local people, reduced aesthetic enjoyment, increased management costs, and ultimately, the possibility that visitation might diminish if impacts are severe enough, reducing local economic benefits (Marion and Farrell 1998).

Visitor use will inevitably result in some degree of natural resource impact, regardless of type of visitor, ecotourist or tourist, requiring management of visitors and recreation resources (Borrie et al. 1998; Marion and Farrell 1998). Additionally, protected area visitation in developing countries is continuing to increase, requiring immediate assessment and management of visitor impacts (Redford and Ostria 1995; Sweeting et al. 1999).

The need for improved protected area management and visitor impact management programs and techniques was identified at two recent international conferences. Management issues and needs identified at the 1992 Fourth World's Park Congress included monitoring and research, assessing environmental impacts related to tourism development and protected area visitation, developing protected area management plans, and training park managers (Ceballos-Lascurain 1996). Similarly, salient issues identified at the First Latin American Congress on National Parks and Other Protected Areas in 1997 included improving communications between resident indigenous groups and the national parks, and managing threats from land degradation related to tourism and protected area visitation (de Groot 1998).

Definition and Role of Recreation Ecology and Visitor Impact Management

Definition of Recreation Ecology and Visitor Impact Management

Recreation ecology and visitor impact management are areas of knowledge that can be used by protected area managers to identify, assess, monitor and minimize visitor-related natural resource impacts and their consequences, and direct the selection of management strategies. Recreation ecology seeks to describe the types, amounts and rates of ecological changes resulting from recreational use, including relationships with use-related, environmental and managerial factors that influence these changes (Marion and Rogers 1994).

Visitor impact management is the process of identifying unacceptable changes related to visitor use (visitor impacts) and selecting one or more impact management actions or strategies (Graefe et al. 1990). Its principles include integrating visitor impact concerns into agency planning and management processes, basing management actions on scientific understandings of impacts and other factors affecting site conditions, understanding relationships between use and impact, and maintaining a principle of non-degradation. Visitor impact management incorporates recreation ecology knowledge and tools with decision-making frameworks like carrying capacity and the Limits of Acceptable Change (Wagar 1964; Stankey et al. 1985). Decision-making frameworks guide protected area staff in the process of identifying, assessing, and selecting strategies for managing visitor impacts.

Need for Integration of Recreation Ecology and Visitor Impact Management into Protected Area Management in Central and South America

Recreation ecology and visitor impact management have been extensively applied in the United States, Canada, Australia, and Great Britain, with fewer examples evident in Central and South America (Cole 1987; Liddle 1997; Hammitt and Cole 1998; Marion and Farrell 1998; and others). However, more empirical studies related to the ecological impacts of ecotourist activities in popular destination areas are being conducted. Ecotourist visitor impact studies have recently applied techniques and procedures developed from the recreation ecology literature, and there is increasing overlap between recreation ecology and tourism in the literature, some of which focuses on protected areas in Central and South America (Leung et al. *in press*).

Further integration of recreation ecology and visitor impact knowledge into protected area management in Central and South America is needed to assist managers in planning and managing for visitor use, including assessing and monitoring visitor impacts, and preventing and minimizing visitor-related natural resource degradation.

PROBLEM STATEMENT

Protected area management requires a balance between several conflicting goals, such as protecting natural resources, sustaining high quality visitor experiences, providing revenue for local people, maintaining local resource needs, and a myriad of other management concerns. As protected area visitation continues to increase, the need for specialized knowledge regarding visitor impact identification, assessment and management will also increase. Recreation ecology and visitor impact management expertise provide such knowledge, though they have not yet been widely applied in Central and South American protected areas.

This dissertation identifies and addresses the need for further incorporating such knowledge into protected area management in Central and South America, by (1) demonstrating that a variety of visitor impacts currently are affecting natural resources at selected protected areas; (2) developing and applying impact assessment procedures adapted from the recreation ecology literature; (3) studying the relative impact contribution of the amount of use compared to other potential contributory factors; and (4) considering the relative utility and applicability of decision-making frameworks like carrying capacity and the Limits of Acceptable Change for use in visitor impact management decision making.

Study Objectives

Study objectives include:

1. To advance our knowledge and understanding of visitor impacts affecting protected areas in Central and South America.
2. To develop and apply impact assessment procedures that can be feasibly applied by protected area staff in Central and South America.
3. To assess the relative impact contribution of use-related factors, compared to environmental and managerial factors.
4. To investigate the current use, advantages and disadvantages of carrying capacity and alternative visitor impact management frameworks in Central and South American protected areas.
5. To propose a new visitor impact management framework that accommodates the unique situations and management constraints of Central and South American protected areas.

Dissertation Structure

The overall theme of this dissertation is identifying visitor impacts and determining how these impacts can be assessed and managed in Central and South American protected areas. The format includes three journal articles: The first paper presents case study findings from eight protected areas in Belize and Costa Rica to characterize visitor impacts, assess trail and recreation site impacts, and apply and compare the management utility of rapid impact assessment procedures. The second paper provides more sophisticated trail monitoring procedures and evaluates the relative contribution of use-related factors compared to environmental and managerial factors as they influence trail impacts at Torres del Paine National Park, in Chile. The third paper describes the positive and negative attributes of current decision-making frameworks and proposes a new framework for selected protected areas in Central and South America.

CHAPTER II. VISITOR IMPACTS AND THEIR MANAGEMENT AT SELECTED PROTECTED AREAS IN COSTA RICA AND BELIZE

ABSTRACT

Protected area visitation is an important component of ecotourism, and as such, must be sustainable. However, protected area visitation may degrade natural resources, particularly in areas of concentrated visitor activities like trails and recreation sites. This is a particularly important concern in ecotourism destinations such as Belize and Costa Rica, because they promote a pristine or undisturbed quality of their natural resources to ecotourists.

Recreation ecology and visitor impact management expertise provide information and tools capable of identifying, assessing and managing visitor-related natural resource impacts. Such knowledge has great potential management utility though it has not widely been applied in Central and South America. This study involved case studies of eight protected areas in Belize and Costa Rica to begin addressing this gap in knowledge. Case studies included interviews with protected area managers and staff to identify their perceptions about impact problems, and assessment of trail and recreation site impacts to provide impact data for protected area managers, and to develop inexpensive, efficient and effective rapid impact assessment procedures.

Interview subjects reported a variety of impacts affecting trails and recreation sites, as well as wildlife, water, attraction features and other resources. Rapid impact assessment procedures were used to record several additional trail and site impacts. In this study, a variety of impacts affecting the case study areas were identified, the potential management utility of rapid impact assessment procedures for evaluating trail and recreation site impacts was demonstrated, and the need for additional rapid impact assessment procedures for wildlife, water, attraction feature and other resource impacts was also identified.

INTRODUCTION

Successful ecotourism and protected area management requires sustainability, necessitating the effective management of natural areas for visitor enjoyment and resource protection in perpetuity, for current and future use (WED 1987). However, undesirable resource impacts related to tourism development and growth and protected area visitation have been documented in developed and developing countries (Mieczkowski 1995; Hunter and Green 1995; Liddle 1997; Epler Wood 1998). In particular, protected area visitation results in trail, recreation site, wildlife and water resource impacts and degrades attractions like coral reefs (Marion and Farrell 1998; Marion and Leung 1998).

Visitor impacts have been identified as important management concerns by protected area managers in developing countries (Alderman 1990; Giongo et al. 1994). Trail and recreation site (e.g., campsite, picnic area, or area surrounding an attraction feature) impacts are of particular concern, because trail-related recreation activities like hiking and wildlife viewing are popular visitor activities, and because trails and recreation sites receive the most intensive visitor use within protected areas (Backman and Potts 1993; Wight 1996).

Visitor impacts frequently occur at initial or low levels of use, result in intense impacts in localized areas, decrease the functionality of facilities like trails and recreation sites, increase safety concerns, reduce aesthetic enjoyment and contribute to visitor displacement, create conflict between visitor groups, and increase management costs (Leung and Marion 1996; Hammitt and Cole 1998; Marion and Farrell 1998).

Visitor impacts are especially relevant for protected areas in ecotourism destinations such as Belize and Costa Rica. Both countries have numerous protected areas comprising a substantial portion of their total acreage and are world renowned for an undisturbed, pristine quality of natural resources (Back and Barry 1996). They also receive intensive visitation and emphasize natural resource protection over visitation in protected area legislation and mandates (Scott 1998; Tenorio 1998). Therefore, research and management of visitor impacts is especially critical for protected areas in these countries.

To date, research of visitor impacts in protected areas in Costa Rica and Belize has been minimal. Boo (1990) listed impacts affecting selected protected areas based on qualitative case study research. Similarly, a few isolated examples of trail and wildlife impact studies exist in Costa Rica (Boucher et al. 1991; Jacobsen and Lopez 1994; Wallin and Harden 1996).

Greater knowledge of the range of impacts affecting protected areas in Belize and Costa Rica would contribute to the larger discussion of visitation impacts in ecotourism destination areas, identify areas of needed research and management, and help in the development of impact monitoring programs. Quantitative research is specifically needed for trails and recreation sites, because these types of settings are found in most protected areas and are locations of heavy visitor concentration. Trail and recreation site impacts are an attractive focus for study, because rapid assessment procedures have been developed that generate useful information relevant for selecting management strategies and actions.

In this paper a diversity of visitor impacts currently affecting natural resources at eight protected areas in Costa Rica and Belize are identified and described. In the beginning of the paper, a discussion of the types of impacts and condition assessment methods commonly reported in the literature is presented. The case studies provide information about visitor impacts as perceived by managers and demonstrate how rapid assessment procedures can be used to quantify selected trail and recreation site impacts. The relative utility of the rapid assessment procedures for case study protected areas is also considered.

Visitor Impacts and Condition Assessment Methods

Visitor impacts identified in the literature include vegetation and soil affects like trail and recreation site proliferation and degradation, attraction feature damage (e.g., physical damage to coral reefs), and wildlife disturbance, habituation, feeding or injury, as well as physical and biological water pollution (Table 1).

Trail and Recreation Site Impacts

Trails and recreation sites exist to concentrate use, offer recreation opportunities, access attraction features, and in the case of trails, provide a means of transportation (Leung and Marion 1996). Degradation of these facilities may decrease their functionality and diminish the quality of visitor experiences. Among the most commonly reported impacts are the proliferation of user-created trails and recreation sites, loss of vegetation, change in vegetation species composition and soil compaction and erosion. Other trail impacts include trail widening, muddiness and multiple treads. Other recreation site impacts include damaged trees and exposed roots. Additionally, natural attraction features within recreation sites such as coral reefs, historic structures or ruin buildings may experience degradation. Coral reef impacts, including physical damage and death of coral organisms, are commonly reported in the literature (Salm 1986; Kay and Liddle 1989; Harriot et al. 1997). Trail and recreation site impacts may diminish the aesthetic value of protected areas or degrade the quality of natural resource conditions and processes (Cole et al. 1987).

Wildlife Impacts

Wildlife impacts include disturbance, habituation, feeding/attraction and injury or death, as well as indirect effects through degradation of habitat quality (Knight and Cole 1995a). Wildlife impacts are important management concerns because rare or endangered species may be threatened and wildlife often represent a primary visitor attraction (Knight and Gutzwiller 1995). However, it is difficult to draw general conclusions about cause-effect relationships between visitor activities, impacts, and wildlife responses because individual and species' responses to visitor activities vary, depending on visitor behavior, the nature of disturbance, and learned wildlife responses (Knight and Cole 1995b).

Water Resource Impacts

Physical and biological water pollution can occur from terrestrial and aquatic based visitor activities (Kuss et al. 1990). Water resource impacts may result in degraded aesthetic qualities, bio-physical and chemical effects on dependent organisms, reduced recreational opportunities (e.g., swimming), and potential threats to human health (Hammitt and Cole 1998).

Other Impacts

Visitors sometimes engage in illegal or inappropriate activities including hunting and fishing in non-designated areas, flora and fauna collection, littering, and vandalism (Cole et al. 1987). Littering is an especially important management concern, often highly rated by developed and developing country protected area managers as an important problem (Boo 1990; Marion et al. 1993; Giongo et al. 1994).

Condition Assessments methods

A variety of trail and campsite condition assessment and monitoring methods have been developed that are easy and fast to apply, cost-effective, easy to demonstrate to others, require minimum equipment, and yield information with high management utility, increasing their feasibility and usefulness in developing country protected areas.

Methods include photographic evaluation (Magill and Twiss 1965), condition class systems (Frissell 1978), rating systems (Cole 1989), measurement-based systems (Cole 1983; Marion 1991; Lemky 1996), trail point sampling (Leung and Marion 1999a) and trail problem assessment (Leung and Marion 1999b).

Rapid, easy and inexpensive condition assessment methods for visitor-related wildlife, water and other resource impacts have not yet been extensively developed and applied. In the context of assessing visitor-related impacts, they are thus far limited to qualitative means of gaining information, such as observation, or expensive, time consuming methods such as studies of wildlife populations or chemical analyses of water. Such methods would be difficult to develop because wildlife and water resource monitoring generally require extensive observation and longer term studies (e.g., wildlife population responses) and also may require intensive sampling and laboratory analysis (e.g., coliform bacteria count in water). In addition to observation, impact information in other studies has been obtained by interviewing knowledgeable protected area staff (Boo 1990; Giongo et al. 1994).

STUDY AREA AND METHODS

Study Areas

Research was conducted in eight protected areas in Belize and Costa Rica, Central America. Belize is a small country (22,960 km^2) located between Mexico's southeastern border and Guatemala. The country is predominantly lowland and includes 298 km of Caribbean coast (Mahler and Wotkyns 1997). Costa Rica (50,984 km^2) is situated between Nicaragua and Panama. The country includes lowland and montane topography, as well as 212 kilometers of Caribbean coast and 1,022 kilometers of Pacific coast (ICT 1998).

Eight protected areas were purposively sampled for this study, representing approximately 10% of the protected areas in Costa Rica and 15% of the protected areas in Belize. Study sites were selected to capture a variety of conditions potentially affecting the type, severity, assessment and management of visitor impacts. For example, protected areas with minimal visitation and limited access, visitor facility development and staff may have different visitor impacts than extensively developed, visited, managed and easily accessible areas. Therefore, the criteria evaluated to select a diversity of protected areas included intensity of development (infrastructure and visitor facilities), access (difficulty and regulation), management capacity (number of staff and funding), type of managing agency (non-government organization, government or private), visitation (number of annual visitors), and environmental characteristics (marine, tropical or temperate) (Table 2).

The sites selected have from one to fifteen permanent staff and offer limited to extensive visitor facilities and services (e.g., guiding services, visitor centers, lodges, bathroom facilities and reinforced trails). They range in size from 1,036 to 71,212 hectares, providing protection for a variety of ecosystems and topographic features including lowland and upland tropical rainforests, volcanic craters, and coral reefs. Annual visitation ranges from 3,000 visitors, at the Community Baboon Sanctuary, to 215,930 visitors at Volcan Poas. Visitor activities include sightseeing, hiking, viewing wildlife, exploring archaeological ruins, boat tours, sunbathing, swimming, snorkeling, and diving. Primary attractions include coral reefs, archeological ruins, rainforests, wildlife, and beaches. Both government and non-government organizations (NGOs) are responsible for protected area management (Table 2).

Visitor impacts are identified and compared in this paper between the protected areas selected. If recurrent patterns appear across such diverse protected areas, one may have some confidence in drawing general conclusions. However, the lack of a random sample and larger numbers of cases requires caution in the interpretation of findings.

Manager Interviews

Research methods included interviews to identify the types of visitor impacts considered important by managers and condition assessments to measure trail and site impacts (*see Appendix I*). In August 1998, these methods were applied at study areas during one-to two-day site visits.

Managers and agency representatives were asked about visitor impacts. This information was used to create a list of visitor impacts currently affecting protected areas and identify impacts of particular management concern. Ten semi-structured interviews were conducted with protected area managers and managing agency representatives who were selected from contact lists provided by The Ecotourism Society, Conservation International and The Nature Conservancy. Interview subjects were selected based on their expertise and knowledge about visitor impact management issues for a given protected area. Interviews were pre-arranged when possible and were conducted in English or Spanish, depending on the native language of the interview subject. Interview data were tape recorded and later summarized.

Questions addressed visitor activities and visitation, potential underlying causes of impacts, and constraints to impact management. Interview subjects also identified and described visitor impacts from a prepared list containing 43 items in 8 impact categories: trails, roads, campsites, recreation sites, wildlife, water, litter/fecal matter, and inappropriate visitor behaviors. This listing was included to ensure a comprehensive documentation of visitor impacts.

Trail and Recreation Site Selection

Protected areas selected generally had few trails and recreation sites, with even fewer trails and recreation sites experiencing significant visitor use. Therefore, we purposively selected and assessed the most heavily visited trails and/or recreation sites within each protected area, based on input from protected area staff. The rationale for purposive sampling was to maintain consistency between protected areas, and ensure that at least minimal visitor use was occurring on the trails and recreation sites sampled so that visitor-related impacts could be observed.

The exclusion of lesser-used facilities obviously biases the findings towards greater impact. However, we wanted to ensure that recreation sites measured were receiving at least some amount of visitor use. We assessed two of the four picnic areas at Manuel Antonio, one of the two plazas at Altun Ha, and one of the two volcanic crater viewing areas at Volcan Poas.

Trails selected are also likely representative of trail systems supporting visitor use since the remaining unselected trails were under construction or were not yet open for public use, were used as travel routes only for local residents, or experienced only minimal visitor use. A single trail was surveyed at protected areas with less than three trails (Volcan Poas, the Community Baboon Sanctuary and Braulio Carrillo), and two trails were surveyed at protected areas with up to eight trails (Monteverde and Manuel Antonio). A total of 5.9 km of trails were measured, ranging from 0.5 km to 1.7 km.

Condition Assessment Methods

Multiple procedures for assessing conditions on trails and recreation sites were developed to generate a variety of different types of impact information. The need for objective and efficient standardized methods suitable for use in monitoring programs guided the development of specific procedures employed in this study. Assessment techniques were selected to maximize accuracy, precision, sensitivity, and to be cost efficient (Cole 1989).

Trail Assessment Procedures

We used multiple trail assessment methods to: (1) characterize overall trail conditions, (2) determine the frequency and extent of selected tread problems, and (3) document trail design and maintenance features. These methods included condition class ratings, point sampling, and problem assessments.

Condition class ratings (Table 3) were assigned to each trail to characterize overall condition of the entire trail based on a visual estimate. These ratings were adapted from campsite condition class systems described by Frissell (1978) and Marion (1991). Whole integer values (e.g., 2) and midpoint values (e.g., 2.5) were used to assign categories. Condition class systems are moderate to highly accurate and precise; however, they only offer one piece of information about multiple impacts and they have low sensitivity (response to change) (Cole 1989). We also estimated the total length, assessed the condition class and selected an erosion category (I= infrequent, C= common and S= severe) for trails on Altun Ha's ruin buildings.

A point sampling method was also used to characterize trail conditions and collect quantitative information for selected indicators (Leung and Marion 1999a). Measurements reflecting the condition of trail treads were taken at a systematic sampling interval of 70 meters, based on research indicating that sampling intervals of less than 100 meters are more accurate than larger sampling intervals (Leung and Marion 1999a). Sampling intervals were located by pushing a measuring wheel (122 cm circumference) along each surveyed trail. Measurements were taken along transects oriented perpendicular to the trail at each sample point.

Trail condition indicators included tread width (width of tread that is devoid of vegetation), tread incision (maximum post-construction incision depth of tread surface), visitor-created trails (number of trails created by visitors to cut switchbacks or access attraction features recorded between each sampling point), and a visual estimate of the tread composition (percent bare soil, organic litter, vegetation, gravel, cement/lattice blocks, and wood planking). Trail point sampling can generate high levels of accuracy in determining overall trail conditions, and is a fairly reliable yet somewhat less accurate means of measuring lineal extent of impact problems (Leung and Marion 1999a).

We collected condition class and point sampling data from seven trails in five protected areas. The remaining protected areas either did not have trails or trails were used almost exclusively by local people (Hol Chan Marine Reserve, Tortuguero and Altun Ha). For the purposes of this study we wanted to be able to distinguish visitor impacts from local impacts. Data were gathered from 9 to 28 sampling points per trail, depending on the total trail length (from 549 to 1,767 meters).

Summary statistics were computed for trail incision (an indicator of soil erosion) and trail width. Measures of central tendency (median and mean), standard deviation, minimum and maximum values are reported. Mean values are presented for normally distributed data, based on Shapiro-Wilks tests (rejection value of p=.05).

A problem assessment method also was used to document the total number, location, and lineal extent of trail impact problems (Leung and Marion 1999b). Using a measuring wheel, distances from the trail head to the beginning and end of each occurrence of six trail impact indicators were recorded for occurrences extending at least three meters (to ensure that we would easily observe each one). Trail condition indicators included wet soil (wet, muddy soil or standing water on more than half the tread width), running water on trail (temporary, permanent or seasonal water flowing over the tread), multiple treads (two or more parallel trail treads), excessive width (expansion of tread width two or more meters greater than adjacent sections), excessive erosion (post construction trail incision of more than one meter to capture post construction erosion) and root exposure (tops and sides of many tree roots exposed). Additional information on these trail impact assessment and monitoring methods may be found in Cole (1983), Lemky (1996), Leung and Marion (1996), and Leung et al. (1997).

The accuracy and precision of determining the start and end points for indicators used in the problem assessment method was sometimes difficult, and has been improved in other studies by using detailed descriptive procedures, color photographs, staff training and supervision (Leung and Marion 1999b). For this study, we also periodically examined inter-rater reliability between the two investigators by comparing our starting and ending points, further refining procedures where necessary.

We compared resource conditions for five of the same trails included in the point sampling. Problem assessment data for the remaining two trails (both at Manuel Antonio) were missing.

Recreation Site Assessment Procedures

We used multiple assessment methods to: (1) inventory recreation site features, (2) characterize overall recreation site conditions, and (3) document conditions for selected indicators of recreation site condition. These methods included condition class ratings, categorical ratings, and measurements.

Condition class ratings (Table 3) were assigned to each recreation site to characterize overall condition. A multi-indicator system to assess recreation site conditions was applied to provide more specific documentation of different types of impacts. Categorical ratings and measurements and counts were employed to assess impacts indicators. Categorical ratings can be more accurate and precise than condition class systems (Cole 1982), but also have low sensitivity and do not indicate the magnitude of change occurring within rating levels (Cole 1989). For this study, we typically selected the same condition and rating classes, indicating good inter-rater reliability.

Recreation site boundaries were defined by pronounced changes in vegetation cover, composition, or disturbance, or by artificial boundaries such as fences or buildings. Recreation site size was determined by measuring the dimensions of one or more geometric figures (e.g., squares, circles and triangles) that closely matched site boundaries (Marion 1991).

Inventory and impact indicators were assessed only within recreation site boundaries, with the exception of off-site vegetation cover. One inventory (non-impact) indicator was documented: site surfacing (vegetation, soil, bedrock, and paved/graveled); each surface was visually assessed as a percentage of the entire site. Nine site impact indicators were assessed: vegetation cover on- and off-site (visually estimated in 20% categories), exposed soil (visually estimated in 20% categories), visitor caused tree damage (counts of severely, moderately, and slightly or non-damaged trees with damage defined as axe marks, graffiti or other markings), tree root exposure (counts of trees with severely, moderately, and slightly or non-exposed roots), and litter (percentage of a 15-liter trash bag filled). Measurements generate a substantial amount of management information with moderately high levels of precision and accuracy (Cole 1989).

Vegetation cover loss due to human trampling was estimated by subtracting the mid-point of the on-site coverage class from the mid-point of the off-site class. Relative vegetation loss would have been used if off-site control areas had not been estimated at 80-100% covered by vegetation. Mineral soil was not exposed in off-site areas so the area of exposed soil was calculated as the mid-point of the on-site estimate. Relatively little tree damage was found so the number of severely and moderately damaged trees were combined as the number of damaged trees. Additional information on these recreation site assessment procedures may be found in Cole (1989) and Marion (1991, 1995).

RESULTS

Interview Information about Visitor Impacts

Interview information revealed a variety of trail, recreation site, attraction feature, wildlife, water, and other impacts affecting the case study protected areas. Note that limited interview information was available for Braulio Carrillo and Tortuguero regarding visitor impacts.

Interview subjects indicated that trail and recreation site impacts were important management concerns. The most commonly reported trail impacts were excessive erosion, exposed roots, muddy soil and visitor-created trails. The most prevalent recreation site impacts included exposed soil, vegetation cover loss, and damaged trees. Attraction feature and facility impacts were also identified, such as erosion of Altun Ha’s stone ruin structures, erosion of soil surrounding tiered benches at a volcanic crater viewing area in Volcan Poas, and coral damage at Hol Chan characterized by broken pieces of coral and bleached areas.

Interview subjects also identified wildlife impacts, including feeding/attraction and disturbance, water impacts, including oil and gas pollution and biological contamination, and litter, illegal hunting or fishing, collecting plants or animals, vandalism, and graffiti. For example, a guide at the Community Baboon Sanctuary fed black howler monkeys and induced their calling, tour boat operation contributed to oil and gas pollution at Hol Chan, Tortuguero and Manuel Antonio, and tourists at Volcan Poas had broken off large leaves from umbrella plants for rain protection, killing many of these plants in trail and recreation site areas.

Trail and recreation site condition assessments measured similar impacts reported by study site managers, with the exception of Volcan Poas, where interview information revealed that we might not have captured trail and site impacts due to recent trail and site development and maintenance efforts.

Trail Impacts: Condition Class System and Point Sampling Method

The Las Palmas, Bremudian Landing and Entrance trails were primarily composed of bare soil, litter and vegetation (Table 4). Other trails were shielded by trail surfacing, paving or other construction materials like embedded cement lattice blocks (Labeled "NA", not applicable in Table 4). Bosque Eterno and Rio Chomorgo trails were a mixture of cement lattice blocks, wood planking and gravel, and the tread of Puerto Escondito was largely composed of cement lattice blocks. Rot-resistant wood planking and sawed tree cross-sections were common composition materials for the Crater trail.

The Las Palmas trail received the worst condition class rating of 4.5, experiencing complete loss of vegetation cover and organic litter, with areas of obvious soil erosion and exposed roots.

Trail width varied from fairly narrow (26 cm for Las Palmas) to fairly wide (386 cm for the Entrance trail). Las Palmas, Puerto Escondito and Rio Chomorgo had smaller mean widths, under 100 cm. We also found median incision values larger than zero for the Entrance trail (3.8 cm), Las Palmas (4.5 cm) and the Bremudian Landing trail (5.1 cm).

We also observed trail proliferation. Eleven visitor created trails branched off of the Entrance trail and another four originated from the Puerto Escondito trail at Manuel Antonio. Six trails were found on three of the six Altun Ha structures, ranging from approximately 15 to 30 meters in length. Two trails received condition class ratings of 1, with the other trails rated 2, 3, 3.5 and 4.

Trail Impacts: Problem Assessment Method

Excessive soil erosion, defined as post construction trail incision of more than 15 cm, was most prevalent on the Las Palmas trail, with 25 recorded instances affecting 14% of the trail (Table 5). Root exposure also was common, with 12 occurrences affecting 18% of the trail. In contrast, Bremudian Landing experienced only three instances of excessive erosion, and the remainder of the trails were unaffected. Bosque Eterno had one extremely long segment of exposed roots, extending 69 meters or 13% of the total trail length. Multiple trails, defined as two or more parallel trail treads, occurred in only two of the protected areas, including eight meters of Las Palmas and 12 meters of Bremudian Landing. Muddy soil was recorded at nine locations on Las Palmas, for a total lineal extent of 40 meters. No instances of multiple trails or muddy soil were recorded for the other trails. Ten excessively wide segments (> 1 m) were measured at Bosque Eterno, affecting 24% of the total trail length. In contrast, only two occurrences of excessively wide segments resulted at Rio Chomorgo and Bremudian Landing. One instance of running water on trails was documented on the Bremudian Landing trail, covering four meters.

Factors Influencing Trail Impacts

Trail impacts appear to be influenced by trail location, construction/design and maintenance factors. Trails at Braulio Carrillo and the Community Baboon Sanctuary and the entrance trail at Manuel Antonio were composed of bare soil, vegetation and litter, had segments in wetter, less resistant areas, and lacked design and maintenance features capable of reinforcing trails or shielding them from impact. These trails experienced erosion, exposed roots, muddy soil, multiple trails and running water on trails. Conversely, the Puerto Escondito trail at Manuel Antonio and Volcan Poas trails were composed of gravel, cement and wood, and had a variety of maintenance features, effectively minimizing these trail impacts.

However, trail construction activities also result in ecological impacts including vegetation cover loss and soil removal, among others. For example, construction activities to accommodate higher volumes of visitors at Monteverde and Manuel Antonio have created larger trail widths (Ricky 1998; Salizar 1998). After the initial changes related to construction have occurred, constructed and maintained trails may be more durable in the long term, more effective in concentrating use, accommodating large numbers of visitors, and minimizing other ecological impacts like trail incision and trail proliferation (Hammitt and Cole 1998).

Visitor-created trails at Altun Ha and Manuel Antonio may have resulted from inappropriate tourist and guide behaviors. At Altun Ha, visitors and guides access ruin buildings without looking for stairs or other passages designated for such purposes (Wallace 1998). At Manuel Antonio, visitors had been walking off of trails to access the beach. The installation of rope borders along trails has begun to successfully minimize trail proliferation and trail widening, though informal trails were still visible at the time of impact assessment.

Recreation Site Impacts

Four recreation sites were surveyed in three protected areas using condition class and multi-indicator impact assessment systems. The condition class system assigns categorical ratings based on soil, vegetation and organic litter conditions (Table 3). The Manuel Antonio picnic sites received a condition class rating of 4, defined as nearly complete or total loss of vegetation cover and organic litter, with widespread bare soil (Table 6). In contrast, the vegetated ruin plaza in Altun Ha was rated a 1, where only a slight loss of vegetation cover and/or minimal disturbance of organic litter occurred. A condition class rating could not be applied to the crater viewing site at Volcan Poas due to the extensive use of gravel to harden the natural substrate.

Recreation site size ranged from Manuel Antonio's relatively small picnic areas (717 m^2 and 812 m^2) to Altun Ha's extremely large grassy plaza (283 ha)(Table 6). The picnic areas at Manuel Antonio experienced the most vegetation cover loss (91%) and the most exposed soil (71%). Conversely, only 10% vegetation cover loss and exposed soil occurred at Altun Ha's ruin plaza. Evidence of soil disturbance and compaction, and three damaged trees also were recorded for the Manual Antonio sites.

Factors Influencing Recreation Site Impacts

Environmental factors (resource resistance and resilience) and the design and maintenance of recreation sites contributed to impacts. Visitor traffic at Altun Ha occurs in a grassy plaza, which is highly resistant to vegetation loss and exposed soil. Conversely, we found extensive vegetation cover loss and exposed soil at the picnic areas at Manuel Antonio, which were located in less resistant areas. The Volcan Poas crater viewing area was fenced in and had a viewing deck, effectively concentrating use and preventing additional site area increases.

DISCUSSION

A variety of visitor-related trail, recreation site, wildlife, water resource and other impacts affecting natural resources were identified in eight protected areas in Belize and Costa Rica. Trail and recreation site impacts, in particular, represented important management concerns according to interview subjects. Several trail impacts were assessed, including trail proliferation, erosion, widening, muddiness, exposed roots, and running water on trails. Similarly, a variety of recreation site impacts were observed, including vegetation cover loss, mineral soil exposure, exposed roots, damaged trees and litter.

Rapid impact assessment procedures were developed and applied at case study areas to demonstrate a diversity of trail and recreation site impact information, and to compare their potential utility.

Impact Information and Utility of Rapid Assessment Procedures

The value of obtaining visitor impact data is that it represents a quantifiable means of comparing the type and severity of different kinds of impacts, and can be used to monitor changes in those impacts over time. Impact data can also provide managers with a means of justifying their decisions. Rapid assessment procedures provide managers with a cost-effective and feasible means of obtaining visitor impact data which can then be used by managers to determine the effectiveness of management actions, direct maintenance efforts to repair specific problems, and can supply information useful for visitor impact decision-making.

Condition class and rating systems were the most simple and quick to apply, generating basic information about a variety of soil and vegetation impacts. Multi-indicator systems, trail point sampling and problem assessment generated more detailed quantitative information about specific impacts, but required more sophisticated knowledge and measurement techniques, in addition to certain equipment like a measuring tape and measuring wheel. For example, the geometric figure method required selection of the most appropriate shape(s) and determination of which aspects needed to be measured and recorded for site area calculations.

Protected areas such as Monteverde, Manuel Antonio and Volcan Poas are heavily visited, with large budgets and staff, and are able to support visitor facility maintenance and employ a variety of trained personnel. Such protected areas are more likely able to prevent certain impacts and develop and implement more complex visitor impact assessment and monitoring programs. Monteverde, in particular, has been able to invest in facility development and maintenance because tourism is self-sustaining, generating revenue to pay for visitor impact management efforts (Ricky 1998).

Conversely, other protected areas, such as the Baboon Sanctuary and Braulio Carrillo, have minimal visitation, less funding, and fewer staff, which may constrain their ability to apply some of the more intensive impact assessment and monitoring programs.

However, our experience training protected area staff in North, Central and South America has indicated that detailed procedural manuals, along with a few days of staff training in the field helps to further refine impact definitions and assessment procedures, greatly reducing potential errors. Impact assessment and monitoring training workshops for Latin American protected area managers have been provided by the National Outdoor Leadership School, Colorado State University, and the Mountain Institute, to name a few. Once staff are trained, most procedures require little time to apply and can be incorporated into existing maintenance or other staff duties.

All of the rapid assessment procedures are potentially useful for protected area managers, depending on the type of information desired and management constraints. For example, managers desiring basic information to characterize vegetation and soil conditions with limited budgets and staff may select condition class and rating systems. However, impact categories may not accurately characterize the extent of change or be sensitive to small changes over time. Therefore, these procedures may be less useful for long-term monitoring though they are useful for comparing areas at one time. Additionally, we found that condition classes and ratings were not applicable for trails or recreation sites that had been surfaced with artificial materials like gravel, limiting their use in more developed areas.

Managers with sufficient funding and staffing may wish to consider multi-indicator systems, trail point sampling, and/or problem assessment. These procedures can address a wide variety of impacts on most trails and recreation sites, and permit quantitative summaries and statistical analyses to determine the extent and magnitude of impacts. For example, in this study, trail point sampling permitted basic comparison of the average and range of trail width and incision on multiple trails. Similarly, trail problem assessment procedures identified the number of impact occurrences, as well as the total lineal impact distance and percent of trail affected for multiple impacts. Case study managers could use this information to determine the total extent of trails affected by specific impacts and direct trail maintenance crews to repair specific problem spots.

One of the drawbacks of these procedures is their complexity and the requirement for a certain degree of technical knowledge, increasing the likelihood of measurement error. Additionally, managers must also consider measurement validity and reliability. For example, condition class and ratings are fairly precise in determining overall resource conditions, which is a desirable monitoring attribute (Cole 1989). Conversely, trail point sampling can achieve higher accuracy but is more time consuming and requires greater staff knowledge and expertise to apply.

Managers must first determine why they want to assess visitor impacts, set assessment or monitoring objectives, define impacts of particular importance, and then review the various positive and negative attributes of alternative rapid assessment procedures to determine which procedures are most appropriate. Managers may also want to quantify and characterize other resource impacts beyond those related to trails and sites.

Rapid Assessment Procedures for Impacts to Wildlife, Water, Attraction Features and Other Resources

Desirable attributes of rapid assessment procedures include cost effectiveness, ease of application, accuracy and precision, and ability to provide information that is useful for managers. For example, staff at Hol Chan sampled snorkellers and divers from larger groups and recorded the number of times individuals kicked coral and handled marine organisms to measure coral reef impact (Alamilla 1998). This method is easy to apply, relatively inexpensive, and identifies a likely contributor to impact, i.e., visitor behavior, which is useful information for managers.

Wildlife, water resource, attraction feature and other impacts were identified by protected area managers as other issues of concern, indicating that condition assessment procedures are needed to assess these impacts. However, developing such procedures for some impacts is difficult. First, the relationships between visitor activities and wildlife responses are complex, requiring more in-depth studies beyond rapid assessment. Research is first needed at each protected area to better understand species' life history characteristics, their responses to various forms of human contact and impacts, and whether or not individuals or populations are affected.

Second, water pollution and littering cannot be easily linked to visitor activities because it is hard to locate point sources. For example, local infrastructure development and the construction and operation of supporting tourism services has increased biological water pollution within Manuel Antonio, the effects of which cannot be easily separated from pollution related to visitor activities (Salizar 1998). Similarly, litter may be contributed by local residents or visitors and is easily transported by wind or water either into or outside of protected area boundaries.

CONCLUSION

This study characterized visitor impacts occurring in selected protected areas using data from interviews and trail and recreation site condition assessments, and applied and compared alternative rapid assessment procedures to illustrate their utility to managers.

Study findings are limited in their generalizability beyond case study sites since protected areas, trails and sites were not randomly sampled. However, the protected areas selected for this study represented a wide range of attributes and characteristics, reflecting a larger diversity of protected areas in these two countries. Additionally, trails and recreation sites were selected to reflect natural resource conditions most directly related to visitor use, to avoid confounding results from local use and to ensure that we measured areas where intensive visitor use was occurring. The primary intent of this study was to characterize and describe impacts and consider some of their potential underlying causes, with less emphasis on determining their severity and magnitude.

The most important findings of this study are that 1) trail and recreation site impacts are particularly important concerns for managers of case study areas; 2) a variety of visitor use-related resource impacts are occurring that can be easily documented with rapid assessment procedures; and 3) alternative rapid assessment procedures with high management utility exist for use in assessing and monitoring visitor impacts.

This study also discovered a relatively new and potentially important area of research interest: attraction feature degradation, and identified the need for developing rapid assessment procedures to measure impacts on wildlife, water resources and attraction features.

CHAPTER III. TRAIL IMPACTS AND TRAIL IMPACT MANAGEMENT RELATED TO ECOTOURISM VISITATION AT TORRES DEL PAINE NATIONAL PARK, CHILE

ABSTRACT

Ecotourism and protected area visitation in Central and South America is largely dependent upon a relatively undisturbed quality of natural resources. However, visitation may impact vegetation, soil, water and wildlife resources, and degrade visitor facilities such as recreation sites and trails. Trail impacts are particularly significant management concerns because trails may receive intensive visitor use within protected areas and because they support a variety of popular ecotourism activities such as hiking and wildlife viewing.

This paper reports findings from trail impact research conducted at a remote yet popular protected area well-known for a variety of ecotourism activities: Torres del Paine National Park in Patagonia, Chile. Park managers had been debating whether or not to reduce visitation in response to trail impacts. Study objectives included assessing the frequency and magnitude of selected trail impacts and determining the relative effect of the amount of use, vegetation type, trail position and trail grade. A point sampling approach was used to measure selected impacts for nine trail segments stratified by three levels of use. Standardized monitoring procedures were employed to obtain quantifiable measures of vegetation and soil disturbance.

Most previous recreation ecology studies have found that once a trail is developed, amount of use does not substantially influence most trail impacts. Our findings differed from these previous studies, in that amount of use was significantly related to both trail width increases and trail incision. However, findings also indicated that vegetation type (at one use level) contributed to the number of informal trails, and that trail grade also influenced trail incision. A variety of management strategies are recommended to minimize trail impacts and replacements for some of the predictor variables for future monitoring studies are suggested. Multicollinearity among predictor variables somewhat confounded our interpretation of results, limiting the applicability of findings for other protected areas.

INTRODUCTION

Ecotourism and protected area visitation are likely to continue to increase in developing countries, due to a growing global environmental awareness and improved transportation and access (World Tourism Organization 1991). The Ecotourism Society defines ecotourism as environmentally sensitive travel that promotes the welfare of local people and does not degrade natural resources (Lindberg et al. 1998). The ecotourism setting generally includes natural areas with special biological, ecological or cultural significance, some of which are formally designated as protected areas (Furze et al. 1996).

Ecotourism and protected areas often are promoted by developing country governments to attract international visitation and associated revenues while avoiding environmental degradation from resource extraction industries. However, protected area visitation can cause soil erosion along trails, campsite proliferation, vegetation damage, wildlife disturbance and water pollution (Marion and Farrell 1998).

Trail impacts are particularly important because trail-related recreation activities such as hiking and wildlife viewing are popular ecotourism activities, and because trails receive some of the most intensive visitor use within protected areas (Backman and Potts 1993; Wight 1996). Trails provide access to protected area attractions and facilities, facilitate recreation opportunities, and protect natural resources by concentrating visitor use (Leung and Marion 1996). Trail deterioration is a concern for protected area managers because trails may become difficult or unsafe, aesthetic aspects of protected areas may be diminished, and because substantial funding or staffing may be required to repair or maintain trails (Cole 1987).

Visitor impacts in Central and South America have been largely addressed through carrying capacity approaches, where visitor numbers are limited (Giongo et al. 1994). However, reducing the amount of use may not be a highly effective or desirable management strategy for managing trail impacts. First, use reduction only addresses one potential factor contributing to trail impacts, when other factors such as trail location and design may be of equal or greater importance (Cole 1983). For example, trails may lack design, construction or maintenance features that can prevent or mitigate many trail impacts. Second, because research has shown that the majority of impact occurs with trail development and low use levels, reducing the effectiveness of use limitation as a management tool (Hammitt and Cole 1998). Third, even if we use limits were effective, they are difficult to implement for practical reasons and because visitors tend to dislike regulatory approaches (Lucas 1990). Limiting the amount of use can, however, reduce cumulative impacts such as trail erosion, particularly in the absence of good trail design and maintenance. Managers need to understand the relative importance of multiple factors that contribute to trail impacts to effectively minimize these impacts.

This research was conducted to identify trail impacts and examine the relative influence of use, environmental and managerial factors at Torres del Paine National Park, in Patagonia, Chile. The factors investigated included the amount of use, vegetation type, trail position and trail grade. Trail impacts studied included the number of informal trails, the number of secondary trails, trail width, and two measures of trail incision. Torres del Paine was selected for the study because current levels of trail impacts are perceived by park managers as unacceptable. The park's management plan indicates that protecting natural resources is a higher priority then providing recreation opportunities (CONAF 1996). Additionally, the park' most favored solution to address trail impacts is to reduce use.

The findings from this research are useful for other protected area managers in Central and South America who are concerned about trail impacts, are interested in learning more about the factors that influence trail impacts, are exploring developing trail impact monitoring programs, or are interested in learning more about potential strategies used to minimize trail impacts.

Trail Impacts

Common trail impacts include soil erosion, trail wetness or muddiness, development of multiple trails, informal trail creation, vegetation cover loss or composition change, soil compaction and trail widening (Cole 1987; Hall and Kuss 1989; Cole and Twill 1992; Leung and Marion 1996). Monitoring surveys have documented these impacts and how they change over time. For example, trampling of herbaceous vegetation in the Andes of central Chile resulted in soil compaction and a decrease in the number and density of plant species (Hoffman and Alliende 1982). In another case, overall path width, extent of bare ground and number of secondary trails increased between two measurement periods in the Mourne Mountains in Ireland (Ferris et al. 1993).

Additionally, wildlife impacts related to trail use, proliferation or degradation may occur. For example, off-road vehicle use in the Maasai Mara Reserve in Kenya caused trail proliferation, and affected the feeding time and movement patterns of lions and Cheetahs (Gakahu 1992).

Factors Contributing to Trail Impacts

Trail impacts may be caused or influenced by use, environmental or managerial factors. Understanding how these factors contribute to trail impacts permits selection of the most effective impact management strategies and actions.

Use-Related Factors

Use-related factors include the amount of use, use distribution, type of use and user behavior (Cole and Spildie 1998; Hammitt and Cole 1998). Of these factors, protected area managers often focus on limiting use to control resource degradation. However, reducing use is most effective if there is a strong and linear relationship between trail impacts and amount of use.

In fact, research has usually questioned the effectiveness of use limits. For example, studies have shown that vegetation cover loss and species composition, bulk density, penetration resistance and trail width are curvilinearly related to the amount of use, indicating that the amount of use most strongly affects certain trail impacts at initial and low levels of use (Bayfield and Lloyd 1973; Dale and Weaver 1974; Cole 1987; Boucher et al. 1991). In this case, use levels would need to be kept extremely low to effectively minimize impact. Such levels would be difficult and perhaps undesirable from the perspective of protected area managers and visitors. Additionally, further increases in use cause minimal additional change, invalidating the utility of reducing use at higher levels. Finally, other studies have found that trail erosion and frequency of problems like trail muddiness are typically unrelated to amount of use (Dale and Weaver 1974; Cole 1983).

Environmental Factors

Environmental factors include vegetation type, soil type, topographic characteristics, ecosystem characteristics, and phenological state (Hammitt and Cole 1998). Resistance is the ability of an area to withstand visitor use without being altered or otherwise disturbed. Resilience is the ability of an area to recover from alterations once they occur. Environmental factors are most effectively addressed by controlling the location and use of trails to promote visitation in resistant and appropriate locations, and preventing visitation in more sensitive areas (Marion 1996).

Vegetation and soil types differ significantly in their resistance to trail impacts or their ability to recover from trail impacts (resilience)(Cole 1987; Cole 1988; Hammitt and Cole 1998). For example, vegetation species that are highly resistant to impact, such as certain grassland vegetation types, may prevent trail proliferation and other impacts like increases in trail width. Conversely, other vegetation species are less resistant to impact, and trails located in them widen or erode quickly (Lance et al. 1991). Some vegetation species also have low resilience, indicating that once trail impacts occur, they may require lengthy recovery periods (Cole 1987). Short growing seasons at higher elevations also lengthen recovery periods.

Soil characteristics affecting impact susceptibility include organic matter content, moisture levels, particle sizes and vegetation and litter cover (Kuss et al. 1990). Generally, soils composed of equal amounts of sand, silt and clay, like loam and silt loam soils, have the best balance of water availability, drainage and aeration, increasing soil resistance to impact (Hammitt and Cole 1998).

Managers can minimize resource impacts by locating trails in more resistant or resilient environments and by avoiding fragile areas (Marion 1996). For example, a study of trail impacts in Kibale National Park Uganda concluded that erosion was highly correlated with slope and vegetation type (Obua and Harding 1997).

Managerial Factors

Managerial factors that affect trail conditions include visitor and site management techniques. The curvilinear use-impact relationship indicates that limiting the amount of use will not effectively minimize most trail impacts. Additionally, dispersing use to previously unaffected areas is ineffective unless visitation can be kept at extremely low levels. Area closures also are only appropriate to protect sensitive or rare species or to relocate use to more resistant areas (Cole 1987; Marion 1996). Furthermore, these actions restrict visitor freedom and may be difficult to implement due to open access issues. Visitor education, such as promoting low impact hiking practices (e.g., Leave no Trace), offer non-regulatory alternatives (see www.lnt.org). The effectiveness of regulatory and education strategies is higher for those impacts related to specific visitor behaviors (e.g., walking off of trails), compared to impacts caused by poor trail location and design.

A variety of trail impacts, such as trail widening and incision, can be managed through trail construction and maintenance to promote trail drainage and harden treads to withstand trampling. For example, a study at Kilimanjaro National Park in Africa recommended that park staff install water diversion features along the trail to minimize trail erosion (Newmark and Nguye 1991). Studies have indicated that trail location, design and maintenance as well as climatic factors such as wind and rainfall intensity are the most important determinants of certain trail impacts like trail erosion (Helgath 1975; Cole 1983; Cole et al. 1987).

METHODS

Study Area

Torres del Paine National Park is located in the Provincia de Ultima Esperanza (Province of Lost Hope), in the Magellan and Antarctic region of southern Chile (50^{o} 45’S, 2^{o} 31’W), which is part of the territory commonly known as Patagonia. The park was founded in 1959 and encompasses 2,422 square kilometers of granite masstifs, some of which exceed 3,000 meters, glaciers and alpine lakes (CONAF 1996). Torres del Paine is managed by the Corperacion Nacional Forestal (National Forestry Corporation) and was designated a UNESCO World Heritage Site in 1978.

The park is surrounded by a large continental ice sheet on its southern border and a windy steppe region on its northern border. The torres (towers) are a combination of pink granite and black shale, which have been carved through glacial action and subsequent water and wind erosion (Lindenmayer 1992). Recreational uses includes climbing, backpacking, hiking, horseback riding, packstock use, motorized and non-motorized boating, fishing, wildlife viewing, and some all terrain vehicle use (Leitch 1990).

The park climatic zone is classified as temperate with highly localized and unpredictable weather conditions (Lindenmayer 1992). Average annual precipitation ranges from 200 to 400 mm, with the rainiest month of March receiving as much as 190 mm. Temperatures average from $-2.5^{o}C$ in the winter to $16^{o}C$ in the summer. Winds often are also strong, with gusts of up to 100 km per hour. General vegetation categories include grassland *(e.g., Mattoral mesofito pre-andino),* forest *(e.g., Bosque magallanico deciduo),* desert *(e.g., Matorral xerofito pre-andino)* and steppe *(e.g., Estepa patagonica)*. Non-vegetated *(e.g., glacial moraine)* areas were also recorded. Unique wildlife found at the park includes guanacos *(Lama guanicoe)* and Darwin's rheas *(Pterocnemia pennata*)(CONAF 1996).

Visitation in 1996 was 50,392 and has been steadily increasing by 16.6% each year for the last ten years (*unpublished data* TDP 1997). Historically, the majority of the visitors were foreigners; however, Chileans now represent nearly one-half of the total visitation. Visitation occurs only in the summer months when the park is open, from November until August (CONAF 1996). Primary access to the park is by paved and graveled roads travelling 150 kilometers from Puerto Natales and 400 kilometers from Punta Arenas. Limited boat and biplane access also occurs (CONAF 1996).

The park infrastructure includes a combination of graveled and dirt roads, trails created by traditional land uses that predate the park, designated no-fee camping areas, pay campgrounds, lodges, restaurants, staff housing, a visitor center, and two entrance stations. A European model hut or "refugio" system also accommodates backcountry visitors. Private concessionaires operate the refugios, lodges, restaurants, pay campgrounds, and offer horseback riding, llama packing, guiding and transportation services.

The 86-km circuit trail is the most popular trail in the park, with approximately 40 kilometers of additional trails available to access peaks, valleys, lakes, and more remote backcountry areas (Lindenmayer 1992). Trail use statistics for 1996 indicated that approximately 18,000 people hiked in the park, with 3,862 hiking the entire circuit trail, and the remainder hiking on one or more segments of the circuit and three connecting trails.

Study Objectives

The first objective of this study was to characterize the frequency and magnitude of trail impacts in Torres del Paine. The second study objective was to assess the relative effect on trail impacts of the amount of trail use, compared to vegetation type, trail position and trail grade.

A monitoring manual was developed to standardize procedures for conducting a comprehensive inventory and assessment of resource conditions on trails (*Appendix II*). The focus of these procedures was on obtaining quantifiable measures of vegetation and soil disturbance. Data were gathered by the primary author of this paper and field staff with assistance and logistical support from park staff. Data collection took place from mid-December, 1996 to mid-January, 1997.

Sampling

Stratified random sampling was used to select three 3.5-kilometer trail segments for each of three trail use categories; low use (<500 visitors per year), medium use (501-1,000 visitors per year) and high use (>1,000 visitors per year). Three Park staff and a National Outdoor Leadership School (NOLS) instructor familiar with the park assigned the use levels to each trail segment based on available trail use statistics and personal experience. Three general use categories were developed to account for missing trail use data.

Eleven trail segments were identified by park staff (Table 7), which were divided into 40 3.5-kilometer segments, each of which was randomly assigned a number within the appropriate use category. Random sampling was used to select nine trail segments, in order to accurately represent trail conditions, represent the diversity of environmental characteristics such as vegetation types, and provide a basis for comparison with future trail monitoring efforts.

A total of 31.5 kilometers of trail was sampled, encompassing one-quarter of the park's 127 kilometer trail system (Table 7). Segment lengths of 3.5 kilometers were chosen to permit inclusion of shorter trail segments into the sampling frame and to generate at least ten to thirteen sampling points per trail segment. Additionally, segments of this length often connected camping areas which were concurrently measured as another component of visitor impact monitoring at Torres del Paine.

A point sampling method was used to gather quantitative data for several inventory and impact indicators. Point sampling is a fairly accurate method for assessing the frequency of trail impact problems and overall trail conditions (Leung and Marion 1999a). However, the point sampling method is less accurate in characterizing the lineal extent of impact problems and other trail features.

A measuring wheel (122 cm circumference) was pushed along each of the nine trail segments. Measurements were taken at a systematic sampling interval of 300 meters. Sampling distances in other studies have ranged from 50-500 meters (Cole 1983; Lemky 1996; Leung and Marion 1999a). An average of eleven data points were generated per trail segment. At each sampling point a transect was established perpendicular to the trail tread to assess a series of inventory and impact indicators. The number of informal trails leaving the survey trail was counted and recorded between sampling points.

Trail Condition Assessment

We recorded use type (hiking, horseback riding or off-road vehicle use), use amount (low, medium or high), both assessed according to staff input and available trail use statistics, vegetation type (grassland, forest, steppe, desert) or non-vegetated, trail position (valley bottom or midslope), and trail grade (0-5^{o}, 6-10^{o}, 11-15^{o} and >15^{o}). Trail grade was assigned a category rather than recording actual values to reduce measurement error and increase precision, which is essential for monitoring purposes (Marion 1991).

Trail substrate characteristics (percent soil, litter, vegetation, rock, muddy soil, standing or running water, exposed roots, running water, gravel, wood or other material across the trail transect) were also recorded to characterize trail tread substrates and conditions. Estimates of percentages for each characteristic were recorded to the nearest 5%.

Trail impact indicators included number of informal trails (a count of user-created trails created to access attraction features or cut switchbacks), number of secondary trails (a count of user-created treads parallel to the main tread), trail width (width in centimeters of trail tread surfaces that accommodate the majority of traffic and differ in substrate composition from trailside areas), maximum incision relative to the current trail tread (depth in centimeters of the deepest erosion from the current tread's substrate surface), and maximum incision relative to the estimated post trail creation surface (maximum depth in centimeters of compacted or eroded soil from the tread surface immediately following trail creation).

The difference between maximum incision from the current trail (MIC) and maximum incision from the post trail creation surface (MIP) is distinguished in Figure 1. According to park staff, trails at Torres del Paine were created for traditional land use purposes and survey work revealed that sidehill construction designs (Figure 1 d-f) were rarely used.

Analysis

Descriptive statistics (means, standard deviations and ranges) are presented for trail substrate characteristics, number of informal trails, trail width, MIC and MIP by level of use. Secondary trails are excluded because almost all data values were zero, resulting in skewness. The best measure of central tendency is reported based on Shaprio-Wilks normality tests (rejection value of $p = .05$). Minimum and maximum values also are presented, along with 95% percentiles (the value below which 95% of the observations fall) for trail substrate types since data were skewed due to multiple zero values.

Statistical tests are conducted to compare impact indicators among use levels, and between use level and vegetation type, use level and trail position, and use level and trail grade. Analyses compare group means and include the independent samples T-Test, one-way analysis of variance (ANOVA) and two-way ANOVAs, with a post-hoc comparison test for one-way ANOVAs for amount of use and trail incision (Tukey's Honestly Significant Difference or HSD test).

Regression analysis was used to examine univariate and multivariate normality assumptions required by ANOVA and two-way ANOVA tests, by regressing observed data on the residuals for amount of use, trail grade, vegetation type and trail position, and testing each response variable (trail width, informal trails, MIC and MIP) separately. Additionally, the spread versus level plots of residuals were examined to detect relationships between the mean level and variance of residuals. Frequency distributions supported regression results of a lack of normality for informal trails and trail width. Natural log transformations were used to achieve normality for these two variables since the spread level plot of residuals indicated a significant positive relationship between mean and variance values.

Dummy variables for level of use, vegetation type, trail position and trail grade were used for a second regression analysis to examine multicollinearity, or a lack of independence among trail inventory indicators (predictor variables). Multicollinearity indicates that either two or more predictor variables are correlated, or that much of the variance for one predictor variable can be explained by other predictor variables (Hayes 1994). Multicollinearity diagnostics include variance inflation factors (VIF), tolerance and eigenvalues. One or more VIFs larger than 1 indicates multicollinearity. Tolerance is the proportion of a variable's variance not accounted for by other independent variables in the equation. A variable with very low tolerance is close to zero with high tolerance variables close to 1. One or more small eigenvalues indicates that near linear dependencies exist between predictor variables, as indicated by the equation $k = \lambda^{max/}\lambda^{min}$, where k >100 is moderate multicollinearity (Montgomery and Peck 1992). SPSS for Windows (8.0) was used for data input and analysis.

RESULTS

Trail Substrate Condition Characteristics

Trails were composed primarily of exposed soil (Table 8). Trails also lacked exposed roots, standing water, running water, and human placed materials such as gravel, steps or water bars (classified as "other").

Medium and high use trails differed somewhat from low use trails in their percentages of rock and vegetation: they were more likely to have some rock, while no rock was present on low use trails (Table 8). Conversely, low use trails frequently had small amounts of vegetation, though no vegetation was found on medium or high use trails. Medium and high use trails also tended to be located in more mountainous terrain, possibly explaining these differences in amount of rock.

An average of 4 to 6 informal trails occurred between sampling points (Table 9). Trail width was relatively narrow, with mean values of 44 cm for low use trails, 54 cm for medium use trails, and 67 cm for high use trails. Average MIC was minimal, but maximum values of 10 cm were recorded for some sampling points. MIP was substantially higher, with mean values of 8 cm for low use trails, 11 cm for medium use trails, and 15 cm for high use trails.

Relational Analyses

Relational analyses were conducted to assess the influence of use-related (amount of use), environmental (vegetation type) and managerial (trail position and grade) factors on the responses of impact indicators. However, multicollinearity diagnostics revealed a relationship between vegetation type and trail position, and between trail grade and trail use. VIF and tolerance values were approximately 1; however, eigenvalue ratios were over 200, indicating moderate multicollinearity, which confounds interpretation of relational analyses.

Implications of Multicollinearity

The implications of multicollinearity are that the effects of use may not be independent from vegetation type, trail position and trail grade. Trail characteristics appear to demonstrate some patterns of association between inventory indicator variables. The majority of high use trails are located in steeper areas because the towers and other mountainous scenic vistas and features represent the park’s primary sources of attraction. Similarly, trails in lowland valley areas do not experience substantial elevation changes, and/or are located in areas off of the circuit trail or along less visited, remote portions of the circuit trail. These lowland valley areas also tend to support grassland vegetation, rather than forests. Therefore, we would expect to find the majority of low use trails in flatter, grassland valley areas and the majority of high use trails in steeper, forested midslope areas regardless of sampling design.

Because of these associations between inventory indicators, multicollinearity may indicate that information from any one or more indicators is equally useful in predicting trail impacts. Future monitoring efforts should therefore include additional low use segments in mountainous terrain and at midslope positions, as well as high use segments in flatter valley areas, to account for potential sampling problems and biases.

Thus we must be careful in our interpretation of the independent effects of trail use compared to vegetation type, trail position or trail grade in predicting a given trail impact.

Amount of Use

One-way ANOVAs revealed that trail width, MIC and MIP differed significantly by use level (p values = .000, .008 and .002, respectively), while the number of informal trails did not differ (p value = .189)(Table 10). The Tukey's (HSD) tests revealed significant differences between low use trails and medium/high use trails for trail width and MIC and between low/medium use trails and high use trails for MIP.

Vegetation Type

The majority of vegetation types represented along surveyed trails were forest (73% of the sample points) and grassland (12% of the sample points), and the remaining vegetation types were not adequately represented for the purposes of statistical analysis. Additionally, 11 of the 12 cases for the grassland vegetation type occurred on medium use trails. Therefore, only the medium use data are used to compare vegetation type effects between forest and grassland areas (N = 29).

Independent samples T-Tests indicate that only the number of informal trails differ significantly by vegetation type (two-sided p value = .000)(Table 11). An average of 10 informal trails were found in grassland areas compared to only 3 in forested areas.

Trail Position

Trails were located in both midslope (N = 44) and valley (N = 53) positions. However, only 4 cases of low use trails in the midslope position were recorded.

Two-way ANOVAs revealed that only the interaction between informal trails and use varied significantly with trail position (interaction p value = .000), whereas trail position (p value=.452), trail use (p value = .251), width (p value = .627), MIC (p value = .835) and MIP (p value = .477) did not differ significantly (Table 12). After controlling for trail position, use level remained significant for MIP (p value = .022), but not for any of the other variables. Two-way ANOVA results were likely confounded due to the small number of low use trails in midslope areas, and the large number of high use trails in midslope areas. Post hoc comparisons were not available for two groups and were not necessary since midslope and valley positions only differed in the interaction between trail position and use.

Trail Grade

The most common trail grade category for surveyed trails was 0-5^{o} (44% of sample points), followed by 6-10^{o} (22% of sample points), >15^{o} (21% of sample points), and 11-15^{o}

(13% of sample points). Sample points were sufficiently distributed across use levels to permit two-way ANOVAs.

Two-way ANOVAs indicated that trail width (model p value = .011), MIC (model p value = .006) and MIP (model p value = .001) differed significantly with use level and/or trail grade whereas informal trails (model p value = .546) did not (Table 13). The interaction between trail grade and amount of use was not significant for any of the impact indicators. The amount of use alone (p value = 0.01) contributed to the model effect for trail width. On the other hand, trail grade (p value = .032) was the only factor influencing MIC. Both trail grade (p value = .000) and the amount of use (p value = .028) contributed significantly to MIP.

One-way ANOVA and The Tukey's (HSD) test supported the effect of trail grade on MIC and MIP. Trail erosion was greatest on the steepest trails, with significant differences between the lowest and highest trail grade categories for both variables (p values = .004 and .000, respectively). Additionally, the 6-10^{o} and <15^{o} categories varied significantly for MIP (p value = .036).

DISCUSSION

Trail impacts assessed at Torres del Paine included informal trails, trail width increases and trail erosion, which have been measured in numerous other studies (Bratton et al. 1979; Bayfield et al. 1988; Cole 1991; 1996, among others). We did not find many instances of secondary trails, and did not measure other trail impacts which have been documented in other studies such as soil compaction, soil muddiness, introduction of exotic vegetation species, or vegetation cover decreases or species composition changes (Boucher et al. 1991; Marion 1994; Adkison and Jackson 1996).

Trail impacts may be related to a variety of factors, including amount and type of use, vegetation and soil characteristics, climatic factors like precipitation and wind, and management actions like trail maintenance programs (Leung and Marion 1996; Marion 1996; Hammitt and Cole 1998).

The importance of use relative to other factors was unexpected and ran counter to other studies. It is possible that unique features of the study site such as soil type contributed to this finding. It is also possible that use emerged as important because these trails have much less use than trails in other studies; the effects of use on many impacts have been found to be detectable at low but not high levels of use.

Some other studies have found that amount of use influences trail width increases but most studies have indicated that trail incision is less affected or is sometimes not at all affected by the amount of use (Bayfield and Lloyd 1973; Cole 1983; Dale and Weaver 1974; Cole 1996). Trail erosion is typically more strongly related to the location of trails (e.g., on steep slopes or in areas of less resistant vegetation or soil) or trail management (e.g., lack of maintenance features), and climatic factors such as wind and rainfall intensity (Helgath 1975; Cole 1983; Jubenville and O'Sullivan 1987; Garland 1987).

Influence of Contributory Factors

Amount of Use

Amount of use contributed to trail width increases and to both measures of trail erosion, and also interacted with trail position, influencing informal trailing. For trail width and MIC, medium use trails differed from low use trails, but medium and high use trails did not differ, indicating that high use trails experienced little additional change. However, when considering the effect of use after controlling for trail position and trail grade (only one level of use existed for vegetation types), trail width was influenced by amount of use but MIC was not (Table 14). This finding supports other studies which have indicated that amount of use contributes to trail width increases, and that initial and low levels of trail use experience greater incremental increases of trail width impact (Cole 1987; 1990; Boucher et al. 1991).

MIP varied significantly between medium and high levels of use, and use was still significant when controlling for trail position and trail grade (Table 14). These findings contradict most other studies. However, Bryan (1977) found increasing erosion with increasing use, though he indicated that other factors such as soil texture (homogenous textures being more susceptible to erosion) were typically more important. He proposed that higher levels of use could contribute to increased trail erosion once a tolerance threshold was reached, where trails were no longer able to resist or recover from impact. Trail use at Torres del Paine is likely contributing to the removal of protective materials, increasing erosion on trails that are already highly susceptible to erosion due to poor location on steep slopes, and a lack of reinforcement materials and maintenance efforts. According to Hammitt and Cole (1998), visitor activities may create the circumstances for erosion and increase the rate of its occurrence, but rarely represent the actual agents of erosion.

We expected similar findings for MIC and MIP when controlling for the effect of use, since both represented measures of erosion (Table 14). One possible explanation for the differences observed between MIC and MIP is that MIC measured a smaller range of values (from 0-10), compared to MIP, which ranged from 0-37. MIC measured localized soil loss, from within the tread surface, and therefore may have reached a maximum potential amount of soil loss at the medium level of use. Conversely, MIP represented larger scale, cumulative soil losses occurring since the time trails were initially created, reflecting longer term erosion, which is likely to be characteristic of unplanned, unmaintained trails.

Vegetation Type

Vegetation type influenced the number of informal trails at medium levels of use. We were unable to test the effects of vegetation at other use levels. Informal trailing is ultimately a function of visitor behaviors, with visitors creating trails to access attraction features and for social reasons (Cole et al. 1987).

Grassland areas had a greater number of informal trails, at least for medium use trails, despite our expectation that grassland areas would be resistant or resilient to informal trailing impacts. In retrospect, forested areas have trees and other natural barriers confining visitors to trails, whereas grassland areas are more open, possibly permitting easier and more inviting off-trail travel. Additionally, trails sampled in grassland areas often paralleled river banks, which may have encouraged hikers and horseback riders to create trails to access rivers as an attraction feature, or for water.

Based on other studies, we assumed that the vegetation categories measured would be somewhat correlated with vegetation and soil characteristics, which would reflect differing susceptibility to trail width increases and erosion. For example, herbaceous vegetation in the Andean areas in Central Chile was found on fine grained soils with thin humus layers, which were linked to increased susceptibility to trampling impacts (Hoffman and Alliende 1982). Trampling resulted in decreased numbers of herbaceous species, increased displacement of stones, and consequent soil erosion. Similarly, some grassland and meadow areas have experienced increased saturation and lengthy stretches of poorly drained, muddy soil, which contributed to problem spots on trails and increased trail widening (Cole et al. 1987).

We found no relationship between vegetation type and trail width or incision. It is possible that there was no relationship because vegetation types, as measured, were not sufficiently different or otherwise did not reflect differing abilities to resist or recover from impacts. Information regarding species types or morphological characteristics may have better reflected such differences.

Trail Position

Trail position had no effect on any of the impact indicators, with the exception of a significant interaction between trail position and amount of use influencing the number of informal trails. However, this finding is difficult to interpret since no main effects occurred.

The position of the trail was measured to indicate trail location, reflecting vegetation and soil characteristics, as well as other environmental factors like precipitation, elevation and topography. Other studies have found that trails at higher elevations exhibited greater soil loss compared to those at lower elevations, due to higher precipitation rates, thinner soils, and increased exposure to wind (Burde and Renfro 1986; Leung and Marion 1996). Additionally, we had suspected that trails located in lower, flatter areas might experience certain kinds of problems such as poor drainage and water saturation, possibly contributing to trail width increases (Leung and Marion 1999b). We also suspected that Torres del Paine trails in midslope positions might be more susceptible to trail incision and width increases since trail construction techniques such as outsloping and switchbacks, and maintenance features like waterbars were not present.

However, the data did not support these relationships. It is possible that no relationships existed between trail position and trail width and incision, though it seems more likely that trail position in this study was not a good proxy for soil and vegetation characteristics, or for environmental characteristics such as precipitation, wind or topography.

Trail Grade

Trail grade significantly influenced both measures of trail erosion, with the steepest trails experiencing the greatest erosion. This effect was also observed when controlling for the amount of use (Table 14). The relationship between trail slope and trail erosion has been observed in several other studies (Helgath 1975; Weaver and Dale 1978; Bratton et al. 1979; Welch and Churchill 1986; Jubenville and O'Sullivan 1987; among others). Some studies have even found that trail erosion increased exponentially with increasing slope (Quinn et al. 1980; Coleman 1981). This finding of trail grade significance is intuitive because trails at Torres del Paine were not planned, often directly ascending steep slopes. Erosion occurs more intensely on slopes because the velocity of water and soil movement is increased, and because protective materials such as stones are more likely to become loosened and consequently removed (Summer 1986). At Torres del Paine, poor trail location and design likely contributed to trail erosion, followed by a lack of tread maintenance such as steps and water drainage features. Runoff may become channelized on trail surfaces, diverting natural flow patterns and accelerating trail erosion. Other studies have found that steeper trails experienced higher rates of soil loss and particle detachment, greater mean annual sediment yield, and increased runoff rates compared to control areas (Garland 1987; Wallin and Hardin 1996).

Trail erosion at Torres del Paine is influenced by some combination of amount of trail use, trail grade, lack of maintenance features, and possibly other factors that were not measured like rain and wind. As modeled by Manning (1979), trampling typically results in removal of vegetation and leaf litter, followed by loss of organic material, reduction in air and water permeability and water infiltration rate, increase in water runoff, and finally, in an increase in soil erosion. Field staff noted that wind erosion of soil was common due to the extreme windiness of the region, lack of sheltering trees and shrub cover, and the creation of tread dust from foot and horse traffic. Wind may accelerate soil erosion on trails, though few studies have examined this factor. In the coastal dunes of the Netherlands a few trampling passes on a community of grasses, mosses and lichens resulted in increased susceptibility to wind erosion (Westhoff 1967). Similarly, vegetation cover loss on horse paths at Cobahm Common in England increased vulnerability to wind erosion (Liddle and Chitty 1981).

Implications for Management

Management Implications

Management strategies can simultaneously consider trail position and vegetation type as underlying causes of informal trailing. Such strategies include avoiding sensitive or fragile areas, targeting educational efforts to specific regions or zones, or designating trails to access specific attraction features. For example, educational materials could be developed to emphasize remaining on previously created trails, or certain trails could be selected and marked as means of accessing specific attractions in grassland and valley areas such as rivers.

Both the amount of use and the trail grade are useful indicators of trail impacts. Trail use is the most significant predictor of trail width, with both trail use and trail grade representing useful predictors of trail erosion. A combination of management strategies are needed to address use and grade as contributory factors. For trail erosion, managers could relocate steeper trail segments to flatter terrain or develop switchbacks, and implement more intensive tread maintenance programs such as installing water diversion features. Additionally, managers might also further examine relationships between amount of use and trail grade. If the trend of increasing trail incision with increasing use is present at higher use levels (e.g., 5,000 people per year), managers may need to consider restricting or limiting visitor access in steeper areas, or in areas continuing to experience erosion in the presence of maintenance features. Trail width impacts may be addressed by encouraging visitors to walk only within primary tread areas, travel single file, and avoid walking around problem areas. The rate of trail width increases typically decreases at higher levels of use, as demonstrated in the curvilinear use-impact relationship, indicating that reducing the amount of use at higher levels will not likely be highly effective (Cole 1987; Hammitt and Cole 1998).

Future Research

ANOVAs seem to indicate that trail use influences trail width; trail use and trail grade affect trail erosion; vegetation type influences number of informal trails and possibly also that some relationship between trail use and trail position contributes to informal trailing. However, multicollinearity indicates that study findings may not be similar in repeat studies, or for protected areas beyond Torres del Paine.

Because inventory indicators are related, future monitoring studies should include or consider adapting current indicators to ensure that information generated has high management utility, and also should consider selecting management strategies that address multiple factors contributing to trail impacts.

Vegetation type, as measured, appears to be the least useful indicator of trail impact. The categorization is generic, indicating that more specific information regarding characteristics that more directly influence vegetation resistance or resilience is required. For example, transects could be set perpendicular to the trail at each sampling point, recording either 1) number or percent cover of all or most of the dominant vegetation species, 2) number or percent cover of mature trees, gramminoids, mosses, lichens, tree seedlings, and forbs (though these may vary in resistance), or 3) morphological characteristics such as growth form (erect, trailing or tufted) and size of structure (small or large) (Hammitt and Cole 1998).

Trail position does not appear to reflect differences in vegetation and soil characteristics, or reflect other potentially important environmental factors like rain, wind or topography. Therefore, additional information regarding rainfall and wind intensity within the different areas of the park should also be considered. Additionally, recording the slope alignment angle where trails are recorded as either parallel or perpendicular to the slope, characterizes the direct influence of trail location relative to topography.

CONCLUSION

Trails are important facilities within protected areas since they support a wide variety of ecotourism related activities and permit access to protected areas. Protected area managers are charged with maintaining trail functions and minimizing trail degradation. This task can be challenging, because visitation inevitably results in a variety of trail impacts.

In response to concerns that trail impacts have been increasing, resource managers at Torres del Paine have been considering reducing use. Trail impact research revealed that amount of use contributed to most trail impacts. Thus, managers concerns about use levels appear to be justified. However, other factors measured here (namely vegetation type and trail grade) also affected trail impacts, suggesting that other avenues such as trail relocation and maintenance might effectively reduce impacts.

One consequence of these findings identifying trail use as an important contributor to most trail impacts at Torres del Paine may be management decisions to limit or restrict trail use. However, use may need to be drastically reduced and kept at very low levels in order to significantly affect changes for certain impacts like trail width. Additionally, reducing use would not decrease informal trailing since the amount of use did not influence informal trailing. Trail erosion does appear to be affected by amount of use, however, other factors such trail location and design are also important. Finally, recovery periods for soil regeneration are lengthy, requiring substantial amounts of time once soil loss has occurred regardless of the amount of use.

Reducing use is also restrictive on visitor freedom, is difficult to achieve without intensive management intervention and resources such as staff and funding, and only addresses one potential underlying factor contributing to trail impacts. Therefore, other management strategies such as relocating trail segments, improving trail design, maintaining trails, and developing visitor education programs may be more effective and feasible to implement. However, use reduction strategies may ultimately be necessary to reduce trail erosion if other strategies are unsuccessful.

Multicollinearity between independent variables indicates that further exploration is required to determine the relative impact contributions of trail inventory indicators. Recommendations for future monitoring efforts include: 1) sampling additional trail segments to better represent a diversity of trail characteristics; 2) conducting specific investigations of trail grade and trail use as they influence trail erosion; 3) developing and comparing responses in multiple vegetation and trail position categories to further examine factors influencing informal trailing; 4) replacing vegetation types by an indicator that provides more specific information about vegetation resistance and resilience (e.g., morphological characteristics); 5) adding trail orientation relative to the prevailing slope as another indicator; and 6) gathering additional information regarding soil characteristics (e.g., soil texture, composition), and rainfall and wind velocity within different areas of the park. Also, staff should consider obtaining trail use numbers, recording actual values of trail grade, and otherwise adapting indicators to gather continuous versus categorical data to explore developing predictive models for amount of use and trail impact, and to better determine the relative, simultaneous contributions of individual inventory indicators to impact.

CHAPTER IV. THE PROTECTED AREAS IMPACT ASSESSMENT AND MANAGEMENT (PAIAM) FRAMEWORK: A SIMPLIFIED PROCESS FOR VISITOR IMPACT MANAGEMENT

ABSTRACT

Increasing ecotourism and protected area visitation in Central and South America have resulted in ecological impacts which some protected areas managers have attempted to address by employing visitor impact assessment and management frameworks.

In this paper we propose a new visitor impact assessment and management framework for selected protected areas in Mexico, Costa Rica, Belize, Chile based on a critique of existing frameworks, including carrying capacity and alternative decision making systems (e.g., the Limits of Acceptable Change). A set of evaluation criteria was developed to compare the relative positive and negative attributes of carrying capacity, alternative decision-making systems and the new framework, within the context of their actual and potential use in Central and South America. These criteria indicated that carrying capacity has often been misapplied and oversimplified in practice and failed to reduce visitor impacts. Evaluation of its alternatives indicated that although they address carrying capacity deficiencies, they require substantial staffing, funding and time to implement, which are less feasible to acquire in developing countries.

The Protected Areas Impact Assessment and Management (PAIAM) framework was adapted from carrying capacity and alternative decision making systems to include several desirable attributes such as simplicity, cost effectiveness, timeliness, and incorporating stakeholders and local residents into decision making. Experimental application of PAIAM in Mexico revealed that it lends itself towards feasible implementation. Although PAIAM is a flexible, iterative and cost effective process, its major drawbacks are that it loses quantitative impact information and involves an expert panel, which raises certain cultural sensitivity issues. Future research was suggested including application and implementation of PAIAM in other developing and developed countries.

INTRODUCTION

Ecotourism, protected area visitation, and related visitor activities are becoming increasingly popular in developing countries, particularly in Central and South America (Boyd and Butler 1996; Boo 1990; De Groot 1983; Fennel and Eagles 1990). These activities have resulted in ecological impacts. Examples include the Galapagos Islands in Ecuador, Monteverde Cloudforest Reserve in Costa Rica, and Ambergris Caye in Belize (Norris 1994; Boo 1990; Wallace 1994; Epler Wood 1998).

Many areas, initially created for resource protection or scientific research, were not prepared for the unchecked, intensive visitation that has occurred (McNeil 1996). Because of this visitation, managers must now address undesirable impacts (Ceballos-Lascurain 1996).

The purpose of this paper is to propose a visitor impact management framework for selected protected areas in Central and South America to assess visitor impact problems and identify management strategies, recognizing the constraints affecting developing country protected area management.

Visitor Impacts and Protected Area Management

Visitor impacts include trail erosion, wildlife disturbance, water pollution, death of coral reef organisms and visitor crowding and conflict (Manning 1986; Shelby et al. 1989; Ceballos-Lascurain 1996; Hammitt and Cole 1998; Marion and Farrell 1998). Visitor impact problems require management attention for the following reasons: 1) some impacts occur rapidly at initial or low levels of use; 2) some impacts are cumulative, increasingly degrading resources over time; 3) impacts may lead to other undesirable consequences such as diminished visitation; and 4) if visitation declines impacts may result in reduced economic benefits (Hammitt and Cole 1998). Proactive visitor impact management programs can prevent visitor impacts or resolve them before costly restoration and rehabilitation programs become necessary.

According to the International Union for the Conservation of Nature (IUCN), protected areas are created to protect and enjoy natural or cultural heritage, and maintain biodiversity and/or ecological life support systems (IUCN 1991). Many countries also recognize the benefits of allowing visitor access, and some explicitly promote visitation; thus, they face a difficult dilemma of balancing access and resource protection. However, these issues are difficult to address without a framework to structure and guide decision making (McCool and Stankey 1992; McCool 1994).

Additionally, frameworks may be required to better integrate local resource needs and systems of resource management into protected area management. National or state control over resources has often resulted in disenfranchisement of indigenous people with resource claims, denying their access to natural resources (Gomez-Pompa and Kaus 1992; Peluso 1993; Pimbert and Pretty 1995). These issues are particularly relevant in South America where indigenous populations reside within the majority of protected area boundaries (Amend and Amend 1992).

Decision Making Frameworks and Paper Objectives

Decision making frameworks include carrying capacity and alternative frameworks such as the Limits of Acceptable Change (Wagar 1964; Stankey et al. 1985). Carrying capacity frameworks are simple and inexpensive to implement, and have therefore been widely adopted by Central and South American protected areas, yet they have been often misapplied in practice and have often failed to minimize visitor impacts (Norris 1994; Wallace 1994; Lindberg and McCool 1998). Conversely, alternative frameworks address carrying capacity deficiencies, but require substantial staffing, funding and time to implement, and therefore may be less feasible for developing countries (Haurron and Boo 1995; Ceballos-Lascurain 1996; McCool and Cole 1997).

In this paper we critique existing frameworks regarding their utility and feasibility for Central and South American protected areas, propose a new decision making framework for protected areas in Mexico, Costa Rica, Belize and Chile, discuss an experimental application of the framework in Mexico, and evaluate its positive and negative attributes.

METHODS

We combine a literature review with information from nine semi-structured interviews conducted with protected area managers and managing agency representatives in Costa Rica, Belize and Chile. We also present information from a workshop conducted with managers and staff from three protected areas in Mexico. Interviews described current decision making frameworks, suggested reasons why some frameworks were favored over others, and compared managers' perceptions of frameworks' effectiveness, utility and feasibility. The workshop was conducted to respond to a Mexican protected area managing agency (PROFAUNA) request for advice about assessing impacts and selecting management strategies.

The study sites included Monteverde Cloud Forest Reserve, Volcan Poas National Park, Manual Antonio National Park, and Braulio Carrillo National Park in Costa Rica, Hol Chan Marine Reserve, Altun Ha Mayan ruin, and the Community Baboon Sanctuary in Belize, Torres del Paine National Park in Chile, and Cuatro Cienegas, Zapaliname and Maderas del Carmen in Mexico. Belize and Costa Rica were chosen because both countries experience significant protected area visitation, are well-known ecotourism destination areas, and because studies have been published of carrying capacity applications. Protected areas within these countries were intentionally selected to represent different levels of visitation, access, types of visitor activities, intensity of management, and type of managing agency. Torres del Paine was chosen because of management interest in applying LAC. The three areas in Mexico were chosen by PROFAUNA to reflect visitor impact problems.

DESCRIPTION AND CRITIQUE OF DECISION MAKING FRAMEWORKS

Description of Decision Making Frameworks

Decision making frameworks can assist protected area managers in making rational and defensible tradeoffs between resource protection and visitor access to these resources. Frameworks incorporate a means of assessing visitor impacts and determining management actions and strategies to minimize or prevent visitor impacts identified as undesirable. Carrying capacity was the first framework used to address these issues.

Carrying Capacity

The concept of carrying capacity was adapted from range management and applied to recreation site management in the early 1960's (Wagar 1964). It is defined as the amount of visitor-related use an area can support while offering a sustained quality of recreation, based on ecological, social, physical and managerial attributes (Stankey et al. 1990). It determines the level of use beyond which impacts exceed acceptable levels specified by evaluative standards (Shelby and Heberlein 1986). Currently, all United States National Park Service units are required to determine site carrying capacities (USDI 1997). Tourism carrying capacity was later developed to include development issues and economic and socio-cultural effects on host cultures (Inskeep 1988; Wolters 1991).

The traditional carrying capacity approach emphasized setting visitor numbers based on mathematical relationships to variables of concern. For example, quotas were set for rafters on the Colorado and Rogue Rivers based on contact preferences (Shelby and Heberlein 1986). Thus carrying capacity includes both descriptive (i.e., management parameters like amount and distribution of use or use-related impacts), and evaluative components (i.e., value judgements regarding the acceptability of different levels of impacts) (Shelby and Heberlein 1984).

Alternative Decision-Making Frameworks

Alternative decision-making frameworks identify recreation and tourism opportunities, assess human use-impact relationships, and provide managers with specific steps to determine acceptable conditions and identify management strategies to ensure desired conditions. These frameworks explicitly recognize that standards are value-laden and develop processes for channeling or justifying the subjectivity. Such frameworks do not discard the concept of carrying capacity, but rather shift emphasis from identifying how much use an area can tolerate to achieving desired conditions, and provide a more explicit process for accomplishing this task (Stankey et al. 1985).

Opportunity spectrums are critical components of alternative frameworks and also have been used to determine zone-specific carrying capacities. The Recreation Opportunity Spectrum (ROS), developed by the US Forest Service, defines a range of recreation settings from pristine wilderness to urban recreation, based on a combination of physical, biological, social and managerial attributes (Clark and Stankey 1979). ROS enhances regional planning for a variety of settings and incorporates information about the supply and demand for recreation opportunities into land and resource planning (Driver et al. 1987). The Tourism Opportunity Spectrum (TOS), adapted for the Canadian Arctic, determines the relative appropriateness of different adventure tourism-related activities and facilities (Butler and Waldbrook 1991). The Ecotourism Opportunity Spectrum (ECOS), proposed by Boyd and Butler (1996), represents a spectrum of ecotourism opportunities.

Alternative decision-making frameworks use a management by objectives approach and are iterative, continuous processes that actively involve the public and other stakeholders (Cole and McCool 1997). Frameworks are used to guide managers in stating the conditions management will maintain or allow, inventory existing conditions to see how these compare with acceptable conditions, and implementing management actions where conditions do not meet objectives or standards. Monitoring then results in a feedback loop to the inventory stage (Hammitt and Cole 1998)(Figure 2).

The Limits of Acceptable Change (LAC) framework, developed by the U.S. Forest Service, is a transactive planning approach (based on shared learning and open dialogue between stakeholders) that provides a means of identifying the appropriate amount and extent of change using indicators, standards and monitoring to identify unacceptable impacts (Stankey et al. 1985; Graefe et al. 1990). LAC, like carrying capacity, may result in setting visitor numbers, but it does not place emphasis on use thresholds. Other such frameworks include Visitor Impact Management (VIM), developed by the U.S. National Parks and Conservation Association (Graefe et al. 1990); Visitor Experience and Resource Protection (VERP) developed by the U.S. National Park Service (USDI 1997); and Visitor Activities Management Process (VAMP), a conceptual planning model developed by Parks Canada to address target markets, appropriate recreation activities, and park-related facilities (Graham et al. 1988). All of these frameworks are quite similar in their process of identifying objectives, inventorying conditions, comparing conditions to desirable states, evaluating and adopting management actions where conditions are undesirable and monitoring to assure achievement of objectives.

Use of Decision-Making Frameworks in Central and South America

Use of alternative frameworks is much more common in the United States and Canada, compared to countries in Central and South America, who tend to favor carrying capacity. Interview information indicated that The Belize Audubon Society will soon require protected areas to determine visitor carrying capacities, and that capacities have already been set for Monteverde, Volcan Poas and Manuel Antonio in Costa Rica. Additionally, The Protected Areas Tourism Carrying Capacity (PATCC) model has been used in the Galapagos Islands and Costa Rican parks to first estimate facility, social and biological capacities, and then correct these numbers based on management constraints (Cifuentes 1992; Haurron and Boo 1995).

Conversely, alternative decision-making frameworks have been scarcely applied in Central and South America. In a 1994 survey of 215 developing country protected areas, less than 10% used LAC and less than 20% used either VIM, VAMP or ROS (Giongo et al. 1994). Of the areas included in this study, Torres del Paine was the only protected area using an alternative framework. Wallace (1993) and interview subjects suggested that alternative frameworks are not as commonly used because protected area managers have fewer financial resources and the awareness of decision making frameworks is relatively low.

Critique of Existing Decision-Making Frameworks

Criteria were developed to evaluate the various frameworks based on attributes identified as desirable by interview subjects and the literature (Stankey et al. 1985; Shelby and Heberlein 1986; Graefe et al. 1990; Haurron and Boo 1995; McCoy et al. 1995; Furze et al. 1996; McCool and Cole 1997; Lindberg et al. 1997; USDI 1997; Anderson et al. 1998; Lindberg and McCool 1998).

This review suggests that an ideal framework would: 1) be easy, quick, inexpensive, and cost-effective to implement; 2) be able to successfully assess and/or minimize visitor impacts; 3) consider multiple underlying causes of impacts; 4) encourage the selection of a variety of management actions; 5) produce defensible decisions; 6) separate technical information from value judgements; 7) encourage public involvement, shared learning, and consensus building;

and 8) incorporate local resource uses and resource management issues. The critique of carrying capacity, alternative frameworks and the proposed framework is summarized in Table 15.

Positive and Negative Attributes of Carrying Capacity

Carrying capacity can be simpler, less expensive and more feasible to implement than alternative decision making frameworks (Haurron and Boo 1995; Lindberg and McCool 1998) (*criterion 1*). One interview subject characterized carrying capacity as quick, flexible, based on expert opinion, and consistent with current protected area legislation. However, carrying capacity often has been misapplied to set visitor numbers without considering how these numbers meet management objectives (Lindberg and McCool 1998)(Table 15).

Carrying capacity numbers often are too simple and based on somewhat arbitrary judgements and have therefore sometimes failed to minimize visitor impacts (*criterion 2*). For example, one interview subject at Monteverde indicated that trail capacities of 25 persons per hour had not minimized visitor crowding and conflict. Similarly, another subject at Volcan Poas indicated that carrying capacity numbers at Volcan Poas National Park were set without factoring in bio-physical and social impact considerations.

Carrying capacity numbers may overemphasize the importance of amount of use and fail to consider other potential underlying causes of impact (Graefe et al. 1990) (*criterion 3*). For a variety of natural resource impacts the amount of use is only one factor contributing to impact, and that the type of use, party size, and environmental characteristics may be more important (Cole 1987). Similarly, visitor experiences are affected not only by amount of use but also by the type of visitors encountered and visitor level of expertise and expectations (Shelby and Heberlein 1986).

By focusing on the amount of use, carrying capacity numbers draw attention away from the broader range of management strategies available to resource managers (*criteria 4*). Managers may overlook more appropriate, effective or less regulatory management actions (Stankey et al. 1990). Limiting visitation also may unnecessarily restrict visitor freedom, and is difficult and expensive to implement (Gunn 1979; Lindberg and McCool 1998). Use reduction and other heavy-handed visitor restrictions also are perceived as a potential threat to generating tourist income, a high priority for many developing countries (Getz 1983; Western 1986).

Carrying capacity limits are difficult to defend and often are exceeded because of the pressure for economic gain from visitation (Williams 1994) (*criterion 5*). Notable examples include the Galapagos Islands and several Costa Rican parks (Norris 1994). Similarly, some protected areas may be concerned about the political unfavorability of limiting visitor use.

A major limitation is that carrying capacity "magic numbers" are subjective. However, the subjective process often is hidden under the false guise of scientific objectivity (Stankey et al. 1990) (*criterion 6*).

Finally, interview information revealed that carrying capacity implementation has not typically included public participation or involvement, or considered local resource uses and management (*criteria 7 & 8*). Harroun and Boo (1995) suggested that local resource needs have not been considered because carrying capacity has been largely implemented in areas without inhabitants. However, many protected areas either directly or indirectly support local populations.

Carrying capacity has been oversimplified in practice, places too much emphasis on limiting visitor use when other management parameters could be manipulated, has in some cases failed to successfully minimize visitor impacts, and does not actively incorporate public involvement or local resource needs.

Positive and Negative Attributes of Alternative Decision-Making Frameworks

Alternative decision-making frameworks assess visitor impact problems, interpret and consider multiple underlying causes of impacts, provide support for informed, defensible decisions, and coordinate planning, research, and monitoring efforts (McCool and Cole 1997). Unlike carrying capacity, they recognize the complicated nature of visitor impact issues without oversimplifying them, and are flexible, continuous, and iterative processes identifying salient issues to determine what impacts are acceptable (Stankey et al. 1985; Lindberg et al. 1997; Borrie et al. 1998)(Table 15).

However, experience implementing Limits of Acceptable Change in developed countries has revealed several potentially formidable barriers for developing countries, including time constraints, substantial costs, and extensive financial and personnel resource requirements (e.g., employee training and data collection and the need for highly competent protected area planners, meeting facilitators, and technical and scientific experts) (Haurron and Boo 1995; Ceballos-Lascurain 1996; McCool and Cole 1997) (*criterion 1*).

Alternative frameworks monitor site conditions, assess management effectiveness, and increase emphasis on zoning to protect more remote or pristine areas, all of which potentially improve managers' ability to assess, manage and minimize visitor impacts (McCool and Cole 1997) (*criterion 2*).

However, in developed countries, protected area managers have found it difficult to determine what is acceptable, select indicators and standards, and develop and implement monitoring programs (McCool and Cole 1997; USDI 1997). Additionally, insufficient scientific knowledge is available for a variety of visitor impacts, subjective judgments are always required to set standards, and management actions have failed to result even when standards are exceeded (McCoy et al. 1995; Ritter 1997; Hof and Lime 1997; USDI 1997).

Alternative frameworks address multiple underlying causes of impact, develop statements of desired and current conditions, emphasize understanding impacts and selecting acceptable conditions over setting user numbers, and propose multiple strategies, thereby avoiding unnecessary visitor restrictions and regulations (McCool and Cole 1997) (*criteria 3, 4*).

Alternative frameworks in the U.S. provide defensible decisions since the process tracks decisions, offers a systematic and cohesive context to make planning decisions over time, heavily integrates public involvement and consensus building into the process, and includes monitoring to provide scientific information supporting management decisions (McCool 1994; McCool and Cole 1997) (*criterion 5*).

Alternative frameworks also attempt to separate technical decisions from value judgements (McCool and Cole 1997) (*criterion 6*). Frameworks stimulate discussion on how much human induced change is acceptable based on legislative mandates and other factors, identify trade-offs between competing goals, clarify the importance of area resources and values, and explicitly show how human values and judgements are incorporated into decision making.

Another key component of alternative frameworks is public involvement and the potential to incorporate local resource needs (*criteria 7 & 8*). Currently, no extensive public involvement has occurred in LAC in developing countries, possibly because these countries do not have formal legislation requiring it, or because of management reluctance to sacrifice control over decisions (Giongo et al. 1994; Pimbert and Pretty 1995). However, alternative frameworks include participation, which could increase the extent of local influence over decisions, increase management use of local knowledge and experience, improve relationships between local residents, managing agencies and other stakeholders, and increase local support and compliance with regulations and laws (Pretty 1994; McCoy 1995; Pimbert and Pretty 1995).

Justification for Developing a New Framework

Carrying capacity and alternative frameworks could be adapted to better suit developing country protected area management needs, permit greater management flexibility, recognize management opportunities and constraints, and better integrate local people. Interview subjects also suggested that developed countries' strict rules of planning do not conform to the reality of work in developing countries and that greater creativity and input from local experts is needed. The framework proposed in this paper adapts existing frameworks, incorporating carrying capacity attributes of simplicity, timeliness, cost effectiveness and consideration of management constraints with alternative framework attributes of flexibility, understanding of multiple factors contributing to impacts, defensibility of decisions, and integration of local people into decision making.

PROPOSING THE PROTECTED AREAS IMPACT ASSESSMENT AND MANAGEMENT (PAIAM) FRAMEWORK

The Protected Areas Impact Assessment and Management (PAIAM) Framework

The Protected Areas Impact Assessment and Management (PAIAM) framework, like carrying capacity, recognizes management constraints, but like LAC, also entails impact problem analyses, the flexibility of multiple strategy selection, and public involvement. PAIAM identifies management opportunities and visitor impact problems, includes a problem analysis step using an expert panel to replace indicators, monitoring and standards, and ultimately results in the selection and implementation of visitor impact management strategies (Figure 3).

Public Participation and the Expert Panel

PAIAM includes public participation and an expert panel because management decisions are ultimately social and political, rather than technical (McCool and Cole 1997). The "public" includes local residents, visitors, and other stakeholders wanting to participate in decision making. Public participation is critical during the first three steps, because that is when protected area values and issues of concern are identified and problems are prioritized, but should ideally occur throughout the remainder of the process. The forum depends on the number of people involved and the contentiousness of issues being considered. Protected area managers play a significant role in developing public participation programs since they are charged with balancing the needs and interests of stakeholders with information about resource conditions and management opportunities and constraints (Ceballos-Lascurain 1996).

The expert panel works with protected area managers and staff to analyze impact problems, select management actions, and assess strategy effectiveness. The panel is composed of individuals with expertise relevant to the highest priority management problems. For example, impacts identified by an interview subject at Volcan Poas included trail erosion, crowding and illegal hunting and fishing. Therefore, the panel may include persons with social science and recreation ecology backgrounds, and those persons familiar with local hunting issues. Experts can include local residents, agency representatives, scientists, non-government organization staff and other persons of local, national or international origin. Experts differ from the public since they are nominated or otherwise selected by protected area managers for their expertise regarding specific problems.

Similar uses of expert panels have been suggested elsewhere. Lawrence (1992) suggested surveying a panel of experts to select indicators of environmental and social impacts related to tourism. Chamberlain (1997) proposed meetings with representatives from tourism industries, local residents, conservationists, and government officials to guide monitoring projects and assess the effectiveness of carrying capacity decisions. Hof and Lime (1997) suggested forming an expert panel to examine current resources and resource conditions, and work with protected area staff to generate recommendations on indicators and standards, monitoring programs, and management actions.

PAIAM Steps

PAIAM is an iterative, flexible process in which participants can simultaneously consider the consequences of zoning options, the acceptability of different impacts, and the implications of selecting various management tactics, all of which have been identified as important decision making framework attributes (McCool 1994).

Step One

The intent of this step is to describe the protected area purpose and significance, characterize recreational, natural, cultural and other resource values, and designate management zones (Figure 3). Issues affecting zoning are discussed, including facilities, access and infrastructure, location of attraction features, resource and social conditions, local community resource uses and other requirements, recreation activities, management intensity, and other economic, political and social considerations. Prescriptive management zones are designated by managers and staff based on extensive public input to set management objectives.

Step Two

The intent of step two is to specify management objectives for each zone based on existing legislation, managing agency policies, and stakeholder and management input (Figure 3). This step is explicitly differentiated from step one to emphasize the importance of clearly defining and stating management objectives. Objectives must be specific, realistic, achievable, and should reflect compromises between competing resource uses.

Step Three

The purpose of step three is to identify visitor impact-related management opportunities and prioritize impact problems (Figure 3). Opportunities are management assets or conditions that contribute to preventing or minimizing impacts. For example, environmental attributes such as trampling-resistant grasses may prevent vegetation loss, and a strong history of good relationships between managers and local residents may facilitate public participation.

Problems refer to specific undesirable resource and experiential visitor impacts such as crowding, wildlife harassment, trail erosion, attraction feature degradation and litter. A range of problems are identified by protected area staff and the public as part of a brainstorming process. A prioritized list is then created in recognition of limited available management resources. The list is based on the types of resources affected, the costs incurred by not addressing the problem, management ability to address the problem, as well as effects on visitor experiences, local residents, and natural and cultural resources. Priorities can also be assigned using risk management techniques, which consider the severity, duration, areal extent of impact, and vulnerability of the resource affected (Cole and Landres 1996).

Step Four

The purpose of step four is to conduct problem analyses involving the expert panel and protected area staff (Figure 3). The history and context of impacts are thoroughly described based on available information, along with a description of management solutions used in the past. If no quantitative data are available, managers may elect to conduct rapid impact assessments (e.g., assessing trail width and depth at various sampling points or assessing site conditions using condition class systems) (Marion 1991; Leung and Marion 1999). Managers can also gather qualitative data (e.g., reports or logs kept by staff regarding specific problems and actions to address those problems). Site visits are then conducted by experts and protected area staff to observe and learn as much as possible about these impact problems, and to postulate potential underlying causes. Experts speculate about impact causes based on existing data and research, personal knowledge and experience, and field observations.

Step Five

The intent of step five is to select and implement management strategies and tactics to address prioritized visitor impact management problems (Figure 3). The full spectrum of available strategies includes reducing use of the entire area, reducing use of problem areas, changing the location of use within problem areas, changing the timing of use, changing the type of use and visitor behavior, changing visitor expectations, increasing the resistance of the resource, and maintaining or rehabilitating the resource (Cole et al. 1987). Tactics are means of achieving strategies (e.g., developing brochures to encourage specific visitor behaviors or providing latrines or human waste facilities to increase the resistance of the resource)(Anderson et al. 1998).

Multiple strategies are discussed by the panel and protected area staff first in generic terms, and are then translated into specific tactics. The appropriateness of any given strategy depends on the management zone and its objectives, implementation difficulty, public acceptability, potential effectiveness, effects on other impacts, and consequences for visitors (Loomis and Graefe 1992). For example, indirect strategies like education tend to be more heavily favored by visitors, compared to more restrictive strategies like reservation systems (McCool and Christiansen 1996). Additionally, managers may elect to consult with public representatives before strategy implementation occurs. Protected area managers make the final decisions selecting strategies and tactics, since they are most knowledgeable about the budget, personnel and expertise available (Anderson et. al 1998).

Step Six

The purpose of step six is to assess the effectiveness of strategies and tactics (Figure 3). The expert panel and protected area staff review previously implemented management actions and their success in resolving targeted resource or social problems. Costs, such as funding and staffing requirements, and the restrictiveness of the action to visitors, are also evaluated. Recommendations for continuing or modifying previous actions or switching to alternative actions are then developed.

PAIAM Implementation in Mexico

PAIAM was partially implemented in Mexico to address visitor impact management problems in three protected areas. An expert panel consisting of PROFAUNA staff, protected area managers and staff, National Outdoor Leadership School staff, and the lead author of this paper was assembled to visit each protected area and examine selected management problems. Protected area staff first generated a list of visitor impact problems (Step three). Workshop participants then conducted a series of site visits within each protected area to observe impacts (Step four). For example, we observed large recreation sites that managers reported had been expanding over time, as well as litter and human waste management problems at Zapaliname. Protected area staff presented the history, context, perceived causes, and other related knowledge about these impacts. The expert panel was then able to contribute to the discussion based on its experience addressing similar problems in other protected areas.

Workshop participants brainstormed a variety of potential management strategies for each impact identified, eventually agreeing upon two or three strategies and a series of tactics (Step five). Using the example of littering in Zapaliname, two strategies selected included changing visitor behaviors (tactic: increasing contacts between local resident wardens and visitors) and increasing the resistance of the resource (tactic: locating trash receptacles close to picnic and other highly trafficked areas).

The effectiveness of tactics, if implemented, will need to be considered by PROFAUNA and protected area staff (Step six). Protected areas must also determine means of involving the public and other interested stakeholders.

Critique of the PAIAM Framework

Like other frameworks, PAIAM is evaluated in terms of the eight desirable criteria identified earlier (Table 15).

Positive and Negative Attributes of PAIAM

PAIAM is more complex than carrying capacity but is simpler, more flexible, less expensive, and faster to implement than alternative frameworks (*criterion 1*). One interview subject indicated that the extensive research, inventories and monitoring studies required by other frameworks were not feasible within their limited budgets. Primary PAIAM costs are related to public participation programs and the expert panel, though experts may be available locally, and costs may be somewhat defrayed by non-government organizations.

The removal of steps involving indicators, monitoring, and standards somewhat limits PAIAM's ability to assess and determine the underlying causes of impacts compared to alternative frameworks (*criteria 2, 3*). Without impact data, impacts may be incorrectly prioritized, misjudged in severity or magnitude, or other more significant impacts may be neglected. The acceptability of conditions may then be determined based on incomplete understandings of impact causes and may be insufficient to justify management actions. Additionally, managers may only react once degradation has become severe, or lack sufficient management direction to act, which may result in resource conditions deteriorating according to whatever evolves through protected area use (Shindler 1992).

However, the science required for alternative frameworks is sometimes unavailable or insufficient to assess and manage visitor impacts, does not necessarily assist managers who have to make politically popular decisions, and does not remove the need for expert judgement to determine what is acceptable (McCool and Cole 1997). Conversely, the expert panel still utilizes quantitative and qualitative data as a decision making tool, but ultimately relies on professional and personal experience and opinion. Experts are sometimes more objective and independent from managing authorities, extensively trained providing competence perhaps not otherwise available, able to apply experience from other projects, able to disseminate new decision making and management tools, able to diagnose and analyze problems, and can be instrumental in finding optimum solutions (Bower 1982; Canback 1998).

However, managers also must realize that experts are indoctrinated by thinking appropriate to their background and experience, which may not translate or apply well to situations in other countries or regions. They may also be expensive, unavailable when needed, may disagree with each other about the nature or significance of problems or how to best address them, or may be biased or otherwise unable to make informed contributions (Kelley 1979; Smith 1994). Therefore, protected area managers need to preferentially recruit experts within the country or region, or at least try to hire foreigners familiar with the protected area. Managers may also need to educate experts about pertinent issues affecting management, convey other crucial contextual information, and moderate panel discussions to facilitate agreement. Ultimately, managers must balance the panel information with other management information regarding implementation constraints and other considerations.

PAIAM, unlike carrying capacity, does not emphasize use thresholds but rather utilizes an expert panel to review all impact information, evaluate the effectiveness of past management actions, and recommend a series of potential management actions (*criterion 4*). The panel encourages an interactive process and exchange of ideas between scientists and other researchers, local people, and protected area managers and staff.

PAIAM's impact problem analyses step can generate pertinent management related information and provide justification for implementing certain strategies (*criteria 5*). An interview subject stated that expert opinion and information often results in greater agency support for management actions.

The PAIAM process, like alternative frameworks, can result in documentation of how impacts were identified and assessed, who was involved in process, what criteria were used to determine the acceptability of impacts, and why certain management strategies were recommended over others (*criteria # 6*).

Compared to carrying capacity the role of public participation is greatly expanded in PAIAM, and may also better incorporate local resource needs and management systems (*criteria 7& 8*). Local people not only participate in public involvement programs but are also selected as experts. Therefore, PAIAM may avoid the historical trend of allowing foreign experts to decide where, when and how much of the natural resources are extracted by local communities without any input from local people, and may better incorporate local decision making and resource management systems into decision making (Pimbert and Pretty 1995).

The expert panel in the PAIAM process yields tremendous power over defining what represents an impact, why it is significant, and what should be done about it. However, with the successful integration of local people, PAIAM could also empower local people, reduce conflict between interest groups, expose multiple perspectives related to natural resource management, improve the quality of decisions due to the diversity of input, and better incorporate local informal networks and political or social institutions (Davis and Whittington 1998; Turner 1999). Managers have the difficult task of achieving this integration and must also ensure that participation occurs within reasonable time limits, and is productive. The assistance of facilitators or conflict resolution experts may also be necessary, both of which may be available through non-government organizations.

CONCLUSION

This paper proposed a decision making framework for selected protected areas in Chile, Costa Rica, Belize and Mexico to manage visitor related impacts and recommend appropriate management strategies. The Protected Area Impact Assessment and Management, or PAIAM framework, provides an in-depth impact assessment beyond setting carrying capacity numbers, represents a more cost effective and timely means of managing visitor impacts compared to alternative decision making frameworks, and may also better integrate local resource needs and systems of management into decision making. PAIAM permits rapid implementation and management of visitor impact problems, as a form of triage, if necessary, but may also be used to identify management opportunities and prevent visitor impacts, and can be used in combination with preexisting frameworks like carrying capacity.

PAIAM may be useful for other developing and developed country areas beyond the scope of this study, particularly if they receive substantial visitation, perceive the existence of visitor impact problems, and have established means of receiving funding, a clear managing authority, and sufficient management structure and agency support to ensure successful implementation. Other issues such as differing political systems, conflicts between local people and protected area managers, and cultural constraints also influence the potential utility and effectiveness of PAIAM.

As initially conceptualized and applied, PAIAM only addresses visitor impact problems affecting natural resources and visitor experiences. However, PAIAM may also be useful for managing economic and socio-cultural impacts related to visitation, and address other specific protected area management issues. For example, an expert panel of local people and tourism businesses could meet with protected area staff to discuss target markets, set management objectives permitting greater economic opportunities, identify barriers to economic earnings, analyze those barriers, and brainstorm potential solutions to increase earnings. PAIAM may be employed to solve a variety of clearly specified management issues related to visitation and visitor impacts, but is not intended to address larger planning and management issues such as protected area designation and boundary definition, or managing impacts related to infrastructure and visitor facility development.

The primary disadvantage of PAIAM is the loss of impact information and diminished defensibility of management decisions due to the omission of monitoring and clear standards. However, PAIAM does incorporate impact data and information into decision making, but in a less formal manner, permitting management flexibility and reducing costs. The expert panel can be instrumental in assessing visitor impact problems and proposing potential solutions, relying upon scientific and expert information, as well as the knowledge and experience of protected area staff. The PAIAM process also results in written documentation of problem analyses and management recommendations, guiding management actions and enabling managers to justify decisions.

To understand the practical utility of PAIAM, it would be useful to apply it in a variety of developing and perhaps developed country protected areas, to compare its positive and negative attributes to those identified for carrying capacity and alternative frameworks.

CHAPTER V. SUMMARY, DISCUSSION AND CONCLUSION

SUMMARY

Ecotourism has been portrayed as a desirable means of protecting natural resources, discouraging more exploitative resource uses like oil exploration and mining, while still providing an alternative source of economic benefits for local communities and host country governments (Boo 1990). However, ecotourism sometimes has failed to generate sufficient economic benefits, resulted in undesirable socio-cultural impacts and has contributed to natural resource degradation (Furze et al. 1996; Epler-Wood 1998; Nepal 1999). The undesirable impacts related to ecotourism have raised the question of whether or not ecotourism is sustainable (Wall 1997). From an ecological perspective, sustainability includes long term resource protection and preventing and minimizing ecological impacts related to ecotourism development and visitation (Ceballos-Lascurain 1996).

A large body of literature has identified environmental impacts related to ecotourism and ecotourism development, but very few studies emphasize site-level ecological impacts (Mathieson and Wall 1982; Buckley and Pannell 1990; Miezecowski 1995; Leung et al. *in press*). Protected areas may experience heavy visitor use, potentially resulting in ecological impacts like trail erosion, wildlife disturbance and attraction feature degradation (Marion and Farrell 1998). Recreation ecology and visitor impact management expertise and knowledge have been widely applied in developed countries to address such visitor impact management issues and could assist developing country protected area managers in identifying, assessing, and managing impacts (Leung et al. *in press*).

Currently, there is only limited cross fertilization between recreation ecology, visitor impact management and ecotourism, although such knowledge represents an excellent potential means of assessing and managing for ecological sustainability (Leung et al. *in press*). For example, visitor impact frameworks define management goals, establish recreation zones, analyze impact problems, and determine specific strategies to minimize those problems. As another example, recreation ecology uses impact assessment and monitoring procedures that are integral components of these frameworks, providing baseline and indicator data to evaluate standards and the effectiveness of management actions. Finally, recreation ecology knowledge can inform mangers in choosing impact management strategies, such as selecting resistant locations for facilities, trails and campsites, or assist in crafting educational messages. Such procedures also generate data specific to visitor impacts, and are inexpensive and efficient, working well within the limited budgets of many protected areas.

Application of visitor impact management and recreation ecology information and tools in developing countries can evaluate the ecological sustainability of ecotourism, identify specific visitor impacts at ecotourism destination areas, and direct protected area managers in selecting management strategies to minimize those impacts.

Dissertation Theme and Intent

Ecotourism and protected area visitation will likely continue to increase in Central and South America, inevitably resulting in some degree of visitor-related natural resource impact. Finding appropriate solutions to address these impacts requires an understanding of their magnitude and extent, causal and influential factors, consideration of protected area management goals and objectives and public interests.

Recreation ecology and visitor impact management expertise can provide much of the information and tools needed by managers to identify and assess visitor impacts, investigate their potential underlying causes, evaluate their potential significance and acceptability, and recommend specific management strategies. Incorporating this expertise into protected area management may help ensure that protected area visitation is sustainable, and assist managers in maintaining the difficult balance between protecting natural resources and permitting protected area visitation.

Although such knowledge and tools have high potential management utility for Central and South American protected areas, few examples of these applications exist. Therefore, this dissertation was written to address this gap by 1) identifying a variety of visitor-related natural resource impacts and applying rapid impact assessment procedures to selected protected areas in Belize and Costa Rica; 2) investigating the relative contribution of the amount of use compared to other factors influencing trail impacts at Torres del Paine National Park in Chile; and 3) developing a new visitor impact assessment and management framework for selected protected areas in Mexico, Belize, Costa Rica and Chile. Results of these applications were reported in three separate papers (Chapters II, III and IV).

Intent and Findings From the Three Papers

The intent of the first paper was to identify and characterize visitor-related natural resource impacts at selected protected areas in Costa Rica and Belize, and apply and compare rapid trail and recreation site impact assessment procedures adapted from the recreation ecology literature. One-to-two day site visits were conducted during the month of August, 1998, to interview managers and staff of protected areas and apply rapid impact assessment procedures. Interview subjects reported a variety of impacts affecting trails and recreation sites, as well as wildlife, water, attraction features and other resources. Impact assessment procedures documented trail proliferation, erosion, widening, muddiness, exposed roots, and running water on trails, in addition to vegetation cover loss, mineral soil exposure, exposed roots, and damaged trees and litter on recreation sites. This study found that trail and recreation site impacts were important case study management concerns, and that many of these visitor-related impacts could be efficiently and effectively measured using rapid assessment procedures, each of which having high potential management utility.

The purpose of the second paper was to measure the frequency and magnitude of selected trail impacts, apply more sophisticated impact assessment procedures, and compare the relative impact contribution of the amount of use, vegetation type, trail position and trail grade at Torres del Paine National Park in Chile. A point sampling approach was used to measure selected impacts on nine 3.5-kilometer trail segments, with three segments randomly sampled at each of three levels of use, conducted mid-December, 1996, to mid-January, 1997. Findings indicated that amount of use contributed to trail width and incision. Findings also indicated that vegetation type (studied at only one use level) contributed to the number of informal trails, and that trail grade also influenced trail incision. This study demonstrated that amount of use contributes to some trail impacts, but that trail grade and vegetation type are also important impact contributors. This study recommended a variety of management strategies to minimize trail impacts.

The purpose of the third paper was to develop a new visitor impact assessment and management framework capable of assessing visitor impacts, identifying management strategies, and recognizing management constraints affecting developing country protected areas. The Protected Areas Impact Assessment and Management (PAIAM) framework was adapted from carrying capacity and alternative frameworks (primarily the Limits of Acceptable Change). It includes several desirable framework attributes such as simplicity, cost effectiveness, timeliness, impact analysis based on understanding multiple contributory factors, and incorporates stakeholders and local residents into decision making. This study also experimentally applied the new framework, revealing that PAIAM lends itself towards feasible implementation in Central and South America.

DISCUSSION

General Contributions of Dissertation Research

This research has made several important contributions. First, the case study research in Costa Rica and Belize (Chapter II) will be submitted for publication to an ecotourism journal, promoting the dissemination of recreation ecology and visitor impact management knowledge. Second, the research of trail impacts at Torres del Paine (Chapter III) investigated one of the primary recreation ecology research topics: the relative contribution of use-related, environmental and managerial factors to impacts. This research applied more sophisticated impact assessment procedures to a unique setting: or, a remote yet heavily visited protected area in the Patagonian region of Chile. Third, development of a new visitor impact management framework (Chapter IV) contributed to the larger on-going discussions about carrying capacity occurring within recreation, tourism and ecotourism fields.

This dissertation research also provided useful information for protected area managers. Research findings directly benefited the study sites by identifying and assessing visitor impacts and recommending management strategies to minimize those impacts. This research also potentially benefits the wider audience of protected area managers in Central and South America by developing low cost, simple and reliable impact assessment procedures, and by creating a visitor impact management framework designed to be implemented within limited management resources.

Significance and Implications of Specific Study Findings

The significance and implications of specific study findings are that 1) a variety of visitor impacts are affecting natural resources in several Central and South American protected areas, implying the need for increased awareness about visitor impacts, as well as increased visitor impact research and management; 2) rapid impact assessment procedures are available to evaluate certain visitor-related natural resource impacts in a variety of settings, but more work is needed; 3) the amount of use is an important factor influencing certain trail impacts, though use restrictions are not the only management option to deal with such impacts and; 4) alternative decision making frameworks with high management utility can be developed and feasibly implemented.

First, this research deliberately focused on Central and South America since it is a heavily visited ecotourist region that currently lacks substantial research on visitor impacts. This study responded to the need for additional visitor impact research, providing data for a variety of visitor impacts. This research also demonstrated that visitor impacts occurred across a diversity of protected area settings and environments, differing in level of visitation, access, and development.

Second, this research developed and demonstrated inexpensive, simple, quick, accurate and precise impact assessment procedures to evaluate trail and site impacts. These procedures can be employed by managers to systematically and objectively evaluate trail recreation and site impact problems, gather data for the purposes of trail and site condition assessment and monitoring, and guide managers in the selection of management strategies. Additionally, this research indicated that these procedures were applicable to most trails and sites, with the exception of condition class systems which were not applicable to constructed trails or sites.

Third, this research found that the amount of trail use at Torres del Paine influenced trail width increases and incision. Protected area managers in Central and South America have often restricted visitor use because it seems intuitive that increases in use should increase impact. However, Torres del Paine and other recreation ecology research has demonstrated that trail impacts are affected by multiple underlying factors, requiring multiple impact management strategies (Cole 1983; Leung and Marion 1996; Hammitt and Cole 1998). In this case, it is likely that management actions such as rerouting trail segments and maintenance efforts would more effectively minimize trail impacts than use limits.

Fourth, this research developed a new visitor impact assessment and management framework to represent an alternative to carrying capacity and the Limits of Acceptable Change. Managers indicated that setting visitor numbers (carrying capacity) was sometimes necessary due to limited available number of staff or facility capacities, but was not highly effective in reducing social and ecological impacts. Limits of Acceptable Change and other frameworks address many carrying capacity deficiencies but are costly and time consuming to implement. Therefore the PAIAM framework was developed to accommodate management constraints yet also address carrying capacity deficiencies, indicating that it may be the best option for protected area managers in Central and South America.

Study Limitations

This study focused on visitor impact assessment and management in Central and South America. The scope of this study did not include socio-cultural and economic impacts related to protected area visitation or other protected area management issues like infrastructure development, though it is recognized that these issues represent important facets of protected area management.

Like similar trail and site impact studies, this study is limited in its ability to assess the causal relationships of visitor impacts and in its ability to distinguish between environmental and human-related factors as they influence resource impacts (Cole 1987). This study also accepts certain limitations related to using simplified impact assessment procedures instead of more in-depth, detailed measurements of visitor impacts. However, this study was oriented and directed towards protected area managers to facilitate the development of visitor impact assessment and management programs in Central and South America.

This study purposively sampled twelve protected areas from four countries, representing only a small proportion of the total number of protected areas in Central and South America, and limiting our ability to extrapolate findings to other protected areas. Similarly, the purposive sampling of sites and trails used in the case study research (Chapter II) biased our findings towards impact and limited our ability to compare trail and site impact findings. However, our task was to characterize visitor impacts and provide qualitative and quantitative impact data, building upon previous case study research (see Boo 1990), and to integrate recreation ecology and visitor impact information into the ecotourism literature. Additionally, the impacts were observed across a diversity of protected areas, which may increase confidence in the representativeness of study findings.

Similarly, the Torres del Paine research (Chapter III) included only nine trail segments, although this represented 25% of the total trail system and random sampling provided from nine to twenty seven points per trail segment. Additionally, low use trails tended to be sampled only in grassland and valley areas, either as a function of sampling error or because such relationships exist between trail use, vegetation type and trail position. Some multicollinearity was identified between predictor variables, which confounded the interpretation of results. The consequences of multicollinearity are that findings may not be similar in repeat studies, or that these findings are not representative of trail impacts affecting other Central and South American protected areas.

The case study and Torres del Paine research assessed trail and site impacts, which reflected only soil and vegetation impacts. However, case study managers were also concerned about wildlife, water, attraction feature and other resource impacts, which were not assessed in this research.

This research also applied simplified trail and site impact assessment procedures in lieu of more detailed impact research and monitoring. The trade-offs of simplifying measurements might be reduced accuracy. However, a combination of procedures were used in both the Torres del Paine and case study research, which may have increased the validity of impact findings without greatly increasing the amount of field time required. Accuracy and precision can be increased in future impact assessment and monitoring studies by developing detailed monitoring manuals, training personnel to administer procedures, periodically examining inter-rater reliability, and refining procedures where necessary. As another limitation, this research did not address quality control issues related to the use of impact assessment procedures by protected area staff.

Other study limitations are related to the development of the PAIAM framework (Chapter IV). Information used to develop the framework was based on purposively sampled protected areas, and relied upon less than twenty interviews, possibly indicating that this framework is applicable only in the protected areas studied. However, these protected areas were fairly different in level of development, access and visitation, and also differed based on the types of issues and situations affecting protected area management. For example, some protected areas supported local people residing within their boundaries, some were co-managed by non-government and local organizations, and some had extensive experience applying and implementing decision-making frameworks. Another study limitation was that additional input from protected area managers was not sought after PAIAM was developed to examine content validity. However, it was experimentally applied in Mexico and has since been presented and discussed at various international conferences and meetings with protected area mangers, academicians, and non-government conservation organization staff.

Future Research

This dissertation sought to increase awareness about visitor impact problems and developed impact assessment procedures and management frameworks to address those problems for protected areas in Central and South America. Several areas of future research are suggested by this dissertation research.

First, further examination of visitor impacts affecting protected areas in Central and South America could increase the generalizability of dissertation findings. Survey research has already been conducted to identify some visitor impact problems in developing and developed countries, which could be used as models to develop detailed visitor impact questionnaires distributed to a large random sample of Central and South American protected areas (see Giongo et al. 1994; Machlis and Tichnell 1985; and Marion et al. 1993).

Second, additional research of trail and site impacts at other protected areas in Central and South America could assist protected area managers in selecting impact management strategies and contribute findings to the recreation ecology literature.

Third, impact assessment procedures could be developed to evaluate wildlife, water, attraction feature and other resource impacts. The development of such impact assessment procedures would require research to determine the nature of relationships between visitor activities and impacts. These procedures would also need to be tested and refined.

Fourth, further testing and experimental application of the rapid trail and site impact procedures developed by this research could result in a more thorough evaluation of their relative management utility, accuracy, precision, sensitivity, cost, and ease of application. Examining other issues like consistency in application, extent of staff training, and ability to record information correctly may also be of interest to managers to ensure quality control.

Fifth, trail impact monitoring at Torres del Paine could permit comparison between monitoring and dissertation impact findings and determine the extent of resource change. Recommendations for trail impact monitoring at Torres del Paine include adding low use trail segments in forested environments, replacing vegetation type with vegetation morphological characteristics, obtaining additional information regarding wind and rainfall, and further investigating the relationships between trail use, trail grade and trail incision.

Sixth, application and implementation of PAIAM in other protected areas in Central and South America are needed to examine its benefits and limitations.

CONCLUSION

Protected areas in Central and South America have experienced substantial visitation increases due to the rapid growth of ecotourism and nature-based travel. From the perspective of protected area managers, permitting protected area visitation is only one of many management goals, and may conflict with other management goals such as protecting natural resources or providing indigenous people with access to natural resources. The act of balancing these potentially conflicting goals requires management systems or frameworks (McCool 1994).

Additionally, protected area visitation results in a variety of natural resource impacts, diminishing certain protected area values, creating aesthetic impacts, and increasing management costs (Hammitt and Cole 1998). Recreation ecology and visitor impact management expertise and knowledge have been widely applied in developed countries to assess and manage visitor impact problems, but few examples exist of similar applications in Central and South America. Perhaps there is a lack of awareness about this information. Alternatively, protected area managers in Central and South America may be constrained by limited funding, staffing or lack other resources required to effectively implement existing visitor impact assessment and management programs.

This dissertation sought to increase the awareness about visitor impact problems and identify potential solutions to address those problems, and also proposed simple, cost effective impact assessment procedures and management frameworks that could be feasibly implemented in Central and South America. It is hoped that this dissertation contributed useful information about visitor impacts and impact management strategies to the protected areas studied. It is also hoped that this work will encourage additional research of visitor impacts and impact management in Central and South America, resulting in better informed visitor impact decision making.

REFERENCES

Adkison, G.P and M.T. Jackson (1996) Changes in ground-layer vegetation near trails in midwestern U.S. forests. *Natural Areas Journal* 16, 14-23.

Alamilla, M. (1998) *Personal communication*. Ministry of Fisheries, Hol Chan Marine Reserve, Manager, San Pedro, Ambegris Caye, Belize, 8/98.

Alderman, C.L. (1990) *A study of the role of privately owned lands used for nature tourism, education and conservation*. Washington DC: Conservation International.

Amend, S. and T. Amend (1992) Espacios sin habitantes? Parques nacionales de America del Sur. Caracas, Venezuela: *Nueva Sociedad*.

Anderson, D.H., D.W. Lime and T.L. Wang (1998) *Maintaining the quality of park resources and visitor experiences*. St Paul, MN: Cooperative Park Studies Unit, Department of Forest Resources, University of Minnesota.

Back, M. and O. Barry (1996) Costa Rica. In A.D. Nystrom and W. Smith (eds.) *Central America,* 2nd edition, pp. 359-444. New York, NY: Fodor's Travel Publications, Inc.

Backman, K.F. and T.D. Potts (1993) *Profiling nature-based travelers: Southeastern market segments*. Clemson, SC: Strom Thurmond Institute.

Bayfield, N.G., A. Watson and G.R. Miller (1988) Assessing and managing the effects of recreational use on British hills. In M.B. Usher and D.B.A. Thompson (eds.) *Ecological change in the Uplands,* pp. 399-414. Oxford, England: Blackwell Scientific Publications.

Bayfield, N.G. and R.J. Lloyd (1973) An approach to assessing the impact of use on a long distance footpath- the Pennine Way. *Recreation News Supplement* 8, 11-17.

Boo, E. (1990) *Ecotourism: The potentials and pitfalls,* Vol. 1. Washington, DC: World Wildlife Fund.

Borrie, W.T, S.F. McCool and G.H. Stankey (1998) Protected area planning principles and strategies. In K. Lindberg, M.E. Wood and D. Engeldrum (eds.) *Ecotourism: A guide for planners and managers*, 2nd ed., 133-154. North Bennington, VT: The Ecotourism Society.

Borrini-Feyerabend, G. (1997) *Participatory management of protected areas: Adapting the methods to the context*. Gland, Switzerland: International Union for the Conservation of Nature, Social Policy Group, 51.

Boucher, D.H., J. Aviles, R. Chepote, O.E. Dominguez-Gil and B. Vilchez (1991) Recovery of trailside vegetation from trampling in a tropical rainforest. *Environmental Management* 15, 257-62.

Bower, M. (1982) The forces that launched management consulting are still at work. *Journal of Management Consulting* 1(1), 4-6.

Boyd, S. and R.W. Butler (1996) Managing ecotourism: An opportunity spectrum approach. *Tourism Management* 17(8), 557-566.

Brown, K., R.K. Turner, H. Hameed and I. Bateman (1997) Environmental carrying capacity and tourism development in the Maldives and Nepal. *Environmental Conservation* 24(4), 316-325.

Bryan, R.B. (1977) The influence of soil properties on degradation of mountain hiking trails at Grovelsjon. *Geografiska Annaler* 59A, 49-65.

Buckley, R. and J. Pannell (1990) Environmental impacts of tourism and recreation in national parks and conservation reserves. *The Journal of Tourism Studies* 1(1), 24-32.

Burde, J.H. and J.R. Renfro (1986) Use impacts on the Appalachian Trail. In R.C. Lucas (Compiler) *Proceedings- National Wilderness Research Conference: Current Research,* pp. 138-143. Ogden, UT: USDA Forest Service, Intermountain Research Station, General Technical Report INT-212.

Burger, J. and M. Gochfeld (1998) Effects of ecotourists on bird behavior at Loxahatchee National Wildlife Refuge, Florida. *Environmental Conservation* 25(1), 13-21.

Butler, R.W. and L.A. Waldbrook (1991) A new planning tool: The tourism opportunity spectrum. *The Journal of Tourism Studies* 2(1), 4-14.

Canback, S. (1998) The logic of management consulting. *Journal of Management Consulting* 10(2), 3-22.

Ceballos-Lascurain, H. (1996) *Tourism, ecotourism, and protected areas*. Gland, Switzerland: International Union for the Conservation of Nature.

Chamberlain, K. (1997) Carrying capacity. *UNEP Tourism Newsletter* 8, 1-8.

Cifuentes, M. (1992) Determinacion de capacidad de carga turistica en areas protegidas. Turrialba, Costa Rica: World Wildlife Fund.

Clark, R.N. and G. Stankey (1979) *The recreation opportunity spectrum: A framework for planning, management, and research*. Seattle, WA: USDA Forest Service, Pacific Northwest Forest and Range Experiment Station, General Technical Report PNW-98.

Cole, D.N. (1983) *Assessing and monitoring backcounty trail conditions*. Ogden, UT: USDA

Forest Service, Intermountain Forest and Range Experiment Station, Research Paper INT-303.

Cole, D.N. (1991) *Changes on trails in the Selway Bitterroot Wilderness, Montana, 1978-89*. Ogden, UT: USDA Forest Service, Intermountain research Station, Research Paper INT-450.

Cole, D. N. (1988) *Disturbance and recovery of trampled montane grassland and forests in Montana*. Ogden, UT: USDA Forest Service, Intermountain Research Station.

Cole, D.N. (1990) Ecological impacts of wilderness recreation and their management. In J.C. Hendee, G.H. Stankey and R.C. Lucas (eds.) *Wilderness Management* , 2nd ed., pp. 425-466. Golden, CO: North American Press.

Cole, D.N. (1995) Experimental trampling of vegetation. I. Relationship between trampling intensity and vegetation response. *Journal of Applied Ecology* 32(2), 203-214.

Cole, D.N. (1987) Research on soil and vegetation in wilderness: A state of knowledge review. In R.C. Lucas (compiler) *Proceedings- National Wilderness Research Conference: Issues, State of Knowledge, Future Directions*, pp. 135-176. Ogden, UT: USDA Forest Service, Intermountain Research Station, General Technical Report INT-220.

Cole, D.N. (1982) *Wilderness campsite impacts: Effect of amount of use*. Ogden, UT: USDA Forest Service, Intermountain Forest and Range Experiment Station, Research Paper INT-284.

Cole, D.N. (1989) *Wilderness campsite monitoring methods: A sourcebook*. Ogden, UT: USDA Forest Service, Intermountain Research Station, General Technical Report INT-259.

Cole, D.N. (1996) Wilderness recreation in the United States. *International Journal of Wilderness* 2(3), 14-18.

Cole, D.N. and P.B. Landres (1996) Threats to wilderness ecosystems: Impacts and research needs. *Ecological Applications* 6(1), 168-184.

Cole, D.N. and S.F. McCool (1997) Limits of Acceptable Change and natural resource planning: When is LAC useful, when is it not? In S.F. McCool and D.N. Cole (eds.) *Proceedings-Limits of Acceptable Change and related planning processes: Progress and future directions*, 69-78. Ogden, UT: USDA Forest Service, Intermountain Research Station, General Technical Report, INT-371.

Cole, D.N. and D.R. Spildie (1998) Hiker, horse, and llama trampling effects on native vegetation in Montana, USA. *Journal of Environmental Management* 53, 61-71.

Cole, D.N. and S.J. Trull (1992) Quantifying vegetation response to recreational disturbance in the North Cascades, Washington. *Northwest Science* 66, 229-236.

Cole, D.N., M.E. Petersen and R.C. Lucas (1987) *Managing wilderness recreation use: Common problems and potential solutions*. Ogden, UT: USDA Forest Service, Intermountain Research Station, General Technical Report, INT-L30.

Coleman, R.A. (1981) Footpath erosion in the English Lake District. *Applied Geography* 1, 121-131.

CONAF (Corporacion Nacional Forestal) (1996) Plan de manejo: Parque Nacional Torres del Paine. *Santiago, Chile: Republica de Chile, Ministerio de Agricultura.*

Dale, D. and T. Weaver (1974) Trampling effects on vegetation of the trail corridors of north Rocky Mountain forests. *Journal of Applied Ecology* 11, 767-772.

Davis, J. and D. Whittington (1998) "Participatory" research for development projects: A comparison of the community meeting and household survey technique. *Economic Development and Cultural Change* 47(1), 73-94.

de Groot, K. (1998) Highlights from "The First Latin American Congress on National Parks and Other Protected Areas". *International Journal of Wilderness* 4(2), 7-11.

de Groot, R.S. (1983) Tourism and conservation in the Galapagos Islands. *Biological Conservation* 26, 291-300.

Deluca, T.H., M.A. Patterson, W.A. Freimund and D. N. Cole (1998) Influence of llamas, horses, and hikers on soil erosion from established recreation trails in Western Montana. *Environmental Management* 22, 255-262.

Dobles, J. (1998) *Personal communication.* Poas, Costa Rica: Ministerio del Ambiente y Energia, Sistema Nacional de Areas de Conservacion, Area de Conservacion Cordillera Volcanica Central, Parque Nacional Volcan Poas, Administrador, 8/98.

Edwards, S.N., W.J. McLaughlin and S.H. Ham (1998) *Comparative study of ecotourism policy in the Americas-1998.* Washington, DC: Inter-Sectoral Unit for Tourism Organization of American States.

Epler-Wood, M. (1998) *Meeting the global challenge of community participation in ecotourism: Case studies and lessons from Ecuador,* Working Paper No. 2. Arlington, VA: The Nature Conservancy.

Fennel, D.A. and P.F.J. Eagles (1990) Ecotourism in Costa Rica: A conceptual framework. *Journal of Park and Recreation Administration* 8(1), 23-34.

Ferris, T.M., K.A. Lowther and B.J. Smith (1993) Changes in footpath degradation 1983-1992: A study of the Brandy Pad, Mourne Mountains. *Irish Geography* 26, 133-40.

Frissell, S.S. (1978) Judging recreation impacts on wilderness campsites. *Journal of Forestry*

76(8), 481-483.

Furze, B., T. Delacy and J. Birkhead (1996) *Culture, conservation and biodiversity*. New York, NY: John Wiley & Sons.

Gakahu, C.G. (1992) *Tourist attitudes and use impacts in Maasai Mara National Reserve*. Nairobi, Kenya: Wildlife Conservation International.

Garland, G.C. (1987) Rates of soil loss from mountain footpaths: An experimental study in the Drakensberg Mountains, South Africa. *Applied Geography* 7, 41-54.

Getz, D. (1983) Capacity to absorb tourism: Concepts and implications for strategic planning. *Annals of Tourism Research* 10, 239-263.

Giongo, F., J. Bosco-Nizeye and G.N. Wallace (1994) *A study of visitor management in the world's national parks and protected areas*. Fort Collins, CO: College of Natural Resources, Colorado State University, The Ecotourism Society, and International Union for the Conservation of Nature.

Gomez-Pompa, A. and A. Kaus (1992) Taming the wilderness myth. *BioScience* 42(4), 271-279.

Graefe, A., F.R. Kuss, and J.J. Vaske (1990) *Visitor impact management: A review of research*. Washington, DC: National Parks and Conservation Association.

Graham R., P. Nilsen and R.J. Payne (1988) Visitor management in Canadian National Parks. *Tourism Management* 9(1), 44-62.

Gunn, C. (1979) *Tourism planning*. New York, NY: Crane Russak.

Hall, C.N. and F.R. Kuss (1989) Vegetation alteration along trails in Shenandoah National Park, Virginia. *Biological Conservation* 48, 211-227.

Hammitt, W.E. and D.N. Cole (1998) *Wildland recreation: Ecology and management*, 2nd edition. New York, NY: John Wiley & Sons.

Harriott, V.J., D. Davis and S.A. Banks (1997) Recreation diving and its impact in marine protected areas in eastern Australia. *Ambio* 26(3), 173-179.

Harroun, L.A. and E.A. Boo (1995) *The search for visitor carrying capacity*. Washington, DC: World Wildlife Fund.

Hayes, W.L. (1994) *Statistics*, 5th ed. Fort Worth, TX: Harcourt Brace College Publishers.

Helgath, S.F. (1975) *Trail deterioration in the Selway-Bitterroot Wilderness*. Ogden, UT: USDA Forest Service, Intermountain Forest and Range Experiment Station.

Hof, M. and D.W. Lime (1997) Visitor Experience and Resource Protection Framework in the

National Park System: Rationale, current status, and future direction. In S.F. McCool and D.N. Cole (eds.) *Proceedings-Limits of Acceptable Change and related planning processes: Progress and future directions*, 29-36. Ogden, UT: USDA Forest Service, Intermountain Research Station, General Technical Report INT-371.

Hoffman, A. J. and C. Alliende (1982) Impact of trampling upon the vegetation of Andean areas in Central Chile. *Mountain Research and Development* 2, 189-94.

Hunter, C. and H. Green (1995) *Tourism and the environment: A sustainable relationship?* London, England: Routledge.

ICT-Costa Rica Tourist Board (1998) *Naturally Costa Rica: The visitor guide to Costa Rica*. San Jose, CR: Costa Rican National Chamber of Tourism, the Costa Rica Tourist Board and the Costa Rican Investment and Development Board.

Inskeep, E. (1988) Tourism planning: An emerging specialization. *American Planners Association Journal*, Summer, 12-20.

(IUCN) International Union for the Conservation of Nature (1991) Ecotourism, special issue. *Parks* 2(3), 2-20.

Jacobson, S.K. and A.F. Lopez (1994) Biological impacts of ecotourism: Tourists and nesting turtles in Tortuguero National Park, Costa Rica. *Wildlife Society Bulletin* 22(3), 414-419.

Jacobson, S.K. and R. Robles (1992) Ecotourism, sustainable development, and conservation education: Development of a tour guide training program in Tortuguero, Costa Rica. *Environmental Management* 16(6), 701-713.

Johns, B.G. (1996) Responses of chimpanzees to habituation and tourism in the Kibale Forest, Uganda. *Biological Conservation* 78(3), 257-262.

Jubenville, A. and K. O'Sullivan (1987) Relationship of vegetation type and slope gradient to trail erosion in interior Alaska. *Journal of Soil and Water Conservation* 42, 450-452.

Kay, A.M. and M.J. Liddle (1989) Impact of human trampling in different zones of a coral reef. *Environmental Management* 13 (4), 509-520.

Kelley, R.E. (1970) Should you have an internal consultant? *Harvard Business Review* 57, 110-120.

Knight, R.L. and D.N. Cole (1991) Effects of recreational activity on wildlife in wildlands. In: *Proceedings, Trans Atlantic 56th North American Wildlands and Natural Resources Conference*, pp. 238-47.

Knight, R.L. and D.N. Cole (1995a) Factors that influence wildlife responses to recreationists. In R. L. Knight and K. J. Gutzwiller (eds.) *Wildlife and Recreationists: Coexistence*

Through Management and Research, pp. 71-80. Washington, DC: Island Press.

Knight, R.L. and D.N. Cole (1995b) Wildlife responses to recreationists. In R. L. Knight and K. J. Gutzwiller (eds.) *Wildlife and Recreationists: Coexistence Through Management and Research,* pp. 71-80. Washington, DC: Island Press.

Knight, R.L. and K.J. Gutzwiller (1995) *Wildlife and recreationists: Coexistence through management and research.* Washington, DC: Island Press.

Lance, A. R. Thaxton and A. Watson (1991) Recent changes in footpath width in the Cairngorms. *Scottish Geographical Magazine* 107, 106-9.

Lawrence, K. (1992) *Sustainable tourism development.* Paper presented at IV World Congress on National Parks and Protected Areas, February 10-21. Caracas, Venezuela.

Leitch, W. C.(1990) Torres del Paine. In *South America's National Parks*, pp. 191-200. Seattle, WA: The Mountaineers.

Lemky, K. (1996) *Review of methodologies for monitoring and assessing trail conditions in wilderness areas: Framework and recommendations for Cape Breton Highlands National Park,* Report for Contract #CBH-96-002. Ingonish Beach, Nova Scotia: Cape Breton Highlands National Park.

Leung, Y-F. and J.L. Marion (1999a) The influence of sampling interval on the accuracy of trail impact assessment. *Landscape and Urban Planning* 43, 167-179.

Leung, Y-F. and J.L. Marion (1999b) Assessing trail degradation in Great Smoky Mountains National Park: Application of a problem assessment method. *Environmental Conservation* 26(3).

Leung, Y-F. and J.L. Marion (1996) Trail degradation as influenced by environmental factors: A state of the knowledge review. *Journal of Soil and Water Conservation* 51(2), 13-136.

Leung, Y-F., J.L. Marion and T.A. Farrell (*in press)* The role of recreation ecology in sustainable tourism and ecotourism. *Paper presented at the Colloquium on Sustainable Tourism, The Seventh International Symposium on Society and Resource Management,* May 27-31, 1998. Columbia, Missouri.

Leung, Y-F., J.L. Marion and J.Y. Ferguson (1997) Methods for assessing and monitoring backcountry trail conditions: An empirical comparison. In David Harmon (ed.) *Making Protection Work: Proceedings of the 9th Conference on Research and Resource Management in Parks and on Public Lands, The 1997 George Wright Society Biennial Conference,* pp. 406-414. Hancock, Michigan: The George Wright Society.

Liddle, M.J. (1997) *Recreation ecology: The ecological impact of outdoor recreation and* *ecotourism.* London, England: Chapman and Hall.

Liddle, M.J. and L.D. Chitty (1981) The nutrient-budget of horse tracks on an English lowland heath. *Journal of Applied Ecology* 18, 841-8.

Liddle, M.J. and H.R.A. Scorgie (1980) The effects of recreation on freshwater plants and animals: A review. *Biological Conservation* 17, 183-206.

Lindberg, K. and S.F. McCool (1998) A critique of environmental carrying capacity as a means of managing the effects of tourism development. *Environmental Conservation* 25(4), 291-292.

Lindberg, K., M. Epler-Wood, and D. Engeldrum (1998) *Ecotourism: A guide for planners and managers,* Vol. 2. North Bennington, VT: The Ecotourism Society.

Lindberg, K., S. McCool and G. Stankey (1997) Rethinking carrying capacity. *Annals of Tourism Research* 24(2), 461-465.

Lindenmayer, C. (1992) *Trekking in the Patagonian Andes*. Oakland, CA: Lonely Planet Publications.

Loomis, L. and A.R. Graefe (1992) Overview of NPCA's visitor impact management process. *Paper presented at IV World Congress on National Parks and Protected Areas,* February 10-21. Caracas, Venezuela.

Lucas, R.C. (1990) Wilderness recreation management: A general overview. In: J. Hendee, G. Stankey and R. Lucas (eds.) *Wilderness Management*, pp. 401-420. Golden, CO: North American Press.

Magill, A.W. and R.H. Twiss (1965) *A guide for recording esthetic and biological changes with photographs*. Berkeley, CA: USDA Forest Service, Pacific Southwest Forest Experiment Station, Research Note PSW-77.

Mahler, R. and S. Wotkyns (1997) *Belize: Adventures in nature*. Santa Fe, NM: John Muir Publications.

Manning, R.E. (1979) Impacts of recreation on riparian soils and vegetation. *Water Resources Bulletin* 15, 30-43.

Manning, R.E. (1986) *Studies in outdoor recreation: Search and research for satisfaction*. Corvallis, Oregon: Oregon State University Press.

Mathieson, A. and G. Wall (1982) *Tourism: Economic, physical and social impacts*. London, England: Longman.

Marion, J.L. (1996) Access and management: Public land perplexities-balancing resource protection and recreation. In H. Kirchner (ed.) *National Outdoor Ethics Conference,* pp.

188-196. Gaithersburg, MD: Izaak Walton League of America.

Marion, J.L. (1994) *An assessment of trail conditions in Great Smoky Mountains National Park*. Atlanta, GA: USDI National Park Service, Southeast Region, Research Resources Management Report, VTCPSU/Supp 24.

Marion, J.L. (1991) *Developing a natural resource inventory and monitoring program for visitor impacts on recreation sites: A procedural manual*. Denver, CO: USDI National Park Service, Denver Service Center, NPS/NRVT/NRR91/06.

Marion, J.L. (1995) Environmental auditing: Capabilities and management utility of recreation impact monitoring programs. *Environmental Management* 19(5), 763-771.

Marion, J.L. and D.N. Cole (1996) Spatial and temporal variation in soil and vegetation impacts on campsites. *Ecological Applications* 6(2), 520-530.

Marion, J.L. and T.A. Farrell (1998) Managing ecotourism visitation in protected areas. In K. Lindberg and D. Englestrom (eds.) *Ecotourism Planning and Management*, pp. 155-182. North Bennington, VT: The Ecotourism Society.

Marion, J.L. and Y-F. Leung (1998) International recreation ecology research and ecotourism management. In W.E. Hammitt and D.N. Cole (eds.) *Wildland Recreation: Ecology and Management*, pp. 328-346. New York, NY: John Wiley & Sons, Inc.

Marion, J.L. and C.S. Rogers (1994) The applicability of terrestrial visitor impact management strategies to the protection of coral reefs. *Ocean & Coastal Management* 22, 153-163.

Marion, J.L., J.W. Roggenbuck and R.E. Manning (1993) *Problems and practices in backcountry recreation management: A survey of National Park Service managers*. Blacksburg, VA: USDI National Park Service, Mid-Atlantic Region, Cooperative Park Studies Unit, NPS/NRVT/NRR-93/12.

McCool, S.F. (1994) Planning for sustainable nature dependent tourism development: The Limits of Acceptable Change system. *Tourism Recreation Research* 19(2), 51-55.

McCool, S.F. and D.N. Cole (1997) Experiencing Limits of Acceptable Change: Some thoughts after a decade of implementation. In S.F McCool and D.N. Cole (eds.) *Proceedings-Limits of Acceptable Change and related planning processes: Progress and future directions*, 72-78. Ogden, UT: USDA Forest Service, Intermountain Research Station, General Technical Report INT-371.

McCool, S.F. and N.A. Christiansen (1996) Alleviating congestion in parks and recreation areas through direct management of visitor behavior. In D.W. Lime (ed.) *Crowding and congestion in the National Park System: Guidelines for management and research*, 67-83. MAES Misc. Pub. 86-1996. St Paul, MN: Department of Forest Resources and Minnesota Agricultural Experiment Station, University of Minnesota.

McCool, S.F. and G.H. Stankey (1992) Managing for the sustainable use of protected wildlands: The Limits of Acceptable Change framework. *Paper presented at IV World Congress on National Parks and Protected Areas*, February 10-21. Caracas, Venezuela.

McCoy, L.K., E.E. Krumpe and S. Allen (1995) Limits of Acceptable Change planning. *International Journal of Wilderness* 1(2), 18-22.

McEwen, D., D.N. Cole and M. Simon (1996) *Campsite impacts in four wildernesses in the South-Central United States*. Ogden, UT: USDA Forest Service, Intermountain Research Station, Research Paper INT-490.

McNeil, J. (1996) *Costa Rica: The rough guide*. London, England: Rough Guides Ltd.

Mieczkowski, Z. (1995) *Environmental issues of tourism and recreation.* Lanham, MD: University Press of America.

Montgomery, D.C. and E.A. Peck (1992) *Introduction to linear regression*, 2nd ed. New York, NY: John Wiley & Sons, Inc.

Nepal, S. (1999) *Tourism-induced environmental changes in the Nepalese Himalaya: A comparative analysis of the Everest, Annapurna, and Mustang Regions*. Ph.D. Dissertation. Berne, Switzerland: Centre for Development and Environment, Institute of Geography, University of Berne.

Newmark, W.D. and P.A. Nguye (1991) Recreational impacts of tourism along the Marangu route in Kilimanjaro National Park. In W. Newmark (ed.) *The Conservation of Mount Kilimanjaro*, pp. 47-51. Gland, Switzerland; International Union for the Conservation of Nature.

Norris, R. (1994) Ecotourism in the National Parks of Latin America. *National Parks* 1, 33-37.

Obua, J. and D.M. Harding (1997) Environmental impact of ecotourism in Kibale National Park, Uganda. *Journal of Sustainable Tourism.* 5(3), 213-23.

Onyeanusi, A.E. (1986) Measurements of impact of tourist off-road driving on grasslands in Maasai Mara National Reserve, Kenya: A simulation approach. *Environmental Conservation* 13(4), 325-329.

Peluso, N.L. (1993) Coercing conservation? The politics of state resource control. *Global Environmental Change* 6, 199-217.

Pimbert, M.P. and J.N. Pretty (1995) *Parks, people and professionals: Putting "participation" into protected area management*. Geneva, Switzerland: United Nations Research Institute for Social Development.

Pretty, J.N. (1994) Alternative systems of inquiry for sustainable agriculture. *IDS Bulletin* 25(2), 37-48.

Quinn, N.W., R.P.C. Morgan and A.J. Smith (1980) Simulation of soil erosion induced by human trampling. *Journal of Environmental Management* 10, 155-165.

Redford, K.H. and M. Ostria (1995) *Parks in peril source book.* Washington DC: America Verde, The Nature Conservancy.

Ricky, R. (1998) *Informant: Personal communication.* Santa Elena, Costa Rica: Centro Cientifico Tropical, Reserva Biologica Bosque Nuboso Monteverde, Guia, 8/98.

Ritter, D. (1997) Limits of Acceptable Change planning in the Selway-Bitterroot Wilderness: 1985 to 1997. In S.F. McCool and D.N. Cole (eds.) *Proceedings-Limits of Acceptable Change and related planning processes: Progress and future Directions*, 25-28. Ogden, UT: USDA Forest Service, Intermountain Research Station.

Salizar, J. (1998) *Informant: Personal communication*. Quepos, Costa Rica: Ministerio del Ambiente y Energia, Sistema Nacional de Areas de Conservacion, Area Conservacion Pacifico Central, Parque Nacional Manuel Antonio, Administrador, 8/98.

Salm, R.V. (1986) Coral reefs and tourist carrying capacity: The Indian Ocean experience. *UNEP Industry and Environment* January/February/March: 11-14.

Scott, P. (1998) *Informant: Personal communication*. Belize City, Belize: Belize Audubon Society, Protected Areas Manager, 8/98.

Shackley, M. (1998) *Visitor management: Case studies from World Heritage Sites*. Centre for Tourism and Visitor Management, Nottingham Trent University. Oxford, England: Butterworth/Heinemann.

Shelby, B. and T.A. Heberlein (1984) A conceptual framework for carrying capacity determination. *Leisure Sciences* 6(4), 433-451.

Shelby, B. and T.A. Heberlein (1986) *Carrying capacity in recreation settings*. Corvallis, OR: Oregon State University Press.

Shelby, B., J.J. Vaske and T.A. Heberlein (1989) Comparative analysis of crowding in multiple locations: Results from fifteen years of research. *Leisure Sciences* 11, 269-291.

Shindler, B. (1992) Countering the law of diminishing standards. In B. Shelby, G. Stankey, and B. Shindler (eds.) *Defining wilderness quality: The role of standards in wilderness management-A workshop proceedings*, 53-60. Portland, Oregon: USDA Forest Service, Pacific Northwest Research Station, General Technical Report PNW-305.

Smith, P.J. (1994) Identifying research priorities in developing countries. *Agricultural Systems* 45, 455-468.

Sorokin, Y. I. (1993) *Coral reef ecology*. Berlin, Germany: Springer-Verlag.

Stankey, G.H. and S.F. McCool (1990) Managing for appropriate wilderness conditions: The carrying capacity issue. In J.C. Hendee, G.H. Stankey and R.C. Lucas (eds.) *Wilderness Management*, 215-240. Golden, CO: North American Press.

Stankey, G.H. and S.F. McCool (1992) Managing for the sustainable use of protected wildlands: The Limits of Acceptable Change Framework. *Paper presented at the Iv^th^ World Congress on National Parks and Protected Areas, Caracas, Venezuela.*

Stankey, G.H., D.N. Cole, R.C. Lucas, M.E. Petersen and S.S. Frissell (1985) *The Limits of Acceptable Change (LAC) system for wilderness planning*. Ogden, UT: USDA Forest Service, Intermountain Forest and Range Experiment Station, General Technical Report INT-176.

Summer, R.M. (1986) Geomorphic impacts of horse traffic on montane landforms. *Journal of Soil and Water Conservation* 35, 85-87.

Sun, D. and M.J. Liddle (1993) A survey of trampling effects on vegetation and soil in eight tropical and subtropical sites. *Environmental Management* 17(4), 497-510.

Sweeting, J.E.N., A.G. Bruner and A.B. Rosenfeld (1999) *The green host effect: An integrated approach to sustainable tourism and resort development*. Washington, DC: Conservation International, Policy Papers.

Tenorio, R. (1998) *Informant: Personal communication.* San Jose, Costa Rica: Ministerio del Ambiente y Energia, Sistema Nacional de Areas de Conservacion, Area de Conservacion Cordillera Volcanica Central, Oficina de Investigaciones Cientificas, Director, 8/98.

Turner, M.D. (1999) Conflict, environmental change, and social institutions in dryland Africa: Limitations of the community resource management approach. *Society and Natural Resources* 12, 643-657.

Unpublished data TDP (Torres del Paine) (1997) *Estadistica general*. Puerto Natales, Chile: Corporacion Nacional Forestal, Parque Nacional Torres del Paine, Programa Recreacion.

USDI National Park Service (1997) *VERP: A summary of the Visitor Experience and Resource Protection (VERP) framework.* Denver, CO: USDI National Park Service, Denver Service Center, .

Wagar, J.A. (1964) *The carrying capacity of wild lands for recreation*. Washington, DC: Society of American Foresters.

Wall, G. (1997) Is ecotourism sustainable? *Environmental Management* 21, 483-491.

Wallace, G.N. (1994) Visitor management: Lessons from Galapagos National Park. In K. Lindberg and D.E. Hawkins (eds.) *Ecotourism: A guide for planners and managers*, pp. 55-81. North Bennington, VT: The Ecotourism Society.

Wallace, G.N. (1993) Wildlands and ecotourism in Latin America. *Journal of Forestry* 91(2), 37-40.

Wallace, R. (1998) *Informant: Personal communication*. Crooked Tree, Belize: Department of Archeology, Altun Ha Mayan ruin, Manager, 8/98.

Wallin, T.R. and C.P. Harden (1996) Estimating trail-related soil erosion in the humid tropics: Jatun Sacha, Ecuador, and La Selva, Costa Rica. *Ambio* 25(8), 517-522.

WED. (1987) Our common future. In *Report of the World Commission on Environment and Development, The Brundtland Commission*. Oxford, England: Oxford University Press.

Welch, D.M. and J. Churchill (1986) *Hiking trail conditions in Pangnirtung Pass, 1984, Baffin Island, Canada*. Ottawa, Canada: Parks Canada

Western, D. (1986) Tourist capacity in East African parks. *UNEP Industry and Environment.* 1, 14-16.

Westhoff, V. (1967) The ecological impact of pedestrian, equestrian, and vehicular traffic on flora and vegetation. In *Towards a New Relationship of Man and Nature in Temperate Lands. Part I: Ecological Impact of Recreation and Tourism Upon Temperate Environments*, pp. 218-223. Morges, Switzerland: International Union for Conservation of Nature and Natural Resources.

Wight, Pamela A. (1996) North American ecotourism markets: Motivations, preferences and destinations. *Journal of Travel Research* 35(1), 3-9.

Williams, P. (1994) Frameworks for assessing tourism's environmental impacts. In B. Ritchie and C. Goeldner (eds.) *Travel, Tourism, and Hospitality Research*. New York, NY: John Wiley & Sons Inc.

Wolters, T.M. (1991) *Tourism carrying capacity*. Paris, France: WTO/UNEP.

Woodley, S. (1993) Tourism and sustainable development in parks and protected areas. In J.G. Nelson (ed.) *Tourism and Sustainable Development*, 1st ed., pp. 83-96. Waterloo, Canada: Department of Geography, University of Waterloo.

World Tourism Organization (WTO) (1991) *Tourism trends*. Madrid, Spain.

World Tourism Organization (WTO) (1997) *Yearbook of tourism statistics*, Vol. 1. Madrid, Spain.

TABLES

Table 1. Examples of literature findings related to visitor activity impacts on natural resources.

Resources Affected	VA[1]	Impact	Related Findings in the Literature	Citations
			General References	(Cole 1987; Kuss et al. 1990; Liddle 1997)
Trails and Recreation sites	HI CA HB OR	Creation of trails and campsites	ORV trail proliferation at Maasai Mara National Reserve, Kenya.	(Onyeanusi 1986)
			Campsite proliferation in four wilderness areas in South-central USA	(McEwen et al. 1996)
		Degradation of trails	Vegetation cover loss, soil compaction, trail widening, trail incision and soil loss, muddiness, and multiple treads.	(Leung and Marion 1996; Marion et al. 1993)
		Degradation of campsites and other recreation sites	Excessive site area, vegetation cover loss, soil compaction, mineral soil exposure, damaged trees, and exposed roots at Kibale National Park, Uganda and Delaware Water Gap Recreation Area, PA, USA.	(Obua and Harding 1997; Marion and Cole 1996)
			Decreased ground vegetation height, cover and biomass, and altered species composition in tropical and temperate regions.	(Cole 1995; Sun and Liddle 1993)
			General References	(Knight and Cole 1991; Knight and Gutzwiller 1995)
Wildlife	HI CA HB OR VW PW	Disturbance /Harassment	Decreased feeding and foraging time in the presence of tourists for water-birds at Loxahatchee National Wildlife Refuge, FL, USA.	(Burger and Gochfeld 1998)
		Habituation	Habituation of chimpanzees to tourists at Kibale National Park, Uganda.	(Johns 1996)
		Feeding /Attraction	Garbage dumps and litter at campsites, altering normal feeding habits and attracting bears, deer, birds, rodents and insects.	(Hammitt and Cole 1998)
		Injury or death	Handling and trampling green turtle hatchlings at Tortuguero National Park, Costa Rica.	(Jacobson and Lopez 1994)
			General References	(Hammitt and Cole 1998)
Water	HI CA HB OR MB NM	Physical pollution	Turbulence and turbidity, sedimentation, and oil, gas, soaps and fecal matter discharges in lakes, rivers and streams in Britain.	(Liddle and Scorgie 1980)
		Biological pollution	Pathogenic bacteria, viruses and protozoa from human waste disposal findings in Grand Teton National Park, OR and other parks.	(Kuss et al. 1990)

1-Visitor Activities: **HI**=hiking, **CA**=camping, **HB**=horseback riding, **OR**=off-road vehicle use, **VW**=viewing wildlife, **PW**=photographing wildlife, **MB**=motorized boat use, **NM**=non-motorized boat use

Table 2. Attributes and characteristics of protected areas[1] selected for case studies in Costa Rica and Belize.

Protected Area Name & Location[2]	Size (ha)	Annual Visitation	Development/ Management	Primary Visitor Activities	Managing Agency	Primary Attractions
Braulio Carrillo National Park, CR 20 km NE of San Jose	≈46,000	13,801	Few facilities/ <5 staff	Sightseeing, hiking, wildlife viewing	Natl. Park Service	Rainforests, mountains, wildlife
Community Baboon Sanctuary, BE 48 km NW of BE City	5,180	≈3,000	Few facilities/ <5 staff	Wildlife viewing, hiking	NGO – local	Black howler monkeys
Altun Ha, BE 50 km N of BE City	1,036	≈15,000	Moderate facilities/ <5 staff	Exploring ruins	Dept. of Archeology	Mayan ruins
Hol Chan Marine Reserve, BE 40 km NE of BE City	1,295	≈40,000	Moderate facilities/ <10 staff	Snorkeling, Diving	Minister of Agriculture & Fisheries	Coral reefs, marine life
Tortuguero National Park, CR 400 km NW of San Jose	71,212	18,946	Moderate facilities/ <10 staff	Wildlife viewing, boat tours	Natl. Park Service	Sea turtles, estuaries, wildlife
Manuel Antonio National Park, CR 275 km S of San Jose	55,682	114,922	Extensive facilities/ <20 staff	Sunbathing, hiking, wildlife viewing	Natl. Park Service	Beaches, forests, wildlife
Monteverde Cloud Forest Reserve, CR 160 km NW of San Jose	10,522	≈50,000	Extensive facilities/ <20 staff	Wildlife viewing, hiking, sightseeing	NGO – research	Cloudforests, wildlife
Volcan Poas National Park, CR 55 km NW of San Jose	≈5,600	215,930	Extensive facilities/ <20 staff	Viewing volcanic craters, hiking	Natl. Park Service	Volcanic craters, dwarf cloudforest

1 - Information was gathered from interviews and available protected area statistics.
2 - CR: Costa Rica, BE: Belize

Table 3. Condition class rating system applied to trails and recreation sites in case study protected areas in Costa Rica and Belize.

Condition Class Definitions	
Class 0	Trail or site barely distinguishable; no or minimal disturbance of vegetation and/or organic litter.
Class 1	Trail or site distinguishable; slight loss of vegetation cover and/or minimal disturbance of organic litter.
Class 2	Trail or site obvious; vegetation cover lost and/or organic litter pulverized in primary use areas.
Class 3	Vegetation cover lost and/or organic litter pulverized within the center of the tread or site, some bare soil exposed.
Class 4	Nearly complete or total loss of vegetation cover and organic litter within the tread or site, bare soil widespread.
Class 5	Soil erosion obvious, as indicated by exposed roots and rocks and/or gullying.

Adapted from Frissel1 (1978) and Marion (1991).

Table 4. Summary of trail condition class and point sampling results for case study protected areas in Costa Rica and Belize.

Impact Indicators	Protected Areas and Locations Affected						
	Braulio Carrillo National Park	**Community Baboon Sanctuary**	**Manuel Antonio National Park**		**Monteverde Cloud Forest Reserve**		**Volcan Poas National Park**
Trail Names:	Las Palmas 1767 m	Bremudian Landing 564 m	Entrance 861 m	Puerto Escondito 946 m	Bosque Eterno 549 m	Rio Chomorgo 615 m	Crater 620 m
Condition Class (0-5)	4.5	3.5	4.0	NA	NA	NA	3.0
Composition (%)					Missing	Missing	
Bare soil	40.6	55.6	90.0	10.7	Data	data	33.1
Litter	14.3	21.7	10.0	5.3	---	---	8.5
Vegetation	0	22.8	0	0	---	---	2.2
Gravel	3.7	0	0	20.7	---	---	34.2
Cement/lattice	7.4	0	0	63.3	---	---	12.2
Wood Planking	35.6	0	0	0	---	---	10.2
Visitor Created Trails (# per sampling point)	2	0	11	4	0	0	0
Incision (cm**)**							
Median	4.5	5.1	3.8	0	0	0	0
Min-Max	0-25	0-13	0-18	0-38	0	0-13	0
N	28	9	12	15	9	10	10
Width (cm)							
Mean (std. dev)[1]	71.9 (21.6)	126.2 (41.7)	252.3 (68.7)	87.7 (43.1)	127.0 (37.5)	91.7(19.7)	157.2 (7.6)
Range	26-117	81-213	152-386	58-198	84-188	84-147	150-175
N	28	9	12	15	9	10	10

1. *Standard deviation.*

Table 5. Summary of trail problem assessment results for case study protected areas in Costa Rica and Belize.

Impact Indicators	Protected Areas and Locations Affected				
	Braulio Carrillo National Park	**Community Baboon Sanctuary**	**Monteverde Cloud Forest Reserve**		**Volcan Poas National Park**
TRAIL NAMES:	Las Palmas 1767 m	Bremudian Landing 564 m	Bosque Eterno 549 m	Rio Chomorgo 615 m	Crater 620 m
Excessive Erosion (> 15 cm)					
Occurrences (#)	25	3	0	0	0
Total lineal distance (m)	241	13	0	0	0
Total lineal distance (%)	13.6	2.3	0	0	0
Exposed Roots					
Occurrences (#)	12	1	1	1	0
Total lineal distance (m)	318	5	69	7	0
Total lineal distance (%)	18.0	0.9	12.6	1.1	0
Multiple Trails					
Occurrences (#)	1	2	0	0	0
Total lineal distance (m)	8	12	0	0	0
Total lineal distance (%)	0.5	2.1	0	0	0
Muddy Soil					
Occurrences (#)	9	0	0	0	0
Total lineal distance (m)	40	0	0	0	0
Total lineal distance (%)	2.3	0	0	0	0
Excessive Width (>1 m width increase)					
Occurrences (#)	0	2	10	2	0
Total lineal distance (m)	0	6	130	6	0
Total lineal distance (%)	0	1.1	23.8	1.0	0
Running Water on Trail					
Occurrences (#)	0	1	0	0	0
Total lineal distance (m)	0	4	0	0	0
Total lineal distance (%)	0	0.7	0	0	0

Table 6. Summary of recreation site condition class and multi-indicator impact assessment system for case study protected areas in Costa Rica and Belize.

Impact Indicators	PROTECTED AREAS AND LOCATIONS AFFECTED			
	Altun Ha-Archeological site	**Manuel Antonio National Park**		**Volcan Poas National Park**
Recreation Site Names:	Ruin plaza	Picnic Area-entrance	Picnic Area-concessionaire	Crater viewing area
Condition Class (0-5)	1	4	4	NA
Composition (100%)	Vegetation	Bare soil	Bare soil	Graveled
Site Size (m^2)	2,828,020 (283 ha)	812	717	1,129
Vegetation Cover Loss (%)	10	91	91	NA
Exposed soil (%)	10	71	71	NA
Damaged Trees (#)	0	1	2	0
Exposed Roots (#)	0	0	0	0
Litter (%)	0	0	5	0

Table 7. Trail segment names, location of sub-segments sampled and use category for Torres del Paine trails.

Trail Segment Names (Total Length)	Location of Sub-Segments Sampled (each is 3.5 kilometers long)	Use Level[1]
Saramiento Lake to Amarga Lake (5.5km)	None sampled	Medium
Amarga Lake to Paine Lake (24km)	None sampled	Low
Paine Lake to Refugio Dickson (8.5km)	None sampled	Low
Refugio Dickson to Los Perros camp (8.5 km)	Dickson West to Camp Los Perros	Low
Los Perros camp to El Paso camp (5.5 km)	None sampled	Low
El Paso camp to Refugio Grey (5km)	Refugio Grey North to El Paso camp	High
Refugio Grey to Refugio Pehoe (12km)	Refugio Pehoe North to Refugio Grey	High
Refugio Pehoe to Brtianico and Italiano (10km)	Britancio Camp South to Italiano Camp	Medium
Refugio Lago Pehoe to administration (17km)	Refugio Pehoe South to the administration	Medium
Amarga Lake to Torres lodge to lookout (16km)	Chileno Camp North to towers	Medium
	Torres Camp South to Las Torres lodge	High
Guardaria Grey Lake to Pingo Lake (15km)	Guardia Grey North to Refugio Pingo	Low
	Refugio Zapata South to Refugio Pingo	Low

1. *Note that use categories may differ within trail segments. Unpublished data TDP, 1997.*

Table 8. Means, medians, ranges and percentiles for trail substrate conditions stratified by amount of use for Torres del Paine trails.

	Impact Indicators[1] (%)				
	Organic Litter	**Exposed Soil**	**Muddy Soil**	**Vegetation**	**Rock**
Low Use (N=32)					
Median[2]	5	60	0	0	0
Range	0-100	0-100	0-0	0-100	0-30
95th Percentile	90	97	0	100	24
Medium Use (N=33)					
Median	0	58	0	0	13
Range	0-95	0-100	0-95	0-0	0-100
95th Percentile	76	100	33	0	100
High Use (N=33)					
Median	0	65	0	0	15
Range	0-50	0-100	0-90	0-0	0-100
95th Percentile	22	100	90	0	93

1. *Impacts categorized as "other" are not included since no values were recorded for this category.*
2. *Medians are presented because data were not normally distributed.*
3. *Percentiles represent the value below which 95% of the observations fall.*

Table 9. Means, standard deviations and ranges for impact indicators stratified by amount of use for Torres del Paine trails.

	Impact Indicators[1]			
	Informal Trails (#)	**Trail Width (cm)**	**MIC (cm)**	**MIP (cm)**
Low Use (N=32)				
Mean	4	44	1	8
Standard Deviation	3.0	12.3	1.1	7.5
Range	0-13	27-85	0-4	0-30
Medium Use (N=33)				
Mean	5	54	2	11
Standard Deviation	4.9	16.2	2.0	7.5
Range	0-16	22-85	0-10	0-32
High Use (N=33)				
Mean	6	67	3	15
Standard Deviation	4.8	30-2	1.9	9.3
Range	0-23	31-151	0-10	2-37

1. *The secondary trails indicator is omitted as transformations failed to satisfy normal distribution requirements.*

Table 10. One-way analysis of variance (ANOVA) for impact indicators stratified by amount of use.

	Impact Indicators			
	Informal Trails (#)	**Trail Width (cm)**	**MIC (cm)**	**MIP (cm)**
Use Level	Mean Values[1]			
Low (N=32)	4[a]	44[a]	1[a]	8[a]
Medium (N=33)	5[a]	54[b]	2[b]	11[a]
High (N=33)	6[a]	67[b]	3[b]	15[b]
ANOVA	Test Statistic Values			
df[2]	2	2	2	2
F Ratio	1.70	9.77	5.03	6.43
p value	.189	.000	.008	.002

1- *Original means are presented though ANOVAs for informal trails and trail width are based on transformed data. Superscripts following mean values refer to results from Tukey's HSD multiple comparison test (p=.05) between group means. Mean values in the same column with different letters are significantly different.*
2- *Degrees of Freedom for between subjects effects.*

Table 11. T-test for impact indicators for medium levels of use stratified by vegetation type.

	Impact Indicators			
	Informal Trails (#)	**Trail Width (cm)**	**MIC (cm)**	**MIP (cm)**
Vegetation Type	Mean Values[1]			
Forested (N=18)	3	59	3	10
Grassland (N=11)	10	47	2	13
T Test	Test Statistic Values[2]			
df	24	27	27	27
T value	-5.10	1.76	.34	-1.50
p value	.000	.090	.734	.145

1- *T-Tests for informal trails and trail width are based on transformed data.*
2- *T and p values are based on equal variances using Levene's Test for Equal Variances and use two-tailed values.*

Table 12. Two-way analysis of variance (ANOVA) for impact indicators stratified by amount of use and trail position.

Trail Position by Amount of Use	Impact Indicators			
	Informal Trails (#)	Trail Width (cm)	MIC (cm)	MIP (cm)
Low Use	Mean Values[1]			
Valley (N=27)	3	44	1	9
Midslope (N=4)	8	48	1	5
Medium Use				
Valley (N=16)	7	54	2	8
Midslope (N=17)	2	54	2	13
High Use				
Valley (N=10)	7	60	3	16
Midslope (N=23)	6	70	3	15
Two-Way ANOVA	Test Statistic Values			
df	5	3	3	3
F Ratio	5.38	1.20	.100	2.19
Model p Value	.005	.319	.959	.069
Use Level p Value	.251	.145	.592	.022
Trail Position p Value	.452	.627	.835	.477
Interaction p value	.000	.585	.874	.251

1. *Original means are presented though Two-Way ANOVAs for informal trails and trail width are based on transformed data.*

Table 13. Two-way analysis of variance (ANOVA) for impact indicators stratified by amount of use and trail grade.

Trail Grade by Amount of Use	Impact Indicators			
	Informal Trails (#)	Trail Width (cm)	MIC (cm)	MIP (cm)
Low Use	Mean Values[1]			
0-5 ^{o} (N=18)	3	43	1	5
6-10 ^{o} (N=7)	4	41	2	9
11-15 ^{o} (N=2)	4	59	3	10
>15^{o} (N=5)	4	43	2	19
Medium Use				
0-5 ^{o} (N=13)	7	48	2	9
6-10 ^{o} (N=4)	6	61	2	9
11-15 ^{o} (N=7)	3	53	2	10
>15^{o} (N=8)	4	60	4	15
High Use				
0-5 ^{o} (N=12)	3	69	2	14
6-10 ^{o} (N=10)	6	56	3	14
11-15 ^{o} (N=4)	7	73	2	14
>15^{o} (N=7)	7	75	4	21
Two-Way ANOVA	Test Statistic Values			
df	11	11	11	11
F Ratio	.898	2.43	2.63	3.36
Model p Value	.546	.011	.006	.001
Use Level p Value	.283	.010	.383	.028
Trail Grade p Value	.994	.487	.032	.000
Interaction p Value	.406	.567	.386	.748

1. Original means are presented though Two-Way ANOVAs for informal trails and trail width are based on transformed data.

Table 14. Significant effects for impact indicators after controlling for other variables for examining trail impacts at Torres del Paine.

	Impact Indicators			
	Informal Trails (#)	**Trail Width (cm)**	**MIC (cm)**	**MIP (cm)**
Inventory Indicators	Indicator Effect After Controlling for Other Variables[1]			
Use Level[2]	No	No/Yes[3]	No	Yes
Vegetation Type	Yes	No	No	No
Trail Position	No	No	No	No
Trail Grade	No	No	Yes	Yes

1- "yes" indicates a significant effect and "no" indicates no significant effect.
2- Use level effect is examined in two-way ANOVAs for use trail position and use* trail grade.*
3- *No significant effect was found for trail position but a significant effect was found for trail grade.*

Table 15. Critique of carrying capacity, alternative decision-making frameworks and the proposed framework using criteria developed from interview information and the literature.

Evaluation Criteria	**Positive(+) and Negative (--) Attributes**		
	Carrying Capacity	*Alternative Frameworks*	*Proposed Framework[1]*
1. Easy, quick, inexpensive and cost-effective to implement.	+	--	+
2. Able to successfully assess and/or minimize visitor impacts.	--	+	+/--
3. Considers multiple underlying causes of impacts.	--	+	+/--
4. Encourages selection of a variety of management actions.	--	+	+
5. Produces defensible decisions.	--	+	+
6. Separates technical information from value judgements.	--	+	+
7. Encourages public involvement and shared learning.	--	+	+
8. Incorporates local resource uses and resource management issues.	--	+	+

1- +/- indicates both positive and negative evaluation.

FIGURES

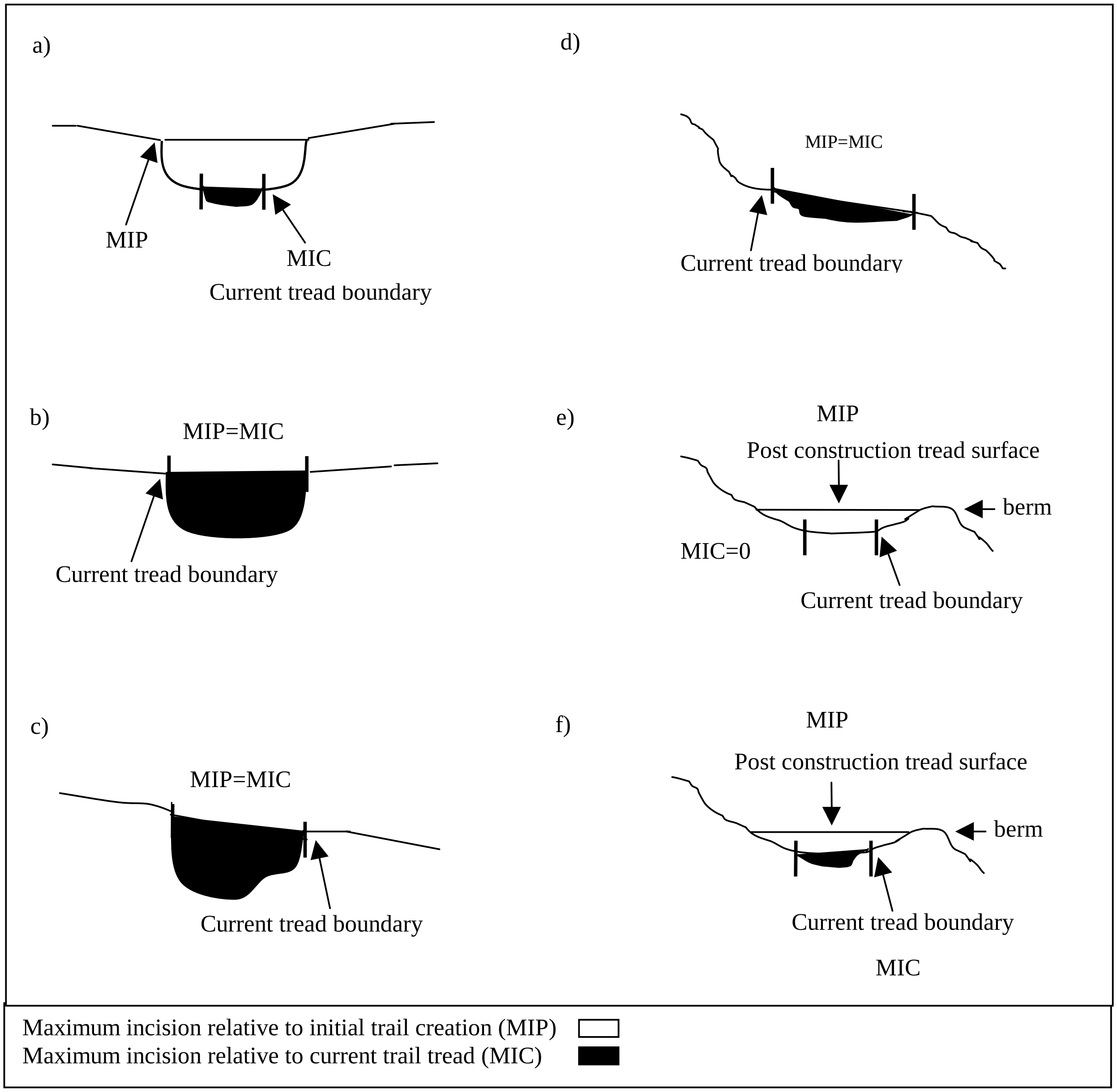

Figure 1. Diagrams of alternative trail incision measurements. *Diagrams illustrate trail tread incision measurements in situations where no cut and fill work was performed (a-c) (characteristic of many Torres del Paine trails), and in locations where sidehill construction required the excavation of substrate to create a tread surface (d-f).*

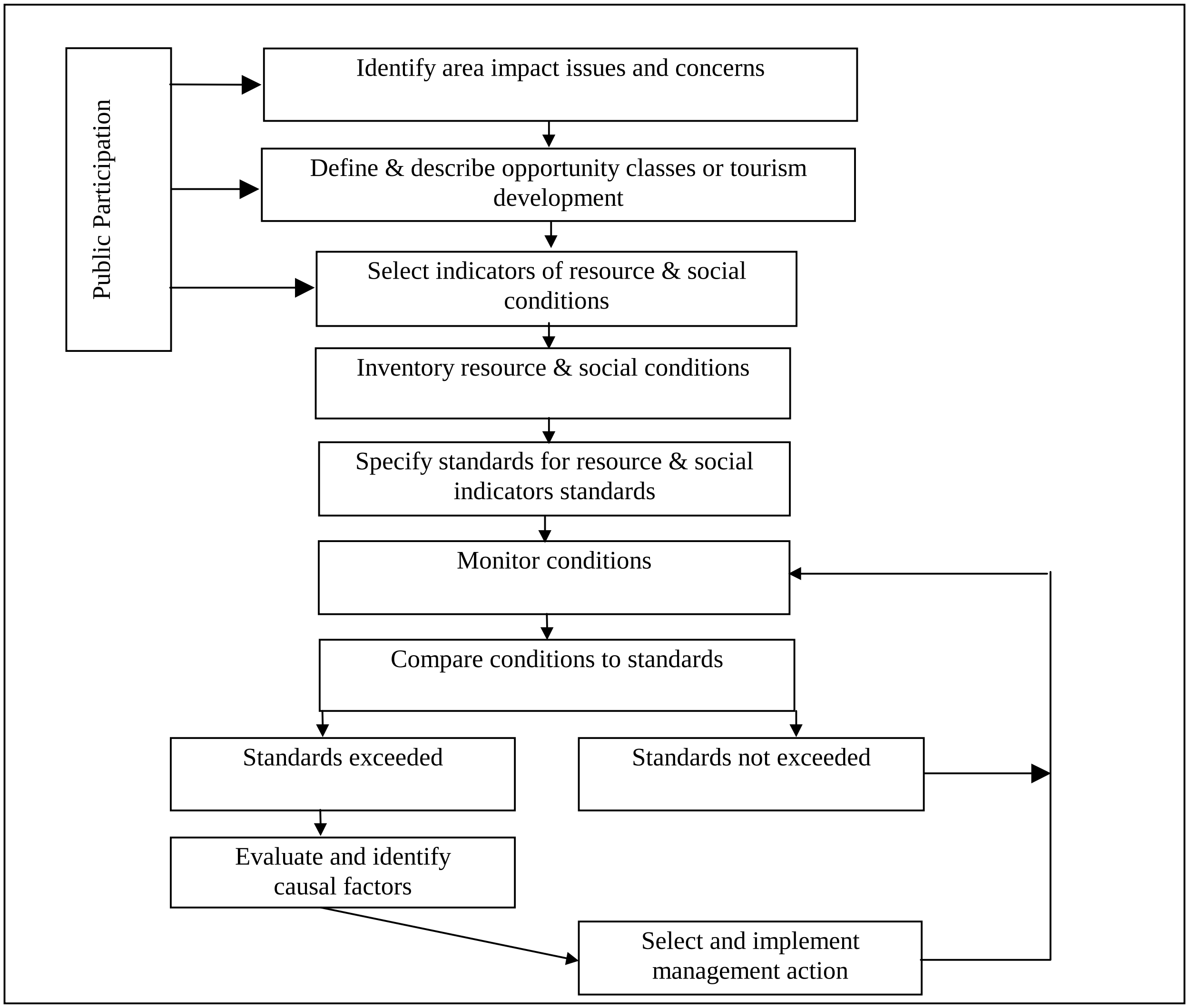

Figure 2. Schematic illustrating LAC, VIM, and VERP planning and management frameworks. Adapted from Marion 1991.

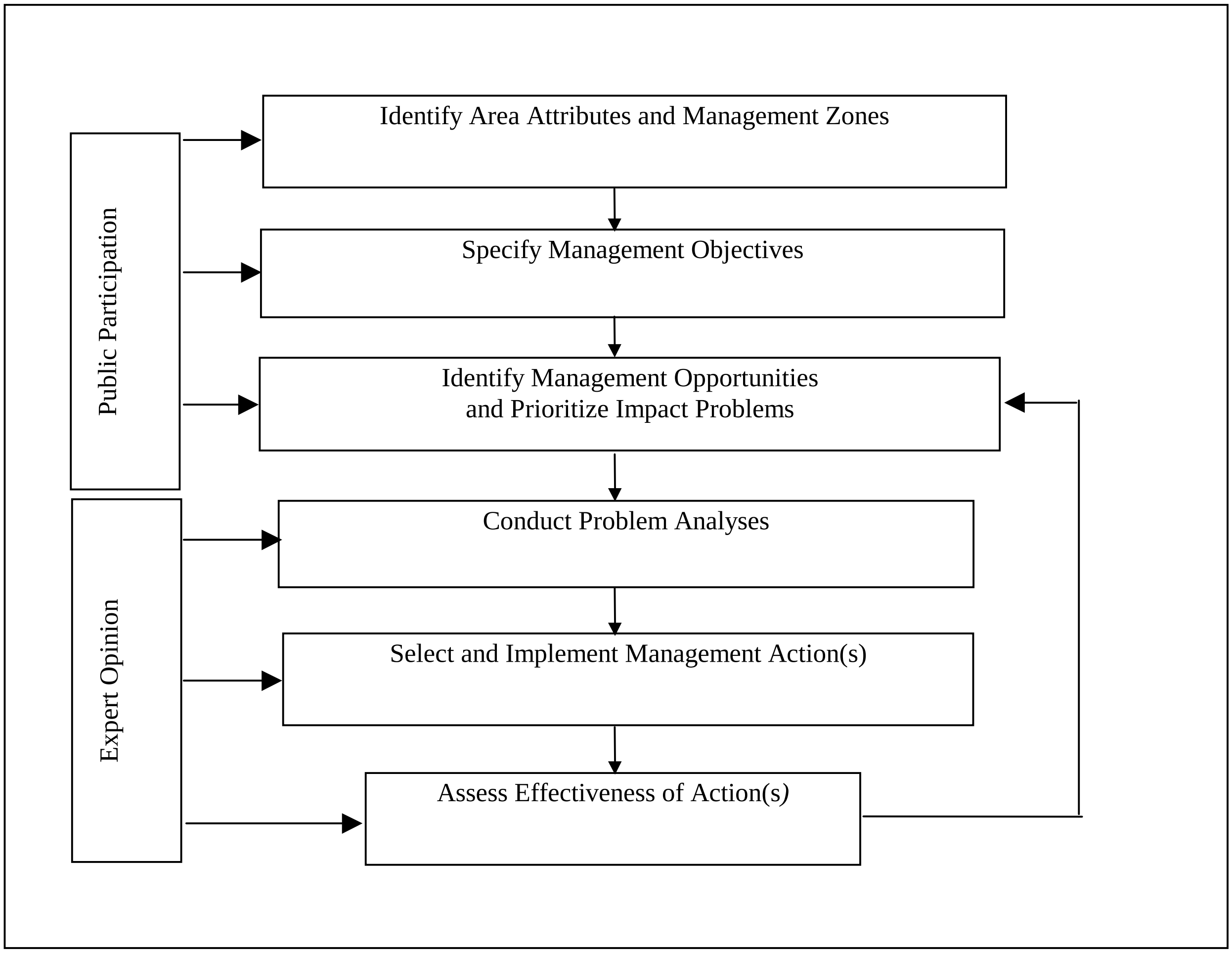

Figure 3. Protected Areas Impact Assessment and Management Framework (PAIAM).

APPENDIX I. CASE STUDY MANUAL FOR CONDUCTING INTERVIEWS AND APPLYING RAPID ASSESSMENT PROCEDURES.

INTERVIEWS

Information Collected Prior to Site Visit

Background information will be gathered through library searches of the literature and by requesting and reviewing park literature to capture the following information:

- DESCRIPTION OF PROTECTED AREA: Including physical and environmental characteristics and natural and cultural resource attractions.

- DESCRIPTION OF USE: Including origin of visitors, visitation by month (historical data by year if available), and common visitor activities. Descriptions of the primary visitor attractions, their locations and accessibility, and types of visitor impacts will also be requested to help us plan the site visits.

- SCALE OF DEVELOPMENT, ACCESS, AND MANAGEMENT INTENSITY: Level of infrastructure development and description of facilities, predominant forms of visitor access, and protected area staff and functions.

Interview with Managers

Our preferred schedule was to interview a protected area manager immediately following arrival, conduct visits to the most popular visitor attractions or to those attractions that have visitor impact management problems. The interview would be used to identify managers' perceptions of what visitor related impacts affect the protected area's resources and to describe any management actions applied to reduce these impacts.

During the interview, managers will be asked to:

- IDENTIFY IMPACT PROBLEMS: Managers will be provided with a comprehensive list of potential visitor impacts (Figure 1). Based on their experience, perceptions, and judgement they will be asked to characterize the frequency and severity of each visitor impact affecting their protected area. The specific locations of the most prevalent or severe impacts will be also be identified to guide site visits.

- EXPLAIN POTENTIAL UNDERLYING CAUSES OF IMPACTS: Managers will be asked to describe the potential influence of environmental elements (e.g. vegetation type or topography) and of use-related elements (e.g. amount of use, type of use, group or party size, and visitor and guide behaviors related to impacts) for the most prevalent or severe resource impacts.

- DISCUSS USE OF MONITORING PROGRAMS AND DECISION-MAKING FRAMEWORKS: Managers will be asked to describe their knowledge or use of any visitor impact monitoring programs and decision-making frameworks such as carrying capacity or Limits of Acceptable Change.

The interview data form is presented as figure 2.

RAPID ASSESSMENT PROCEDURES FOR TRAIL AND SITE IMPACTS

Using the checklist of potential impact problems (Figure 1), impacts will be assessed by observing site conditions and through qualitative and quantitative measurement techniques. Specific attention will be given to the more prevalent or severe trail and site impact problems identified by managers

Assessment techniques will include a combination of written descriptions, qualitative assessments, and quantitative measurements. We also developed and field tested efficient measurement procedures to quantify visitor-related trail and site impacts for a number of common problems, such as those listed in Figure 1. These indicators, such as area of soil exposure at attraction sites or depth of erosion on trails, can be incorporated into management frameworks such as the Limits of Acceptable Change. Standards may then be set and monitored for these indicators, providing a decision framework to guide managers in selecting and evaluating the effectiveness of appropriate impact management strategies and tactics.

Trail Impact Assessment

Trail measurements are taken at sample points located at a standard interval, every 70 meters, along the trail. Distances are measured with a trail measuring wheel. At sample points a variety of measures are made to characterize the trail's condition at that point. These data are then computer input and summarized to characterize the condition of the entire trail segment. During future assessments it is not necessary to relocate the same sample points for repeat measures.

The principal objective of these procedures is to quantify and monitor visitor-related trail impacts that occur following trail construction.

The sampling interval can be adjusted to better characterize shorter trails or trails with diverse conditions. Generally, about 15-20 sample points should be assessed to characterize conditions on a typical trail, 25-30 should be assessed for trails with diverse tread conditions. For example, if accurate monitoring of tread erosion is a primary objective and trail erosion on a particular trail varies widely (say from 0 to 4 feet), then a large number of sample points are needed to accurately detect changes in tread erosion over time. Trail distance can be divided by the desired number of sample points to determine the sampling interval. However, for longer trails a standard sampling interval of no longer than 1000 feet will permit evaluations of shorter trail segments.

Materials

Survey procedures manual   Measuring wheel   Topographic maps   Wire flags (4)   Telescoping pointer
Tape measure (12ft)   Clipboard   Pencils   Field forms   Tent pole (shock-corded) with a line level taped to a middle segment

Survey Procedures for Trail Point Sampling

Record data for all indicators. Push the measuring wheel along the middle of the tread with even handling so that it does not bounce or skip in rough terrain. Lift the wheel over logs and larger rocks, adding distance manually where necessary to account for the horizontal distance over which the wheel was lifted. Your objective is to accurately measure the distance of the primary trail tread. As you hike be sure to monitor the wheel counter and stop at your specified sampling interval to conduct the sampling point measures. If you go over this distance stop immediately and conduct your sampling at that point, recording the actual distance from the wheel, not the "missed" distance. Most measuring wheels do not permit you to backtrack to take feet off the counter. See Figure 3 Form A for the data form.

1) **Protected Area Name**: Record the protected area name.

2) **Trail Name:** Record the trail segment name from the trail listing sheets.

3) **Condition Class Assessment**: Using the classification system presented in Figure 4, select a condition class rating for each trail.

4) **Distance:** In the first column record the distance from the beginning of the trail segment to the sample point in meters from the measuring wheel counter. If measuring wheel units are in something other than meters then record that number and clearly label the form with the conversion from these units to meters.

5) **Informal Trails (IT):** Sum and record your tallies of informal or visitor-created trails that intersected with the survey trail since the last sample point (*do not count formal trails or roads of any type*). Informal trails are trails that visitors have created to access streams, scenic attraction features, camping areas, or other features or to cut switchbacks. Count both ends of any informal trails that loop out and return to the survey trail. Include animal or game trails as these are often indistinguishable from human trails and their true origin is likely unknown. This indicator is intended to provide an approximation of the number and extensiveness of unofficial trailing in the vicinity of the survey trail.

6) **Tread Width (TW):** From the sample point, extend a line transect in both directions perpendicular to the trail tread. Identify the endpoints of this trail tread transect as the most pronounced boundary of visually obvious human disturbance created by visitor use. These boundaries are defined as pronounced changes in ground vegetation height (trampled vs. untrampled), cover, composition, or, when vegetation cover is reduced or absent, as pronounced changes in organic litter (intact vs. pulverized). Your objective is to define the trail tread that receives the majority (>75%) of traffic, selecting the most visually obvious boundary that can be most consistently identified by other trail surveyors. The presence of bedrock, boulders, tree trunks, or other odd situations may require boundary placements based on areas adjacent to the actual transect that are more representative of the trail tread width in the vicinity of the sampling point.

Include all secondary treads (see #7) within the transect unless there are undisturbed areas between treads (as defined by the tread boundary definition). In this latter case, establish the transect and conduct measurements for the primary tread. Temporarily place wire flags at the boundary points. Measure and record the length of the transect (the tread width) to the nearest centimeter (e.g. 57 centimeter).

7-12) **Tread Condition Characteristics:** Along the trail tread width transect estimate to the nearest 10% (5% where necessary) the cumulative lineal length occupied by any of the mutually exclusive tread surface categories listed below. **Be sure that your estimates sum to 100%**.

Bare Soil:	All soil types including sand and organic soils, excluding organic litter unless it is highly pulverized and occurs in a thin layer or smaller patches over bare soil.
Organic Litter:	Surface organic matter including intact or partially pulverized leaves, needles, or twigs that mostly or entirely cover the tread substrate.
Vegetation :	Live vegetative cover including herbs, grasses, mosses, and low-growing shrubs that are rooted within the tread boundaries. Ignore all overhanging vegetation.
Gravel:	Naturally-occurring rock surfaces (bedrock, boulders, rocks, cobble, or natural gravel). If rock or native gravel is embedded in the tread soil estimate the percentage of each and record separately.
Cement/Lattice:	Cement or lattice blocks placed on trails for shielding purposes.
Wood:	Human-placed wood planking

13) **Maximum Incision, Post Construction (MIP):** Study the trail tread surface and try to judge or estimate the original post-construction tread surface. Extend and use the shock-corded tent pole as a measurement aid. In

flat terrain simply lay the tent pole down so that it approximates the level of the substrate (below vegetation or litter) on either side of the trail tread. In sloping terrain, place one end of the pole directly on the substrate of the berm (lower slope side of trail). If possible, adjust the other end so that the pole extends across the tread and is level as indicated by the attached line level bubble. If the trail is outsloped and you can determine the post construction tread surface then place the tent pole to mimic that surface regardless of the reading on the line level. Manually adjust the pole to compensate for any downward bowing and use the tape measure to determine and record (nearest inch) an estimate of the maximum incision from the pole to the deepest portion of the trail tread. Measure to the surface of the tread's substrate, not the tops of rocks or the surface of mud puddles. In other words, your objective is to record a measure that reflects the maximum amount of soil that has been compacted or eroded from the tread following original trail creation.

Survey Procedures for Trail Problem Assessment

Use form B (Figure 5) and require surveyors to record the distance at which the trail attributes and features are located. In the beginning distance column record the cumulative trail distance from the measuring wheel to the beginning distance of the impact. In the ending distance column record the cumulative trail distance from the measuring wheel to the end of the impact.

14) **Wet Soil**: Record for trail sections which exhibit temporary, seasonally, or permanently wet or boggy soils on more than half the width of the tread. We soils typically occur in low areas, depressions or are associated with hillside seeps. Mudholes and other situations with standing water should be assessed with this parameters.

15) **Running Water on Trail**: Sections of tread greater than two meters in length traversed by moving water from intercepted seeps, springs, or small streams. Disregard water in lateral drainage ditches.

16) **Multiple Treads**: Recorded the beginning and ending points where multiple treads diverge from a single tread and are parallel to the main tread. Record this parameter only when multiple treads are obvious, typically separated by some feature which divides the trail into two of more treads.

17) **Excessive Width**: Record when the trail exhibits a greater than two meter expansion in width that is clearly attributable to recreation al uses, such as walking/riding around tree falls, wet of muddy areas, eroded areas, multiple treads, etc. Trail boundaries, like campsite boundaries, areas indicated by pronounced changes in ground vegetation cover, composition, and height, or organic litter.

18) **Excessive Erosion**: Sections of tread greater than two meters in length with soil erosion exceeding 15 centimeters in depth from the estimated post construction tread surface. Careful attention to the general natural contour of the land in adjacent off-trail areas and to telltale clues regarding the surface of the original tread location and subsequent erosion is necessary. In particular, look for large rocks or boulders and tree roots whose tops were likely at the original trail surface but, through subsequent erosion, have been exposed more fully.

19) **Root Exposure**: Record for trail sections exhibiting severe tree root exposure such that the tops and sides of many roots are exposed.

Site Impact Assessment

Two general approaches are used for assessing recreation site conditions: 1) a condition class assessment determined by visual comparison with six described levels of recreation site impact, and 2) predominantly measurement-based assessments of several impact indicators. These procedures require two trained field staff about 15 minutes to assess a typical site. See Figure 6 for data form.

For the purposes of this manual, recreation sites are defined as areas of disturbed vegetation, surface litter, or soils caused by overnight camping or intensive day-use recreation activities such as observation points or other areas that attract concentrated visitor use. In areas with multiple sites there may not always be undisturbed areas separating sites and an arbitrary decision may be necessary to define separate sites to simplify application of measurement procedures.

Site re-measurement - Due to phenological and recreation site use changes which occur over the use season, it is critical that recreation sites be re-measured as close to the initial assessment month and day as possible, preferably within 1 to 2 weeks.

Materials

Topographic maps — Tape measure (100 feet in tenths or 30 meters) — Flagged wire pins
Clipboard, monitoring manual, field forms (some on waterproof paper), pencils

Survey Procedures for Site Impact Assessment

General Recreation Site Information

1) **Protected Area Name**: Record the name of the protected area.

2) **Name of Site**: Record the name of the site of describe it so that it can be clearly identified in re-measurement.

3) **Locate/Label Recreation Site on Topo Map**: Mark the topographic map with a dot precisely indicating the recreation site's location and label with its site number. Be as accurate as possible. For example, on a 1/24,000 scale map, 1/4 inch on map = 500 ft. on ground.

4) **Site Location/Description**: On separate paper, describe the site's location using local geographic features and measure distances by pacing where necessary. Use sufficient descriptive detail so that someone else five years later could relocate the recreation site. Draw area maps for campgrounds or other larger areas where needed to differentiate sites when clustered together. Area map should illustrate the relative locations of each recreation site.

Inventory Indicators

5) **Surface Type**: Record the percentage of the site falling into each of the following surface types:
Paved of graveled
Bedrock
Soil
Vegetation
Other (name)

Impact Indicators

The first step is to establish the recreation site's boundaries and measure its size. Walk around the recreation site to identify the outer boundaries, based on pronounced changes in vegetation cover, vegetation height/disturbance, vegetation composition, surface organic litter, and topography. Many recreation sites with dense forest overstories will have very little vegetation and it will be necessary to identify boundaries by examining changes in organic litter, i.e. leaves which are untrampled and intact vs. leaves which are pulverized or absent. In defining the recreation site boundaries be careful to include only those areas which appear to have been disturbed from human trampling. Natural factors such as dense shade can create areas lacking vegetative cover. Do not include these areas if they appear "natural" to you. When in doubt, it may also be helpful to speculate on which areas typical visitors might use based on factors such as slope or rockiness. Project recreation site boundaries straight across areas where trails enter the recreation site.

These procedures describe the use of the **Geometric Figure Method** for determining site size. This method involves superimposing one or more imaginary geometric figures (rectangles, circles, or triangles) on the site boundaries and measuring appropriate dimensions to calculate its total area (refer to the illustrations shown below). This method is relatively rapid and can be quite accurate if applied with good judgement. Begin by carefully studying the recreation site's shape, as if you were looking down from above. Mentally superimpose and arrange one or more simple geometric figures to closely match the recreation site boundaries. Any combination and orientation of these figures is permissible, see the examples below. On the back of the field form sketch the site and the geometric figures used. Measure and record (nearest 1/10th meter) the dimensions necessary for computing the area of each geometric figure. Conduct area computations in the office with a calculator to reduce field time and minimize errors.

Good judgement is required in making the necessary measurements of each geometric figure. As boundaries will never perfectly match the shapes of geometric figures, you will have to mentally balance disturbed and undisturbed areas included and excluded from the geometric figures used. For example, in measuring an oval recreation site with a rectangular figure, you would have to <u>exclude</u> some of the disturbed area along each side in order to balance out some of the undisturbed area <u>included</u> at each of the four corners. We recommend temporary placement of wire flags at the corners of each geometric figure to facilitate taking measurements. Be sure that the opposite sides of rectangles or squares are the same length.

<u>Measure Island and Satellite Areas.</u> Identify any undisturbed "islands" of vegetation inside recreation site boundaries (often due to clumps of trees or shrubs) and disturbed "satellite" use areas outside recreation site boundaries (often due to tent sites or cooking sites). Use recreation site boundary definitions for determining the boundaries of these areas. Use the **Geographic Figure Method** to determine the areas of these islands and satellites and label these on the back of the field form as well.

6) **<u>Condition Class</u>**: Record a recreation site Condition Class using the descriptions above. If a recreation site is underlain entirely by bedrock or sand, record "-1" for this item and others that are not applicable for this type of recreation site. Include an explanation in the field form "Comments."

7) **<u>Vegetative Ground Cover Onsite</u>**: An estimate of the percentage of live vegetative ground cover (including herbs, grasses, mosses, tree seedlings, saplings, and shrubs) less than 4 feet in height within the recreation site boundaries using the coded categories listed below (refer to photographs following these procedures). <u>Include any disturbed "satellite" use areas and exclude undisturbed "islands" of vegetation.</u> For this and the following two indicators, it is often helpful to narrow your decision to two categories and concentrate on the boundary that separates them. For example, if the vegetation cover is either category 2 (21-40%) or category 3 (41-60%), you can simplify your decision by focussing on whether vegetative cover is greater than 40%.

	1 = 0-20%	2 = 21-40%	3 = 41-60%	4 = 61-80%	5 = 81-100%
Midpoints:	10	30.5	50.5	70.5	90.5

8) **Vegetative Ground Cover Offsite**: An estimate of the percentage of live vegetative ground cover (including herbs, grasses, and mosses and excluding tree seedlings, saplings, and shrubs) in an adjacent but largely undisturbed "control" area. Use the codes and categories listed above. The control site should be similar to the recreation site in slope, tree canopy cover (extent of sunlight penetration), and other environmental conditions. The intent is to locate an area which would closely resemble the recreation site area had the site never been used. In instances where you cannot decide between two categories, select the category with less vegetative cover. The rationale for this is simply that the first visitors would have selected a recreation site with the least amount of vegetation.

9) **Exposed Soil**: An estimate of the percentage of exposed soil, defined as ground with very little or no organic litter (partially decomposed leaf, needle, or twig litter) or vegetation cover, within the recreation site boundaries and satellite use areas. Dark organic soil, the decomposed product of organic litter, should be assessed as bare soil when its consistency resembles peat moss. Assessments of exposed soil may be difficult when organic litter forms a patchwork with areas of bare soil. If patches of organic material are relatively thin and few in number, the entire area should be assessed as bare soil. Otherwise, the patches of organic litter should be mentally combined and excluded from assessments. Code as for vegetative cover above.

10) **Tree Damage**: Tally each "damaged" live tree (>3 cm diameter at 3 meters.) within or on recreation site boundaries, excluding satellite use areas. Damaged trees are defined as trees with broken or cut limbs or trunk scars from axes or knives. Assessments are restricted to trees within the recreation site boundaries in order to promote consistency with future measurements. Multiple tree stems from the same species which are joined at or above ground level should be counted as one tree when assessing damage to any of its stems. Assess a cut stem on a multiple-stemmed tree as tree damage, not as a stump. Do not count tree stumps as tree damage. Include only damage that is clearly human-caused i.e. obvious axe or saw cuts, disregard old scars whose cause cannot be determined and scars from animal antler rubbing or lightning strikes.

11) **Root Exposure**: Tally each live tree (>3 cm diameter at 3 meters) with exposed roots within or on recreation site boundaries, excluding satellite use areas. Trees with root exposure must have at least the top half of many major roots exposed >0.5 meters from base of tree. Assessments are restricted to trees within the recreation site boundaries in order to promote consistency with future measurements. Where obvious, do not include trees with roots exposed by natural causes (e.g., erosion due to river flooding).

12) **Litter/Trash**: Estimate the percentage of a single garbage bag (15 Liter size) or number of bags that could be filled with recreation-related litter from the recreation site, including adjacent offsite areas. Use decimals to indicate fractions of a bag (e.g. 0.5 equals half a bag). Record a 0 if the recreation site is clean or has only a handful of smaller items.

13) **Total Recreation site Area**: Using a calculator in the office, calculate the recreation site size using the data recorded on the back of the form for each geometric figure used. Use the appropriate formulas. Sum the areas of each figure and enter the total on the front of the form.

Comments: An informal list of comments concerning the recreation site: note any assessments that you felt were particularly difficult or subjective, problems with monitoring procedures or their application to this particular recreation site, suggestions for clarifying monitoring procedures, descriptions of particularly significant impacts, or any other comments you feel may be useful.

*** Collect all wire flags and other equipment.**

Campsite Impacts
- vegetation cover loss
- vegetation compositional change
- tree and shrub damage/loss
- soil exposure/erosion
- excessive site size
- multiple fire sites
- user-constructed facilities
- campsite proliferation
- other

Cultural or Natural Attraction Impacts
- vegetation cover loss
- vegetation compositional change
- tree and shrub damage/loss
- soil exposure/erosion
- excessive area of disturbance
- damage to attraction features
- other

Trail Impacts
- soil erosion/rutting
- trail widening
- braided of multiple treads
- excessive trail muddiness
- proliferation of undesired trails
- excessive root exposure
- other

Road Impacts
- soil erosion/rutting
- road widening
- braided or multiple track roads
- excessive road muddiness
- proliferation of undesired roads
- other

Water Impacts
- biological contamination
- chemical contamination
- sedimentation pollution
- other

Wildlife Impacts
- harassment/disturbance of wildlife
- displacement of wildlife from important habitats
- attraction/feeding of wildlife
- disturbance of threatened/endangered species
- other

Litter/ Fecal Matter
- excessive litter
- improperly disposed human fecal matter
- horse/packstock manure

Visitor Crowding/Conflict
- crowding at popular features
- crowding along trails
- crowding on lakes/rivers (boats)
- conflicts between groups of tourists
- incompatible visitor activities
- other

Inappropriate visitor behavior
- theft
- vandalism
- illegal collecting of plants, animals, or artifacts

Adapted from Cole, Petersen and Lucas 1987.

Figure 1. List of potential impact problems.

Protected Area Name ______________________________

Subject title or position______________________

1) Briefly describe the nature of visitation to your protected area- origin of visitors, number of visitors, recreation opportunities, etc.

2) Discuss the role of local peoples in your protected area- are their local people living within the protected area boundaries? Is there a shared use of park facilities e.g., trails? If so, what percentage? Is there conflict between visitors, management, and local peoples?

3) Identify visitor related impact problems. Managers will be provided with a comprehensive list of potential visitor impacts (Figure 1). Which four or five are the most prevalent in your protected area? If possible, rank them from "1" as the most significant impact to "5" as the least.

4) Explain potential underlying causes of the most four or five severe resource impacts. Describe the potential influence of environmental elements (e.g. vegetation type or topography) and of use-related elements (e.g. amount of use, type of use, group or party size, and visitor and guide behaviors related to impacts).

5) Discuss the use of monitoring programs to guide impact decision making.

6) Discuss both informal and formal means of making decisions related to visitor impact management. Discuss your familiarity with decision-making frameworks used in other parks.

7) Rank the major constraints or limitations related to implementing preferred management strategies (e.g. funding, conflicts with local resident, political issues, personnel expertise, language barriers).

Figure 2. Interview data form.

Protected Area Name _______________________Trail Name____
Date______________________________________Condition Class Rating ____________________________________

Dist	IT	TW	Tread Condition Characteristics (Sum to 100%)										MIP
			Bare Soil	Organic Litter		Vegetation		Gravel	Cement/ Lattice		Wood Planking		
			10	20	30	40	50	60	70	80	90	100	

Codes:
- Dist = Wheel Distance
- IT = Informal Trails
- TW = Tread Width
- MIP = Maximum Incision, Post Trail Creation

Figure 3. Form A: Trail condition class and point sampling data form.

Condition Class Definitions	
Class 0	Trail or site barely distinguishable; no or minimal disturbance of vegetation and/or organic litter.
Class 1	Trail or site distinguishable; slight loss of vegetation cover and/or minimal disturbance of organic litter.
Class 2	Trail or site obvious; vegetation cover lost and/or organic litter pulverized in primary use areas.
Class 3	Vegetation cover lost and/or organic litter pulverized within the center of the tread or site, some bare soil exposed.
Class 4	Nearly complete or total loss of vegetation cover and organic litter within the tread or site, bare soil widespread.
Class 5	Soil erosion obvious, as indicated by exposed roots and rocks and/or gullying.

Adapted from Fissel1 (1978) and Marion (1991).

Figure 4. Condition class rating system applied to trails and recreation sites.

Protected Area Name _________________________ Trail Name______________________________________

Name of Impact	Impact Lineal Extent	
	Distance Begin	Distance End

Names of Impacts:

Wet soil
Running water on trail
Multiple treads
Excessive width
Excessive erosion
Root exposure

Figure 5. Form B: Trail problem assessment data form.

General Recreation Site Information

1) Protected Area Name.________________________ 2) Name of Site_______________________________

3) Locate/Label Site on Map_____________________ 4) Write Site Location/Campground Descriptions

____

Inventory Indicators

5) Surface Type: Record the percentage of the site falling into each of the following surface types:

Paved or graveled	______________________
Bedrock	______________________
Soil	______________________
Vegetation	______________________
Other _____	______________________

Impact Indicators

6) Condition Class (0 to 5) ______________

7) Vegetative Ground Cover Onsite (Use categories below) ______________

(**1**=0-20% **2**=21-40% **3**=41-60% **4**=61-80% **5**=81-100%

Midpoints: 10 30.5 50.5 70.5 90.5

8) Vegetative Ground Cover Offsite (Use categories above) ______________

9) Exposed Soil (Use categories above) ______________

10) Damaged Trees

Slightly (tally) ______________

Moderate (tally) ______________

Severe (tally) ______________

11) Root Exposure, Tally ______________

12) Litter/Trash ______________

13) Total Recreation Site Area (Office) ____________ft^2

Geometric Figure Method data for site and satellite/island sites:

Figure 6. Site condition assessment data form.

Appendix II. Trail Monitoring Manual

Torres del Paine National Park, Chile
Description of Procedures
(*version 12/97*)

This manual describes standardized procedures for conducting an assessment of resource conditions on recreation trails. The focus of these procedures is on obtaining quantifiable measures of vegetation and soil disturbance. They do not include procedures for evaluating impacts to water quality, wildlife, or cultural features. These trail monitoring procedures rely on a sampling approach to accurately characterize trail conditions. Trail measurements are taken at sample points located at a standard interval, every 300 meters, along the surveyed trail segment. Distances are measured with a trail measuring wheel. At sample points a variety of measures are made to characterize the trail's condition at that point. These data are then computer input and summarized to characterize the condition of the entire trail segment. During future assessments it is not necessary to relocate the same sample points for repeat measures.

The principal objective of these procedures is to quantify and monitor visitor-related trail impacts that occur following trail construction.

Materials

Survey procedures manual	Measuring wheel	Topographic maps	Wire flags (4)	Telescoping pointer
Tape measure (12ft)	Clipboard	Pencils	Field forms	

Tent pole (shock-corded) with a line level taped to a middle segment

Survey Procedures

Record data for indicators on the data form (Figure 1, Form A). Push the measuring wheel along the middle of the tread with even handling so that it does not bounce or skip in rough terrain. Lift the wheel over logs and larger rocks, adding distance manually where necessary to account for the horizontal distance over which the wheel was lifted. Your objective is to accurately measure the distance of the primary trail tread. As you hike be sure to monitor the wheel counter and stop at your specified sampling interval to conduct the sampling point measures. If you go over this distance stop immediately and conduct your sampling at that point, recording the actual distance from the wheel, not the "missed" distance. Most measuring wheels do not permit you to backtrack to take feet off the counter.

1) **Trail Segment Code:** Record a trail segment code (can be added later).

2) **Trail Name/Location:** Record the trail segment name and describe location (also mark on a map).

3) **Surveyors:** Record name(s) of trail survey crew.

4) **Use Type (UT):** Record the type of use permitted on the trail. This may be recorded after measuring other indicators for trail segments if desirable. Categories will vary, examples include: Tourist Hiking (TH), Tourist Horseback Riding (TR), Local Resident Travelway (LT), and Mixed Tourist and Local Uses (MU).

5) **Use Level (UL):** Record the level of use (high, medium, low) this trail segment receives as estimated by park managers. Document boundaries of use estimates as number of trail users per some unit of time for future reference.

6) **Distance:** In the first column record the measuring wheel distance from the beginning of the trail segment to the

sample point.

7) **<u>Informal Trails (IT):</u>** Sum and record your tallies of informal or "visitor-created" trails that intersected with the survey trail since the last sample point (*do not count formal trails or roads of any type*). Informal trails are trails that visitors have created to access streams, scenic attraction features, camping areas, or other features or to cut switchbacks. Count both ends of any informal trails that loop out and return to the survey trail. Include animal or game trails as these are often indistinguishable from human trails and their true origin is likely unknown. This indicator is intended to provide an approximation of the number and extensiveness of unofficial trailing in the vicinity of the survey trail.

8) **<u>Tread Width (TW):</u>** From the sample point, extend a line transect in both directions perpendicular to the trail tread. Identify the endpoints of this trail tread transect as the most pronounced boundary of visually obvious human disturbance created by visitor use. These boundaries are defined as pronounced changes in ground vegetation height (trampled vs. untrampled), cover, composition, or, when vegetation cover is reduced or absent, as pronounced changes in organic litter (intact vs. pulverized). Your objective is to define the trail tread that receives the majority (>75%) of traffic, selecting the most visually obvious boundary that can be most consistently identified by other trail surveyors. The presence of bedrock, boulders, tree trunks, or other odd situations may require boundary placements based on areas adjacent to the actual transect that are more representative of the trail tread width in the vicinity of the sampling point.

Include all secondary treads within the transect unless there are undisturbed areas between treads (as defined by the tread boundary definition). In this latter case, establish the transect and conduct measurements for the primary tread. Temporarily place wire flags at the boundary points. Measure and record the length of the transect (the tread width) to the nearest centimeter (or inch).

9-18) **<u>Tread Condition Characteristics:</u>** Along the trail tread width transect estimate to the nearest 10% (5% where necessary) the cumulative lineal length occupied by any of the mutually exclusive tread surface categories listed below. **Be sure that your estimates sum to 100%**.

S-Soil:	All soil types including sand and organic soils, excluding organic litter unless it is highly pulverized and occurs in a thin layer or smaller patches over bare soil.
L-Litter:	Surface organic matter including intact or partially pulverized leaves, needles, or twigs that mostly or entirely cover the tread substrate.
V-Vegetation Cover:	Live vegetative cover including herbs, grasses, mosses, and low-growing shrubs that are rooted within the tread boundaries. Ignore all overhanging vegetation.
R-Rock:	<u>Naturally-occurring</u> rock surfaces (bedrock, boulders, rocks, cobble, or natural gravel). If rock or native gravel is embedded in the tread soil estimate the percentage of each and record separately.
MS-Muddy Soil:	Seasonal or permanently wet and muddy soils that show imbedded foot or hoof prints from previous or current use (omit temporary mud created by a very recent rain). The objective is to include only transect segments that are frequently muddy enough to divert trail users around problem, possibly leading to an expansion of trail width.
SW-Standing Water:	Portions of mudholes with non-moving water.
ER-Exposed Roots:	Exposed tree or shrub roots.
RW-Running Water:	Moving water from seeps or streams intercepted by the tread.
G-Gravel:	<u>Human-placed</u> (imported) gravel.
W- Wood:	<u>Human-placed</u> wood (water bars, bog bridging, cribbing)
O-Other:	Explain.

19) **<u>Maximum Incision, Current Tread (MIC):</u>** Extend the telescoping pointer so that it spans the tread at the sample point, resting on the substrate surface (below vegetation or litter) precisely at your tread boundaries (at the wire flags if used). Use the tape measure to determine the maximum incision (distance) from the pointer to the current deepest portion of the trail tread. Measure (centimeter or nearest half inch) to the surface of the tread's substrate, not the tops of rocks or the surface of mud puddles. In other words, your objective is to record

a measure that reflects the maximum amount of soil that has been compacted or eroded from the tread within the tread boundaries at the sample point.

20) **Maximum Incision, Post Construction (MIP):** Study the trail tread surface and try to judge or estimate the original post-construction tread surface. Extend and use the shock-corded tent pole as a measurement aid. In flat terrain simply lay the tent pole down so that it approximates the level of the substrate (below vegetation or litter) on either side of the trail tread. In sloping terrain, place one end of the pole directly on the substrate of the berm (lower slope side of trail). If possible, adjust the other end so that the pole extends across the tread and is level as indicated by the attached line level bubble. If the trail is outsloped, and you can determine the post construction tread surface, then place the tent pole to mimic that surface regardless of the reading on the line level. Manually adjust the pole to compensate for any downward bowing and use the tape measure to determine and record (nearest centimeter) an estimate of the maximum incision from the pole to the deepest portion of the trail tread. Measure to the surface of the tread's substrate, not the tops of rocks or the surface of mud puddles. In other words, your objective is to record a measure that reflects the maximum amount of soil that has been compacted or eroded from the tread following trail creation.

21) **Trail Grade (TG):** Two field staff will position themselves about 3 meters from the sampling point in opposite directions along the trail. A clinometer will be used to determine the grade (% slope) by sighting a spot on the opposite person at the same height as the first person's eyes. After becoming practiced in this procedure the clinometer may not be necessary in most instances. Record the percent grade as the midpoint value for one of four categories: 0-5% (3), 6-10% (8), 11-15% (13), 16-20% (18).

22) **Trail Alignment (TA):** Consider the trail's alignment with respect to the prevailing landform in the vicinity of the sample point. If the trail is roughly ascending/descending (parallel) to the prevailing slope (± 22.5^{o}) then record a S. If the trail is roughly on the contour (perpendicular) to the prevailing slope (± 22.5^{o}) then record a C. Otherwise record a O.

23) **Vegetation Type (VT):** Use the vegetation classification system most common for the area and easily applied by field staff: G= grassland, F= forest, S= steppe, D= desert or non-vegetated.

24) **Trail Position (TP):** Use the descriptions below to determine the trail position of the sampling point. Record the corresponding letter code in the TP column.
   V - Valley Bottom: The trail is within 20 meters (elevation gain not distance) (3 1:2400 topographic lines) vertically from the lowest area in the closest valley bottom.
   M - Midslope: The trail is located at least 20 meters above the closest valley bottom and 20 meters below the crest of the closest ridge or mountain.
   R - Ridge Top: The trail is located within 20 meters of the crest of a ridge or mountain.

Trail Segment Code ________ Trail Name/Location ___________________________
Surveyors _______________________________________ Date ________________ Use Type(s) ___________ Use Level

Dist	IT	ST	TW	Tread Condition Characteristics (Sum to 100%)	MIC	MIP	TG	TA	VT	TP
				0 10 20 30 40 50 60 70 80 90 100						

Codes: <u>Tread Condition Characteristics</u>

Dist =Wheel Distance
IT=Informal Trails
ST=Secondary Treads
TCW=Trail Corridor Width
TW=Tread Width
TP= Trail Position (Valley=V, Midslope=M, Ridge Top=R)

S=Soil
L=Litter
V=Vegetation Cover
R=Rock
MS=Muddy Soil

SW=Standing Water
ER=Exposed Roots
RW=Running Water
G=Gravel
W=Human-placed Wood

MIC=Max. Incision, Current
MIP=Max. Incision, Post Construction
TG=Trail Grade (0-5=3, 6-10=8, 11-15=13, 15-20=18)
TA=Alignment (Parallel to Slope = S, Contour = C, Other = O)
VT=Vegetation Type O=Other (Specify)

Figure 1. Form A: Point Sampling

VITA

Tracy Ann Farrell completed a semester abroad program in Ecuador sponsored by the School of International Training in 1991, graduated from the State University of New York, College at Buffalo with a Bachelor of Science in Environmental Studies (Political Science minor) in 1992, and obtained a Master of Science degree in Forest Resources Management-Recreation and Tourism from the State University of New York, College of Environmental Science and Forestry in 1995. She received her Ph.D. degree in Forestry from Virginia Polytechnic Institute and State University in December, 1999.

During her doctoral program at Virginia Polytechnic Institute and State University, she was employed as a Graduate Research Assistant and conducted visitor impact and ecotourism research projects in Mexico, Belize, Costa Rica, and Chile. She also participated in writing management plans and reports for several other recreation management projects in the United States. She was also the course instructor for the Outdoor Recreation Senior Seminar and served as a Graduate Teaching Assistant for Nature and American Values and Outdoor Recreation Management.

Her primary research and teaching interests include visitor impact assessment, monitoring and management, recreation ecology, protected area planning and management, visitor experience and management preference evaluation, and tourism planning and development. She is particularly interested in protected area management and visitor impact management issues in Central and South America and is fluent in Spanish.